TRANSACTIONS

OF THE

NATURAL HISTORY SOCIETY

OF

NORTHUMBRIA

Editor:

R. B. CLARK

Assistant Editor:

M. A. PATTERSON

Volume 56

THE NATURAL HISTORY SOCIETY OF NORTHUMBRIA

THE HANCOCK MUSEUM

NEWCASTLE UPON TYNE NE2 4PT

1993-1996

ISSN 0144-221X

CONTENTS

Erratum

* The page numbers should read 421-442 (not 393-414 as shown in Part 7)

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Printed by Bealls, Newcastle upon Tyne.

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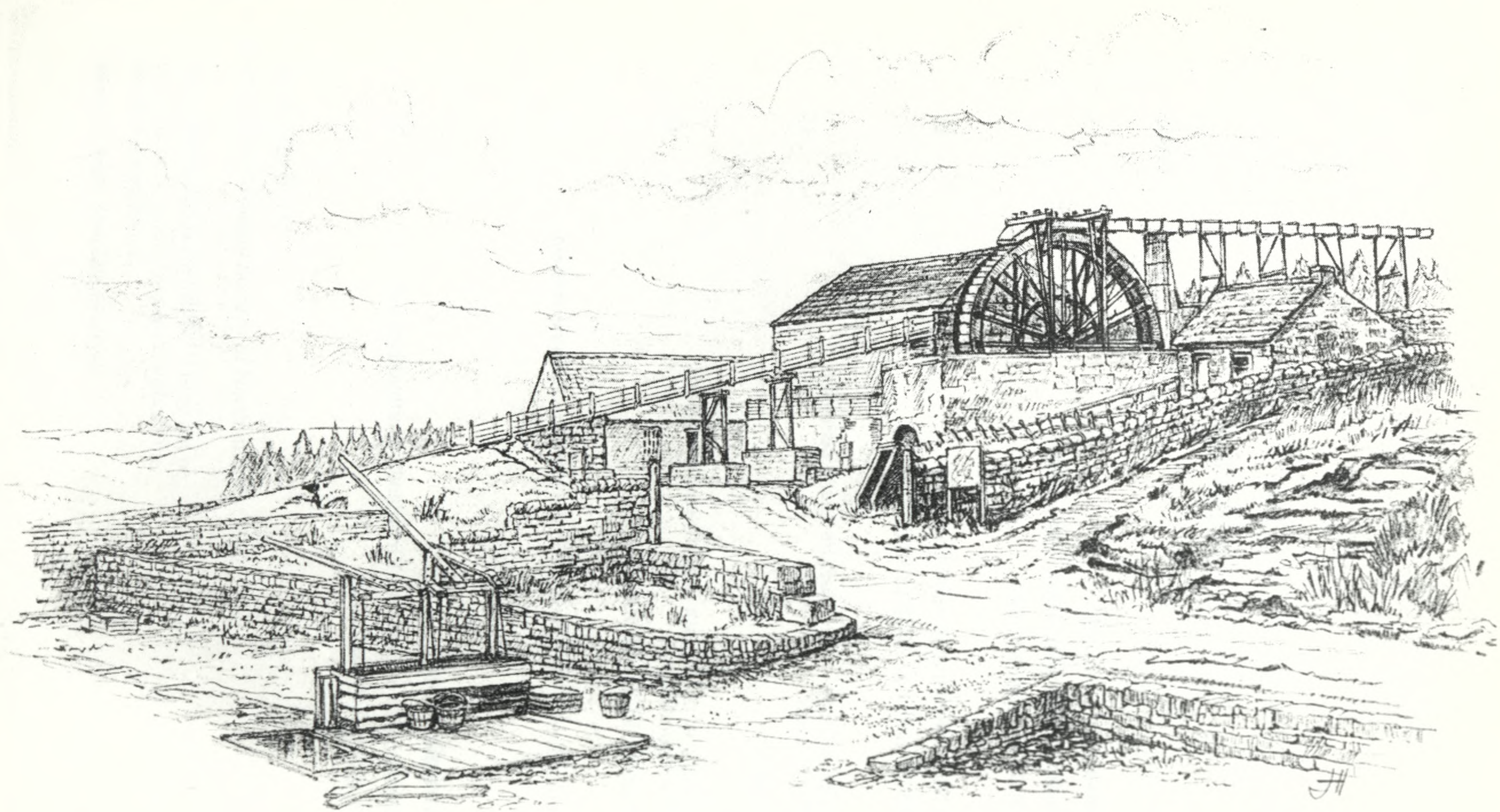

The Killhope Wheel Lead Mining Centre (drawn by J. Holding)

THE PYBUS MEMORIAL LECTURE 1991

ORE GENETICS IN THE NORTHERN PENNINES, 1948-1990

by

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It is an honour to be invited to give this lecture on ore genetics, in memory of one of Newcastle's greatest surgeons and a benefactor of the Society. My subject is, I fear, remote from his interests, save that I hope he would have approved the scientific reasoning I wish to set out. There is a connection with Newcastle because throughout John Pybus' years here, galena concentrates were being brought from the orefield to a works just west of the High Level Bridge for conversion into metal and lead shot.

My interest in the orefield began in 1930 with work for a doctoral dissertation. Before and during the early stages of World War II, as an officer of the Geological Survey I was in the area to assist the Controller of the Ministry of Supply to increase the supply of war materials, particularly iron ore and fluorspar for steelmaking, zinc ore to save shipping from Australia, barytes for its inert properties and witherite for barium chemicals. There was an appreciable scientific spin off, and in 1948 this provided the data for a 353-page Geological Survey Memoir (Dunham, 1948).

The deposits occur in 440 named veins in the northern half of the orefield, and 419 in the southern half. Replacement deposits in limestone accompany a minority of the veins, but it must be made clear at the outset that the deposits are in no case sedimentary; they have been introduced into their host rocks long after these had consolidated. The good case that can be made for direct sedimentation of metallic sulphides, in some districts worldwide, cannot be supported here. Thus the genetic problems include the nature and sources of the solutions that introduced the minerals, and the plumbing system by which this became possible. As background I shall summarize briefly the genetic position reached in 1948 (Dunham, 1948), but concentrate on the developments since my return to Durham in 1950, leading to the publication of volume II (Dunham & Wilson, 1985) and last year of a second edition of volume I (Dunham, 1990). Background papers also include those of Dunham (1970) and Smith (1980).

THE POSITION TO 1948

The Northern Pennine Orefield, historically the most prolific lead-producer in Britain, lies between Hadrian's Wall in the north and the Craven country in the south. The Carboniferous host-rocks range from basement conglomerates through Melmerby (= Great) Scar Limestone, through an essentially cyclothemic sequence ranging from the Asbian Stage up to Westphalian B. Structurally, the orefield occupies the Alston and Askrigg fault-blocks where the Carboniferous rocks are less than half as thick as in the troughs of Northumberland, Stainmore (that separates them) and Craven. The series of quartz-dolerites at various horizons known collectively as the Whin Sill, and the ENE dykes that may have fed them, were intruded at 290 Ma. These are confined to the Alston block and to Northumberland. The two blocks were distorted into gentle domes by pre-Permian movements that also tilted to form the Durham coalfield. This distortion gave rise to a geometrical pattern of minor faults trending ENE, E-W, WNW and NNW. In the Alston block, the first pair came under tension, providing opening channels for mineralizing fluids. The significant directions in the Askrigg block were E-W and WNW. In both areas the cross faults (NNW) are mostly barren. Up to the Pendleian Stage the unit cyclothem is in upward succession, limestone-shale-sandy shale-sandstone-(coal) and this is repeated sixteen times. At higher levels, the limestones disappear, but in the Westphalian thick coals appear. Essentially the picture throughout is of hard, brittle beds (limestone, quartzitic sandstone) alternating with soft shaly beds. The minor faults stand steeply in the former and may have given rise to open channels, while in the latter no open space persisted. Few individual beds reach as much as 10m in thickness. Thus the channels available to mineralizing fluids were of small height, but of great length.

It is maintained that the fluids rose into the system at a few central points, marked by early massive quartz with chalcopyrite, pyrrhotite and marcasite. In the Alston field these places (Tynehead, Wearhead, Groverake, Bollihope) form focal points for a regional mineral zonation. They are surrounded by a broad zone in which every deposit carries fluorite, but in which the quantity of galena increases outwards. This zone is surrounded by a broad outer zone in which every deposit contains barite or witherite. The relationship between fluorite and barite had previously been noticed by J. A. Smyth (1921, 1922) and E. G. Hancox (1934) had shown that the witherite resulted from carbonation of barite. In the barium zone the relative quantity of galena diminishes outward, so that the large barium deposits round the margins of the field; Settlingstones, South Moor, New Brancepeth, Closehouse, Dufton and Silverband are almost free from this mineral. Between the fluorine and barium zones a narrow intermediate area carries neither element, or both, but here the sulphides of lead and zinc reach their maximum development. As this intermediate zone is approached, the colour of fluorite changes from purple or green to the rare earth-poor amber variety. Siderite and ankerite, with some calcite, complete the main mineral assemblage. When erosion brought the deposits above to the meteoric water table, the iron-bearing carbonates were oxidized to yield Bilbao-type iron ores. The close similarity of this zonal arrangement with the outer zones of the mineralization of Cornubia, until recently believed to be due to juvenile hydrothermal solutions representing the watery residue from the crystallization of the exposed granites, led me to suggest, as long ago as 1934, that there might be granite concealed beneath the Northern Pennines (Dunham, 1934).

The juvenile hydrothermal hypothesis received great impetus from the work of the United States Geological Survey in the Western States, where nearly every important metalliferous area is associated with a high-level granitic stock or batholith of Tertiary age. At about this time (1936) I had the good fortune to spend two years mapping one such intrusion in New Mexico and studying the material at Harvard (Dunham, 1936). A remarkable variety of metals and sulphides was concentrated around the final, coarsely crystallized phase of quartz monzonite, disseminated in the rock, intergrown with lime-silicates in contact marbles, and in veins. The case for juvenile mineralization seemed very strong save that the pegmatites had concentrated only feldspar and hedenbergite, and the largest ore deposit had been emplaced in a N-S fault, sympathetic to and not far from the great Basin-and-Range fault that terminates the complex to the west, and which certainly postdates the igneous activity, perhaps by a long period.

In the case of the Askrigg block, the picture was a little less clear in that the pure fluorine zone is much less in evidence than the intermediate zone, and calcite is more abundant in the outer zone. The foci are also less obvious, but may exist at Surrender, Gunnerside Gill and along the Craven faults.

In 1948, it was quite clear that the mineralizing fluid was not meteoric water, as some earlier writers had implied, but there was no proof that the zonation was temperature-controlled. The fluids were known, from the wallrock alteration of the Whin dolerite adjacent to the veins, to add potash and to remove magnesium and iron. The latter two elements were evidently fixed as carbonates, and it is significant that in the Askrigg block, where there is no Whin dolerite, siderite and ankerite are virtually unknown.

Post-Triassic, assumed Tertiary, movements terminated the Alston block at the Outer Pennine Fault (displacement about 3km) converting the gentle dome into a half-dome, and the Craven faults similarly left the Askrigg block in this condition. The movements left their mark in the mineral veins in the form of strong horizontally grooved slickensides.

Thus although it had been possible by 1948 to give an account of the 440 veins and related replacement deposits in the Alston orefield, with statistics of production and some estimate of the structural and mineralogical factors controlling the orebodies, there were some important fundamental questions that remained unanswered. Meteoric water above the water table could not be the primary agent because of its oxidizing effect. Rainwater below the water table was incapable of dissolving most of the elements in question. It was not yet established that the lateral mineral zonation was temperature-controlled. Finally, if the juvenile hydrothermal hypothesis were to be invoked, it would be necessary to establish that a post-Carboniferous granitic intrusion was concealed beneath the orefield.

1950 TO 1990 CONCEALED GRANITE

In 1951, by very good fortune, Mr W. B. Harland in Cambridge stimulated two of his new graduates, M. H. P. Bott and D. Masson-Smith, to undertake a detailed gravimeter survey of the Alston block, to follow up a single line by J. Hospers and P. Willmore that had shown a gravity low over the area. Here at last was the chance to obtain definite evidence about the basement. Their detailed survey and the laborious task of applying the necessary terrane correction in pre-computer days, completed by 1954, showed a Bouguer anomaly with long axis ENE and deep minima, beneath Rookhope and Tynehead, corresponding remarkably well with the outline of my fluorine zone. Measurement over Cornish and some Scottish granites showed anomalies with exactly comparable shapes, and the two geophysicists (1957) concluded that only a concealed batholith below the Alston block could explain the data. Martin Bott had by this time joined us in Durham as Turner and Newall Fellow. Application was now made to the Department of Scientific and Industrial Research for funds to prove the granite by boring. Sir William Pugh, for the Geological Survey, was friendly and suggested that provision to bore to 8,000 ft should be made. Bott, on the other hand, believed that the granite would be reached at less than 2,000 ft, and published this opinion just before boring commenced at Rookhope (Bott, 1960). The hole started in the Great Limestone, and was cored throughout; the cores, stored on steel racks, have proved a valuable asset for teaching and research during the past thirty years, and have been seen by thousands of students. In February 1961 the full Dinantian succession beneath Rookhope had been drilled, and the hole passed from unmetamorphosed Carboniferous through a thin soil with mica and quartz fragments, into granite. I had been at the borehole when this happened, and was lecturing in this room that evening; but I did not reveal what had happened at 1,281 ft (390.5m) because I was not sure whether highly foliated granite or ancient orthogneiss had been cut. Drilling was continued into the granite to 2,650 ft (807.72m); the low-dipping foliation, appropriate to the top of a cupola, gradually diminished (Dunham *et al.*, 1961, 1965).

The implication of the result from the genetic standpoint was that it was now necessary to abandon the juvenile hydrothermal hypothesis. A number of laboratories dated the granite, which averages close to 400 Ma, and there cannot be any question that residual fluids from its magma mineralized the overlying Carboniferous. There were sufficient vein intersections in the granite, probably of Boltsburn Vein or flyers from Red Vein, to suggest that fluids rose through the granite, and the most reliable age for the mineralization comes from uraninite associated with fluorite in one of these, 292 ± 20 Ma. To a speculation that the potassium content of the fluids might still indicate a deeper, post-Carboniferous source, it was pointed out that fluids if equilibrated with the granite would have this characteristic, so the ultimate source of the fluid remains unclear (Dunham, 1983, 1988).

TEMPERATURE OF MINERALIZATION

The Rookhope borehole created some international interest among ore geologists and I was invited by the Society of Economic Geologists to give their first 'Distinguished Research Lecture' at their annual meeting in Dallas in 1963 (Dunham, 1964). The visit enabled me to meet some of the younger men at the USGS, notably Don White, who was engaged on a very detailed study of the chemistry of deep and shallow groundwaters, and Edwin Roedder, who had revived interest in the microscopy of fluid inclusions in minerals, a technique first proposed as long ago as 1855 by H. C. Sorby, the Sheffield metallurgist. With the help of Roedder and Dick Holland, F. J. Sawkins was persuaded to come from Princeton as a post-doctoral fellow to apply the fluid inclusion technique to the Pennine zones. His results (Sawkins, 1966) showed temperatures as high as 212°C at the focal points marked by early quartz-chalcopyrite, a range from 186 down to 100°C across the fluorine zone, and possible figures as low as 50 in the barium zone. Temperature control was clearly vindicated. Subsequently these results were amplified greatly by Smith & Phillips (1974) and numerous measurements for the Askrigg orefield contributed by P. J. Rogers (1978). Generally the temperatures for the southern orefield in the fluorine areas are less than in the northern, a result that could have been anticipated from the prevalence of intermediate zone, fluorite-barite paragenesis. The technique in all these cases is the observation of two-phase inclusions in thin sections on a heated-stage microscope. When the gas phase disappears, the temperature of formation can be read, subject to a small correction for pressure. Provided that no leakage from the inclusions has occurred, the results have been shown to be reproducible and reliable.

NATURE OF THE FLUID

Here there are two lines of approach. Freezing under the microscope enables the salinity of the fluid to be obtained from the depression below zero of the freezing point, and here, for the Pennines as for other ores, salinities up to six times sea water are common. Crushing of the mineral followed by collection and analysis of the fluid shows that in some cases the K-Na ratio is higher than in sea water. Concentration of metallic elements is generally very low. Reference to Don White's results, and to petroleum exploration experience, shows that hypersaline fluids similar to those in the inclusions are very widespread in the earth's crust at depths over 300m below surface (White, 1968). Some may be due to solution of evaporites, others to trapping of sea water during sedimentation, with membrane filtration by clays increasing the salinity. In short, the mineralizing fluids and the formation waters of the oil men are the same (Dunham, 1970). The solvent power of such waters is far greater than that of fresh groundwater, since it promoted the formation of chlorine (and probably fluorine) complexes. The final confirmation of the hypersaline fluids as mineralizers comes from the Red Sea deeps, and more eloquently still from the presence, described by Carpenter *et al.* (1974) of similar fluids in sandstone reservoirs over an area of 1,200 sq km of Mississippi with lead and zinc contents so high that these metals are deposited as galena and sphalerite as the waters are pumped from 3.5km depth towards the surface.

More recently an interesting approach to the question of palaeotemperature in the Northern Pennines has come from Creaney (1980) who measured by vitrinite reflectance the temperatures reached by the thin coals on the Alston block. Trotter (1954) had long ago suggested that the devolatilization of coal was related to the mineralization, but though the local coincidence is admitted, it is impossible to think of solutions flowing through channels normally a mile apart as heating the whole countryside. Creaney showed that when the Whin sills were intruded, the whole area containing semianthracites was already at 180°C: in short, powerful heat flow from the mantle had preceded the intrusions, whose local heating effect was severely restricted. It will be noted that the orefield had cooled substantially below this general figure before the mineralization began.

EVIDENCE FROM STABLE ISOTOPES

In 1962, consultation with M. L. Jensen at Yale, as one of the leaders in the interpretation of the distribution of the isotopes of sulphur, indicated that useful evidence as to the origin of the element in Pennine sulphides and barite could be obtained. Dr M. Solomon, from Tasmania, joined us for this project and the necessary mass spectrometry was undertaken by Dr Athol Rafter at the Nuclear Energy Laboratories in Wellington, New Zealand. Sulphur directly originating from a magmatic source varies by only a few per cent from a standard, the Canon Diabolo meteorite, used as the basis for delta ^{34}S. Sulphur from Pennine sulphides, however, showed wide-ranging variations, from +6 to -28 ‰, figures comparable with those for some Mississippi Valley deposits, and taken to indicate a wide range of sedimentary rock sources. On the other hand, much more consistent values were obtained for barite sulphur, at around +12 ‰, again suggesting a sedimentary source, but much more restricted in character.

In 1966 my friend the late C. F. Davidson engaged with me in a staged debate on genetic topics in which he suggested that the mineralizing fluids in the orefield were waters of surface origin which had become saline by dissolving Permian halite, and then descended to a sufficient depth in the crust to become heated before being driven surfacewards by Hercynian earth pressures (Davidson, 1966). The range of delta ^{34}S values obtained by Solomon *et al.* (1971) made it possible to test this hypothesis, since world-wide data for S in evaporites is available, era by era. Our figure for barite does not correspond with a Permian source, but would fit a Lower Carboniferous origin very well. Only the barite in and near the Durham Permian shows values appropriate to that formation. On the other hand, the wide-ranging delta ^{34}S values indicate that source rocks belonging to more than one era have contributed. The sole area where a range restricted enough to suggest an igneous source is at Greenhow, but here we fear that the small number of results obtained by Mitchell & Krouse (1971) may have been insufficient.

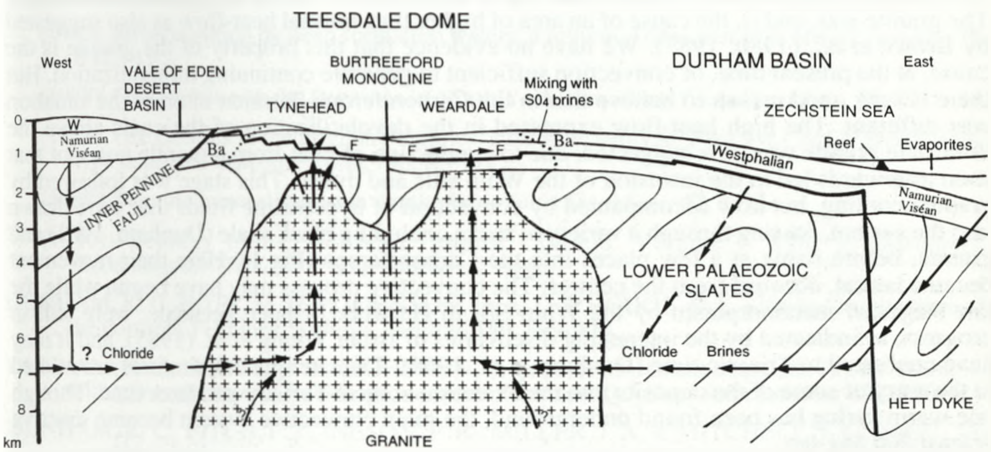

Fig. 1. Hypothetical cross section of the Northern Pennine Orefield showing the geology in late Permian time and the possible path of chloride brines rising beneath the Weardale and Tynehead areas. Revised after Solomon, Rafter and Dunham (1971, fig.8) with the form of emplacement of the Whin Sill following Francis (1982).

THE ASKRIGG FIELDS

Most of the results so far discussed have been derived from the Alston block, the northern half of the orefields. My return to Durham in 1976 made it possible to assemble the details for the southern half. Here I was fortunate to have the collaboration of Dr A. A. Wilson of the Geological Survey, who produced a very full account of the Carboniferous stratigraphy. The Institute of Geological Sciences drilled the Raydale Borehole to test the gravity evidence by Bott (1967) indicating that the Askrigg block also has a concealed granite core (Dunham, 1974). The granite was entered 1,624 ft (495m) below surface. The fluorite-bearing deposits in this part of the orefield are by no means so obviously related to the granite stock as in the case of Weardale, and towards the west there is a large unmineralized area in 1:50,000 Sheet 40, Kirkby Stephen. This may in part be due to the fact that the Main Limestone, the bearing bed *par excellence* of the Swaledale-Arkengarthdale mineral belt, from which has come a high proportion of the lead mined in the southern field, has been eroded off. Chalcopyrite occurrences are ambiguous. Those around Settle might suggest feeders related to the North Craven Fault, but the small Richmond-Middleton Tyas area may well have been highly enriched by proximity to the land surface of Permian times. In volume II of *Geology of the Northern Pennine Orefield*, which appeared in 1985, the concept of mineralization by hypersaline brines was fully endorsed, but the route taken during their rise proved less evident than in the north.

CONVECTIVE FLOW

It is by no means satisfactory to leave it that the rise of the brines from depth was solely due to earth pressures; the long periods of apparent stability when mineralization was probably in progress denotes an additional driving force for the fluids. The clue to this was supplied by the heat-flow studies at Rookhope by Bott *et al.* (1972) who found that the thermal conductivity of the granite is appreciably greater than that of the rocks into which the granite was intruded. The granite was, and is, the cause of an area of higher than normal heat-flow as also suggested by Brown *et al.*, (1980; 1987). We have no evidence that this property of the granite is the cause, at the present time, of convection sufficient to generate continuing mineralization. But there is very good reason to believe that in the Carboniferous-Permian interval the situation was different. The high heat-flow expressed in the devolatilization of the coals above the Weardale granite was, it is suggested, due to conduction of heat from a mantle hot-spot that soon afterwards led to the intrusion of the Whin sills and dykes. This stage was followed by gradual cooling, but now accompanied by convection of hypersaline fluids that were drawn into the system, passing through a variety of rocks, including black shale (Dunham, 1961) and granite, before rising at a few places into the Carboniferous (Fig.1). Here their movement became lateral, outward from the centres. The convective process may have begun while the late stages of metamorphism by the Whin Sill in Harwood, Upper Teesdale, were still in progress, as indicated by the interesting discoveries of Brian Young *et al.* (1985), and it may have continued to Triassic time (Dunham *et al.*, 1968). The later genetic features are related to the entry of some of the deposits into the oxidation zone in Tertiary and later time. Though one warm spring has been found underground, the main convective system became inactive at least 200 Ma ago.

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GOSFORTH PARK NATURE RESERVE ANNUAL REPORT FOR 1991

by

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SUMMARY

The paper is a report for Gosforth Park Nature Reserve of the species in the area and the management and research activities recorded during 1991. The main objective is to give greater detail of the reserve than could appear in the Society's annual report. The systematic lists were compiled from daily records entered in the members' logbook. Birds and mammals were the best documented groups with ninety-five species of birds and thirteen species of mammals recorded.

INTRODUCTION

This report follows the layout of that written for 1990 to provide comparative information regarding the management and use of the reserve and systematic lists of the fauna. Birds and mammals are again the most easily recognized and thus the best documented groups: however there is a slight increase in the number of records of insects and flora but, as yet, not enough for systematic listing. It is hoped that with the continued production of a regular report, members will be encouraged to take more interest in the reserve and provide a wider coverage of flora and fauna records.

The account has been divided into three main areas: the Reserve Management Committee report and the bird and mammal reports, with systematic lists for both the latter. A list of miscellaneous entries has been included at the end.

METHODS

The general information about the reserve has been provided by the Management Committee, and the systematic lists compiled from daily records entered in the members' logbook. Most of the entries are observations by the warden and his assistants on their regular rounds, but members using the reserve have also contributed, and the names of all recorders (those whose signatures were legible) are given at the end of this report.

The bird list includes species observed from the reserve or seen flying over the area. Though birds moving over the area are not strictly part of the fauna, the records could be indicative of their future use of the reserve and be compared in subsequent reports.

The complete report was submitted to all members of the Management Committee for their critical appraisal, and has been revised accordingly.

RESERVE MANAGEMENT COMMITTEE REPORT

Reserve Management

The chairman of the Reserve Management Committee, I. D. Moorhouse, regretfully had to resign in September as he was going to Madrid for two years. The Society is very grateful to him for his enthusiasm and commitment to the conservation and management of the reserve over the past years. E. Slack was elected as the new chairman and during the year two new committee members were elected: D. Holgate the ex-warden and Mrs P. Hammock who compiled the 1990 annual report.

The Society has not been allowed to undertake any major work during the year. The owners of the reserve, High Gosforth Park Plc, were approached by the Society with an autumn work programme based on the management plan for the *Phragmites* reed beds, the main strategy of which was to conserve and enhance the reed beds and control their natural succession to willow carr. It was planned to achieve this by improving the water retention of the lake: by repairing or replacing the sluice, excavating some of the drainage channels, reducing the level of accumulated organic matter in specific areas and removing new willow growth along the reed bed margins. These improvements would help raise the water level, thus encouraging an increase in the density of new reed growth and delaying successional change. The programme was rejected by the owners on the grounds that no major work should take place before the outcome of the public enquiry into the development plans proposed by the Company and their agents Bellway. The enquiry was expected to take place in June 1992 and the outcome known by March 1993. This therefore only allowed the Management Committee to undertake the normal reserve management which is outlined below.

Routine Maintenance and Woodland Management

Regular working parties were busy throughout the year. They installed a wire mesh non-slip surface to the boardwalk, cleared the island in order to attract common terns, sprayed bulrushes, kept paths clear of weeds and cut back rhododendrons and willow carr. Community Service groups built a new path to improve access to the Pearce hide, maintained the footpath bridges and early in the year undertook major clearing of the reed beds in a large area adjacent to the boardwalk, thus successfully improving the growth of *Phragmites* in that area.

Wardening and Activities Report

The new warden, P. Drummond, and his family settled into Lake Lodge for their first year and the Society is grateful for his hard work and enthusiasm. In June, the family adopted a two week old female roe deer found on the roadside outside the reserve after its mother had been killed. The fawn was cared for until early November when it was successfully returned to the wild, within the reserve.

There were cases of trespass throughout the year which included an unsuccessful attempt at badger digging during the February snows, mountain bikers and five men thieving from the Scout Camp. The warden has now received written authority from both High Gosforth Park Plc and the Scout Association, authorizing him to apprehend trespassers on their land, and he has been provided with a powerful electric hand torch to use at night when confronting intruders.

In May, as part of environment week, the warden and his son helped the Tyneside Supporters Group of the World Wide Fund for Nature (WWF) to make fifty bat boxes, with wood supplied at a reduced price by M. H. Southern of Jarrow. The completed boxes were then donated to the Society. As a follow up, J. Steele and E. Morton led a mammal section field meeting to the reserve on 12 October which was attended by several Society members and six members of the WWF. Participants built more bat boxes and installed nine on trees around the Lodge and the remainder were erected by the warden around the reserve at a later date.

Ringing Report

During the year there were twenty-three ringing visits to the reserve between 28 April and 27 October. Most of these ringing activities formed part of the constant effort ringing programme in which six mist nets (originally five, but increased to six for the 1991 season and beyond) were operated at fixed sites during set periods from May to August. Additional nets were operated during most constant effort sessions and extra visits were made to supplement the data.

The ringing totals are summarized in Table 1. Although the five species of tits form 30% of the 484 birds ringed, the warblers made the biggest contribution to the total with 165 birds of seven species. Willow warblers and sedge warblers were the most numerous, with much smaller numbers of blackcaps, chiffchaffs, reed warblers, garden warblers and grasshopper warblers. Both the grasshopper warblers were juveniles suggesting that at least some of the birds 'reeling' in the reserve earlier in the year may have bred successfully. As in the past only a few garden warblers were caught, but one on 27 October was notable for its lateness and body condition: whereas most garden warblers in summer weigh about 17g, this particular bird tipped the scales at 25.9g! Many migrant warblers lay down fat at this time of year to fuel their journey south, which is often visible as an accumulation of fat in the tracheal pit at the base of the neck, as was the case with this bird.

In contrast to previous years, the total number of goldcrests ringed was very low, only two individuals. The number of reed warblers ringed was also low, although the number of birds singing in the reserve remained similar to previous years, thus continuing the trend of reducing numbers of reed warblers caught (Hammock & Noble-Rollin, 1991).

There was only one recovery of a bird ringed in 1991 or before: a sedge warbler ringed as a nestling in the reserve, one of a brood of five, was caught at Shibdon Pond, Blaydon, in June 1992. This emphasizes the value to the north-east of a vigorous wetland habitat, acting as a reservoir for species such as *Acrocephalus* warblers which are then available to colonize suitable habitat elsewhere in the region.

Table 1

Numbers of birds ringed during the 1991 season in Gosforth Park Nature Reserve

SPECIES	PULLUS[1]	FG[2]	ADULT	JUVS[3]	TOTAL
Blackbird	0	0	19	4	23
Blackcap	0	0	8	11	19
Blue Tit	0	0	45	52	97
Bullfinch	0	0	1	4	5
Chaffinch	0	0	9	1	10
Chiffchaff	0	0	2	1	3
Coal Tit	0	0	4	1	5
Dunnock	0	0	4	14	18
Garden Warbler	0	0	1	1	2
Goldcrest	0	1	0	1	2
Grasshopper Warbler	0	0	2	0	2
Great Tit	0	0	27	9	36
House Sparrow	0	0	1	0	1
Jay	0	0	3	4	7
Long-tailed Tit	0	1	2	4	7
Redpoll	0	0	2	0	2

SPECIES	PULLUS[1]	FG[2]	ADULT	JUVS[3]	TOTAL
Reed Bunting	16	0	6	11	33
Reed Warbler	0	0	4	5	9
Robin	0	0	9	29	38
Sedge Warbler	5*	0	27	34	66
Siskin	0	0	1	0	1
Song Thrush	0	0	3	1	4
Sparrowhawk	0	0	0	1	1
Treecreeper	0	1	1	0	2
Willow Tit	0	0	0	4	4
Willow Warbler	4	0	24	35	63
Wren	0	0	4	17	21
Yellowhammer	0	0	0	2	2
TOTAL	25	3	209	246	483

[1]Ringed prior to fledging.

[2]Full grown, indeterminate age.

[3]Recently fledged.

*One from this brood was controlled (caught by another ringer) at Shibdon Pond, Blaydon, in June 1992.

BIRD REPORT

Ninety-five species were seen during the year, a drop of twelve compared to the previous year. The flooded fields adjacent to the reserve proved more attractive to wintering wildfowl than the lake from early March until the end of April and the area was used by a wintering greylag goose *Anser anser* and a Canada goose *Branta canadensis* which paired and successfully raised five hybrid young. Three rare ducks provided interesting records: a female smew *Mergus albellus* was the first since 1977; a male pintail *Anas acuta* was the second record since 1983 and three goldeneye *Bucephala clangula* the third record since 1983. These last two species were regular winter visitors before 1983 but the draining of the lake and subsequent change in habitat resulted in a change of status for both species, the pintail becoming an uncommon winter visitor and the goldeneye a rare winter visitor (Noble-Rollin *et al.*, in press). A wintering green woodpecker attracted a mate during the spring but left the reserve in mid-April, and the first breeding pair of spotted flycatchers *Muscicapa striata* since 1984 (Noble-Rollin *et al.*, in press) nested in an old blackbird's nest outside Lake Lodge: unfortunately the eggs were predated.

Twenty-five species used the feeding station including four new species: carrion crow *Corvus corone*, reed bunting *Emberiza schoeniclus*, brambling *Fringilla montifringilla* and a woodpigeon *Columba palumbus*.

SYSTEMATIC LIST

The systematic list follows the order and scientific nomenclature of Voous (1977), with the status for each species taken from Noble-Rollin *et al.* (in press).

Little Grebe *Tachybaptus ruficollis*

Resident breeding species.

Up to seven were recorded from 9 March until 19 October with frequent sightings during the breeding season. Two pairs were present and an individual was recorded several times on its nest in mid-July. A juvenile was seen in September. This season has been shorter than that of 1990 with only two pairs present and breeding apparently less successful, with only one chick raised (Hammock & Noble-Rollin, 1991).

Grey Heron *Ardea cinerea*

Resident non-breeding species.

Recorded regularly in every month up to a maximum of six in October. A dead juvenile was found on 28 June, an adult was mobbed by lapwings in the flooded field and another chased by a sparrowhawk on 22 August.

Recorded more frequently in the flooded field than in the reserve, during March and April.

Mute Swan *Cygnus olor*

Resident breeding species.

Two were recorded regularly throughout the year but absent from the end of June until 24 August, a similar pattern to 1990. On 18 May courtship displays and mating were noted and subsequently a nest was built which was visible from the Pyle Hide, but again breeding was unsuccessful (Hammock & Noble-Rollin, 1991). Others visited the reserve, another pair being noted on 26 August, two additional adults and up to eight juveniles stayed for five days in mid-September and a flock of fifteen including three juveniles frequented the flooded field from 27 December until 29 December.

Greylag Goose *Anser anser*

Uncommon winter visitor.

Up to five were recorded regularly from 3 March to 1 April, usually in the flooded field with occasional sightings in the reserve. An individual remained in the reserve from April until the end of July and bred successfully with a Canada goose; their six goslings were first seen on 12 May and five frequently thereafter until the end of July. No more records until 18 December when eight frequented the flooded field until the end of the year.

Canada Goose *Branta canadensis*

Uncommon visitor.

An individual arrived on 10 March and was recorded frequently, usually in the flooded field, until 10 April. From 23 May until 26 July it was seen often with its family (see *Anser anser*, above), and then on its own in early August. Two were noted in the flooded field on 23 March, nine in the reserve on 9 June, five on 22 September and during October eleven rested in front of the Pyle Hide while on migration and twenty-nine flew over the lake towards Big Waters.

Shelduck *Tadorna tadorna*

Uncommon visitor.

One was recorded in the flooded field in March and one in April. Three were noted in the reserve on 12 October.

Wigeon *Anas penelope*

Common winter visitor.

Recorded during most months outside the breeding season (see Appendix). Up to four were occasionally seen early in the year, usually on the flooded field, but from September to December numbers within the reserve increased steadily to a maximum of forty-three in December, a substantial increase since 1990 (Hammock & Noble-Rollin, 1991) and comparable to early winter numbers recorded before the lake was drained (Noble-Rollin *et al.*, in press).

Gadwall *A. strepera*

Uncommon visitor.

Up to three were recorded from 13 to 18 March and a pair from 15 to 22 April. Individuals were seen on 22 September, 1 October and 29 December.

Teal *A. crecca*

Common winter visitor and resident.

Recorded in every month except June and July, favouring the flooded field during March and April. The encouraging trend of returning numbers seen in the 1980s (Noble-Rollin *et al.*, in press) does not seem to have continued through 1990 and 1991 (see Fig.1). The winter of 1989-90, with a maximum count of 200 in September followed by a gradual decrease until May, would appear to have been the last time that the lake attracted an overwintering population. During the winter of 1990-91 numbers peaked at seventy-eight in September followed by a decline to a very low wintering population. 1991 shows two peaks of thirty in March and eighty in September, separated by a very low potential breeding population and followed by a sharp decline to winter. The seasonal fluctuations in numbers this year suggest that the lake has merely become a stop for passage migrants, indicating a decline in its suitability for this species.

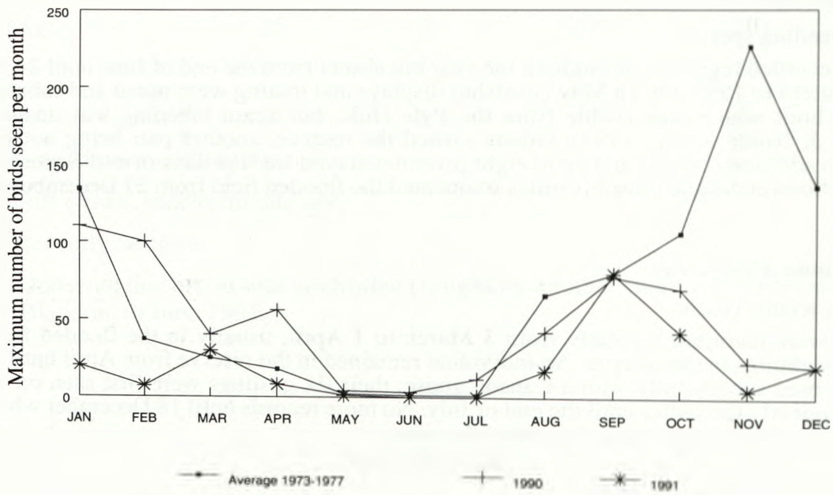

Fig.1. The highest monthly totals of teal *Anas crecca* for 1991 compared with the previous year and with an average taken from the 1973-77 counts to represent the numbers occurring before the lake was drained on 19 March 1981.

Mallard *A. platyrhynchos*

Common winter visitor and breeding resident.

Recorded in every month, favouring the flooded field during March and April. Three pairs and four broods of up to nine young were seen during the breeding season which would appear to have been more successful than last year (Hammock & Noble-Rollin, 1991). Fig.2 shows a large drop in the comparative wintering populations followed by a peak of 138 during autumn passage with numbers declining sharply into winter. The changes in seasonal fluctuations in numbers mirrors the trend of the changing patterns of the teal, again suggesting that the lake habitat is becoming less suitable for both species.

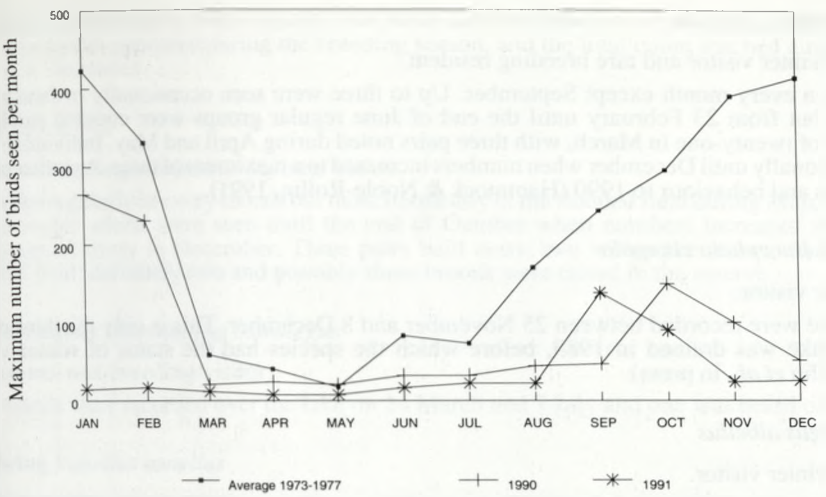

Fig.2. The highest monthly totals of mallard *Anas platyrhynchos* for 1991 compared with the previous year and with an average taken from the 1973-77 counts to represent the numbers occurring before the lake was drained on 19 March 1981.

Table 2

The highest monthly totals of teal *Anas crecca* and mallard *Anas platyrhynchos* respectively for 1991 used in Figs 1 and 2.

SPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Teal	20	7	30	8	1	0	0	17	80	42	5	20
Mallard	14	16	11	7	7	16	22	22	138	90	24	25

Pintail *A. acuta*

Uncommon winter visitor.

A male was recorded on 27 December. This is only the second record since the lake was drained in 1983; before this event the species had a status of winter visitor (Noble-Rollin *et al.*, in press).

Shoveler *A. clypeata*

Uncommon winter visitor and rare breeding species.

One was recorded in the flooded field on 30 January, individual females on 8 September, 11 and 13 October and three females on 29 September.

Pochard *Aythya ferina*

Common winter visitor and former breeding species.

Up to six were seen from 23-26 February and up to three occasionally in March. Pairs were noted occasionally during May and September and there were four records of up top three in December.

Tufted Duck *A. fuligula*

Common winter visitor and rare breeding resident.

Recorded in every month except September. Up to three were seen occasionally in January and February, but from 23 February until the end of June regular groups were counted reaching a maximum of twenty-one in March, with three pairs noted during April and May. Individuals were seen occasionally until December when numbers increased to a maximum of three. A similar pattern of numbers and behaviour to 1990 (Hammock & Noble-Rollin, 1991).

Goldeneye *Bucephala clangula*

Rare winter visitor.

One to three were recorded between 25 November and 8 December. This is only the third record since the lake was drained in 1983, before which the species had the status of winter visitor (Noble-Rollin *et al.*, in press).

Smew *Mergus albellus*

Very rare winter visitor.

One female was recorded on 1 April. This is the first record since 1977 (Noble-Rollin *et al.*, in press).

Sparrowhawk *Accipiter nisus*

Common breeding resident.

One or two were seen regularly throughout the year, with a pair noted in April and June. They were observed "putting up woodpigeons", "catching jays" and "harried by crows". One was seen killing a blackbird at the feeding station, where individuals were noted regularly during the winter. One juvenile was ringed.

Kestrel *Falco tinnunculus*

Common breeding resident.

Up to three were seen with records in every month except September. A pair was noted in March and seen courting and mating in April. Two juveniles were seen regularly within their family group during July. Only individuals were sighted during the remainder of the year, except for two displaying on 4 October.

Grey Partridge *Perdix perdix*

Common breeding species.

Recorded only occasionally, but regularly from February to November . The largest covey of seven was noted on 16 February and a family of seven in Oliver's field on 10 August.

Pheasant *Phasianus colchicus*

Common resident.

Recorded in every month, most frequently at the feeding station where groups reached a maximum of fourteen in February. Four juveniles were noted on 23 August.

Water Rail *Rallus aquaticus*

Breeding resident.

One or two were seen or heard (often from the reed beds by Colley's Bridge) in most months (see Appendix) and noted at the feeding station for the first time in February. No evidence of breeding was recorded.

Moorhen *Gallinula chloropus*

Common breeding resident.

Recorded occasionally in every month, with adult numbers between two and four until August. Up to four juveniles appeared during the breeding season, and the total count reached a maximum of fifteen in December.

Coot *Fulica atra*

Common breeding resident and winter visitor.

Recorded regularly in every month but most frequently in the flooded field during March and April. Up to twelve adults were seen until the end of October when numbers increased steadily to a maximum of thirty in December. Three pairs built nests, two within the reserve and one in the flooded field; definitely two and possibly three broods were raised in the reserve.

Oystercatcher *Haematopus ostralegus*

Occasional non-breeding visitor.

Individuals were recorded over the lake on 24 March and 7 July and one was heard on 27 April.

Lapwing *Vanellus vanellus*

Regular visitor.

One was seen on 25 February and then flocks of up to ten were recorded frequently in the flooded field from 5 March until 27 April, including four pairs, one of which was observed courting on 22 March. An individual was seen in the reed bed on 27 May, three in the reserve on 8 June and two flocks in the ajoining fields in August.

Snipe *Gallinago gallinago*

Breeding and common winter visitor.

Occasional sightings of up to eight were recorded throughout the year but not in every month (see Appendix). Individuals were heard drumming over the adjoining fields three times in May.

Woodcock *Scolopax rusticola*

Winter visitor and former breeding resident.

Occasional sightings of up to three were recorded throughout autumn and winter (see Appendix) but most frequently during February and March. Six were seen on 23 November in the new plantation, two noted at the feeding station in March and one seen in October.

Curlew *Numenius arquata*

Occasional non-breeding visitor.

The only three records were of individuals outside the reserve and were confined to the latter half of March: in the flooded field, flying over the reserve, and calling.

Redshank *Tringa totanus*

Breeding visitor.

Up to a maximum of eighteen were recorded regularly in the flooded field between 13 March and 18 April. Two flew over the lake on 6 May. There was no evidence of breeding this year (Hammock & Noble-Rollin, 1991).

Green Sandpiper *T. ochropus*

Occasional migrant.

One was recorded on 22 September.

Common Sandpiper *Actitis hypoleucos*

Occasional non-breeding visitor.

Individuals were recorded on 10 April and 5 May and two on 1 October.

Black-headed Gull *Larus ridibundus*

Regular non-breeding visitor.

One was seen in the reserve on 20 February followed by regular sightings of up to seventeen in the flooded field throughout March. From June to October there were occasional records in the reserve of up to eleven, including some juveniles.

Common Gull *L. canus*

Regular non-breeding visitor.

A flock of two hundred was recorded outside the reserve in February and regular flocks of up to 100 used the flooded field during March. This larger wintering flock is similar to records from the 1960s and 1970s rather than the smaller wintering flocks of the 1980s (Noble-Rollin *et al.*, in press). Eight were seen in the reserve on 3 June and individuals, one a juvenile, on 31 July and 4 and 14 August.

Lesser Black-backed Gull *L. fuscus*

Regular non-breeding visitor.

Two were recorded in the flooded field on 5 March and four seen circling over the lake on 28 April. Individuals were noted on 1 and 21 May, 7 June and 29 September.

Herring Gull *L. argentatus*

Regular non-breeding visitor.

Three records of up to six including two juveniles were observed using the flooded field between 23 March and 2 April and two were noted over the lake on 21 May.

Great Black-backed Gull *L. marinus*

Occasional non-breeding visitor.

One was recorded in the flooded field on 22 March.

Common Tern *Sterna hirundo*

Uncommon visitor.

Up to two were seen regularly, often fishing in the lake, between 26 May and 20 July.

Stock Dove *Columba oenas*

Regular breeding species.

Individuals were seen on 18 April and 1 November, a pair on 7 May and three on 24 September. No breeding was recorded although the birds would almost certainly have been present.

Woodpigeon *C. palumbus*

Common breeding and winter visitor.

Recorded occasionally throughout the year but not in every month (see Appendix). The maximum flock size was about 300, with a smaller flock of thirty put up by a sparrowhawk on 26 July. This species appears to be under-recorded (Hammock & Noble-Rollin, 1991).

Cuckoo *Cuculus canorus*

Uncommon breeding species.

Two were heard calling on 16 June and one from the Black Wood on 23 June. An individual was seen on 8 July.

Tawny Owl *Strix aluco*

Common breeding resident.

Up to two were seen and heard occasionally in every month except September and November. An individual was mobbed by jays on 29 March.

Swift *Apus apus*

Common summer visitor.

The first record was of one on 5 May and flocks were then seen regularly, often over the lake, until 26 August.

Kingfisher *Alcedo atthis*

Occasional non-breeding visitor.

One was recorded on 2 October.

Green Woodpecker *Picus viridis*

Occasional non-breeding visitor.

Individuals were heard calling on 26 January and 3 February, and thereafter up to two were seen and heard frequently from 9 March until 8 April. The lack of records after this date suggests that the pair left the reserve to breed elsewhere.

Great Spotted Woodpecker *Dendrocopos major*

Common breeding resident.

Up to six were recorded in every month but most frequently from January to June. Two pairs were identified and noted at their nests and feeding young. The feeding station was used regularly.

Skylark *Alauda arvensis*

Uncommon non-breeding species.

Recorded on 15 May and 14 and 20 June.

Sand Martin *Riparia riparia*

Common summer visitor.

The first record was of an individual on 15 April followed by further sightings of two on 26 August and four on 31 August.

Swallow *Hirundo rustica*

Common summer visitor.

The first record was of two on 26 April and thereafter flocks of up to thirty were noted regularly, sometimes over the lake. The last record was of eight on 14 September.

House Martin *Delichon urbica*

Common summer visitor.

The first record was of an individual seen over the lake on 15 April, and occasional flocks were noted until 2 July. The last record was of four on 22 September.

Pied Wagtail *Motacilla alba*

Uncommon breeding species.

There were six records of one or two individuals on 9 and 22 May, 17 and 20 June, 11 July and 11 November.

Wren *Troglodytes troglodytes*

Common breeding resident.

Recorded in every month except July, with a maximum of eight singing males on 11 March. Young were noted during the breeding season and one or two seen occasionally at the feeding station during the winter.

Dunnock *Prunella modularis*

Breeding resident in small numbers.

Recorded throughout the year but not during the summer (see Appendix), usually up to six at a time at the feeding station, but with a maximum of nine seen around the reserve on 23 March. Two males were noted singing on 22 March. Eighteen were ringed, including four adults.

Robin *Erithacus rubecula*

Common breeding resident.

Recorded in every month with a maximum of ten in early April. Frequent sightings were made during January, February and March, usually at the feeding station. Singing was heard during spring and a pair seen on 14 June, and juveniles were noted at the end of July and in the first half of August. Thirty-eight were ringed.

Blackbird *Turdus merula*

Common breeding resident.

Recorded in every month except July but most frequently at the feeding station during January, February and March, with a maximum of twenty on 4 February. Twenty-three were ringed.

Fieldfare *T. pilaris*

Common winter visitor.

There were six sightings during spring and autumn passage, including three at the feeding station on 12 February and a flock of ten on 28 October.

Song Thrush *T. philomelos*

Common breeding resident.

There were occasional sightings of up to four throughout the year (see Appendix), including one singing on 11 March, two pairs during May and a nest with eggs on 27 May.

Redwing *T. iliacus*

Common winter visitor.

Flocks of up to twenty were recorded on spring passage with two using the feeding station on 12 February and a flock of eight on autumn passage on 17 November.

Mistle Thrush *T. viscivorus*

Common breeding resident.

Occasional sightings of one or two were recorded throughout the year (see Appendix) with a pair and a family of six noted during the breeding season.

Grasshopper Warbler *Locustella naevia*

Uncommon breeding visitor.

Individuals were seen and heard occasionally from 30 April to 31 July but most frequently during May. Although there were no positive breeding records birds were again present throughout the breeding season; two juveniles were caught, possibly suggesting that the birds heard singing early in the year had bred (Hammock & Noble-Rollin,1991).

Sedge Warbler *Acrocephalus schoenobaenus*

Common breeding visitor.

Two were heard singing on 3 May, followed by regular sightings of groups, including eight males, until 4 August. The last record was of one on 3 September. Thirty-four juveniles and twenty-seven adults were ringed.

Reed Warbler *A. scirpaceus*

Uncommon breeding visitor.

Groups including two pairs were seen and heard regularly between 11 May and 4 August. Two males were present by 23 May and six singing males in June. Five juveniles and four adults were ringed.

Whitethroat *Sylvia communis*

Uncommon breeding visitor.

One was recorded on 26 May. Less frequent than in 1990 (Hammock & Noble-Rollin, 1991). None was ringed compared with four caught in 1990.

Garden Warbler *S. borin*

Regular breeding visitor.

The first record was of an individual singing on 17 May, then two were seen on 19 May and individuals seen or heard on 26 May and 11 and 16 June. Three were ringed.

Blackcap *S. atricapilla*

Common breeding visitor.

Up to six, including five males, were recorded regularly from 25 April to 21 July. Singing was noted and one juvenile seen on 8 July. Eleven juveniles and eight adults were ringed, the last on 15 September.

Wood Warbler *Phylloscopus sibilatrix*

Regular non-breeding summer visitor.

The first record was of one singing on 9 May, two were seen on 12 May and individuals on 10 and 28 May and 4 July. For the period that this species has been recorded it could be interpreted as breeding, but no real evidence such as food carrying or recently fledged young has been noted to support this speculation.

Chiffchaff *P. collybita*

Regular breeding summer visitor.

The first record was of one heard on 4 April, and thereafter up to three were seen and heard occasionally until 21 July. Three were ringed, the last one on 8 September.

Willow Warbler *P. trochilus*

Common breeding visitor.

The first record was of an individual on 10 April followed by regular groups of up to fourteen seen and heard until 16 June. Occasional sightings of one or two were then recorded until 31 August. Thirty-five juveniles and twenty-eight adults were ringed, the last on 8 September. This was the third most abundant species caught during the ringing programme.

Goldcrest *Regulus regulus*

Common winter and uncommon breeding resident.

Occasional sightings of up to ten were recorded during the winter months with an individual seen on 6 May. Only two were ringed, both during October.

Spotted Flycatcher *Muscicapa striata*

Uncommon breeding visitor.

A pair was recorded at the nest on 21 July, but it was found abandoned on 27 July.

Long-tailed Tit *Aegithalos caudatus*

Common breeding resident.

Recorded in every month except July, with regular sightings of small flocks of up to fifteen in December and in mixed flocks of tits. A family was noted on 23 June and birds seen occasionally at the feeding station during the winter. Seven were ringed.

Marsh Tit *Parus palustris*

Uncommon winter visitor.

Individuals were recorded on 3 March, 23 April and 5 and 6 October.

Willow Tit *P. montanus*

Common breeding resident.

Individuals and groups were recorded occasionally throughout the winter months (see Appendix) usually at the feeding station. A pair was noted on 3 May. Four were ringed.

Coal Tit *P. ater*

Common breeding resident.

Recorded in every month except July and September with flocks frequently noted at the feeding station during the winter months. A pair and young were seen during June. Five were ringed.

Blue Tit *P. caeruleus*

Common breeding resident.

Recorded in every month with flocks frequently seen at the feeding station during the winter months. Nests were noted and families seen between 23 June and 4 August. Ninety-seven were ringed.

Great Tit *P. major*

Common breeding resident.

Recorded in every month with flocks frequently seen at the feeding station during the winter months. Three pairs were noted and nests and young seen between 1 June and 2 July. Thirty-six were ringed.

Nuthatch *Sitta europaea*

Uncommon visitor.

One or two were recorded in every month but most frequently during winter and early spring, with birds seen at the feeding station in February and December. There was one record of three on 8 September.

Treecreeper *Certhia familiaris*

Common breeding resident.

Up to three were recorded from January to April, with a pair seen at their nest in April. A family was noted in August but subsequent records were of individuals, usually at the feeding station. Two were ringed.

Jay *Garrulus glandarius*

Common breeding resident.

Recorded regularly in every month often at the feeding station with numbers reaching a maximum of twenty-five in March when a flock was seen mobbing a tawny owl. A pair was noted in April and a juvenile seen fighting a sparrowhawk on 7 September. Seven were ringed.

Magpie *Pica pica*

Common resident, breeding adjacent to reserve.

Between one and four were recorded occasionally in every month, but there were two records of ten and one of twelve during autumn and winter. One was seen at the nest in April and individuals at the feeding station from October.

Rook *Corvus frugilegus*

Common winter visitor.

Recorded occasionally throughout the year (see Appendix). An immature was seen on 4 October and an individual at the feeding station on 10 December. A mixed pre-roost of 2,000 with jackdaws was noted on 9 February.

Carrion Crow *C. corone*

Common breeding resident.

Occasional records throughout the year except in May, with flocks reaching a maximum of seventy in December. Noted using the flooded field and the feeding station and seen on the nest near the Pearce Hide. On 20 April one was recorded as being mobbed by lapwings in the flooded field and on 18 August six were 'harried' by two sparrowhawks.

Jackdaw *C. monedula*

Common winter visitor.

Occasional records of individuals and flocks were noted in autumn and winter (see Appendix). A mixed pre-roost of 2,000 with rooks was seen on 9 February.

Starling *Sturnus vulgaris*

Common breeding resident.

Small groups were recorded occasionally during the year (see Appendix), mostly during March and April. In May a pair and a nest were noted. A flock was seen flying around the lake on 11 October and an individual noted on 20 February.

House Sparrow *Passer domesticus*

Uncommon breeding resident.

Seen regularly in the hawthorn hedge by the south path and the reserve entrance, particularly in late summer and autumn.

Tree Sparrow *P. montanus*

Uncommon visitor.

One was recorded on 7 July.

Chaffinch *Fringilla coelebs*

Common breeding resident.

Recorded in every month except July and September. Most frequently seen in flocks at the feeding station, with few records during the breeding season or early autumn.

Brambling *F. montifringilla*

Rare winter visitor.

Between 10 and 24 February up to eleven were recorded, usually at the feeding station. Individuals of both sexes were noted from 13 November to 18 December, again usually at the feeding station.

Greenfinch *Carduelis chloris*

Probable breeding resident.

Two sightings of two or three were recorded in March and a pair in May, followed by a family on 20 June. This is the first evidence of breeding (Noble-Rollin *et al.* in press) and combined with the observations made in Hammock & Noble-Rollin (1991) of a presence throughout the summer, a more suitable status of breeding resident could be recorded. An individual was seen at the feeding station on 3 December.

Goldfinch *C. carduelis*

Common visitor.

One or two were seen occasionally throughout the year but not in every month (see Appendix).

Siskin *C. spinus*

Common winter visitor.

Up to three were recorded on 16 and 17 February and three on 8 September. One was ringed on 27 July.

Linnet *C. cannabina*

Common visitor.

One was recorded on 12 June.

Redpoll *C. flammea*

Common resident.

Recorded occasionally throughout the year but not in every month (see Appendix). Numbers varied from single birds to a flock of fifteen on 26 December, with one at the feeding station on 8 and 26 December. Individuals were ringed on 30 June and 7 July.

Bullfinch *Pyrrhula pyrrhula*

Common breeding resident.

Individuals and small groups were recorded throughout the year but not in every month (see Appendix), occasionally at the feeding station. A family was noted on 10 August. Five were ringed.

Yellowhammer *Emberiza citrinella*

Common resident.

One or two were recorded occasionally between 9 March and 22 July. Two were ringed.

Reed Bunting *E. schoeniclus*

Common breeding resident.

Recorded in every month except November. but most frequently from February to July, usually in groups of up to twenty. Juveniles were noted on 4 July and a male was at the feeding station on 10 December. Thirty-three were ringed.

MAMMAL REPORT

Thirteen species were recorded throughout the year, with four records of unspecified small bats. Up to nine red squirrels *Sciurus vulgaris* were seen and although for security reasons, there was only one badger *Meles meles* record in the logbook, the population was active throughout the year and was monitored by the warden.

The roe deer *Capreolus capreolus* population appears to have increased slightly this year, and at least two sets of twin fawns have been seen.

Mink *Mustela vison* were recorded occasionally throughout the year thus confirming their presence in the reserve. During 1990 there had been signs of their activity, but no positive sightings were made (Hammock & Noble-Rollin, 1991).

The feeding station attracted rabbits *Oryctolagus cuniculus*, red squirrels, bank voles *Clethrionomys glareolus*, field voles *Microtus agrestis*, foxes *Vulpes vulpes* and roe deer.

SYSTEMATIC LIST

This follows the order and nomenclature of Corbet & Harris (1991).

Mole *Talpa europaea*

Dead individuals were recorded on 12 and 21 October.

Bats

Daubenton's *Myotis daubentoni*, **Noctule** *Nyctalus noctula*.

Six records of up to four unspecified small bats were noted from March to July. Four Daubenton's were seen on 11 April and several noctules on 9 May.

Rabbit *Oryctolagus cuniculus*

Recorded occasionally in every month with numbers peaking at ten in July. A juvenile was seen in June and individuals twice at the feeding station.

Red Squirrel *Sciurus vulgaris*

Recorded regularly in every month but most frequently in March and April, with numbers reaching a maximum of nine in April. Individual juveniles were noted twice in September and one was seen at the feeding station on 28 October.

Bank Vole *Clethrionomys glareolus*

Two were seen at the feeding station on 21 February and an individual noted on 13 March.

Field vole *Microtus agrestis*

Individuals were recorded at the feeding station on 15 and 27 January.

Fox *Vulpes vulpes*

One or two were recorded occasionally in every month. Four cubs appeared in May, and individuals were seen at the feeding station on 15 January and 17 November.

Weasel *Mustela nivalis*

Individuals were recorded on 24 and 30 March, 12 and 14 April and 4 May.

Mink *M. vison*

Up to three were recorded occasionally throughout the year but not in every month. A pair was noted near the Pyle hide from the end of January until mid February, after which the female remained throughout the summer and probably reared young. An individual was seen with prey, swimming in the new sluice on 14 June. These positive sightings have now confirmed the presence of mink and suggest that a breeding pair may be resident in the reserve.

Badger *Meles meles*

One was recorded on 20 August.

Feral Cat *Felis catus*

Individuals were recorded on 20 and 21 October.

Roe Deer *Capreolus capreolus*

Recorded regularly in every month with maximum counts in March, as in 1990. The total population was estimated at twenty-two adults (eighteen in 1990). The estimated male population reached seven (five in 1990), and the estimated female population reached fifteen (thirteen in 1990) (Hammock & Noble-Rollin, 1991).

A stranded female was retrieved from the police compound at Killingworth, and released into the reserve after receiving veterinary attention. A fawn was found dead on 14 July and another hand reared and successfully returned to the reserve, with a yellow ear tag, by the warden. At least two sets of fawns were produced this year. Two were seen at the feeding station on 17 February and one, a male, on 16 November.

ENTOMOLOGY SECTION FIELD MEETING REPORT

Traps were set during the evening of Friday 12 July and the catch identified on 13 July. Over thirty species were caught and the following identified:

GEOMETRIDAE
Apeira syringaria Lilac Beauty
Biston betularia (F. insularia) Peppered Moth
Cabera exanthemata Common Wave
Campaea marginata Light Emerald
Eulithis pyraliata Barred Straw
Hydriomena furcata July Highflier
Idaea aversata Riband Wave
Opisthograptis luteolata Brimstone Moth
Peribatodes rhomboidaria Willow Beauty
Xanthorhoe fluctuata Garden Carpet

HEPIALIDAE
Hepialus fusconebulosa Map-winged Swift
Hepialus lupulinus Common Swift

NOCTUIDAE
Agrotis exclamationis Heart and Dart
Amphipyra tragopoginis Mouse Moth
Apamea monoglypha Dark Arches
Diachrysia chrysitis Burnished Brass
Diarsia mendica mendica Ingrailed Clay
Euoxa nigricans Garden Dart
Graphiphora augur Double Dart
Mesapamea secalis Common Rustic
Mythimna ferrago Clay
Ochropleura plecta Flame Shoulder
Oligia strigilis Marbled Minor
Orthosia gothica Hebrew Character

NOTODONTIDAE
Pheosia gnoma Lesser Swallowtail Prominent
Ptilodon capucina Coxcomb Prominent

SPHINGIDAE
Laothoe populi Popular Hawkmoth

MICRO-MOTHS
Many micro-moths were encountered including the Grass Moths (PYRALIDAE) and the Tortrix Moths. Two which were easily identified were *Pandemis corylana* and *Nemophora degeerella*. In the latter the male has the largest antenna of all British moths.

MISCELLANEOUS

Lesser Celandine *Ranunculus ficaria*, Violet *Viola* sp., Primrose *Primula vulgaris*, Cowslip *Primula veris*, Tormentil *Potentilla erecta*, Bird's-foot Trefoil *Lotus* sp., Bush Vetch *Vicia sepium*, Bugle *Ajuga* sp., Dandelion *Taraxacum* sp., Bluebell *Hyacinthoides non-scripta*, Yellow Flag *Iris pseudacorus*.

Large White *Pieris brassicae*, Small White *Pieris rapae*, Orange Tip *Anthocharis cardamines*, Red Admiral *Vanessa atalanta*, Painted Lady *Vanessa cardui*, Meadow Brown *Maniola jurtina*, Small Heath *Coenonympha pamphilus*, Wall Brown *Lassiommata megera*, Small Copper *Lycaena phlaeas*, Common Blue *Polyommatus icarus*, Large Skipper *Ochlodes venatus*.

Blue-tailed Damselfly *Ischnura elegans*, Small Brown Dragonfly *Sympetrum* sp., Hawker Dragonfly (Aeshnidae).

Ruby-tailed Wasp *Chrysis ignita*.

Frog *Rana temporaria*.

ACKNOWLEDGEMENTS

The authors are very grateful to the members of Council for their support throughout the year, to Dr C. Redfern for the ringing report and to Mrs J. Holding for her illustrations. They would also like to thank I. D. Moorhouse, I. S. Davidson, D. Holgate, P. Drummond, Mrs J. Lindsay, J. T. Nicholson, Mrs M. Patterson, Dr C. Redfern, D. R. Shannon, E. Slack and A. M. Tynan of the Reserve Management Committee for their help in reviewing this report. Thanks also go to P. Drummond and his family, helpers and members of the working parties and to those who have acted as assistant wardens.

The following members have contributed to this report: E. Anderson, J. Annan, A. Atkinson, R. Atkinson, A. Baker, K. Barratt, K. Barry, S. Beeby, J. Bennett, K. Burns, P. Buskin, G. Carr, S. Chambers, D. Charlton, J. Charlewood, P. Charlewood, T. Cox, J. Craigie, I. S. Davidson, A. Davis, H. Dobson, M. Drummond, P. Drummond, S. Drummond, T. Dudding, G. Dudley, R. Ellis, J. Falcus, G. Ferguson, J. E. Fergusson, I. Fisher, D. Frain, J. Frain, P. Frain, M. P. Frankis, B. Gajdus, D. Gearing, M. T. Gerrard, A. A. Heinson, D. Heward, J. D. Holding, J. O. Holding, D. Holgate, K. Holgate, S. Holgate, J. Howar, K. Howar, M. Howar, A. Hull, C. Jackson, A. Johnston, A. Keys, J. Keys, M. H. Laurence, B. Law, S. Lee, D. Lockwood, A. Lowes, C. Lovel, R. Lovett, D. Matheson, J. Matheson, C. Mathewson, B. McCoy, F. Moorhead, I. D. Moorhouse, S. Mullan, S. Murtough, A. Nagel, A. Newson, M. Newson, S. Newson, E. Nicholson, J. Nicholson, D. Noble-Rollin, B. O'Doherty, D. O'Malley, P. O'Malley, M. Patterson, B. Rains, K. Rains, M. Rains, D. Rath, A. Reay, C. Redfern, W. Reeds, P. Ritson, D. Robertson, P. Robertson, L. Scott, R. Scott, V. Scott, E. Slack, M. Smith, G. Storey, P. Tankard, M. Toland, P. Wallbank, M. Yoland, L. Young.

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Appendix

Months in which each species was recorded in the reserve

B = Positive breeding record FS = Species seen at the feeding station

SPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	B	FS
Little Grebe	-	-	*	*	*	*	*	*	*	*	-	-	*	-
Grey Heron	*	*	*	*	*	*	*	*	*	*	*	*	-	-
Mute Swan	*	*	*	*	*	*	-	*	*	*	*	*	-	*
Greylag Goose	-	-	*	*	*	*	*	-	-	-	-	*	*	-
Canada Goose	-	-	*	*	*	*	*	*	*	*	-	-	*	-
Shelduck	-	-	*	*	-	-	-	-	-	*	-	-	-	-
Wigeon	-	*	*	*	-	-	-	*	*	*	*	*	-	-
Gadwall	-	-	*	*	-	-	-	-	*	*	-	*	-	-
Teal	*	*	*	*	*	-	-	*	*	*	*	*	-	-
Mallard	*	*	*	*	*	*	*	*	*	*	*	*	*	-
Pintail	-	-	-	-	-	-	-	-	-	-	-	*	-	-
Shoveler	-	-	*	-	-	-	-	-	*	*	-	-	-	-
Pochard	-	*	*	-	*	-	-	-	*	-	-	*	-	-
Tufted Duck	*	*	*	*	*	*	*	*	-	*	*	*	-	-
Goldeneye	-	-	-	-	-	-	-	-	-	-	*	*	-	-
Smew	-	-	-	*	-	-	-	-	-	-	-	-	-	-
Sparrowhawk	*	*	*	*	*	*	*	*	*	*	*	*	-	*
Kestrel	*	*	*	*	*	*	*	*	-	*	*	*	*	-
Grey Partridge	-	*	*	*	*	*	*	*	*	*	o	-	-	*
Pheasant	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Water Rail	*	*	*	+	-	-	*	*	-	*	*	*	-	*
Moorhen	*	*	*	*	*	*	*	*	*	*	*	*	*	-
Coot	*	*	*	*	*	*	*	*	*	*	*	*	*	-
Oystercatcher	-	-	^	+	-	-	^	-	-	-	-	-	-	-
Lapwing	-	*	o	o	*	*	-	o	-	-	-	-	-	-
Snipe	*	*	*	*	o	*	-	-	*	*	*	-	-	-
Woodcock	*	*	*	*	-	-	-	-	-	*	*	*	-	-
Curlew	-	-	o	-	-	-	-	-	-	-	-	-	-	-
Redshank	-	-	o	o	^	-	-	-	-	-	-	-	-	-
Green Sandpiper	-	-	-	-	-	-	-	-	*	-	-	-	-	-
Common Sandpiper	-	-	-	*	*	-	-	-	-	*	-	-	-	-
Black-headed Gull	-	*	o	-	-	*	*	*	*	*	-	-	-	-
Common Gull	-	o	o	-	-	*	*	*	-	-	-	-	-	-
L B-b Gull	-	-	o	^	*	*	-	-	*	-	-	-	-	-
Herring Gull	-	-	o	o	^	-	-	-	-	-	-	-	-	-
G B-b Gull	-	-	o	-	-	-	-	-	-	-	-	-	-	-
Common Tern	-	-	-	-	*	*	*	-	-	-	-	-	-	-
Stock Dove	-	-	-	*	*	-	-	-	*	-	*	-	-	-
Woodpigeon	*	*	*	*	*	-	*	*	*	*	-	*	-	*

SPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	B	FS
Cuckoo	-	-	-	-	-	+	*	-	-	-	-	-	-	-
Tawny Owl	+	*	*	+	+	+	*	*	+	+	-	*	-	-
Swift	-	-	-	-	*	*	*	*	-	-	-	-	-	-
Kingfisher	-	-	-	-	-	-	-	-	-	*	-	-	-	-
Green Woodpecker	+	+	*	+	-	-	-	-	-	-	-	-	-	-
G S Woodpecker	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Skylark	-	-	-	-	-	*	-	-	-	-	-	-	-	-
Sand Martin	-	-	-	*	-	-	-	*	-	-	-	-	-	-
Swallow	-	-	-	*	*	*	*	*	*	-	-	-	-	-
House Martin	-	-	-	*	*	*	*	-	-	-	-	-	-	-
Pied Wagtail	-	-	-	-	*	*	*	-	-	-	*	-	-	-
Wren	*	*	*	*	*	*	-	*	*	*	*	*	*	*
Dunnock	*	*	*	*	*	-	-	-	-	*	*	*	*	*
Robin	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Blackbird	*	*	*	*	*	*	-	*	*	*	*	*	*	*
Fieldfare	-	*	-	*	-	-	-	-	-	*	*	-	-	-
Song Thrush	-	-	*	*	*	-	-	*	*	-	-	-	*	-
Redwing	-	*	*	-	-	-	-	-	-	?	*	-	-	-
Mistle Thrush	-	-	*	-	*	*	*	-	-	-	*	-	*	-
G'hopper Warbler	-	-	-	*	*	-	*	-	-	-	-	-	-	-
Sedge Warbler	-	-	-	-	*	*	*	*	*	-	-	-	*	-
Reed Warbler	-	-	-	-	*	*	*	*	-	-	-	-	-	-
Whitethroat	-	-	-	-	*	-	-	-	-	-	-	-	-	-
Garden Warbler	-	-	-	-	*	*	-	-	-	*	-	-	-	-
Blackcap	-	-	-	*	*	*	*	-	*	-	*	-	*	-
Wood Warbler	-	-	-	-	*	-	*	-	-	-	-	-	-	-
Chiffchaff	-	-	-	*	*	*	*	-	*	-	-	-	-	-
Willow Warbler	-	-	-	*	*	*	*	*	*	-	-	-	*	-
Goldcrest	*	*	*	-	*	-	-	-	-	*	*	*	-	-
Spotted Flycatcher	-	-	-	-	-	-	*	-	-	-	-	-	*	-
L-t Tit	*	*	*	*	*	*	-	*	*	*	*	*	*	*
Marsh Tit	-	-	*	*	-	-	-	-	-	*	-	-	-	-
Willow Tit	*	-	*	*	*	-	-	-	-	*	*	*	-	*
Coal Tit	*	*	*	*	*	*	-	*	-	*	*	*	*	*
Blue Tit	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Great Tit	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Nuthatch	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Treecreeper	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Jay	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Magpie	*	*	*	*	*	*	*	*	*	*	*	*	-	-
Rook	-	*	-	*	*	-	-	-	-	*	-	*	-	*
Carrion Crow	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Jackdaw	-	*	*	-	-	-	-	-	-	*	-	*	-	-
Starling	-	*	*	*	*	-	-	-	-	*	-	-	*	-

SPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	B	FS
House Sparrow	see text													
Tree Sparrow	-	-	-	-	-	-	*	-	-	-	-	-	-	-
Chaffinch	*	*	*	*	*	*	-	*	-	*	*	*	*	*
Brambling	-	*	-	-	-	-	-	-	-	-	*	*	-	*
Greenfinch	-	-	*	-	*	*	-	-	-	-	-	*	*	*
Goldfinch	*	*	-	-	-	-	-	*	-	-	-	*	-	-
Siskin	-	*	-	-	-	-	-	-	*	-	-	-	-	-
Linnet	-	-	-	-	-	*	-	-	-	-	-	-	-	-
Redpoll	*	*	-	*	*	-	-	-	-	*	-	*	-	*
Bullfinch	*	*	*	-	*	-	-	*	-	*	*	*	*	*
Yellowhammer	-	-	*	*	*	-	*	-	-	-	-	-	-	-
Reed Bunting	*	*	*	*	*	*	*	*	*	*	-	*	*	*

* positive sightings
^ overhead
? unsubstantiated sightings

\+ heard singing or calling
o outside reserve

A SMALL COLLECTION OF FISHES FROM MADEIRA ISLAND DEPOSITED IN THE HANCOCK MUSEUM

by

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SUMMARY

Records of thirty species of marine fishes collected at Madeira Island by Mr D. C. Geddes in 1953-54 are reported along with their Madeiran vernacular names which he recorded at the time. Thirty-seven of the original forty-seven specimens making up the collection were among the zoological material of the late Lord Richard Percy stored in the Department of Zoology of the University of Newcastle upon Tyne. These specimens, belonging to twenty-six species from fifteen families, include a number of rare and interesting fishes and have been deposited in the Hancock Museum.

INTRODUCTION

Among the fish collections of the late Lord Richard Percy (1921-89) stored in the Department of Zoology of the University of Newcastle upon Tyne was an interesting collection of fishes obtained at Madeira Island by D. C. Geddes (a student in Zoology at King's College, University of Durham, who graduated with First Class Honours in 1955) in May 1953 and during August-September 1954. When the Department recently moved buildings this collection came to the author's attention. The original extent of the collection was ascertained from Lord Richard Percy's meticulous catalogue of specimens and associated manuscript notes. Of the forty-seven fish specimens listed, thirty-seven were found to be extant. The original identifications of these have been checked in the light of recent taxonomic work and the collection has now been relabelled, curated and placed in the Hancock Museum.

Mr Geddes purchased the fishes in the collection at Funchal fish market on the main island of Madeira (32° 40'N 16° 55'W) in late May 1953 and between 14 August and 7 September 1954. He made enquiries in each case as to the local names which he duly recorded. The collection contains a number of rare and interesting fishes, several of which are deep water forms which live at depths of 100m to 1000m. Such depths are found within a few kilometres of the coast of Madeira Island.

British naturalists have had a long tradition of collecting Madeiran fishes. Among the first was Daniel Solander, scientist on Captain Cook's first voyage on HMS *Endeavour*. On the outward journey in 1768 he collected thirty-five fish specimens from the Atlantic of which eighteen were from Madeira Island (Wheeler, 1984). Half a century later, Thomas Edward Bowdich (1791-1824), an intrepid African traveller visited the island. His *Excursions in Madeira and Porto Santo*... published by his wife Sarah a year after his early death in the Gambia contained a section on the fishes of Madeira (Bowdich, 1825) which included descriptions of several species new to science including two of those reported below. Before making his third and final voyage to Africa he spent time in Paris studying with the eminent French naturalist Georges Cuvier, who with his co-worker Achille Valenciennes originally described five others of the species reported below (Cuvier & Valenciennes, 1828-49). Richard Thomas Lowe (1802-74), who had graduated from Cambridge as a senior optime in 1825 and then taken holy orders, came to Madeira in 1828 for his health. He later became English chaplain there and stayed until 1854. He was a very talented naturalist and published on all aspects of the flora and fauna of the island, including seventeen papers and a book (Lowe, 1843-60) on the fishes of Madeira. He described over twenty new species of fish from Madeira including five of the species reported below. A few years later, James Yate Johnson, continuing the British tradition, published nine papers on the fishes of Madeira between 1862 and 1890 and a book on the natural history of the island. These nineteenth century works have resulted in the fishes of Madeira being one of the best known of the oceanic islands of the tropical and warm-temperate Atlantic (Briggs, 1974).

RECORDS OF FISHES FROM MADEIRA ISLAND

The specimens are identified by their Hancock Museum registration numbers, *e.g.* **HM F0602** and/or the original catalogue numbers assigned to them by Lord Richard Percy, *e.g.* RCP 2316. Length measurements of specimens are expressed either as standard length (SL) or as fork length (FL). After the scientific name of each species the vernacular name in use at Madeira (as reported by Mr Geddes) is given. A brief note of the geographic distribution of each species is also given and where pertinent the vernacular names gathered by Geddes are discussed. Lord Richard Percy's manuscript catalogue has also been deposited in the Hancock Museum (Accession number 10/1992).

Aulopodidae

Aulopus filamentosus (Bloch, 1792) Lagarto do rols

The name 'Lagarto de rolo' is applied to the superficially similar-looking lizard fish *Synodus saurus* (see below) according to Fowler (1936) who listed the common Madeiran name for this species as 'Lagarto do mar' [sea-lizard]. This deepwater benthic species is found on the continental shelf and slope to about 1000m depth and is known from Madeira, the Canaries, the coast of north-west Africa and the Mediterranean Sea.

RCP 2316, Funchal fish market, 14 August 1954 (specimen not found).

Synodontidae

Synodus saurus (Linnaeus, 1758) Lagarto do rols

Fowler (1936) noted the Maderian names for this species as 'Lagarto de rols' and 'Lagarto da costa' [lizard of the coast]. This species is known from the Mediterranean, the Azores, Madeira, Canaries, Cape Verde Islands and coast of Morocco in the eastern Atlantic and also occurs in the tropical western Atlantic.

RCP 2323, Funchal fish market, 1 September 1954. **HM F0601** (1: 255mm SL).

Polymixiidae

Polymixia nobilis Lowe, 1836 Salmonete de alto

This species was first described from Madeira but is now known from warm waters of both the western and eastern Atlantic at depths of 100-650m. It appears also to occur in the Indo-Pacific.

RCP 2318, Funchal fish market, 31 August 1954. **HM F0605** (1: 246mm SL).

Berycidae

Beryx decadactylus Cuvier, 1829 Alfonsin de costa larga

Widespread in warm waters at depths of 200-600m in both the Atlantic and Indo-Pacific.

RCP 2317, Funchal fish market, 31 August 1954. **HM F0593** (1: 290mm SL).

Beryx splendens Lowe, 1834 Alfonsin de costa streita

This specimen was first described from Madeira but is now known to be widespread in warm waters of the Atlantic and Indo-Pacific at 200-600m depth.

RCP 2315, Funchal fish market, 14 August 1954. **HM F0592** (1: 228mm SL).

Scorpaenidae

Pontinus kuhlii (T. E. Bowdich, 1825) Requeme

This species was first described from Madeira but is now known from the Bay of Biscay to Senegal in the eastern Atlantic and also from the Azores and Canary Islands. It tends to live at depths of 100-460m.

RCP 2338, Funchal fish market, 31 August 1954. **HM F0591** (1: 176mm SL) (one specimen not found).

Serranidae

Anthias anthias (Linnaeus, 1758) Castanheta do alto

Known from the subtropical and tropical eastern Atlantic and Mediterranean from the littoral to depths of 200m.

RCP 2327, Funchal fish market, 4 September 1954. **HM F0598** (2: 131.5, 134mm SL).

Mycteroperca fusca (Lowe, 1836) Badejo

Known from tropical and subtropical waters of both the eastern and western Atlantic.

RCP 2319, Funchal fish market, 31 August and 6 September 1954. **HM F0590** (2: 241, 252mm SL).

Serranus atricauda (Günther, 1874) Garoupa

Known from Madeira, Canary Islands, Azores, Mediterranean and eastern Atlantic coast between Portugal and Mauritania.

RCP 2320, Funchal fish market, 31 August 1954. **HM F0596** (2: 126, 138mm SL).

Priacanthidae

Heteropriacanthus cruentatus (Lacepède, 1801) Alfonsin do costa

Fowler (1936) noted the Madeiran name as 'Alfonsin de Rolo'. This species is circumtropical in distribution.

RCP 2330, Funchal fish market, 6 September 1954. **HM F0607** (1: 216mm SL).

Carangidae

Pseudocaranx dentex (Bloch and Schneider, 1801) Encharéu

Fowler (1936) spells the Madeiran name as Enxaréo. This species is widely distributed in the subtropics and fringes of the tropics in the Atlantic and Indo-Pacific Ocean.

RCP 2326 Funchal fish market, 1 and 6 September. **HM F0602** (1: 206mm FL) (one specimen not found).

Trachinotus ovatus (Linnaeus, 1758) Facaio

This species is widespread in the tropical and temperate eastern Atlantic. The local name recorded by Geddes differs from those attributed to Madeira by Fowler (1936).

RCP 2324, Funchal fish market, 1 September 1954. **HM F0586** (1: 198mm FL).

Trachurus picturatus (T. E. Bowdich, 1825) Chicharro

This species was first described from Madeira and is now also known from the Azores and the Canaries, the coast of Morocco and southern Portugal and the western Mediterranean.

RCP 2332, Funchal fish market, 6 September 1954. **HM F0583** (3: 140-154mm FL).

Coryphaenidae

Coryphaena hippurus (Linnaeus, 1758) Dourado

Fowler (1936) noted Madeiran name as 'Dourado macho'. This species occurs worldwide in tropical and subtropical seas.

RCP 2333, 2335, Funchal fish market, 7 September 1954. **HM F0603** (2: 468, 499mm FL).

Sparidae

Boops boops (Linnaeus, 1758) Boga

This species is widespread in the eastern Atlantic, being known from Norway to Angola. It occurs also in the Mediterranean Sea.

RCP 2339, Funchal fish market, 1 September 1954. **HM F0594** (1: 188mm SL) (one specimen not found).

Diplodus sargus cadenati de la Paz, Bauchot and Daget, 1974 Sargo

This subspecies of *Diplodus sargus* is known from the coast of West Africa from Gibraltar to Senegal, and from Madeira and the Canary Islands.

RCP 2328, Funchal fish market, end of May 1953 and 6 September 1954. **HM F0599** (2: 132, 132.5mm SL).

Diplodus vulgaris (E. Geoffroy St Hilaire, 1817) Seifia

This species is widespread in the subtropical east Atlantic.

RCP 2313, Funchal fish market, 14 August 1954 (two specimens not found).

Oblada melanura (Linnaeus, 1758) Dobrada

Known from the Mediterranean and widespread in the eastern Atlantic from the Bay of Biscay southwards to Angola.

RCP 2337, Funchal fish market, 14 August 1954. **HM F0595** (2: 132, 135mm SL).

Spondyliosoma cantharus (Linnaeus, 1758) Choupa

Known from the Mediterranean and widespread in the eastern Atlantic from Scandinavia to Angola.

RCP 2331, Funchal fish market, 4 and 6 September 1954. **HM F0600** (1: 168mm SL) (one specimen not found).

Pomacentridae

Chromis limbata (Valenciennes, 1833) Castanheta

This species is known from the Azores, Madeira, Canaries and coast of West Africa from Senegal to the Congo. The closely related *Chromis chromis* (Linnaeus) occurs in the Mediterranean and in the Atlantic along the southern coast of Spain and Portugal.

RCP 2314, Funchal fish market, 14 August 1954. **HM F0588** (2: 81, 89.5mm SL).

"Abudefduf luridus" (Cuvier, 1830) Castanheta preta

This species, although customarily placed in the genus *Abudefduf*, is not an *Abudefduf* and will form the type of a new genus being described by D. A. Hensley and J. Van Tassell. It was first described from Madeira and is now recorded from the Azores, Canaries, Cape Verde Islands and mainland coast of West Africa from Senegal to Ghana.

RCP 2341, Funchal fish market, 1 September 1954. **HM F0597** (2: 88.5, 101mm SL).

Sphyraenidae

Sphyraena sphyraena (Linnaeus, 1758) Bicuda

This species is widespread in the warm waters of the western and eastern Atlantic.

RCP 2322, Funchal fish market, 1 September 1954. **HM F0604** (1: 620mm SL).

Labridae

Bodianus scrofa (Valenciennes, 1839) Peixe cão

This species is known from Madeira, Canary Islands, Cape Verde Islands and mainland coast of West Africa in the vicinity of Cap Vert, Senegal.

RCP 2321, Funchal fish market, 31 August 1954. **HM F0584** (1: 194mm SL).

Centrolabrus trutta (Lowe, 1833) Truta verde

Fowler (1936) lists another Madeiran common name 'Truta do alto'. This species is known only from Madeira and the Canaries.

RCP 2342, Funchal fish market, end of May 1953. **HM F0589** (1: 135.5mm SL).

Xyrichtys novacula (Linnaeus, 1758) Papagaio

Known from the Mediterranean, the Azores, Madeira, Canary Islands and mainland coast of West Africa in the eastern Atlantic. Also widespread in the tropical western Atlantic.

RCP 2340, Funchal fish market, 1 September 1954. **HM F0587** (1: 131mm SL).

Scaridae

Sparisoma cretense (Linnaeus, 1758) Bodião

This species is known from the Azores, Madeira, Canary and Cape Verde Islands, from the Mediterranean, and from the mainland coast of West Africa southwards to at least Senegal.

RCP 2343, Funchal fish market, 6 September 1954. **HM F0585** (2: 124, 189mm SL).

Blenniidae

Ophioblennius atlanticus atlanticus (Valenciennes, 1836) Caboz

This subspecies of the amphi-Atlantic species *O. atlanticus* is known from Brazil, the central Atlantic islands of the Azores, St Paul's Rocks, Ascension and St Helena and is apparently widespread in the tropical and subtropical eastern Atlantic. Fowler (1936) lists another Madeiran common name, 'Cavallo'.

RCP 2334, Funchal fish market, 31 August 1954. **HM F0582** (1: 115mm SL).

Trichiuridae

Aphanopus carbo Lowe, 1839 Espada

Fowler (1936) lists also 'Espada preta' as a Madeiran common name. This benthopelagic species, which was first discovered at Madeira, is found between 20m and 1,600m depth. It is most common over the continental slope at about 200-650m, rising nearer the surface at night. It is widespread in the Atlantic and Pacific Oceans. *Espada* means 'sword', and *espada preta* means 'black sword'.

RCP 2329, Funchal fish market, 6 September 1954 (specimen not found).

Lepidopus caudatus (Euphrasen, 1788) Espada branca

Espada branca means 'white sword', an appropriate name for a cutlass-fish. This benthopelagic fish is generally found at 100–200m depth. It is probably worldwide in distribution.

RCP 2312, Funchal fish market, 14 August 1954 (specimen not found).

Scombridae

Scomber japonicus Houttyn, 1782 Cavala

This species is known from temperate and subtropical seas worldwide.

RCP 2325, Funchal fish market, 1 September 1954. **HM F0606** (1: 264mm FL) (one specimen not found).

ACKNOWLEDGEMENTS

I would like to thank Mr Peter Davis of the Hancock Museum for his considerable help with curating and relabelling the collection and the late Lord Richard Percy for his notes on the material and permission to re-examine the specimens.

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QUANTITATIVE SAMPLING OF COLEOPTERA IN NORTH-EAST WOODLANDS USING FLIGHT INTERCEPTION TRAPS

by

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SUMMARY

A flight interception trap was operated in Tyne and Wear in 1989 (Gosforth Park Woods) and 1990 (Lockhaugh Bank Wood). The Coleoptera collected, 2263 individuals in 239 species, include several species regarded as indicators of ancient woodland conditions as well as several rare species, some (*Colon zebei*, *Atomaria pulchra, Oligota apicata* and *Acalles roboris*) not previously recorded from Vice-County 66 (Durham). The trap catches are discussed in relation to previous knowledge of woodland beetle assemblages in north-east England and briefly compared with a previous study of flying Staphylinidae in northern England.

INTRODUCTION

The north-east of England lacks broad-leaved woodlands with assemblages of insects that approach the richness of those found at sites such as Sherwood, Windsor Forest and Great Park or the New Forest. For this reason, few thorough entomological studies have been made of north-east English woodlands.

By using the results of flight interception trapping at two sites, Gosforth Park Woods and Lockhaugh Bank Wood, this paper aims to provide some base-line data with respect to the richness and composition of woodland beetle assemblages in the area. At the same time the quantitative aspects of the results obtained represent part of the continuing evaluation and calibration of flight interception trapping as a means of comparing woodland insect faunas in Britain (see Hammond & Harding, 1991).

SURVEYING COLEOPTERA

As elsewhere, traditional methods of collecting beetles by beating, sweeping, sieving and searching have in the past resulted in extensive lists of beetle species being amassed for some sites in north-east England. For instance Luff and colleagues listed 450 species from Castle Eden Dene (Luff *et al.*, 1974; Luff & Sheppard, 1980), and 447 species were recorded from Gibside in the 19th century (Jessop & Eyre, 1992). Such traditional surveying is highly labour-intensive and the results achieved depend very much on the individual skills of the entomologists as well as the amount of time devoted to collecting.

Methods such as pitfall trapping, malaise trapping, canopy insecticide fogging and flight interception trapping collect specimens automatically and devote a quantifiable effort to trapping that allows comparison between one site or habitat and another (Eyre & Rushton, 1989, Luff *et al.*, 1989; Hutcheson, 1990).

Methods useful for gathering reliable quantitative data on forest insects, albeit in a tropical setting, are reviewed by Hammond (1990), while methods for sampling saproxylic invertebrates, *i.e.* those associated with wood decay, in British woodlands are discussed by Hammond & Harding (1991).

A flight interception trap is a means of continuously passively sampling populations of low-flying insects. It comprises a black fine-mesh (about 300 meshes cm^{-2}) plastic net suspended vertically, with preservative-filled trays placed on the ground along the bottom edge of the net. Beetles that hit the net during flight and fall downwards are collected in the trays. Catches may be larger if the net of the trap is treated with insecticide. Flight interception traps are further discussed and figured by Cooter (1991).

The trap has low visibility to most insects, but those that do not fall on meeting a barrier, including many Lepidoptera, aculeate Hymenoptera and Diptera, and a high proportion of plant-associated Coleoptera are not well-trapped. On the other hand, a flight interception trap is an extremely effective means of collecting beetles of many families, including those associated with slime mould fruiting bodies, with subterranean fungi, the nests of ants, *etc.* (see Hammond, 1990). Many of the species of beetles collected by flight interception traps are not often taken by other collecting methods.

As flight interception traps share with Malaise traps high visibility to humans and consequent high risk of theft or vandalism, the range of sites in which they can be placed is limited to areas of restricted public access.

STUDY SITES

GOSFORTH PARK

Gosforth Park Nature Reserve is an area of about 80ha lying at the northern outskirts of Newcastle upon Tyne. Habitats within the park include a lake with extensive *Phragmites* beds, alder carr, mixed broadleaved woodland planted in the 19th century and coniferous plantation dating from the mid-20th century. Dead and dying trees have not been removed from the broadleaved woodland, so it houses much timber in various stages of decay.

Other than Prestwick Carr Plantation, Gosforth Park is the only area of woodland of any notable extent in the boroughs of Newcastle and North Tyneside.

The entomological interest of Gosforth Park is already recognized: forty-seven species of invertebrates were listed in the Invertebrate Site Register (Ball, 1986), including three Red Data Book Category 3 species, one 'notable a', fifteen 'notable b' and twelve 'regionally notable' species (for the meaning of these categories, see below).

The park is a Site of Special Scientific Interest and is managed by the Natural History Society of Northumbria.

LOCKHAUGH BANK WOOD

Lockhaugh Bank Wood is an area of 7.5ha of mixed deciduous woodland in the lower Derwent Valley in Gateshead. It is part of the most extensive belt of woodland in the county of Tyne and Wear. Lockhaugh Bank Wood was recognized as an area of ancient broadleaved woodland by Cooke (1987) on the evidence of continuity of habitat on old and recent maps. Woodland is depicted at Lockhaugh in J. M. W. Turner's (1817-19) painting 'Gibside from the South' (in the Bowes Museum, Barnard Castle).

The wood contains a mixture of broadleaved tree species. There is evidence of extensive felling of the wood near the trapping site, probably about fifty years ago (S. McKelvey, *pers. comm.*). There are no large fallen trunks or overmature trees near the trap, but large quantities of dead birch branches of various sizes litter the ground.

Previous to this study, Lockhaugh Bank Wood was not known as a site of any particular importance for Coleoptera: there is no entry in the Invertebrate Site Register for this site and it has no formal designation as a site of natural interest. It is managed as part of the Derwent Walk Country Park, by Gateshead Borough Council's Parks Department.

METHODS

In 1989 a home-made flight interception trap with a net 156cm long and 106cm high was sited in Gosforth Park Nature Reserve at grid reference NZ259700. The trays (25cm x 15cm x 10cm deep) beneath the net were filled to a depth of two centimetres with ethylene glycol (blue anti-freeze).

The trap was sited at ground level on level ground with the net oriented east-west (*i.e.* facing south). The surrounding vegetation comprised broadleaved plantation woodland, dominated in the immediate vicinity by ash and oak, and with sparse undergrowth of low-growing vegetation, mainly grasses.

The trap was erected on 25 June 1989 and emptied at weekly intervals until 1 October. Weekly catches were kept separate.

A trap following the design of Hammond (1990) (see illustration in Hammond & Harding, 1991) was used in 1990. The net of this flight interception trap was 240cm long and 104cm high, about 50% larger than the home-made net used in 1989. The trap was placed in Lockhaugh Bank Wood (grid reference NZ173593) along a south-facing slope among oak and birch trees with an understorey of *Rubus*. The net was sited at ground level, oriented east-west. Trays and preservative were similar to those used at Gosforth. The trap was erected on 4 May and emptied at irregular (two-week or three-week) intervals until 1 October. Catches for each trapping period were kept separate.

In both years short series of the Coleoptera collected were mounted on card and longer series stored in spirit. Insects other than Coleoptera collected in 1989 were discarded, material from 1990 was retained in spirit for onward transmission to other specialists.

Coleoptera of most families were named by L. Jessop, using appropriate identification guides, and their identification checked against material in the Bold collection in the Hancock Museum, Newcastle. Aleocharine and a few other Staphylinidae were named by P. M. Hammond, Ptiliidae and Atomariinae by C. Johnson, Leiodidae by J. Cooter and *Meligethes* by A. Kirk-Spriggs.

RESULTS

A total of ninety-four species of Coleoptera was collected at Gosforth Park in 1989 and 204 species at Lockhaugh Bank Wood in 1990. In all, 234 species were detected: thirty-five of the species taken at Gosforth Park were not found at Lockhaugh Bank, while 134 of the species taken at Lockhaugh Bank were not found at Gosforth Park. The larger trap used at Lockhaugh Bank caught approximately 1.3 times as many individual Coleoptera and, over an identical period (9 July-10 October) some 2.2 times as many species.

Catch rates for the two sites are summarized in Table 1 and a list of species annotated with numbers of specimens trapped, seasonal data, indication of rarity and Ancient Woodland Indicator status forms is given in Appendix. Details of the number of specimens of each species caught in all trapping periods are held at Sunderland Museum.

DISCUSSION

Typically of flight interception trap catches many of the species taken, especially the more abundant, are substrate dwellers. Staphylinidae, with ninety-seven species, comprise the dominant family in the trap catch, whereas among the substrate dwellers the Carabidae are notably under-represented. Only eight carabid species were taken, two of which (*Cychrus caraboides* and *Pterostichus cristatus*) are flightless. Indeed, the only carabids on the list that fly at all regularly are *Dromius quadrimaculatus* and *Amara plebeja*, and the remaining species probably crawled into the trays.

Table 1

Trapping period and numbers of individuals and species trapped

Gosforth Park

	Number of trap days	Individuals per trap day	Species per trapping period
25 Jun- 1 Jul	7	3.1	16
2- 8 Jul	7	6.9	16
9-15 Jul	7	11.0	20
16-23 Jul	7	9.3	27
24-30 Jul	7	7.4	17
31 Jul- 6 Aug	7	7.1	20
7-13 Aug	7	8.1	17
14-20 Aug	7	6.7	16
21-27 Aug	7	6.0	12
28 Aug- 3 Sep	7	5.4	15
4-10 Sep	7	6.6	12
11-17 Sep	7	5.9	15
18-24 Sep	7	8.7	18
25 Sep- 1 Oct	7	4.1	8
Mean	7	6.9	16.4

Lockhaugh Bank Wood

	Number of trap days	Individuals per trap day	Species per trapping period
4-24 May	21	8.1	51
25 May- 6 Jun	13	11.9	65
7-20 Jun	14	19.9	69
21 Jun- 8 Jul	18	9.1	39
9-23 Jul	15	11.2	51
24 Jul-13 Aug	21	12.6	65
14-28 Aug	15	11.8	59
29 Aug-17 Sep	20	6.4	38
18 Sep- 1 Oct	14	5.6	25
Mean	16.8	10.7	51.3

Plant-associated species that are poorly sampled are, among the Coleoptera, mostly of the 'hit and stick' type, *i.e.* they have tarsi capable of ready adhesion and react quickly in attaching themselves to the surface on hitting the net. Some other beetles, like many Diptera, are of the 'hit and buzz' type, *i.e.* they may fall a little on hitting the net but do not stop flying like many Coleoptera, instead they buzz around in front of the trap wall.

Some species do not fly low enough to be caught (*e.g.* some woodland Buprestidae and Cerambycidae), but these may be relatively few in number.

Aquatic coleoptera are almost absent from these woodland traps, only one species of aquatic Hydrophilidae, *Helophorus brevipalpis*, being found.

Some of the species trapped are distinctly northern in their British distribution. *Anthophagus caraboides, Philonthus rotundicollis* and *Pterostichus cristatus* are absent from southern England, whereas *Philonthus puella, Tachinus pallipes, T. proximus, Leptusa pulchella, Atheta subtilis* and *A. brunneipennis* are rare in the south.

There were no superabundant species in trap catches at either site, and the abundant species were generally those found abundantly in flight interception traps in southern England (Hammond, unpublished). The two exceptions are *Tachinus pallipes*, a species that is rare in the south and *Aleochara stichai*, apparently local in the south. As in southern England, the activity of *Tachinus humeralis* is bimodal.

Comparing the two sites (over the comparable period of 9 July-1 October only) the five most abundant species at each site are all different. Coupled with the high proportion of species found uniquely at one or other (about 75%), this suggests that the sites are indeed very different.

RARE AND NOTABLE SPECIES

English Nature has graded insect species in a hierarchical system of rarity, the rarest species being listed in the Red Data Book (Shirt, 1987). To qualify for category RDB3 of the Red Data Book classification, the category that includes the least-rare species, a species must be present in fifteen or fewer 10km squares (0.5% of all squares in Britain).

Species whose British distribution probably includes thirty or fewer 10km squares are classified in Ball (1987) as 'notable a', and those occurring in one hundred or fewer as 'notable b'. The term 'local' is less well defined, but includes species that are less common or less widespread than those given the classification 'common'.

GOSFORTH PARK

Five 'notable b' species were taken, *Pterostichus cristatus, Leiodes litura, Philonthus rotundicollis, Enicmus testaceus* and *Anaspis thoracica*, of which the last four are newly recorded from Gosforth Park.

Pterostichus cristatus is a ground beetle that is not uncommon in north-east England, its distribution in Britain being centred on the Tyne, where it was probably introduced last century (Eyre *et al.*, 1986).

Philonthus rotundicollis is a northern species, which is probably under-recorded in the north-east: there are only three records in Ball (1987) but Bold (1871) described its north-east distribution as 'sparingly but generally spread'.

Enicmus testaceus is a specialist that feeds on slime moulds and spores, and is predominantly a southern species. It occurs in all types of woodland and is probably much overlooked: there is only one record from north-east England, from Gibside (Ball, 1987). Like other slime mould associates it is frequently collected in great numbers in flight interception traps.

Like other species of *Leiodes, L. litura* is associated with hypogeal fungi and thus, inevitably, under-recorded. It has a widespread distribution in Britain and was recorded by Bold from Wallington and Gosforth, but there are no recent records from the north-east.

Anaspis thoracica is a mainly southern species for which there is only one north-east record (from Haydon Dene) (Ball, 1987). It was recorded by Bold (1871) as "apparently rare". The adults are associated with blossom of various plant species and the larvae live under dead bark or in rotten wood.

A further seventeen local species collected are all additions to the known fauna of Gosforth Park.

LOCKHAUGH BANK

The Lockhaugh Bank list of rarities is considerably longer than that of Gosforth Park, and in addition includes two species classified as 'notable a': one male was taken of *Colon zebei* and two specimens of *Atomaria pulchra.*

Colon zebei is widely distributed in Britain but like many species of *Colon* is rarely collected and its ecology is only poorly understood: as far as is known, all *Colon* species are feeders on hypogeal fungi. It has not previously been recorded from Vice-County 66 (Durham).

Atomaria pulchra has been under-recorded in Britain because of the difficulty in separating species of *Atomaria.* Most species of *Atomaria* live among moss or vegetable detritus, but *A. pulchra* is reportedly ant-associated. This species is newly recorded for Vice-County 66, but has in recent years been found regularly in flight interception traps in British woodland.

Thirteen 'notable b' species were recorded from Lockhaugh Bank:

Colon brunneum is the most common British member of the genus, although Bold (1871) commented that this species is a 'rare insect with us'. The one modern record in Ball (1987) is from Castle Eden Dene.

Microscydmus nanus lives among decaying wood and leaves, and is probably much overlooked because of its minute size. The first and only other previous record of this species in Vice-County 66 was from Gibside by Walsh in 1919 (Ball, 1987).

Oligota apicata is one of the smallest of the British Staphylinidae, and likely to be overlooked by most collectors. The species appears to have a southern British distribution, and has not been recorded from Vice-County 66.

Malthodes mysticus was first added to the British list in 1866 by T. J. Bold, who had collected the species at Gibside. Its continued presence in Lockhaugh, across the river from the site of the former Gibside woods, is therefore of interest. The species is widespread in Britain, and there are three north-east records in the Invertebrate Site Register (Ball, 1987). Like other *Malthodes*, this species is predacious and lives openly on trees and shrubs.

Epuraea rufomarginata was said to be 'somewhat rare' by Bold (1871), and there are no recent records from the north-east. The species is widespread in Britain, being mainly found in faggots and under bark of fir trees.

Rhizophagus nitidulus is, according to Peacock (1977) commonest in the midlands of England and in western Scotland. There are two north-east records listed by Ball (1987). *R. nitidulus* is a woodland species found under bark and in association with lignicolous fungi.

Henoticus serratus was recorded by Bold (1871) from a wood near Washington, but has otherwise not been seen in the north-east. It is associated with decaying wood and fungi growing on wood, and is presumably a spore feeder like other Cryptophagidae.

Cis festivus is associated with hard bracket fungi. Bold (1871) recorded this species from three localities, and there is one modern north-east record, from Haydon Dene.

Hallomenus binotatus was described by Bold (1871) as being rare, and there are no modern north-east records. Associated with fungus on old trees, it is mainly restricted to old woodland.

Acalles roboris, a species normally found among dead twigs and faggots, has not been previously recorded from north-east England.

Dryocoetes autographus. The only known north-east record for this species is by Bagnall in 1905, from Gibside. Found, like other Scolytidae, under bark or in dead tree trunks, this species is normally associated with firs.

Philonthus rotundicollis, *Anaspis thoracica* and *Enicmus testaceus* (see above under Gosforth Park) were also found at Lockhaugh Bank.

A further forty-one species from Lockhaugh Bank are classed as local.

Two further species, though not rare, are of some interest. *Omalium rugatum* is the name now applied to an insect that Bagnall described as a new taxon, *Omalium caesum* var *sub ruficorne*, with Gibside as the type locality. When the specific status of *Omalium rugatum* was recognised in 1953 only three localities were known, but it has since been shown to be a widespread species (Allen, 1970). It is distinctly associated with woodland.

The sphindid species *Aspidiphorus orbiculatus* was caught in small numbers at both Gosforth and Lockhaugh. This species, which feeds on slime mould spores, is often collected by flight interception traps but overlooked by other collecting methods; it is probably to be found virtually everywhere that slime mould fruiting bodies occur. Bold (1871) recorded it as 'rare' in his *Catalogue of the Coleoptera of Northumberland and Durham*, but his record was, unusually, omitted by Fowler. Pope (1953) misleadingly summarized the distribution of this species as 'Southern England'.

THE INVERTEBRATE INDEX, AND HABITAT EVALUATION

In recent years, workers at Newcastle University have classified habitats in north-east England by means of the presence of invertebrate species, and subsequently defined the rarity and typicalness of those habitats (Eyre & Rushton, 1989; Luff *et al.*, 1989). Part of their process of habitat assessment involves counting the number of tetrads from which each species present at a site has been recorded in north-east England. This in turn relies on an extensive database for the distribution of the species being assessed: there are published databases for Carabidae and water beetles (Eyre *et al.*, 1985; Eyre *et al.*, 1986), but not for any other Coleoptera. Indeed, the difficulty of identifying species of groups such as aleocharine Staphylinidae means that there may never be information on their distribution in north-east England sufficiently detailed to allow their inclusion in habitat assessments of this type. Other species may be readily identifiable but because of their habits or habitat infrequently collected either by casual collecting or by traps.

A less precise method of site evaluation is to assess species that are present according to their national or regional rarity. The *Invertebrate Site Register* (Ball, 1986) uses a factor called The Invertebrate Index based on this approach. To calculate the index each rare species is allocated a score, as follows:

Category of species	Score
RDB 1, 2, 3, 5	100
RDB 4, pRDB	50
Notable a	50
Notable b	40
Notable r	40
Regionally notable	20

The total of scores for all species recorded from a site since 1950 is called The Invertebrate Index. An index value of 200 is the nominal limit set by English Nature to consider a site for Site of Special Scientific Interest status, but in practice this score is too low to facilitate significant comparison between sites.

The scores obtainable from the species collected in the flight interception trap are: for Gosforth Park, five 'notable b' species (5 x 40) = 200; for Lockhaugh Bank, thirteen 'notable b' and two 'notable a' species (13 x 40) + (2 x 50) = 600.

ANCIENT WOODLAND INDICATORS

Harding and Rose (1986) listed the British Coleoptera that they considered to be possible indicators of ancient woodland, their list being an update of Harding's earlier list (Harding, 1978). Species were graded by them into three categories:

Grade 1: species known to have occurred in recent times only in areas believed to be ancient woodland, mainly pasture-woodland.

Grade 2: Species that occur mainly in areas believed to be ancient woodland with abundant dead-wood habitats, but that also appear to have been recorded from areas that may not be ancient or for which locality data are imprecise.

Grade 3: Species that occur widely in wooded land, but that are collectively characteristic of ancient woodland with dead-wood habitats.

Although a 'national' list, the categorizations employed by Harding and Rose (1986) work well only for southern lowland British broad-leaved pasture woodland. Many of these indicator species are confined to southern England; for none of Harding and Rose's Grade 1 species is there a reliable north-east record, although one species assigned grade one status in Harding's earlier list (*Hylecoetus dermestoides*) has been recorded at Castle Eden Dene (Luff *et al.*, 1974).

Table 2

Ancient woodland indicator species from Lockhaugh Bank

	Northern AWI Grade (Garland, 1983)	National AWI Grade (Harding & Rose, 1986)
Agathidium nigripenne	2	-
Anisotoma humeralis	3	-
Cerylon ferrugineum	2	-
Enicmus testaceus	3	-
Glischrochilus hortensis	1	-
Hallomenus binotatus	2-3	3
Henoticus serratus	3	-
Rhizophagus ferrugineus	1-2	-
Rhizophagus nitidulus	1-2	3
Xyloterus domesticus	2-3	3

In an attempt to overcome this problem Garland (1983) re-assessed Harding's earlier list on the basis of conditions prevailing in the 'Sorby Area' (within about 30km radius of Sheffield) and took a first step towards the production of a list more suited to assessing woodland quality in northern England.

Of the ten ancient woodland indicator species present in the Lockhaugh Bank flight interception trap samples, three find a place in Harding and Rose's national list. The remaining seven, listed as indicators only by Garland, include some species that, in southern England at least, may be found regularly in secondary woodland (Table 2). The indicator value of one in particular, *Glischrochilus hortensis*, which is commonly found in garden compost heaps, is very questionable.

The list in Table 2 indicates strongly that Lockhaugh Bank Wood is indeed an ancient woodland relict. Only Castle Eden Dene and Gibside in north-east England have been shown to possess a more substantive ancient woodland beetle fauna (Jessop & Eyre, 1992). The Gibside fauna was extensively surveyed during the 19th century, but most of the wood has subsequently been clear-felled and we may assume that many of the beetle species no longer live there. The Castle Eden Dene woods are part of a National Nature Reserve, and the beetle fauna retains its interest.

Two of Garland's Grade 3 indicator species (*Anisotoma humeralis* and *Enicmus testaceus*) were also found in Gosforth Park. Both are slime mould associates that are much overlooked but of frequent occurrence in secondary woodland.

To allow for comparisons between sites, Alexander proposed a scoring system for ancient woodland indicator species (Welch, 1988, Hammond & Harding, 1991) giving three points for a grade 1 species, two for a grade 2 and one for a grade 3. An index can be calculated simply by summing the scores of all indicator species present. English sites with the highest calculated indices were Windsor Great Park and Forest (score of 228), the New Forest (168) and Moccas Park (91). The two best-known sites in north-east England are Gibside (16) and Castle Eden Dene (8). On the basis of the flight interception trap catches alone Lockhaugh Bank scores three and Gosforth Park zero.

In order to separate otherwise low-scoring northern woodlands Jessop and Eyre (1992) suggest the application of Alexander's scoring system to Garland's northern list, with a score of 2.5 assigned to species graded 1-2, and 1.5 to species graded 2-3. The regional index value for Lockhaugh Bank is 18, and for Gibside 67.

COMPARISON WITH AN UPLAND STAPHYLINID FAUNA

There is one previous published study of trapping for flying Coleoptera in north-east England: Bauer (1989a, b) sampled populations of flying Carabidae and Staphylinidae by means of window traps in two upland localities in the Northern Pennines, Moor House National Nature Reserve (NY7532) and Tailbridge Hill (NY8004).

Window traps are similar in principle to the flight interception traps employed in the present study, but the vertical component comprises two interlocking perspex sheets, each $0.5m^2$ in area. Bauer's traps were in place between April and October 1984 and 1985 at Moor House, and during 1986 at Tailbridge Hill.

In common with the present study, Bauer trapped few Carabidae (four species) and many Staphylinidae (sixty-five species). Detailed statistical analysis comparing these upland sites with the lowland woodlands is inappropriate because of differences in details of the trapping methods: Bauer's traps were much smaller than the flight interception traps, were solid rather than being made of net, were in place over three years and covered a longer season each year. A broad comparison of the species lists of Staphylinidae from the three sites (merging the faunal lists of Moor House and Tailbridge Hill as 'upland sites') shows that the similarity between the faunal lists of Lockhaugh and Gosforth is much greater (28% overlap) than between either of the wooded sites and the upland sites (16% and 12% respectively), while the proportion of species found at all three sites is very low (4%). The percentage of species unique to each site is high in the case of Lockhaugh (53%) and upland sites (65%) and lower for Gosforth (27%).

CONCLUSIONS

The trap catches show a clear disparity between Gosforth Park and Lockhaugh Bank woods, both in the numbers of species collected and in their quality in terms of their national rarity and as indicators of ancient woodland. This disparity cannot be explained purely on the difference in size of the two traps used, but must reflect in part the 'quality' of the two woods. In this respect it is ironic that the Gosforth Park woods form part of a Site of Special Scientific Interest, whereas the higher quality Lockhaugh Bank has no recognized status.

Flight interception trapping is clearly effective as a means of environmental recording in woodlands. In two seasons the traps collected 52% of the number of species taken in Castle Eden Dene (450) in three seasons by a team of surveyors using a variety of methods and of those taken at Gibside (447) over a fifty-year period of casual collecting. About 15% of all beetle species reported from north-east England (*ca* 1500) were sampled.

The usefulness of flight interception traps in comparative ecological studies has yet to be demonstrated fully, although initial comparison with samples of flying Staphylinidae from the North Pennines shows that it may be possible to categorize staphylinid faunas of broadly differing habitat types.

The lists of species obtained by flight interception trapping lend themselves to mathematical manipulation in the same way as pitfall trap catches (*e.g.* Luff *et al.*, 1989), but the time involved in processing the samples is high and if several sites are to be surveyed then it may be necessary to concentrate on only a part of the catch, for instance on fungivorous families.

ACKNOWLEDGEMENTS

Thanks are due to English Nature and the Secretary of the Natural History Society of Northumbria for allowing permission to site the flight interception trap in Gosforth Park, the curators of the Hancock Museum for allowing access to the Bold collection, and C. Johnson, J. Cooter and A. Kirk-Spriggs for identifying specimens.

The Lockhaugh Bank trap was set up and operated in conjunction with S. McKelvey of the Derwent Walk Country Park.

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Appendix

COMPARATIVE LIST OF THE TWO SITES, WITH THE STATUS OF EACH SPECIES

This table lists the total number of specimens collected in Gosforth Park and in Lockhaugh Bank, national status of each species (as in Ball, 1987) and its grade as an indicator of ancient woodland allocated by Garland, 1983 ('G') or Harding and Rose 1986 ('H').

Seasonality is indicated by month of occurrence: as most of the trap samples do not coincide precisely with calendar months, these data are slightly approximated.

	Gosforth Park	Lockhaugh Bank	Seasonality May	Jun	Jul	Aug	Sep	Status	A.W.I. Grade
Carabidae									
Cychrus caraboides	1	0	.	.	+	.	.	local	
Carabus problematicus	0	2	.	.	+	.	.	common	
Notiophilus biguttatus	1	0	.	.	.	.	+	common	
Amara plebeja	0	1	.	.	.	+	.	common	
Pterostichus cristatus	1	0	.	.	.	+	.	notable b	
Pterostichus madidus	0	8	+	.	+	+	+	common	
Calathus piceus	0	1	.	.	.	+	.	common	
Dromius quadrimaculatus	1	0	.	.	.	.	+	common	
Hydrophilidae									
Helophorus brevipalpis	1	1	.	.	.	+	.	common	
Cercyon analis	1	0	+	.	.	.	.	common	
Cercyon atomarius	0	1	+	.	.	.	.	common	
Cercyon lateralis	0	18	+	+	.	+	+	common	
Cercyon melanocephalus	0	2	.	+	.	+	.	common	
Megasternum obscurum	1	0	.	.	.	+	.	common	
Cryptopleurum minutum	1	0	.	.	+	.	.	common	
Histeridae									
Hister striola	9	3	+	+	.	+	.	common	
Ptiliidae									

(The species of this family are extremely difficult to separate. Three specimens were taken in Gosforth Park but destroyed during dissection by L. J. The specimens from Lockhaugh were identified by C. Johnson. All of the species are common and widespread in Yorkshire (Johnson, 1990) except *Acrotrichis rugulosa*, which is said to be "very local and scarce, though once in large numbers".)

	Gosforth Park	Lockhaugh Bank	May	Jun	Jul	Aug	Sep	Status	A.W.I. Grade
Ptenidium nitidum	0	4	.	+	+	+	.	common	
Acrotrichis cognata	0	22	.	+	+	+	+	common	
Acrotrichis danica	0	3	.	.	+	+	.	common	

	Gosforth Park	Lockhaugh Bank	May	Jun	Jul	Aug	Sep	Status	A.W.I. Grade
Acrotrichis fascicularis	0	2	.	+	.	.	.	common	
Acrotrichis grandicollis	0	2	.	.	.	+	.	common	
Acrotrichis insularis	0	1	.	.	+	.	.	common	
Acrotrichis intermedia	0	1	.	.	+	.	.	common	
Acrotrichis rosskotheni	0	5	.	+	.	+	.	common	
Acrotrichis rugulosa	0	2	+	+	.	.	.	local	
Acrotrichis sp. *indet.*	3	0	.	+	+	.	.		
Leiodidae									
Leiodes litura	1	0	.	.	.	+	.	notable b	
Leiodes polita	1	0	.	+	.	.	.	local	
Anisotoma humeralis	8	56	+	+	+	+	+	local	G.3
Anisotoma orbicularis	3	17	.	+	+	+	.	local	
Agathidium nigripenne	0	5	+	+	.	.	.	local	G.2
Agathidium rotundatum	0	2	+	+	.	.	.	local	
Agathidium varians	3	2	+	.	.	+	+	local	
Colon brunneum	0	1	.	+	.	.	.	notable b	
Colon zebei	0	1	+	.	.	.	.	notable a	
Cholevidae									
Choleva angustata	0	1	+	.	.	.	.	common	
Sciodrepoides watsoni	12	46	+	+	+	+	+	common	
Catops morio	68	9	.	+	+	+	+	common	
Catops nigrita	0	4	+	+	.	.	.	common	
Silphidae									
Nicrophorus vespilloides	2	17	+	+	+	+	.	common	
Scydmaenidae									
Stenichnus collaris	1	0	.	.	.	+	.	common	
Microscydmus nanus	0	1	.	.	+	.	.	notable b	
Staphylinidae									
Proteininae									
Megarthrus depressus	0	3	+	.	+	+	.	common	
Megarthrus sinuatocollis	0	5	+	+	.	+	.	common	
Proteinus brachypterus	5	3	.	.	.	.	+	common	
Proteinus macropterus	0	1	.	.	.	+	.	local	
Proteinus ovalis	0	3	+	.	.	.	.	common	

	Gosforth Park	Lockhaugh Bank	Seasonality					Status	A.W.I. Grade
			May	Jun	Jul	Aug	Sep		
Omaliinae									
Acrulia inflata	0	1	+	.	.	.	.	local	
Anthophagus caraboides	25	0	.	+	+	+	+	local	
Lesteva longoelytrata	0	8	+	+	.	.	.	common	
Omalium caesum	0	1	+	.	.	.	.	common	
Omalium italicum	6	0	.	+	.	.	.	local	
Omalium rivulare	0	2	+	+	.	.	.	common	
Omalium excavatum	0	2	.	.	+	.	.	common	
Omalium rugatum	0	2	.	.	.	.	+	local	
Xylodromus concinnus	3	0	.	.	+	.	.	common	
Acrolocha sulcula	0	1	.	.	.	+	.	local	
Phloeonomus pusillus	0	1	+	.	.	.	.	common	
Philorhinum sordidum	0	1	.	+	.	.	.	local	
Oxytelinae									
Anotylus rugosus	2	1	.	+	+	.	.	common	
Anotylus sculpturatus	0	5	+	+	.	+	.	common	
Anotylus tetracarinatus	1	6	.	.	.	+	.	common	
Oxytelus sculptus	0	1	.	.	.	.	+	common	
Steninae									
Stenus impressus	2	0	.	.	.	.	+	common	
Paederinae									
Rugilus erichsoni	0	1	+	.	.	.	.	common	
Staphylininae									
Xantholinus glabratus	1	0	.	.	+	.	.	common	
Philonthus addendus	0	7	+	.	.	+	.	local	
Philonthus cognatus	0	1	.	.	+	.	.	common	
Philonthus decorus	0	1	+	.	.	.	.	common	
Philonthus fimetarius	157	73	+	+	+	+	+	common	
Philonthus laminatus	2	0	.	.	+	+	.	common	
Philonthus marginatus	8	2	+	.	+	.	.	common	
Philonthus puella	1	0	.	.	.	+	.	local	
Philonthus rotundicollis	1	2	.	.	+	+	.	notable b	
Philonthus succicola	1	20	+	.	+	+	+	common	
Philonthus tenuicornis	1	0	.	.	+	.	.	common	

	Gosforth Park	Lockhaugh Bank	Seasonality May	Jun	Jul	Aug	Sep	Status	A.W.I. Grade
Ontholestes tessellatus	1	0	.	.	+	.	.	common	
Quedius cinctus	4	0	.	.	.	.	+	common	
Quedius fumatus	0	5	+	+	.	.	.	common	
Quedius lateralis	3	4	.	.	.	+	+	local	
Quedius mesomelinus	0	3	+	+	.	+	.	common	
Quedius scintillans	1	0	.	.	.	.	+	common	
Tachyporinae									
Mycetoporus lepidus	2	0	.	.	+	+	.	common	
Lordithon exoletus	72	1	.	.	+	+	+	local	
Lordithon lunulatus	12	4	.	.	+	+	+	common	
Lordithon thoracicus	40	1	.	.	+	+	+	common	
Bolitobius analis	0	1	.	.	.	+	.	common	
Tachyporus hypnorum	1	2	.	.	+	+	.	common	
Tachyporus nitidulus	2	1	.	.	.	+	+	common	
Tachinus humeralis	79	22	.	+	+	+	+	common	
Tachinus laticollis	5	20	+	+	+	+	+	common	
Tachinus marginellus	3	1	.	+	+	.	.	common	
Tachinus subterraneus	0	4	+	+	.	.	+	unknown	
Tachinus signatus	0	10	.	.	+	.	.	common	
Tachinus pallipes	0	62	+	+	+	+	.	local	
Tachinus proximus	0	5	.	+	+	.	+	local	
Aleocharinae									
Oligota apicata	0	3	.	+	+	.	.	notable b	
Gyrophaena fasciata	0	1	.	.	+	.	.	common	
Gyrophaena gentilis	4	1	.	.	.	+	+	common	
Gyrophaena latissima	0	6	+	.	.	.	+	common	
Gyrophaena strictula	0	1	.	+	.	.	.	local	
Leptusa fumida	0	1	.	.	.	+	.	common	
Leptusa pulchella	0	5	.	.	+	.	.	local	
Leptusa ruficollis	0	2	+	.	+	.	.	common	
Bolitochara obliqua	0	7	+	+	.	.	.	common	
Autalia impressa	2	1	.	.	.	.	+	common	
Autalia longicornis	0	6	.	.	.	.	+	common	
Aloconota gregaria	1	4	+	.	.	+	.	common	

	Gosforth Park	Lockhaugh Bank	Seasonality May	Jun	Jul	Aug	Sep	Status	A.W.J. Grade
Geostiba circellaris	0	1	.	+	.	.	.	common	
Atheta amplicollis	1	10	+	+	+	+	+	common	
Atheta brunneipennis	0	17	+	+	+	+	.	local	
Atheta cadaverina	0	1	.	.	.	+	.	common	
Atheta castanoptera	1	59	+	+	+	+	+	common	
Atheta cinnamoptera	0	40	+	+	+	+	.	local	
Atheta crassicornis	6	62	+	+	+	+	+	common	
Atheta excelsa	0	1	.	.	.	+	.	local	
Atheta hepatica	0	2	+	.	.	.	.	local	
Atheta hypnorum	0	1	.	.	.	+	.	common	
Atheta luridipennis	0	1	.	+	.	.	.	local	
Atheta nigricornis	0	2	.	.	+	+	.	common	
Atheta nigripes	0	2	.	.	.	.	+	common	
Atheta pallidicornis	1	0	.	.	+	.	.	common	
Atheta palustris	0	1	.	+	.	.	.	common	
Atheta parvula	0	3	.	+	.	+	.	common	
Atheta pertyi	0	5	.	+	+	+	.	common	
Atheta repanda	1	0	.	.	.	.	+	common	
Atheta ravilla	0	3	.	+	.	+	.	common	
Atheta sodalis	1	6	+	+	+	+	.	common	
Atheta subtilis	2	1	+	+	+	.	.	local	
Atheta trinotata	0	2	.	.	+	+	.	common	
Atheta xanthopus	1	1	.	.	+	+	.	common	
Ocalea picata	0	1	.	.	.	+	.	common	
Oxypoda alternans	3	15	.	+	.	.	+	common	
Oxypoda opaca	0	1	+	.	.	.	.	common	
Oxypoda umbrata	0	7	+	.	+	+	.	common	
Haploglossa pulla	0	1	.	+	.	.	.	common	
Tinotus morion	0	1	.	.	.	+	.	common	
Aleochara lanuginosa	1	2	.	+	.	+	.	common	
Aleochara stichai	0	83	+	+	+	+	+	?local	
Pselaphidae									
Bibloporus bicolor	4	4	+	+	+	+	+	common	
Euplectus piceus	0	3	+	+	.	.	.	common	

	Gosforth Park	Lockhaugh Bank	May	Jun	Jul	Aug	Sep	Status	A.W.I. Grade
Scarabaeidae									
Aphodius depressus	0	1	.	.	.	+	.	common	
Aphodius rufipes	0	14	+	+	+	+	+	common	
Scirtidae									
Cyphon coarctatus	1	0	.	.	.	+	.	common	
Elateridae									
Melanotus erythropus	0	1	+	.	.	.	.	common	
Athous haemorrhoidalis	2	6	+	+	+	.	.	common	
Dalopius marginatus	5	11	+	+	+	+	.	common	
Agriotes pallidulus	0	210	+	+	+	+	.	common	
Denticollis linearis	0	5	+	+	+	.	.	common	
Cantharidae									
Cantharis decipiens	0	1	+	.	.	.	.	common	
Cantharis nigricans	0	3	+	.	.	+	.	common	
Rhagonycha lignosa	0	1	+	.	.	.	.	common	
Malthinus flaveolus	0	11	.	+	+	+	.	common	
Malthodes marginatus	1	1	+	+	.	.	.	common	
Malthodes minimus	3	0	.	+	+	.	.	common	
Malthodes mysticus	0	3	.	.	+	+	.	notable b	
Malthodes pumilus	0	1	.	+	.	.	.	local	
Anobiidae									
Ptilinus pectinicornis	0	5	.	+	+	+	.	local	
Nitidulidae									
Meligethes aeneus	18	42	+	+	+	+	.	common	
Meligethes brunnicornis	0	2	+	+	.	.	.	common	
Epuraea aestiva	2	5	+	.	+	.	.	common	
Epuraea deleta	0	6	.	.	+	+	+	common	
Epuraea pusilla	0	74	+	+	+	.	+	common	
Epuraea rufomarginata	0	14	.	+	+	+	.	notable b	
Epuraea unicolor	0	1	.	.	.	.	+	common	
Pocadius ferrugineus	1	1	.	+	+	.	.	common	
Omosita depressa	0	2	.	.	.	.	+	local	
Soronia grisea	0	2	.	+	.	.	.	local	
Glischrochilus hortensis	0	1	.	.	.	+	.	common	G.1

	Gosforth Park	Lockhaugh Bank	May	Jun	Jul	Aug	Sep	Status	A.W.I. Grade
Rhizophagidae									
Rhizophagus bipustulatus	0	4	+	+	.	.	.	common	
Rhizophagus dispar	0	2	.	.	+	.	.	common	
Rhizophagus ferrugineus	0	2	+	+	.	.	.	local	G.1-2
Rhizophagus nitidulus	0	1	+	.	.	.	.	notable b	G.1-2 /H.2
Monotoma longicollis	0	2	+	.	.	.	.	local	
Sphindidae									
Aspidiphorus orbiculatus	1	3	.	.	+	+	+	local	
Cryptophagidae									
Henoticus serratus	0	1	.	.	.	+	.	notable b	G.3
Micrambe vini	0	1	.	+	.	.	.	common	
Cryptophagus badius	1	0	.	.	.	.	+	local	
Cryptophagus dentatus	0	6	.	.	.	+	+	common	
Cryptophagus pallidus	0	1	.	+	.	.	.	common	
Cryptophagus pubescens	2	7	.	.	+	+	.	common	
Cryptophagus scanicus	0	2	.	.	.	.	+	common	
Cryptophagus setulosus	1	0	.	.	.	+	.	local	
Caenoscelis subdeplanata	0	5	+	+	.	+	.	local	
Atomaria atricapilla	14	1	.	.	+	+	.	common	
Atomaria fuscata	1	2	.	.	.	+	+	common	
Atomaria nitidula	4	2	.	.	+	.	.	local	
Atomaria pulchra	0	2	+	.	.	.	.	notable a	
Byturidae									
Byturus tomentosus	0	6	.	.	+	+	+	common	
Cerylonidae									
Cerylon ferrugineum	0	1	.	.	.	+	.	local	G.2/H.3
Coccinellidae									
Adalia bipunctata	1	0	.	.	.	.	+	common	
Adalia decempunctata	1	2	.	.	+	+	+	common	
Lathridiidae									
Stephostethus lardarius	3	3	+	.	+	+	.	common	
Aridius bifasciatus	5	12	+	+	+	+	+	common	
Aridius nodifer	2	57	+	+	+	+	+	common	
Enicmus fungicola	0	1	+	.	.	.	.	local	

	Gosforth Park	Lockhaugh Bank	Seasonality May	Jun	Jul	Aug	Sep	Status	A.W.I. Grade
Enicmus histrio	4	2	+	+	+	+	+	local	
Enicmus testaceus	4	3	+	.	+	+	.	notable b	G.3
Corticaria elongata	2	0	.	+	.	.	.	common	
Cortinicara gibbosa	1	1	.	.	.	.	+	common	
Corticarina similata	0	1	.	.	.	.	+	common	
Cisidae									
Cis boleti	1	7	+	+	.	+	+	common	
Cis festivus	0	1	.	.	+	.	.	notable b	
Octotemnus glabriculus	0	4	+	+	+	.	.	common	
Salpingidae									
Vincenzellus ruficollis	0	4	.	+	+	.	+	local	
Rhinosimus planirostris	0	2	+	.	.	+	.	common	
Melandryidae									
Hallomenus binotatus	0	1	.	.	+	.	.	notable b	G.2-3 /H.3
Scraptiidae									
Anaspis maculata	0	1	+	.	.	.	.	common	
Anaspis regimbarti	1	0	.	.	+	.	.	common	
Anaspis rufilabris	7	1	.	.	+	+	.	common	
Anaspis thoracica	6	4	.	+	+	+	.	notable b	
Cerambycidae									
Rhagium mordax	0	2	+	+	.	.	.	local	
Grammoptera ruficornis	0	3	+	.	+	.	.	common	
Chrysomelidae									
Phyllotreta nemorum	0	1	.	.	+	.	.	common	
Longitarsus luridus	0	13	+	.	.	+	+	common	
Longitarsus melanocephalus	0	3	.	.	.	+	+	common	
Batophila rubi	0	1	.	+	.	.	.	local	
Chaetocnema concinna	2	1	.	+	.	+	+	common	
Psylliodes napi	1	0	.	.	.	.	+	common	
Apionidae									
Apion curtirostre	0	1	+	.	.	.	.	common	
Apion subulatum	0	1	.	.	.	.	+	common	
Apion ulicis	0	1	.	+	.	.	.	common	
Apion viciae	1	0	.	.	.	.	+	local	

	Gosforth Park	Lockhaugh Bank	May	Jun	Jul	Aug	Sep	Status	A.W.I. Grade
Curculionidae									
Otiorhynchus singularis	0	4	.	+	.	+	+	common	
Phyllobius argentatus	1	2	.	+	+	+	.	common	
Phyllobius pyri	0	1	+	.	.	.	.	common	
Barypeithes pellucidus	0	2	.	+	+	.	.	common	
Strophosomus melanogrammus	0	3	.	.	+	+	+	common	
Leiosoma deflexum	0	7	+	+	+	+	.	common	
Euophryum confine	0	2	+	.	.	+	.	common	
Acalles roboris	0	1	.	+	.	.	.	notable b	
Coeliodes rubicundus	0	3	+	+	.	+	.	common	
Ceuthorrhynchus assimilis	0	4	.	.	+	+	.	common	
Curculio pyrrhoceras	0	1	+	.	.	.	.	common	
Rhynchaenus fagi	0	2	+	.	.	.	.	common	
Rhynchaenus quercus	1	0	.	.	.	+	.	common	
Scolytidae									
Xyloterus domesticus	0	1	.	+	+	+	+	local	G.2-3 /H.3
Dryocoetes autographus	0	1	+	.	.	.	.	notable b	
Total number of specimens	684	1579							
Total number of species	94	204							

SOME NEW OCCURRENCES OF BARYTOCALCITE IN THE NORTHERN PENNINE OREFIELD

by

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SUMMARY

Two new occurrences of barytocalcite are described from the northern Pennine orefield: Ouston Mine, West Allendale, Northumberland and California Mine, Teesdale, Co Durham. Descriptions of newly collected specimens from Settlingstones Mine, Northumberland are also presented. Pseudomorphs of barytocalcite after baryte from Ouston and Blagill mines suggest that a previous mineralizing event in which primary baryte was replaced by witherite may locally have produced significant quantities of barytocalcite.

INTRODUCTION

Barytocalcite, the monoclinic dimorph of barium calcium carbonate ($BaCa(CO_3)_2$), is a rare mineral which was first described by Brooke (1824) from specimens thought to have been obtained from Blagill mine, Alston. Although since reported from the Himmelsfurst mine, Freiberg, Germany (Palache *et al.*, 1951, p. 221) and Langban, Sweden (Roberts *et al.*, 1990, p.72) recorded occurrences remain almost wholly confined to the English Pennines. Barytocalcite has been identified in small quantities from a handful of veins in the Yorkshire Pennines (Dunham & Wilson, 1985, p. 93) but in the northern Pennines between the Tyne valley and Stainmore it is present in a considerable number of veins in the outer barium zone of the orefield (Young, 1985). At Blagill, its probable type locality, it is the main constituent of a vein up to 3.0m wide (Dunham, 1990, p. 78) and in a recent review of barium carbonate minerals in the orefield Young (1985) has shown it to be a major constituent of several other veins. Described below are descriptions of two occurrences of barytocalcite within the orefield which have been discovered since the publication of this review and new observations on the form and paragenesis of the mineral from two previously described localities.

Ouston Mine, Ninebanks, West Allendale, Northumberland [NY 775 531]

The ENE trending Ouston vein, the northernmost mapped vein in West Allendale, has been explored in a level driven above the Great Limestone on the west side of the valley. The dump is composed mainly of dark grey shale though a few blocks of limestone are also present adding support to Dunham's suggestion (1990, p. 151) that trial sumps were sunk into the Great Limestone.

Vein minerals are scarce on the dump: most abundant are white tabular baryte, calcite and a little galena. A few specimens of barytocalcite have also been obtained. In most of these the barytocalcite occurs as fine-grained, rather sugary, white to colourless crystalline masses which clearly post-date coarsely crystalline rhombic calcite and galena.

Locally small vugs, up to 5mm across, within this material are lined with sharply terminated white to colourless monoclinic crystals, up to 0.25mm long. In some examples several crystals are united into small fan-like aggregates.

A few specimens have been collected which at first sight resemble very rough, weathered, aggregates of tabular baryte crystals up to 50mm across. When broken these are seen to consist of fine-grained, granular, crystalline barytocalcite almost identical to that already described. One or two small vugs up to 2mm across have been observed in this material. These are also lined with sharply terminated colourless monoclinic crystals up to 0.25mm long. In these specimens the barytocalcite is clearly pseudomorphing an earlier mineral. The outer surfaces are very rough and weathered and whereas they exhibit no clear indication of original crystal faces, the overall form is most reminiscent of baryte. Young (1985, p. 204) commented that no instances had then been found of either barytocalcite, or its dimorph alstonite, replacing or pseudomorphing an earlier mineral. These specimens from Ouston and those described below from Blagill give strong evidence that barytocalcite locally replaces original tabular baryte.

California Mine, Eggleston, Teesdale, Co Durham [NY 990 315]

Lead ore-bodies within the roughly E-W trending Little Eggleshope Vein in Namurian sandstone wall-rocks were worked last century at California Mine. Fluorite and quartz were the main gangue minerals at California where the vein lies within the outer part of the fluorite zone of the orefield. Dunham (1948, p. 309) observed that baryte was present only in the very highest workings at California.

A single specimen of barytocalcite has been collected from a small excavation in the dump from a trial level [NY 9900 3153] driven to Little Eggleshope Vein, near the head of a left bank tributary of Little Eggleshope Beck. This trial is the highest working in the vein. The mineral here forms a white to colourless compact crystalline mass composed of crudely radiating subhedral, rather tabular crystals, up to about 2mm long: the radiating form is most apparent on weathered surfaces. No other minerals are associated with the barytocalcite in this specimen and it is therefore impossible to comment on the position of the mineral in the vein's paragenesis. Apart from this single specimen of barytocalcite no other barium carbonate minerals have been obtained from the dump despite a careful search. The original presence in the vein of barium carbonate minerals may however be inferred from the occurrence here of abundant fragments of baryte which exhibit the small sharply terminated crystals regarded by Dunham (1990, pp. 91 and 252) as characterizing the secondary baryte capping of barium carbonate deposits.

No fluorite was found on this dump. The spoil from this trial thus appears to suggest that the Little Eggleshope Vein provides one of the few instances in the orefield in which a fluorite-bearing vein may be traced upwards into a barium mineral-bearing vein. Young (1985, p203) noted the incoming of secondary baryte at high levels into the fluorite-dominated Rampgill Vein at Nenthead. The presence of witherite within a fluorite vein near the centre of the orefield at Eastgate Quarry, Weardale, has recently been described by Young (1991).

Settlingstones Mine, Newbrough, Northumberland [NY 843 683]

Although Hancox (1934, p. 78) and Dunham (1948, p. 322) mentioned the presence of traces of barytocalcite in the Settlingstones witherite orebody, Young (1985, p. 202) was unable to trace specimens from the mine in any collection. A few small specimens have recently been collected from the remaining dumps at Settlingstones. In these barytocalcite occurs as colourless, very thin, sharply terminated monoclinic prismatic crystals up to about 0.5 mm long encrusting colourless pseudohexagonal witherite crystals in small vugs in witherite veinstone. The Settlingstones barytocalcite is late in the primary paragenesis of the vein, like many other occurrences in the orefield described by Young (1985).

Blagill Mine, Alston, Cumbria [NY 741 473]

As has already been noted, Blagill Mine is almost certainly the type locality for barytocalcite. Some was mined here last century for barium chemical manufacture before the discovery of abundant witherite elsewhere in the orefield (Dunham, 1948, p. 147). Blagill appears to have been the only mine from which barytocalcite was ever raised as a commercial product. The mineral is the main gangue in the vein known as Fistas Rake which is up to 3.0m wide: flats are said to have been associated with the vein (Dunham, 1948, p. 146). Beautifully crystallized specimens of Blagill barytocalcite are well known in most major mineralogical collections and have been described by Greg and Lettsom (1858, pp. 49-50) and Rudler (1905, p. 171). Whereas many may have been obtained from 'vuggy' portions of the vein, many appear to have originated from replacement flats in either the Great or Four Fathom Limestone as noted by Young (1985, p. 202).

Recent quarrying of the dumps for fill material has provided several blocks of mineralized limestone in which barytocalcite exhibits relationships not previously described. Several large blocks were found in which large tabular masses of barytocalcite up to 70mm across occur embedded in recrystallized and partially ankeritized limestone (Fig. 1). In these, the barytocalcite typically occurs as compact white to pale cream crystalline aggregates of anhedral crystals, though locally euhedral crystals with characteristic monoclinic terminations project into small vugs. The markedly tabular form of the barytocalcite aggregates is extremely reminiscent of baryte crystals found in metasomatic replacement flats in limestone in a number of deposits within the orefield. Whereas no trace of primary baryte has been observed in any of these specimens from Blagill, the form of the barytocalcite aggregates very strongly suggests that primary tabular baryte is here pseudomorphed by barytocalcite. Hancox (1934) first drew attention to the widespread replacement of primary baryte by witherite throughout the orefield and Dunham (1990) has provided further confirmation of this. Young (1985, p. 205) attributed the widespread occurrence of barytocalcite, and in places alstonite, as late stage primary encrusting minerals, to a local enrichment of these carbonating fluids with calcium derived from limestone wall-rocks. However he found no instance (1985 p. 204) of either barytocalcite or alstonite replacing or pseudomorphing any earlier mineral. The recently discovered specimens from Blagill indicate that at least some of the barytocalcite within the orefield may have been produced by the same mineralizing process whereby large quantities of primary baryte were replaced and pseudomorphed by witherite. Direct replacement of baryte by barytocalcite may thus account for the formation of veins such as Fistas Rake in which barytocalcite is such a major component.

Fig. 1 Tabular masses of barytocalcite (white) pseudomorphing original tabular crystals of baryte in recrystallized and ankeritized limestone.

ACKNOWLEDGMENTS

X-ray determinations of barytocalcite specimens by the late B. R. Young, formerly of the British Geological Survey, and the Department of Mineralogy, British Museum (Natural History) are gratefully acknowledged. E. Anderson is thanked for taking the photograph. Mrs J. Dunkley and Mrs S. Clothier are thanked for preparing the typescript. This paper is published with the approval of the Director, British Geological Survey (NERC).

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SHORT COMMUNICATION

VIVIANITE OF POST-ROMAN ORIGIN FROM VINDOLANDA, NORTHUMBERLAND

Vivianite $Fe_3+2(PO_4)_2.8H_2O$ is typically found in one of two distinct environments. It occurs occasionally as a supergene mineral in the oxidized upper zones of some metalliferous ore deposits where it is commonly well-crystallized. Notable British examples of this paragenesis include Wheal Jane, Truro and other mines in Cornwall (Collins, 1892, p. 104; Rudler, 1905, p. 70; Embrey and Symes 1987, p. 52). Vivianite is also found in organic and phosphate-rich sediments where it is commonly associated with bone, lignite, decaying wood and other organic remains (Palache *et al.*, 1951, p. 744). In this paragensis the mineral is typically found as small concretions, earthy coatings and impregnations within organic debris. Greg and Lettson (1858, p. 268) note the presence of earthy vivianite in alluvium at Clifton, near Bristol; Toxteth Park, Liverpool; Bury St Edmunds, Suffolk and the Isle of Dogs, Kent. These authors also record the presence of this mineral encrusting fossil bones and horns from Ballagh in the Isle of Man and comment on the presence of vivianite in the interior of the horns of an Irish elk of unspecified provenance in the British Museum collection.

Vivianite has recently been found in considerable abundance in organic-rich layers encountered during archaeological work at Vindolanda Roman site, near Bardon Mill, Northumberland [NY 769 663]. We have been able to discover only one previous published reference to the presence of what we believe is vivianite in Northumberland.

In a letter dated 2 October, 1826, to the Secretary of the Newcastle Antiquaries, John Adamson, the Rev. Anthony Hedley reported on the discovery of Roman shoes in a midden at Whitley Castle fort, on the county boundary near Alston (Hedley, 1832). He drew attention to the fact that 'the nails were a bright blue colour probably a coating of prussic acid'. This blue material is almost certainly vivianite.

Over the past eighteen years, the excavations at Vindolanda have been concentrated upon the deeply buried remains of the early wooden forts, dating from *ca* AD 85 to *ca* 140. Due to a combination of frequent changes in garrison and to the use of unseasoned softwoods for much of the constructional timber, five successive wooden forts were erected on the site within a matter of forty years. Before reconstruction, the Romans recovered whatever useful timber remained and then spread turf or clay, up to 40cm deep, over the remaining debris, to create a clean and level site for the next buildings. The process was repeated four times, sealing the rich organic occupation deposits from both air and water penetration. The uppermost of the timber remains is now buried 2.1m below the modern surface.

In this slightly damp, but not waterlogged, environment, the Roman floor coverings of bracken, moss and straw, up to 25cm deep, have survived in exceptionally good condition, along with the artifacts and other occupation debris hidden in the organic layers. Analysis at Bradford University, under the supervision of Professor Mark Seaward, has revealed a wide range of flora and fauna, together with insect remains and bacteria (Seaward *et al.*, 1976). The bulk of the occupational material consisted of wooden objects, textiles, writing tablets and a mass of food debris. This latter included egg-shells, nuts, shell-fish and fruit stones, but was dominated by the bones of cattle, pigs, deer and a variety of smaller mammals, including dogs, hare and badger.

When the covering layers of turf or clay were removed from the organic deposits, the material appeared in various colours, predominantly shades of brown, yellow and green, but within minutes everything turned a uniform shade of black. After exposure to the air for a few hours, some of the timber, bones, leather and iron objects began to exhibit bright blue earthy or powdery stains and coatings, which proved very difficult to remove in the laboratory, before chemical conservation was undertaken.

X-ray power photography (8673F[1]) of this blue mineral by the Department of Mineralogy, British Museum (Natural History) confirmed the mineral as vivianite. The colour changes observed at Vindolanda is consistent with many descriptions of vivianite (e.g. Palache *et al.*, 1951, p. 743) in which the mineral is stated to be colourless when pure and unaltered, becoming blue on exposure. In an investigation of this colour change Watson (1918) showed that it was due to partial oxidation of the iron to the ferric state. The varietal name kertschenite has been applied by some authors e.g. Palache *et al.* (1951) and Nriagu (1972) to oxidized vivianite.

The formation of vivianite requires an abundant supply of iron and phosphorus under strongly reducing conditions (e.g. Mackereth, 1966; Rosenqvist, 1970; Nriagu, 1972). The anaerobic conditions within the pre-Hadrianic deposits at Vindolanda which have provided ideal conditions for the preservation of organic remains and artifacts have also offered ideal conditions for the development of abundant vivianite. The mineral has formed here within the last 1900 years.

ACKNOWLEDGEMENTS

X-ray determination of vivianite by staff of the Department of Mineralogy, British Museum (Natural History) is gratefully acknowledged. This note is published with the approval of the Director, British Geological Survey (NERC).

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TRANSACTIONS

OF THE

NATURAL HISTORY SOCIETY

OF

NORTHUMBRIA

Editor:
R. B. CLARK

Assistant Editor:
M. A. PATTERSON

Volume 56
Part 2

THE NATURAL HISTORY SOCIETY OF NORTHUMBRIA
THE HANCOCK MUSEUM
NEWCASTLE UPON TYNE NE2 4PT
1994

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ISSN 0144-221X

Printed by Bealls, Newcastle upon Tyne.

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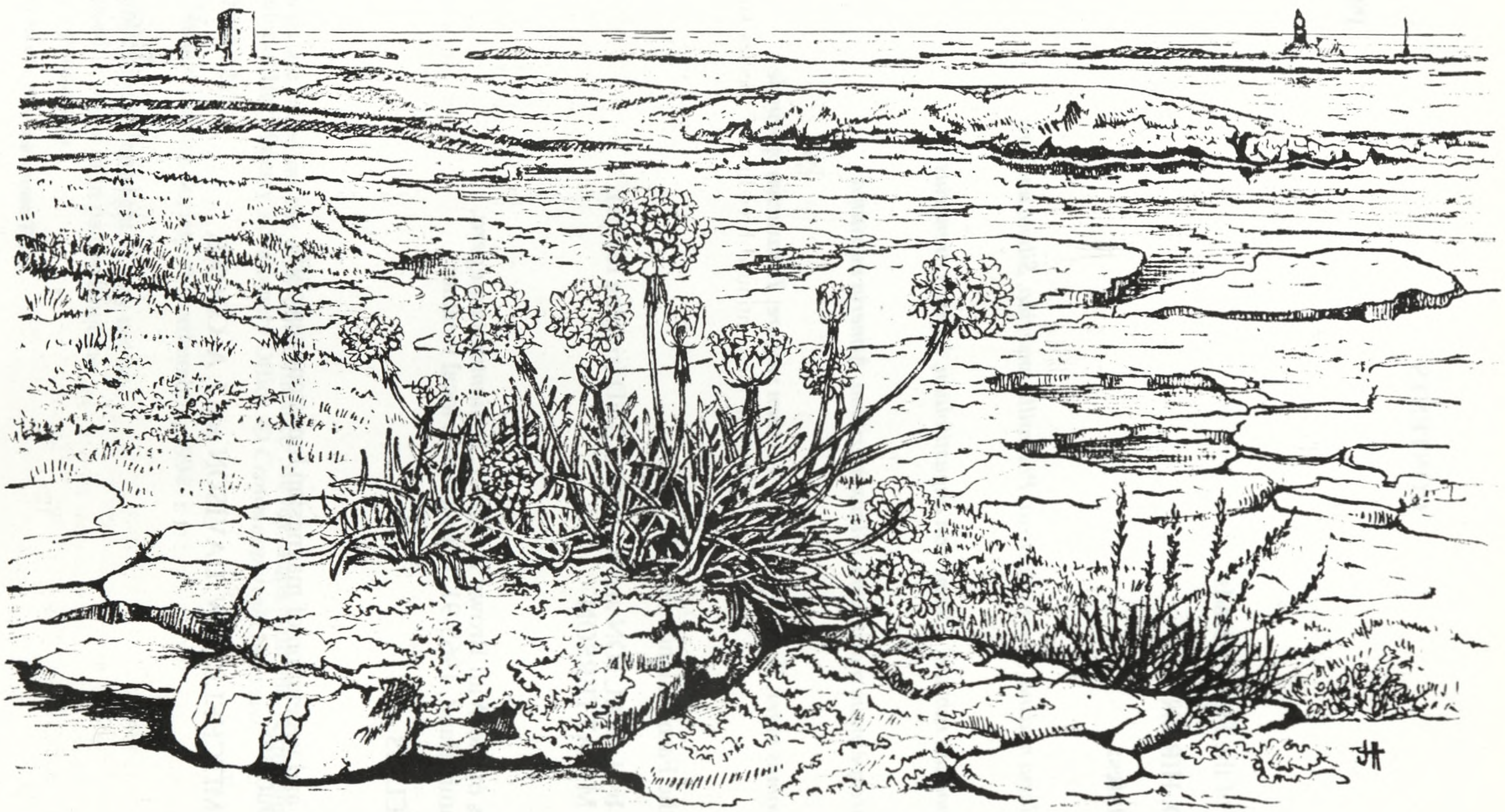

Thrift on the Farne Islands by Joan Holding

Trans. nat. Hist. Soc. Northumb. **57**, 69-114 (1994)

THE FLORA OF THE FARNE ISLANDS

by

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SUMMARY

A systematic list is given of the land plants recorded on the Farne Islands since Tate's monograph on the islands published in 1857. Some of the factors that influence the fluctuating success of different species are discussed as well as the interactions between plants, birds and seals.

INTRODUCTION

This paper gives a systematic account of all the species of land plants that have been recorded on the Farne Islands since the middle of the last century when modern records began. The flora has shown some fluctuation during this period and this has been in part due to the interaction between breeding seabirds and seals and the vegetation.

The Farne Islands are well known for their large populations of breeding seabirds, and the islands also support a large colony of the Atlantic grey seal. Increased protection of nature during this century has resulted in a great increase in the size of the breeding colonies of both seabirds and seals on the islands. While this change has, of course, been welcome, it has led to a considerable loss of vegetation in several places and this has been followed by serious erosion of the fragile soil cover, so threatening the continued breeding of species such as puffins, terns and eiders that require a soil and plant cover. Thanks to remedial measures that have been undertaken, this problem is now much reduced.

The plant populations on the islands are isolated from those on the mainland and have to contend with frequent gales from the North Sea as well as the pressure from the birds. A number of plant species are prominent and constant members of the flora, but other species fluctuate. From time to time species appear which have no doubt been transported from the mainland by birds or perhaps human visitors, but these generally survive only a few seasons.

A large proportion of the plant species can be found on Inner Farne and Staple Island, and many of them will be seen by visitors landing on these islands. Trampling by human feet is at least as destructive of the flora as the depredations of seabirds, and the continued preservation of it requires confining the visitors to recognized pathways where no damage can be done.

GEOGRAPHY OF THE FARNE ISLANDS

The Farne Islands (Fig. 1) lie off the Northumberland coast in a line which extends for a distance of 6.8km west to east. The number of islands varies between fifteen and twenty-eight, depending on the state of the tide. The nearest point on the mainland is Monk's House, and the nearest island is Inner Farne, 2.4km offshore and the largest island (2ha) in the group. Knivestone is the outermost island at a distance of 9.2km from the coast.

The islands are divided into an inner group consisting of Inner Farne, the Wideopens and Knoxes Reef and, separated from them by Staple Sound, an outer group consisting of Staple Island, Brownsman and the Wamses, the Big and Little Harcars, Longstone, the Northern Hares and Knivestone. Megstone and Crumstone are two outliers to the west and east, respectively.

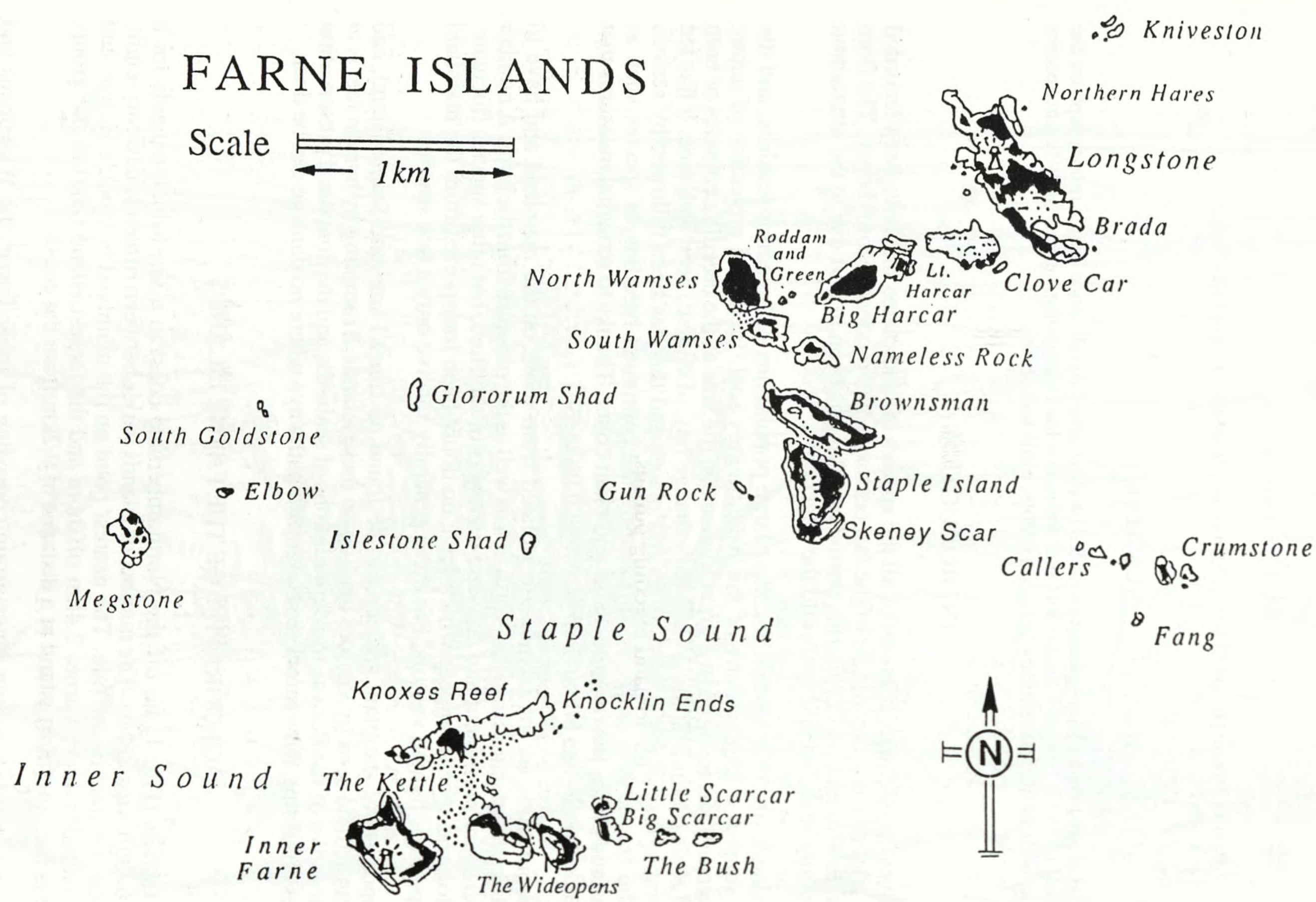


Fig. 1 The Farne Islands.

Geology and topography

The Farne Islands represent the most easterly exposure of the Great Whin Sill which stretches across Northumberland and Durham and is composed almost entirely of hard quartz dolerite. The islands apparently represent several different sills situated on different horizons, and although the dip of the whin surface varies from island to island, the general pattern is a slope from south-west to north-east. As a result, the cliffs on the larger islands are on the southern side. The highest of these, 20m above sea-level, occur near the lighthouse on Inner Farne and along the south-east of Staple Island. The Pinnacles, a group of 17m stacks, are situated just off the east cliffs of Staple Island.

Inner Farne has a stack on the south side and a blowhole, the Churn, reputed to be capable of a spout 30m high. The Whin Sill of this island is particularly fissured and includes St Cuthbert's Gut, Churn Gut and Churn Fissure, all running roughly 30° west of north.

Stratified rocks occur in four places, two on Brownsman, one on Nameless Rock, and one on The Bridges to the east of the Kettle which connects the Wideopens to Knoxes Reef and is exposed only at low tide. Glacial striae may be observed on a number of islands and these run approximately east-south-east.

Deposits of glacial drift material occur on Inner Farne, Staple Island, Brownsman and West and East Wideopens. On Staple Island this deposit is some 4m thick, and consists of a reddish clay containing boulders of Silurian graywackes, porphyrites and Carboniferous sandstones. This deposit forms a wide plateau running down the entire length of the island.

Soils

Nine of the islands have some soil cover. These are Inner Farne, East Wideopen, West Wideopen, Staple Island, Brownsman, South Wamses, North Wamses, Big Harcar and Longstone End. Although the last two islands have only a sand area with a soil cap, it is sufficient to support vegetation and breeding puffins.

A peaty soil has developed particularly where the glacial deposits overlie the quartz dolerite. The soil is rarely more than 30cm thick, though there are some thicker layers on parts of Inner Farne. Much of this island has been ploughed and ridge and furrow markings can be detected in aerial photographs across much of the island. Soil profiles in such areas lack a clear transition between organic peat and the underlying glacial drift, which is seen in other parts of the island (Brown, *pers. comm.*). Enclosed vegetable gardens have also been cultivated on Brownsman and Staple Island at various times.

Peat has developed directly on the Whin Sill on North and South Wamses, Big Harcar and Longstone, though much of this has now been lost. These peats tend to be darker than those developed over drift material and are also more susceptible to waterlogging.

All the soils have been considerably enriched with guano.

In the 1950s, 1960s and 1970s, soil erosion became a serious problem on several of the Farne Islands. Progressive loss of vegetation exposed bare soil which in dry weather was subject to wind erosion or in wet weather was washed off (Fig. 2). In several areas, all soil was lost leaving only bare rock which was unsuitable for most of the breeding birds for which the islands are famous. As a direct result of this problem a detailed study of the vegetation was started and still continues.

EARLIER STUDIES OF THE VEGETATION

The earliest account of the Farne Islands' flora in modern times is included in the monograph written by George Tate (1857) and published in the *Proceedings of the Berwickshire Naturalists' Club.* It included a description of the geology, zoology, botany and history of the islands, together with an account of the buildings on Inner Farne which had been renovated and restored by Archdeacon Thorp a few years earlier in 1848. The account of the flora is brief;

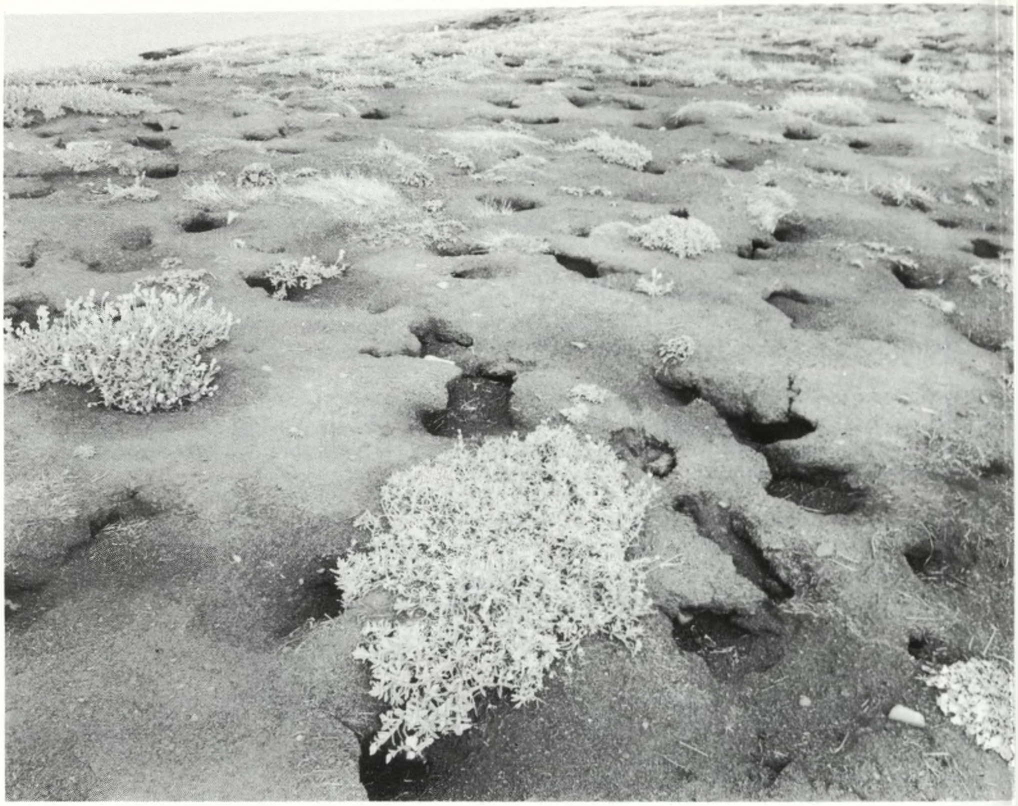


Fig. 2 Abandoned puffinry on Brownsman, where pressure of the birds and drought conditions resulted in a complete loss of vegetation. Many of the puffin burrows collapsed but by 1989, when this photograph was taken, some plants had begun to recolonize the area.

it merely lists species and the islands on which they had been recorded.

On Whit Monday, 6 June 1876, a party of members of the Tyneside Naturalists' Field Club made an expedition to the Farne Islands and this is graphically described in the Presidential Address to the club reviewing that year's activities (Philipson, 1880). Tyneside naturalists were evidently made of stern stuff in those days and it is worth recounting their experiences. The party caught the North Mail from Newcastle Central Station at 6.08am and alighted at Chathill. A four and a half mile walk took them to North Sunderland where they partook of a hearty breakfast at the White Swan inn. They then walked down to the harbour. A strong wind and white-capped waves persuaded some of the party not to venture the crossing and they, instead, explored the links towards Bamburgh, but about thirty ("including several ladies") set sail for the islands. They landed on Staple Island and Brownsman, but because of the deteriorating weather could not visit other islands and returned to North Sunderland, none the worse apart from the loss of a few hats in the wind. Mrs Robson, landlady of the White Swan, had by this time converted a hayloft into more spacious accommodation for their dinner. After they had eaten, the party received a lecture on the history of the Farne Islands, made various votes of thanks and then walked or were conveyed back to Chathill Station. There, "thanks to the kindness of officials of the North Eastern Railway Company, the 8.00pm train was stopped to receive them".

This account of the visit to Staple Island and Brownsman includes a list of the plant species, but gives no further details about them apart from noting that the sea campion was very abundant.

Mr J. Cordeaux (1892) described a visit to the islands in June, presumably of that year, in which he with two other adults and three boys, plus four boatmen, sailed round the islands. He enjoyed calm weather and was able to land on Longstone, Staple Island, Brownsman, one of the "Wedums" (Wideopens) and Inner Farne. His principal interest was the birds, but he included notes on some of the plants seen in his report.

In 1927, the Rev. J. E. Hull gave a rather general account of the natural history of the islands. He recorded a few plants seen on Longstone and mentions that sea campion and ragwort "have taken possession" of the Wideopens. He gives a more detailed account of the flora of Inner Farne, but adds that as he had visited the islands only in August and September, he could not give a comprehensive list of the plants.

Mr T. Russell Goddard was Curator of the Hancock museum from 1923 until his death in 1948. He made frequent visits to the Farne Islands throughout this period, except for the war years when the islands were closed to civilians, and from 1924 he kept a meticulous journal of his observations. He had a particular interest in the seabirds and seals, but the journal makes occasional comments on plants. He records in his journal that in summer 1931 he made a special collection of the plants of the Farne Islands. Presumably this collection was deposited in the Herbarium of the Hancock Museum, but a detailed search has failed to identify Goddard's own material or plants specifically relating to the Farne Islands. Goddard's observations were never published, but Watt (1951) included a list of the species of plants he had collected in her book on the islands. His journal which was deposited in the Hancock Museum library has been consulted and used in preparing the present Flora of the islands.

The British Ecological Society held its 1948 summer meeting in Newcastle and on 6 July a group of members visited Inner Farne and Staple Island. A list of the plants identified during this visit was included in the report of the meeting.

In 1953, when a field studies centre was opened on Inner Farne, the student Natural History Society of King's College (now Newcastle University) began an ecological study of the island. Observations of the fauna and flora were made during various periods in spring and summer 1953-56. Apart from an introductory note in the *Transactions* (Sowerby, 1958), the results of these investigations were not published. Mr W. B. H. Sowerby had kindly made these records available, together with his additional records made between 1956 and 1962.

At various times other authors have published notes recording the incidence of particular species on the islands.

PRESENT STUDIES

I first visited the Farne Islands in 1964 to collect sea campion material from a number of islands so that I could compare the chromosomes with those from material on the mainland. One of the photographs I took at that time portrayed puffin burrows among the campions near the centre of South Wamses. Since then, much of the soil cover of the island has disappeared, and with it the puffins, leaving an area of bare pebbles which was probably a former storm beach.

My detailed studies of the flora of the island began in 1971 (Hirons, 1971). By this time, soil erosion was apparent on nearly all the islands. The Farne Islands are renowned for their seabirds and grey seals. Increased protection of the fauna during this century had resulted in rapidly growing breeding populations of both seabirds and seals. This growth in numbers has been associated with a loss of vegetation and the subsequent rapid erosion of the bare soil.

My investigations on the islands since 1971 have required one or two periods on the islands each year and have been concerned with the understanding of the fluctuations in the plant cover.

The wardens under Peter Hawkey and John Walton have collected the data from my standard set of belt transects and quadrants at monthly intervals each year (April-November) so that we have a continuous record since 1971. The wardens have also brashed selected areas of eroding soil and carried out replanting under cage exclosures in areas of sheet erosion. Much of this

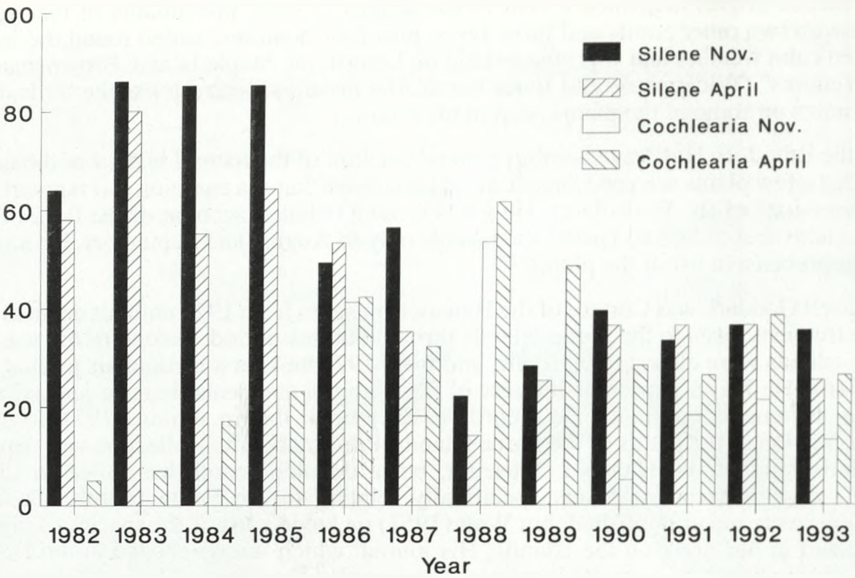


Fig. 3 Percentage ground cover provided by *Silene uniflora* and *Cochlearia officinalis* along a line transect on Brownsman in April and November 1982-93

work has resulted in the restoration of the vegetation cover.

I have carried out detailed quadrats, additional belt transects and mapping to monitor the results of this work. The need to avoid disturbing the nesting terns on Brownsman and nesting puffins on a number of islands has placed some limitations on the detail with which these vegetation studies could be carried out.

In addition I have taken each year a standard set of photographs both in black and white and colour to supplement the botanical survey work.

At various times during this long period of study the wardens, who are present on the islands for much of the year, have assisted and have been able to make supplementary observations for me.

FACTORS AFFECTING THE VEGETATION

Records of the vegetation of the Farne Islands suggest that it is in a continual state of change. Often, very significant changes can occur within a few years. Figure 3 shows the changes in the percentage of ground cover provided by *Silene uniflora and Cochlearia officinalis* along a line transect surveyed on Brownsman in November and April each year from 1981 to 1993, and this illustrates a dramatic decline in *Silene* and increase of *Cochlearia*. This change was reflected over the whole of Brownsman where *Silene* provided 83% of the ground cover in July 1979, but only 19% in July 1988. Even more dramatic changes have been recorded from one year to the next: also on Brownsman, the cover provided by *Cochlearia* declined from 27% in July 1987 to 1% in July the following year. Significant changes may also occur within a single year and the ground cover provided by a species in spring contrast markedly with that

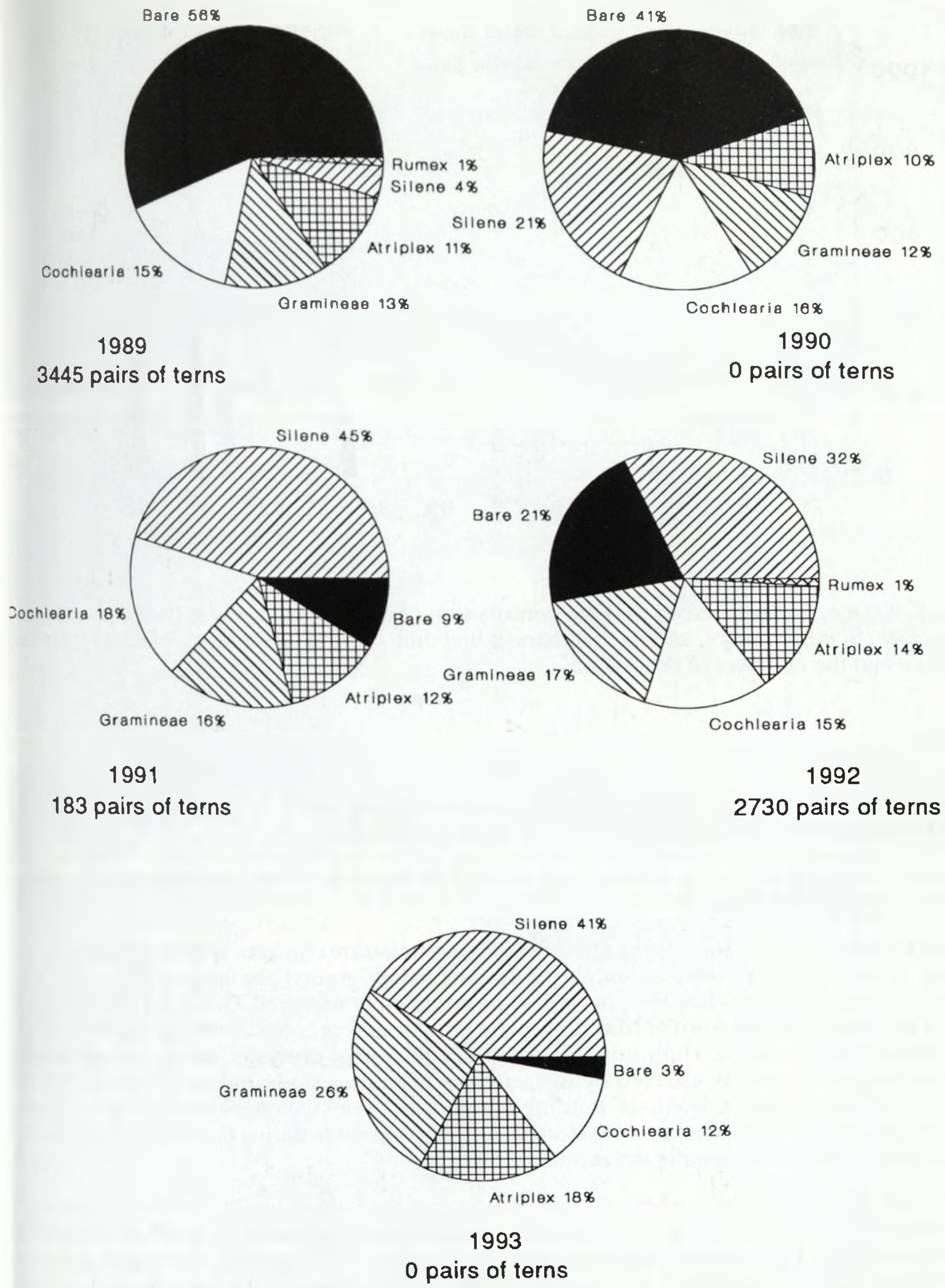


Fig. 4 Extent of ground cover on North Hill, Brownsman and the number of Sandwich terns breeding there, 1989-93.

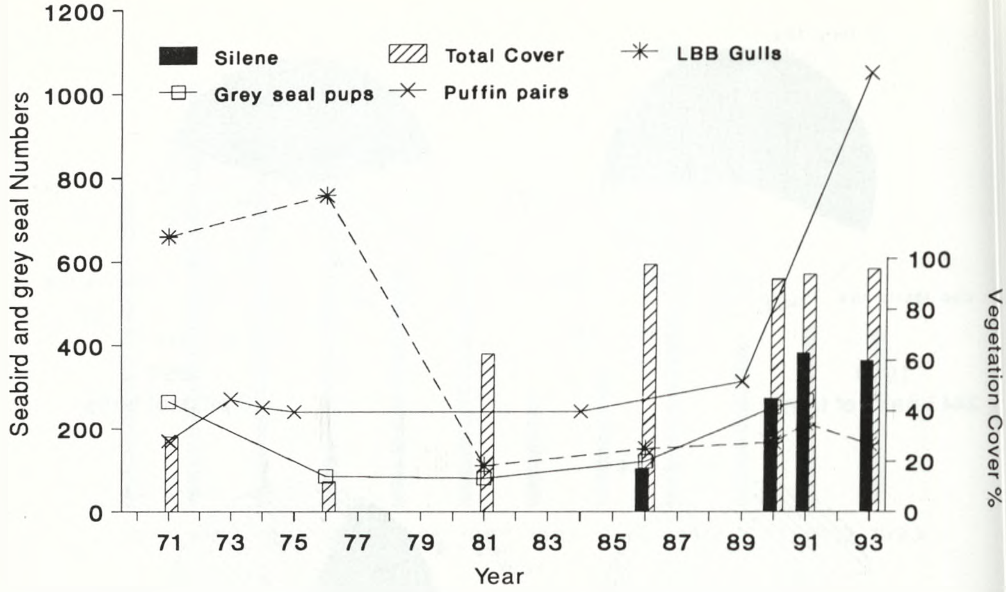


Fig. 5 Extent of ground cover and the contribution of *Silene uniflora* to it (hatched and solid blocks) on South Wamses, and the numbers of breeding pairs of lesser black-blacked gulls and puffins, and the numbers of seal pups.

in summer. This is exemplified by *Atriplex glabriuscula* on Staple Island which provided 1% of the ground cover in April 1981 but 31% in September that year.

Several factors operate to determine such marked fluctuations in the cover provided by plant species (Hirons & Hirons, 1972).

The most important abiotic factors affecting the vegetation are climatic. Winter storms remove many of the stems of *Silene* although the crowns below ground are undamaged unless the exposed soil is eroded when the plants may be completely removed. Gales are frequent and when they occur during April or May, new plant growth suffers considerable damage resulting in poor growth that year. High rainfall, especially in spring, promotes the growth of plants before they are adversely affected by the activities of nesting birds, but lack of rain leads to stress conditions and growth is inhibited especially for shallow-rooted species. Thus, *Cochlearia* normally produces a considerable amount of growth during the winter, but this did not appear in the exceptionally dry winter of 1985-86.

The great increase in the number of birds breeding on the islands has had a major impact on the flora. This is illustrated by the pressure of Sandwich terns on the vegetation of North Hill on Brownsman. This colony numbered 3456 pairs in 1986, 2870 pairs in 1987, 2408 pairs in 1988 and 3445 pairs in 1989. During this period 57% of the ground was bare and *Silene* provided only 4% of the ground cover. In subsequent years, the number of breeding Sandwich terns has generally been much smaller and has fluctuated widely; the amount of bare ground has been correspondingly reduced (Fig. 4). Control measures to reduce the number of lesser black-backs in and after 1981 had a similar beneficial effect on the vegetation of South Wamses (Fig. 5). Birds destroy the vegetation by plucking it for nest material and trampling it, especially during territorial disputes. In experiments carried out in 1979 (Figs 6-8), areas of *Silene vulgaris* which had been badly plucked by puffins for nest material were protected by cage

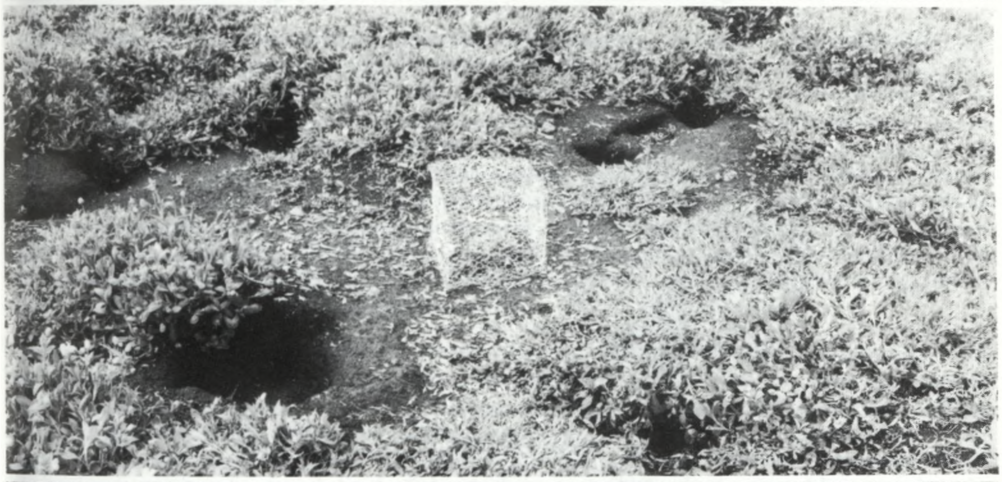


Fig. 6 (top) The experimental area. Near puffin burrows, the vegetation is torn up and areas of soil completely denuded. **Fig. 7 (centre)** Wire mesh cage to exclude the puffins was installed on 30 May 1979. **Fig. 8 (bottom)** By 18 July 1979, the protected plants showed vigorous growth, unlike near-by unprotected plants.

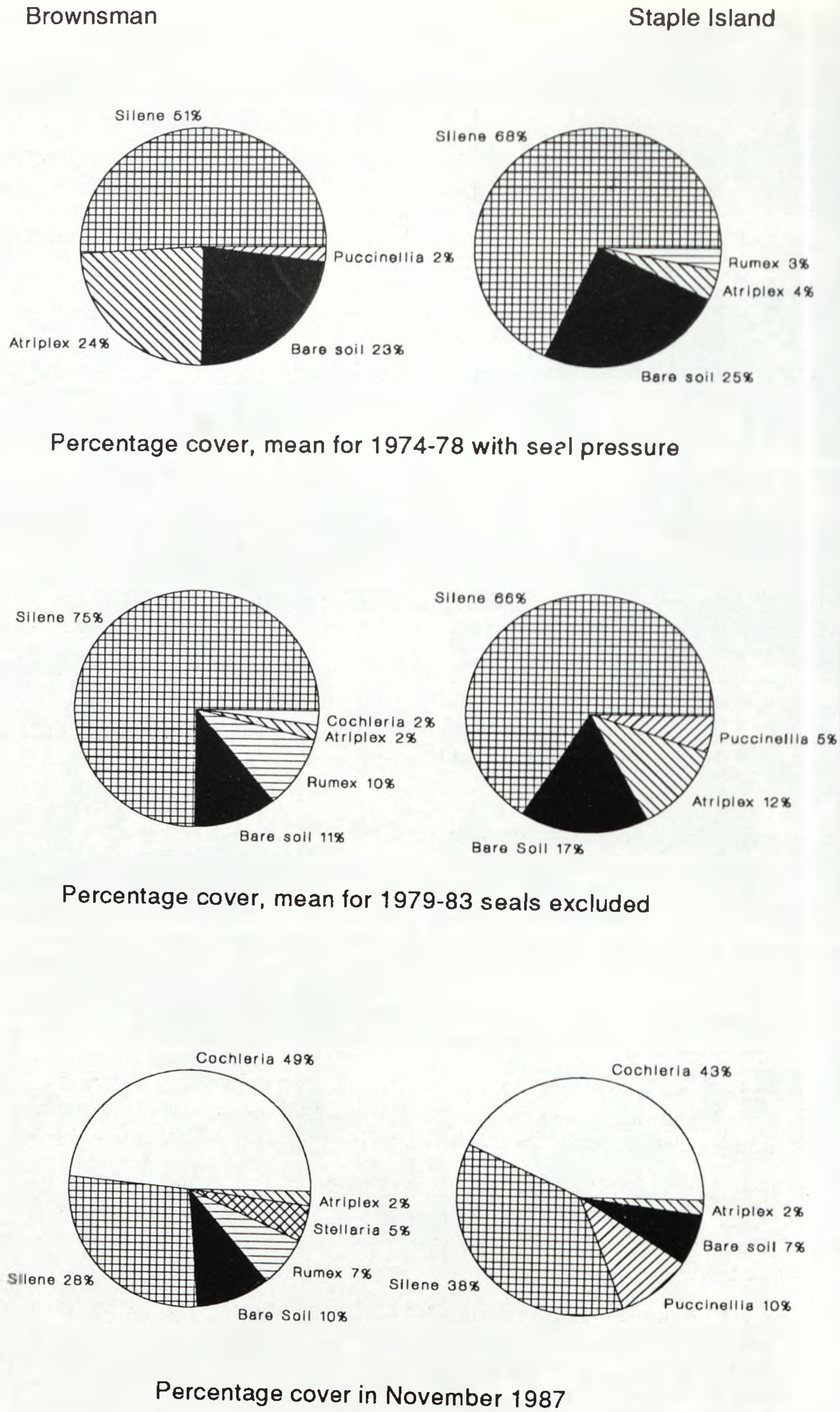


Fig. 9 Changes in the ground cover of *Atriplex glabriuscula, Silene uniflora, Cochlearia officinalis, Rumex acetosa, Puccinellia maritima* and *Stellaria media* on Staple Island and Brownsman following the exclusion of breeding seals.

enclosures. Surrounding, badly plucked plants showed little growth by the end of the growing season, but protected plants completely recovered. Birds do not have an entirely negative influence and the annual deposition of guano from them may promote vegetation growth.

Rabbits also have a strong influence on the vegetation. They were introduced and in the past there were colonies on Inner Farne, Brownsman, Staple Island and the Wideopens, but they are now present only on Inner Farne, having been reintroduced in 1974 following eradication in 1968. Rabbits can have a beneficial effect on the vegetation in the following ways. They help maintain floral diversity by removing tall grasses, they produce lawn-like areas of turf, their wastes help fertilize the soil, and disused rabbit burrows can be used by puffins for nesting. The harmful effects they have are most conspicuous when numbers become high. These include damage to the vegetation by over-grazing and trampling; the young shoots are damaged or weakened so that they do not survive the winter. By eating seedlings, rabbits prevent many species of plant becoming important components of the vegetation cover, and the dominant plants tend to be those with anti-herbivore adaptations, such as thistles, ragwort and nettles. By scraping and burrowing, the soil is exposed and desiccates, exposing it to wind erosion.

For some years it was supposed that grey seals caused serious damage to the vegetation by making mud wallows when they came ashore for breeding in November. While recolonization of seal wallows by plants is slow, the relation between seal numbers and the loss of vegetation is complicated. After seals were excluded from Staple Island and Brownsman there was a significant increase in perennials covering the soil but by 1987 there had been a tremendous increase in the abundance of *Cochlearia* at the expense of *Silene* (Fig. 9). This was due to the *Cochlearia* seedlings not being destroyed by the seals. *Silene* is a long-lived perennial and is the most important species maintaining soil cover, but *Cochlearia* appears to be chiefly a biennial on the Farne Islands, flowering in May and June but dying off in July with the result that considerable areas of soil are left bare and liable to erosion. The replacement of large areas of *Silene* by *Cochlearia* has been a mixed blessing.

The most serious areas of sheet erosion of the soil have been on West Wideopen and South Wamses. No seals have ever been recorded on the soil cap of the Wideopens, but, on the other hand, seals have bred regularly on South Wamses and there was a renewal of vegetation there during the period when the seal population increased (Fig. 5, above). In 1976, when there was only 12% vegetation cover, ninety-six seal calves were produced, but ten years later, when 123 seal calves were produced on the island, there was 98% plant cover (due mainly to a reduction in the number of lesser black-backed gulls and direct remediation methods).

Although the situation may well fluctuate in future years, the plant species that are at present the most significant in providing ground cover on the various islands are as follows:

On Inner Farne, the most significant ground-cover species are *Silene uniflora, Rumex obtusifolia, Urtica dioica, Festuca rubra, Holcus lanatus, Cirsium vulgare, C. arvense, Senecio jacobaea, Conium maculatum, Atriplex glabriuscula* and *Sonchus asper.*

On the Wideopens, the important species are *Silene vulgaris, Urtica dioica* and *Atriplex glabriuscula; Cirsium vulgare, Senecio jacobaea* and *Conium maculatum* also contribute to the ground cover on West Wideopen, and *Cochlearia officinalis* contributes ground cover on East Wideopen.

Brownsman and Staple Island are similar and both depend largely on *Silene uniflora, Cirsium arvense, Cochlearia officinalis* and *Atriplex glabriuscula* for ground cover. *Puccinellia maritima* and *Festuca rubra* provided only a small percentage of ground cover in 1991 but this may increase due to planting out of seedlings of these species, which was carried out in the eroded areas.

Ground cover on South Wamses is provided by *Silene uniflora, Puccinellia maritima, Festuca rubra, Holcus lanatus* and *Cochlearia officinalis*. On North Wamses, Harcar, Longstone and Northern Hares, *Puccinellia maritima* provides ground cover, while on Knoxes Reef it is provided by *Puccinellia maritima* and *Leymus arenarius*.

DIFFERENCES BETWEEN THE ISLANDS

The greatest variety of plants is found on Inner Farne where, historically, ninety-seven species have been recorded and sixty were present in 1990-91. Next in species richness is Brownsman with historically fifty-seven species of which forty-six are still present. The number of species recorded on the Wideopens (forty-eight historically, forty-five in 1990-91) appears large when compared with Staple Island (thirty-one species historically, twenty-four in 1990-91), but this is due to the presence of an area of very sandy soil at the eastern end of West Wideopen, with a very diverse flora including a number of strand species absent from the rest of the island and absent from Staple Island.

A similar explanation accounts for the richness of the flora on Knoxes Reef with twenty-six species. Here, there is a small area of sand and shingle above high tide mark which provides a suitable habitat for strand plants. A number of these are annuals and do not appear every year.

THE DISAPPEARING FLORA

In all, 115 species have been reliably identified at various times on the Farne Islands, but thirty-six of these species appear to be no longer extant. Some, such as *Ranunculus acris, Luzula campestris, Dactylorhiza incarnata* and *Carex flacca*, were first recorded in 1857 and have not been seen since, but the majority of the disappearing species were present until the 1950s (Sowerby, 1953-62) but have not been recorded since then, and *Primula vulgaris* has disappeared since 1972.

Nearly all the species that have disappeared were recorded on Inner Farne and there is evidence that this island has become much drier in recent years; the marshy area has disappeared and the pond is dry for much of the year. Twelve species have been adversely affected by this drying out: *Ophioglossum vulgatum, Ranunculus acris, R. trichophyllum* and *R. baudotii* (four species which could survive only in the pond), *R. hederaceus, Spiraea ulmaria, Rumex hydrolapathum, Carduus acanthoides, Juncus bulbosus, Dactylorhiza incarnata, Carex distans* and possibly *Potentilla erecta, Veronica montanum* and *Carex flacca.*

The flora undergoes some natural fluctuation. The variable occurrence of annuals on Knoxes Reef has already been referred to, but some species may also have escaped detection if they were present only in small numbers. Thus, Watt (1951) listed sixteen species which had apparently disappeared since 1857, but six of them were recorded subsequently: *Lotus corniculatus, Galium aparine, Cirsium arvense, Agrostis stolonifera, Poa annua* and *P. trivialis.* It is not certain if these had re-established themselves or had been present but escaped detection in the interval. Similarly, it is possible that *Cerastium semidecandrum*, last recorded in 1962, has survived but careful searches have not been made among the nesting colonies of seabirds where it may still occur.

SYSTEMATIC LIST

The following pages list all species that have ever been recorded from the Farne Islands. A number of records are of doubtful validity and are likely to be the result of misidentifications; these have been included in square brackets.

The information given for each species includes a brief description of the life-form and biology, habitat preference and British distribution. The life-forms and habitat preferences are as designated by Clapham, Tutin & Moore (1987). The sequence and nomenclature of species in the systematic list follow those in Swan (1993). The British distribution is as shown in Perring & Walters (1962) *Atlas of the British Flora.*

The life forms are:

Therophyte plants which pass the unfavourable season as seeds.

Hydrophyte water plants.

Helophyte marsh plants.

Geophyte herbs with buds below the soil surface.

Hemicryptophyte herbs (very rarely woody plants) with buds at soil level.

Chamaephyte woody or herbaceous plants with buds above the soil surface but below 25cm

Phanerophyte woody plants with buds more than 25cm above the soil level.

The habitat preferences are:

Ruderal species occurring in waste places, disturbed ground, arable land or roadsides.

Grassland species occurring in grassy places, grassland, meadows or fields.

Maritime species occurring on or sufficiently close to the shoreline to be influenced by marine conditions.

Aquatic species occurring in or by slow streams, ditches and shallow ponds.

Woodland species occurring among stands of trees.

The British distribution is either:

Ubiquitous, distributed throughout almost the whole of Great Britain, or *Maritime*, with a distribution limited to coastal 10km squares.

***Ophioglossum vulgatum* Adder's tongue**

Life form: geophyte; British distribution: ubiquitous; habitat preference: grassland.

Miller (1945) reported that he had discovered this fern growing at two sites on Brownsman between 1911 and 1914. Goddard collected a specimen in 1931 (Watt, 1951), and Sowerby (1953-62) recorded a specimen on Inner Farne. An exhaustive search of both Inner Farne and Brownsman in 1972 failed to find any specimens (Hickling, *pers. comm.*) and it has apparently disappeared from the islands. It occurrs at a number of sites on the north Northumberland coast (Swan, 1993).

***Urtica dioica* Stinging Nettle**

A coarse unbranched perennial up to 140cm on Inner Farne. Well known for its stinging hairs and as a weed difficult to eradicate. Roots are yellow, tough and much branched and the stems creep and branch at the nodes producing erect shoots. The male and female flowers are found on different plants.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: ruderal.

Recorded by Tate (1857) on Inner Farne and by Goddard (1924-48) on Inner Farne in 1926 and 1935 and on Knoxes Reef in 1946. I found extensive stands on West Wideopen and Brownsman which no doubt had been overlooked. It is still thriving on these four islands. This species has proved to be advantageous in preventing soil erosion on the islands. Common around the buildings on Inner Farne except when they have been treated with herbicides. On Brownsman this plant dominates the heap of stones which were part of the old lighthouse tower. This stand of nettles provides an ideal nesting site for eider ducks.

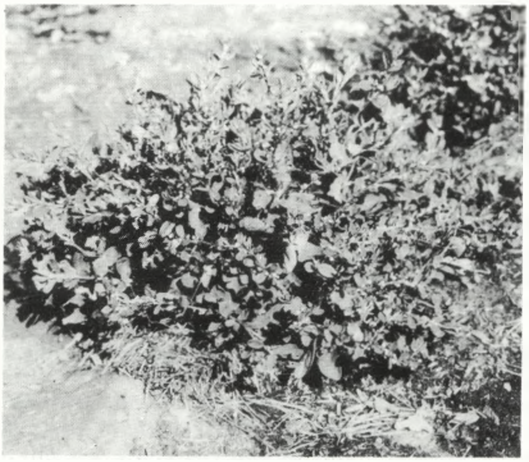
Urtica urens **Small Nettle**

An annual, much smaller plant than the more common Stinging Nettle with more rounded, less hairy and greener leaves. This nettle bears both male and female flowers on the same plant. Usually found on light soils.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

Recorded by Tate (1857) on Inner Farne, the Wideopens and Brownsman. It was present on the Farne Islands in 1931 when it was collected by Goddard (Watt, 1951). Sowerby's (1953-62) record was from Inner Farne, but in 1971, I found it thriving on the same islands as Tate and it is still present on each of these islands.

Polygonum aviculare **Knotgrass**



A widespread annual which is prostrate on the Farne Islands. Leaves lanceolate, alternate and with silvery sheaths at the base. Flowers from June onwards; the flowers are tiny, pink (sometimes white) and arise in the axils producing a knotted effect.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

Recorded on Inner Farne by Sowerby (1953-62). In 1971, I found it in flower on this island, Knoxes Reef, Staple Island, North and South Wamses and Harcar. It was again recorded from all these islands in 1983 by the wardens and also on the Wideopens and Brownsman. In 1989, I failed to locate it on Brownsman and the Wamses, but in 1992 it was the dominant plant in the pond area on North Wamses.

Persicaria persicaria **Red Shank, Redleg**

An annual up to 55cm high with reddish stems swollen at the nodes. Leaves lanceolate, silky and often with a dark blotch in the middle.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

There was a plant in flower on Harcar in 1973 and ten years later the wardens recorded a single plant on the same island and several on Knoxes Reef and on Brownsman. A casual plant probably often overlooked.

Persicaria amphibium **Amphibious Bistort**

Perennial, aquatic forms are found close to, or in still or slowly flowing fresh water, but terrestrial forms are often found as arable weeds.

Life form: hydrophyte/hemicryptophyte; British distribution: ubiquitous; habitat preference: aquatic.

I found a well developed terrestrial form in flower on Knoxes Reef in 1987.

Rumex acetosa **Common Sorrel** **Plate 1**

An erect common perennial, growing up to 60cm high on the Farne Islands. Leaves are arrow-shaped with long stalks but those higher up the stems are unstalked. The male and female flowers are produced on separate plants.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

First recorded by Tate (1857). It was present in 1931 when it was collected by Goddard (Watt, 1951) and he recorded it on the Wideopens in 1946 (Goddard, 1924-48). Sowerby (1953-62) recorded it on Inner Farne. In 1971, I found it on the Wideopens, Brownsman, Staple Island and South Wamses as well as on Inner Farne. The wardens found several plants on North Wamses in 1983.

Common Sorrel is an important component of the vegetation of the main islands. On Brownsman in 1971, 8% of the plant cover was Common Sorrel. This had dropped to less than 1% in 1976, increased to 26% in June 1981 but then gradually decreased to again 1% in June 1992. In June 1981 Common Scurvy-grass had only reached 1% cover but then increased dramatically. It therefore appears that the Common Sorrel may be adversely affected by competition with the Common Scurvy-grass.

Rumex hydrolapathum **Water Dock**

A huge erect perennial up to 200cm, with lanceolate leaves up to 110cm.

Life form: hydrophyte/helophyte; British distribution: ubiquitous; habitat preference: aquatic.

Recorded by Hull on Inner Farne in 1927. This must have been close to, or in the pond at the centre of the island. This is a plant which has disappeared, almost certainly due to the drier conditions which now prevail on the island.

Rumex crispus **Curled Dock**

A variable weedy perennial, growing up to 150cm high with long leaves up to 30cm, which are lanceolate, wavy and crisped. An abundant weed of cultivated fields and grassland and common in waste places, dune slacks and shingle beaches.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: ruderal.

Recorded on Inner Farne by Tate (1857) and others up to Sowerby (1953-62). It had probably been overlooked on some of the other islands as in 1971 it was not only common on Inner Farne but also on the Wideopens, Knoxes Reef and Staple Island. In a survey in 1983, the wardens failed to find it on Knoxes Reef but they recorded several plants close to the cottage on Brownsman.

Rumex obtusifolius **Broad-leaved Dock**

The most sturdy of our two commonest docks, widespread and a weed of farms, waste ground and disturbed soil so that it is a plant we would expect to find on the Farne Islands. Leaves up to 25cm and the cover provided by this plant is often used by nesting eider ducks, but it appears that this species is not advantageous for other breeding seabirds.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: ruderal.

First recorded by Tate (1857) on Inner Farne. All subsequent records up to 1962 are from the same island. It was no doubt far more widespread but unrecorded. In 1971 it was present on the Wideopens, Knoxes Reef and Brownsman as well as on Inner Farne. I also found a huge plant thriving on North Wamses in 1989. The cover on Inner Farne varies due to the use of herbicides.

Chenopodium rubrum **Red Goosefoot** **Plate 2**

An annual up to 60cm high but many plants on the Farne Islands are prostrate. The stems are usually reddish, and the leaves variable, often diamond-shaped and deeply toothed.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

Recorded by Tate (1857) on Brownsman, Hull (1927) on Inner Farne and Sowerby (1953-62) also on Inner Farne. In 1971 I found this species on Inner Farne, the Wideopens, Knoxes Reef, Brownsman and Staple Island.

This plant is frequently found on bare ground close to the sea on the mainland.

[*Chenopodium chenopodiodes* **Saltmarsh Goosefoot**

This was recorded by Tate (1857) from the Farne Islands, but has not been observed there since then. The species is not otherwise known north of Lincoln (Perring & Walters, 1976), and Tate's record is therefore probably erroneous.]

Chenopodium album **Fat Hen**

A very widespread and often abundant annual weed in cultivated and waste ground. Stems up to 90cm which are sometimes reddish. The leaves are variable, deep green and mealy with the lower ones usually toothed.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

Goddard (1924-48) recorded a *Chenopodium* on the Wideopens in 1946. I first recorded this species on the Wideopens in 1971 but in 1983 the wardens recorded it on Brownsman, Staple Island, Longstone and Northern Hares.

Atriplex laciniata **Frosted Orache**

A plant of gravelly and sandy shores of the British Isles, usually growing close to the high tide line. An annual, mealy white or silvery with leaves up to 2cm very mealy on both upper and lower surfaces.

Life form: therophyte; British distribution: maritime; habitat preference: maritime.

It was recorded on Staple Island in 1958 (Anon, 1960) and I found several plants on Knoxes Reef in 1971.

Atriplex patula **Common Orache**

Another widespread and abundant annual weed found inland and on the coast. Variable, often prostrate and mealy. Leaves may be entire or toothed.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

Recorded on Inner Farne by Tate (1857, as *A. angustifolia*) and by all subsequent recorders. I found the species on the Wideopens in 1971 and it was still on this island in 1983.

Atriplex prostrata **Hastate Orache, Spear-leaved Orache**

An annual usually found near the sea.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

Recorded by Hull (1927) on Inner Farne and by Sowerby (1953-62); these are the only two records for the Farne Islands.

Atriplex glabriuscula **Babington's Orache**

An annual, generally prostrate and mealy with the flowering stem up to 20cm high.

Life form: therophyte; British distribution: maritime; habitat preference: maritime.

This plant was first recorded by Hull (1927) on Longstone at the foot of the lighthouse. The British Ecological Society recorded it in 1948 on Staple Island. Sowerby (1953-62) found it on Inner Farne and in 1971, I found it on all the islands except Northern Hares. It is one of the characteristic plants of the islands, especially where the soil has been disturbed. After the demise of perennial species leaving large areas of bare eroding soil, this species is invariably the initial colonizer, often forming pure stands, e.g. on Inner Farne, East Wideopen, Brownsman and Staple Island. On Staple Island, *Atriplex glabriuscula* reached 56% of the plant cover in 1991.

[***Atriplex rosea***

This species was recorded by Tate (1857) for the Farne Islands. It is a Linnaean species but is a rare alien in the British flora and is not included in Clapham, Tutin & Moore's (1987) *Flora of the British Isles*. Tate's record is therefore probably erroneous.]

[*Atriplex angustifolia* **See under** *A. patula.*]

Salsola kali **Prickly Saltwort**

A prickly, leafy, prostrate annual. The tips of the short leaves end in a spine. Typically a plant of the drift-line.

Life form: therophyte; British distribution: maritime; habitat preference: maritime.

Only recorded by Cordeaux (1892) on Brownsman.

Honkenya peploides **Sea Sandwort**

A prostrate, fleshy, hairless creeping perennial on coastal shingle and sand. male and female flowers on separate plants. Petals greenish white.

Life form: hemicryptophyte; British distribution: maritime; habitat preference: maritime.

The only record for the Farne Islands is on Staple Island and/or Brownsman in 1876 (Philipson, 1880).

Stellaria media **Common Chickweed**

Ubiquitous, weak, prostrate pale green annual which sometimes overwinters. Distinguished by its rounded stems which have a vertical (sometimes two) row of hairs.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

First recorded by Tate (1857) on Inner Farne and Staple Island. It can now be found on Inner Farne, the Wideopens, Knoxes Reef, Brownsman, Staple Island and Harcar. Cage enclosures have shown that this plant, with its rapid growth, is able to smother and kill small seedlings of Sea Campion, *Silene uniflora.*

Cerastium fontanum **Common Mouse-ear Chickweed**

A very common plant throughout the British Isles. A short lived perennial with dark green hairy leaves. The flowers are small, white with petals deeply cleft.

Life form: chamaephyte (-therophyte); British distribution: ubiquitous; habitat preference: ruderal.

Recorded by Tate (1857) on Inner Farne, Brownsman and Staple Island. Since then, it has only been recorded on Inner Farne, except for one plant in 1983 recorded on the Wideopens by the wardens.

Cerastium semidecandrum **Little Mouse-ear Chickweed**

An annual or overwintering species. Upper half of the upper leaves is transparent.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

Recorded by Tate (1857) on Inner Farne, Brownsman and Staple Island, and by Hull (1927) on Inner Farne. Last recorded by Sowerby (1953-62) for the Farne Islands.

Cerastium diffusum **Sea Mouse-ear Chickweed**

An annual with a slender tap root which is often common along our coasts.

Life form: therophyte; British distribution: maritime; habitat preference: maritime/ruderal.

Recorded by Tate (1857) from Inner Farne, Brownsman and Staple Island. Since then, the only records on Inner Farne have been by the British Ecological Society (1948) and Sowerby (1953-62). I found it near the pond on Brownsman in May 1985, but by July that year the area was bare, apparently because of the activities of puffins.

Cerastium diffusum

Sagina procumbens **Procumbent Pearlwort**

A perennial Pearlwort found throughout the British Isles on bare soil. Leaves in a dense central rosette, each leaf ending in a minute bristle. Flowers with minute petals (sometimes petals absent) much shorter than the four blunt sepals.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: ruderal.

First recorded by Tate (1857) on the Wideopens, Brownsman and Staple Island. Recorded by Hull (1927) on Inner Farne and there have been numerous records for this island up to the present day. A few plants were found on the Wideopens by the wardens in 1983.

Sagina maritima **Sea Pearlwort**

A dark green sometimes purplish annual up to 7cm high with thick blunt leaves which do not end in a short bristle.

Life form: therophyte; British distribution: maritime; habitat preference: maritime.

First recorded by Tate (1857) and subsequently by others, all on Inner Farne. I found several plants on Brownsman in 1971.

Spergularia marina **Lesser Sea-spurrey** **Plate 1**

An annual with numerous flattened shoots. The leaves are bright yellow-green, flat above and rounded underneath. Flowers often have white centres with the petals shorter than the sepals.

Life form: therophyte; British distribution: maritime; habitat preference: maritime.

This species was not recorded on the Farne Islands until found by the British Ecological Society on Staple Island in 1948. Sowerby (1953-62) found it on Inner Farne and in 1971, I found it growing on all the islands except the Wamses and Harcar.

[*Spergularia neglecta*

This was reported by Hull (1927). Doubtless the record refers to *S. salina* var. *neglecta* which is now included in *S. marina*]

Silene uniflora **Sea Campion** **Plate 1**

One of the most characteristic plants of the Farne Islands and one of the most important for the retention of the soil cover.

A perennial with an extensive, somewhat branched rootstock. A large number of non-flowering shoots arise from this rootstock and form a thick cushion more spreading than in the subspecies *vulgaris*, the Bladder Campion, found on the mainland. The leaves are lanceolate, bluish and glabrous.

Erect flowering stems up to 25cm high arise from the centre of the cushion and many floras add "usually with solitary flowers". On Brownsman 390 stems were collected from typical plants unaffected by puffins or other birds. The number of stems with single flowers was 74 (19%); with three flowers 132 (33%), and with twelve flowers (maximum number) 2 (0.5%). The mean was 3.2 flowers per stem, and the total number of flowers examined was 1248.

Flowers usually white, 20-25mm (in diameter) with deeply cleft petals. On the Farne Islands the flowering period extends from early April until early August.

Seed is produced in a broad ovoid capsule with a ring of teeth around the wide mouth. The capsules are often dispersed by the wind before all the purplish seeds have been released. I collected 100 capsules on Brownsman in 1979. These contained 7420 seeds, the minimum number in a capsule was 10, the maximum 167; mean number in 100 capsules was 74.04.

The percentage of viable seed varies from year to year. In some years I have not been successful in obtaining more than 15% germination and it appears that light is an important factor.

On the Farne Islands many seeds are destroyed by the larvae of the Marbled Coronet moth *Hadena confusa* which is very abundant in some years, destroying up to 80% of the seeds. In spite of all the seed produced in some years, it is difficult to find a single Sea Campion seedling, at least on Brownsman and Staple Island. Many seedlings which are produced are smothered and destroyed by dense mats of the more quickly growing Chickweed *Stellaria media.*

The low mats of Sea Campion are well adapted to survive on the windswept Farne Islands and plants which are partly buried by the shifting soil readily form new shoots.

This plant often suffers when the new spring growth is destroyed by gales. It is also adversely affected by treading and plucking by puffins, gulls and shags. Shags continually add fresh Campion to their nests during the breeding season and when puffins return in spring they pluck the stems of Sea Campion to reline their nesting chambers. Many of these plucked stems are dropped and these are not picked up but fresh ones are plucked, leaving some large Campion plants almost denuded of their leaves. Puffins then stand on the denuded crowns so that the plants are unable to recover. The use of wire enclosures to prevent this happening has been described above (Figs 6-8).

Puffins also burrow under campion plants resulting in a much reduced moisture regime which also damages the plants (Fig. 2).

The extent of ground cover provided by *Silene* varies from year to year, depending on the intensity of these factors and the amount of rainfall. Thus on Brownsman, *Silene* provided 56% of ground cover in September 1982, but only 14% in April 1988. On Staple Island, it provided 70% ground cover in June 1983, and 24% in April 1988.

Life form: chamaephyte; British distribution: maritime; habitat preference: maritime.

Tate (1857) recorded the Sea Campion on Inner Farne, Brownsman, Staple Island and South Wamses in 1857. He also added "Fosseland now called Brownsman. Formerly sheep were kept on Fosseland, but now no animal lives on it. The effect of this change of treatment is singular, for the grasses adapted to the maintenance of sheep and cattle are withering away before the unchecked inroads of the vigorous Sea Campion (*Silene maritima*), which is spreading over the whole island". Philipson (1880) reported *Silene* to be very abundant, as did Cordeaux (1892) but made no reference to individual islands. Hull (1927) recorded it on the Wideopens and Goddard (1924-48) frequently commented on its abundance on Inner Farne between 1925 and 1947 and also reported it on Brownsman, Staple Island, Knoxes Reef and the Wideopens. The British Ecological Society (1948) recorded it on Inner Farne and Staple Island. In 1971, I recorded it on Inner Farne, the Wideopens, Knoxes Reef, Brownsman, Staple Island and South Wamses. It is still found on all these islands.

PLATE 1

Spergularia marina **Lesser Sea-spurrey**

Rumex acetosa **Common Sorrel**

Potentilla anserina **Silverweed**

Silene uniflora **Sea Campion**

Ranunculus repens **Creeping Buttercup**

Perennial which overwinters as a corm-like stock.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

Recorded by Tate in 1857 on Inner Farne and the Wideopens. Goddard (1925-48) recorded it as being in full flower in July 1947 on Inner Farne. It is more tolerant of trampling than *R. acaris*. Tate's is the only record for the Wideopens but the plant still occurs on Inner Farne in very small numbers.

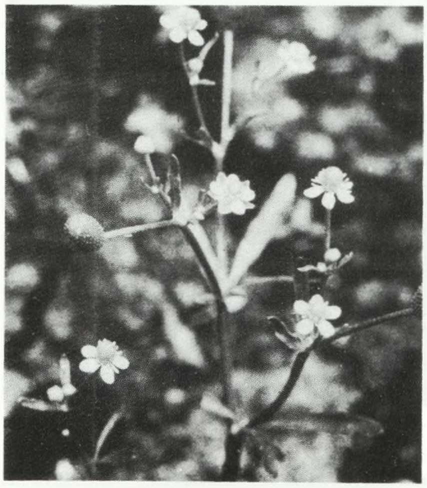
Ranunculus acris **Meadow Buttercup**

This is a common buttercup on the mainland. The seed has no obvious mechanism for dispersal and it does not tolerate disturbed soils. It is doubtful if it was ever a common species on the Farne Islands.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

Recorded by Tate (1857) on Inner Farne and the Wideopens but according to Watt (1951) had disappeared since then.

Ranunculus sceleratus **Celery-leaved Crowfoot**



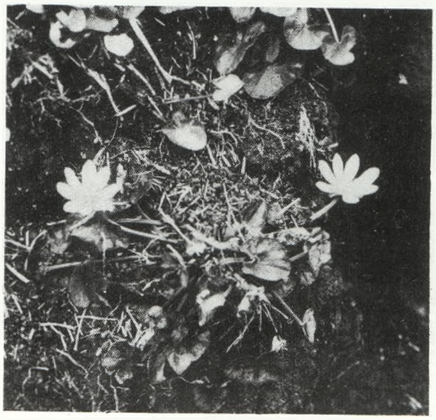
An annual or overwintering herb with pale yellow petals no longer than the turned-down sepals.

Life form: therophyte/helophyte; British distribution: ubiquitous; habitat preference: aquatic.

I first recorded it in 1973 on West Wideopen and Brownsman. It is characteristically a plant of the edges of pools. It regenerates entirely by seed and the number of plants varies from year to year. The pond on West Wideopen is no longer extant but there were several plants flowering in a damp depression in 1988.

The pond on Brownsman was dug out in 1989, resulting in a larger area of fertile mud so this plant may well increase.

Ranunculus ficaria **Lesser Celandine**



A perennial with numerous root tubers. Flowers from March onwards and this reduces competition with other species.

Life form: geophyte; British distribution: ubiquitous; habitat preference: grassland/woodland.

It was present in 1931 when it was collected by Goddard (Watt, 1951). The specimen was probably from Inner Farne where it still occurs near the chapel. I found five plants growing south-east of the cottage on Brownsman in 1971 and it still occurs there.

Ranunculus hederaceus **Ivy-leaved Crowfoot**

An overwintering or spring germinating annual herb, sometimes perennial, attached to wet mud in shallow water. This plant must have occurred in one of the ponds on Inner Farne.

Life form: therophyte/hydrophyte; British distribution: ubiquitous; habitat preference: aquatic.

The only record is on Inner Farne by Sowerby (1953-62).

Ranunculus baudotii **Maritime Water Crowfoot**

An annual or perennial herb with branching stems which are prostrate in terrestrial plants and usually erect in water.

Life form: therophyte/hydrophyte; British distribution: maritime; habitat preference: aquatic.

It was collected by Goddard in 1931 (Watt, 1951). This was presumably from Inner Farne, where it was recorded by the British Ecological Society during a visit in July 1948. The last record is that of Sowerby (1953-62). This is another species which has disappeared due to the demise of the ponds. It appears to be the only recorded site for Vice County 68 North Northumberland.

Ranunculus trichophyllus **Water Crowfoot**

An annual or perennial aquatic herb with white buttercup flowers, floating and submerged leaves.

Life form: therophyte/hydrophyte; British distribution: ubiquitous; habitat preference: aquatic.

It was present in 1931 when it was collected by Goddard (Watt, 1951). The last record was made by Sowerby (1953-62) from Inner Farne. The remaining pond on this island is now dry for much of the year so the habitat for this plant has disappeared.

Papaver **Sp. Poppy**

Annual or overwintering herbs. Common weeds of arable fields.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

The only record is from Knoxes Reef in June 1946 by Goddard (1924-48). He added that "Archbold told me that the top of the reef is red with poppies in July". Mr Archbold was one of the Seahouses' boatmen at that time. This record presumably refers either to the Field Poppy *P. rhoeas* or the Long-headed Poppy *P. dubium.*

Fumaria muralis **Common Ramping Fumitory**

An annual herb climbing by its petioles. Flowers in spikes of various shades of pinkish-purple.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

The only record is by Sowerby (1953-62).

Rorippa nasturtium-aquaticum **Watercress**

A perennial plant of shallow water and wet soil. In May 1980, I found a number of plants in flower in the pond on Brownsman.

Life form: helophyte/therophyte; British distribution: ubiquitous; habitat preference: maritime.

Chenopodium rubrum **Red Goosefoot**

Chamerion angustifolium **Rosebay Willow Herb, Fireweed**

Leymus arenarius **Lyme-grass**

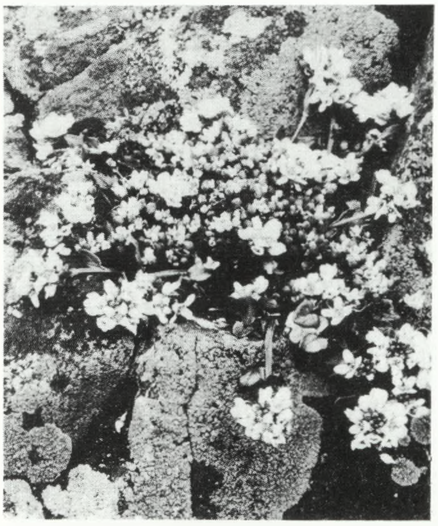
Tripleurospermum maritimum **Sea Mayweed**

Glaux maritima **Sea Milkwort**

Armeria maritima **Thrift, Sea Pink**

Rorippa nasturtium-aquaticum

Cochlearia danica Early Scurvy-grass



A locally common plant on sandy and rocky shores. It is an annual which overwinters. Size varies from 5-20cm. Leaves at the base are long stalked and heart-shaped. The upper leaves are usually ivy-shaped and stalked, which is the distinguishing feature between this species and the Common Scurvy-grass with its stalkless upper leaves. Flowers are usually lilac, sometimes appearing during April on the Farne Islands and plants still in flower may be found in September.

Life form: therophyte; British distribution: maritime; habitat preference: maritime.

This plant was recorded by Tate (1857) on Inner Farne, the Wideopens, Brownsman and Staple Island. Goddard (1924-48) noted that there were several fairly extensive areas of it along the top of the west cliffs on Inner Farne in 1946 and 1947, and that all the *Cochlearia* on East Wideopen in 1947 was *C. danica* unlike West Wideopen where all the *Cochlearia* was *C. officinalis* (see below). Harrison found it in flower on Longstone in 1962. I found it in flower on Knoxes Reef in 1980 and it still occurs on Inner Farne, Knoxes Reef, Brownsman and Staple Island but is always designated as 'occasional'.

Cochlearia officinalis Common Scurvy-grass

A biennial sometimes perennial with a stout tap root, growing up to 30cm high on the Farne Islands. Root leaves long-stalked, dark green, entire, fleshy, heart-shaped or kidney-shaped. Upper leaves bluntly pointed and stalkless. This is the key feature which distinguishes it from the Early Scurvy-grass with its stalked upper leaves. It produces an oil and in the days of sailing ships the leaves were eaten by sailors to protect them from scurvy.

Life form: hemicryptophyte; British distribution: maritime; habitat preference: maritime.

It has been recorded on the Farne Islands by Tate (1857), in 1876 (Philipson, 1880) and in 1931 when it was collected by Goddard (Watt, 1951). Goddard (1924-48) noted in 1947 that all the *Cochlearia* on West Wideopen was this species. Sowerby

(1953-62) recorded it on Inner Farne.

In 1971 I found it growing on all the islands except Knoxes Reef. In 1983 the wardens recorded it from all the islands except North Wamses. There is no evidence that it was more than an occasional species until 1981 when it was recorded from the main transect on Brownsman as 1% cover, and the same percentage cover on Staple Island in 1983. This species increased dramatically, reaching a cover value of 61% on Brownsman in 1988 and 43% on Staple Island the same year (Fig. 9). This increase may have been connected with the exclusion of breeding seals from the two islands.

The seeds germinate in the autumn and would not be able to withstand the seal pressure, but after the seals ceased to breed on these islands the seedlings could become established and give rise to the spectacular increase in percentage cover, becoming the dominant plant on Brownsman and Staple Island in 1988. It is still abundant on both islands. Flowering takes place in May and June, and if the rainfall is low the plants very quickly become mature and collapse. On Brownsman in 1989, 48% of the soil cover was *Cochlearia* but early in July this cover was only 6% resulting in an increase of bare ground by 42%; this plant which had replaced the Sea Campion could therefore result in increased soil erosion.

The visitors' path from the west face landing on Staple Island passes through the stand of *Cochlearia*.

[***Cochlearia scotica*** **Scottish Scurvy-grass**

This was recorded by Cordeaux (1892) (as *C. groenlandica*, Greenland Scurvy-grass) on the south side of Brownsman. This species has not otherwise been reported from the Farne Islands and there have been very few records of it from Northumberland. It is likely that Cordeaux' record refers to *C. danica*, the Early Scurvy-grass.]

Capsella bursa-pastoris **Shepherd's Purse**

A familiar garden weed and common plant of disturbed ground. It has been described as one of the "world's worst weeds". It has a short life span but can germinate in most months and may produce three generations each year.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

It was first recorded on Inner Farne by Sowerby (1953-62). The next record appears to have been in 1971 when I found it thriving on Inner Farne, the Wideopens, Brownsman and Harcar.

Sinapis arvensis **Charlock**

A summer (or winter) annual. A ruderal species but probably not native.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

It was present in 1931 when it was collected by Goddard (Watt, 1951) and he recorded finding one plant on Knoxes Reef in 1947 (Goddard, 1924-48). It was recorded on Inner Farne by Sowerby (1953-62). I found two plants on Brownsman in 1971 and the wardens recorded a plant on the Wideopens in 1983.

Seeds may pass undamaged through the intestines of birds. Such seeds may therefore be deposited on any of the islands in the group and give rise to new plants.

Cakile maritima **Sea Rocket**

An annual herb with succulent leaves and a very long tap root. Flowers may be lilac or white. This is a plant of coastal sand and shingle growing up to 40cm high.

Life form: therophyte; British distribution: maritime; habitat preference: maritime.

Tate (1857) recorded this species on the Wideopens and Knoxes Reef, both of which have

Hyoscyamus niger **Henbane**

Senecio jacobaea **Ragwort**

Cirsium vulgare **Spear Thistle**

Taraxacum officinale **Dandelion**

areas of sand. Goddard (1924-48) recorded it in St Cuthbert's Cove on Inner Farne in 1947 and Sowerby (1953-62) recorded it on Inner Farne where it still has a foothold on the small sandy beach just south of the path leading from the quay to the chapel. It is still found in some years on the Wideopens and Knoxes Reef.

Sedum acre **Wall Pepper, Biting Stonecrop**

Perennial (sometimes biennial) 2-10cm high, often mat-forming with bright star-like yellow flowers.

Life form: chamaephyte; British distribution: ubiquitous; habitat preference: grassland.

Recorded only on Staple Island or Brownsman in 1876 (Philipson, 1880).

Filipendula ulmaria **Meadowsweet**

Perennial, 60-120cm high with clusters of cream coloured flowers. Leaves pinnate, upper surface green but silvery green below.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland/aquatic.

This is a plant of wet habitats recorded on Inner Farne in 1931 when it was collected by Goddard (Watt, 1951). It was recorded from the same island by Sowerby (1953-62). This is the last record and it is one of the plants which has disappeared due to the drying out of the central part of the island.

Potentilla anserina **Silverweed** **Plate 1**

Perennial, prostrate with creeping stems, silvery pinnate leaves and large yellow flowers on long stalks. Propagation is by means of long creeping stolons which root to produce new flowering plants.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: ruderal/grassland.

Recorded by Tate (1857) on Inner Farne and by others up to 1962 on the same island. I found it 'frequent' on this island in 1971 and also on the Wideopens and Knoxes Reef. The wardens recorded it on Brownsman in 1983 where it survived until 1989. It is still 'frequent' on Inner Farne but there is a considerable variation in its abundance, probably due to disturbance by birds.

Potentilla erecta **Tormentil**

A prostrate downy perennial. Leaves in a terminal rosette with three toothed leaflets and two toothed stipules at the base. Flowers bright yellow with four petals.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

Recorded only by Sowerby (1953-62), probably on Inner Farne.

Potentilla reptans **Creeping Cinquefoil**

Another low perennial, downy, with prostrate stolons which readily root at the nodes to produce new plants. The leaves are palmate and on long stalks. The flowers with five yellow petals are much larger than those of Tormentil.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: ruderal/grassland.

Recorded only on Staple Island or Brownsman in 1876 (Philipson, 1880).

Medicago sativa **Lucern, Alfalfa**

A perennial, native in East Anglia. A well known fodder plant frequently found in grassy and waste places.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

A plant was recorded by the wardens on Brownsman in 1983. This appears to be the only record.

Trifolium repens **Dutch Clover**

The 'wild white' clover of agriculture.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

First recorded on Inner Farne by Tate (1857). All subsequent records are from this island. It still thrives on Inner Farne, especially in the area designated 'Picnic Site'. This plant was more abundant during the period when the rabbits were absent from the island in 1968-74.

Lotus corniculatus **Common Birdsfoot Trefoil**

Perennial, perhaps the best known of our yellow pea-flowers, which is generally distributed in the British Isles in pastures and grassy places. Flowers up to eight in a head are often tipped with red. The pods are up to 2.5cm long, resembling a bird's foot.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

All records are from Inner Farne. It was first recorded by Tate (1857) and then by Sowerby (1953-62). Watt (1951) included it in her list of plants which had disappeared since 1857, but Brown (1972) found one or two plants in 1970 and I found two (probably the same plants) in 1971. This appears to be the last record of this plant on the islands.

Lotus glaber **Narrow-leaved Birdsfoot Trefoil**

A taller, more erect plant with narrower, fewer, small yellow flowers.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

First recorded by Sowerby (1953-62) on Inner Farne. It was still on this island in 1971 but it appears that this was the last record.

Chamerion angustifolium **Rosebay Willow Herb, Fireweed** **Plate 2**

A striking perennial now widespread and often abundant on waste ground, heaths, railway banks and sometimes in woodland clearings.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: ruderal.

I found five plants close to the bothy on South Wamses in 1973. These increased to seventeen plants by 1983 but, except for two plants sheltered by the bothy, they all suffered from the effects of exposure and this species has not been recorded since on this island. The wardens found a single plant on Brownsman in 1983.

Epilobium hirsutum **Great Hairy Willow Herb, Codlins and Cream**

A tall perennial herb up to 150cm. Leaves covered with soft spreading hairs. Flowers deep purplish-rose up to 20+mm in diameter. The stigmas have four curved lobes which protrude much further than the stamens. A plant which is often abundant in damp places.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: aquatic.

Recorded on Inner Farne by Sowerby (1953-62). I could find only four large and three small plants in 1971. This appears to be the last record. This is probably another plant which has disappeared due to the drier soil conditions that now prevail on Inner Farne.

Conium maculatum **Hemlock**

A tall hairless biennial up to 2m. Distinguished from other white umbellifers by its purple spotted hollow stem.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: woodland/aquatic/ruderal.

It was first recorded by Tate (1857). Goddard (1924-48) found it on Inner Farne in 1933 but noted that it was not typical because it was odourless. The British Ecological Society recorded it on Inner Farne in 1948, and in 1971 there was a stand of this plant across the west side of West Wideopen, and smaller stands on Inner Farne near the path leading up to the chapel. It was still growing there in 1992 but was less dominant on West Wideopen than it was in 1971.

Primula vulgaris **Primrose**

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: woodland/grassland.

Present in 1931 when it was collected by Goddard (Watt, 1951). He also noted that in May 1947, several were in flower on a bank near the Fishe House on Inner Farne (Goddard 1924-48). Sowerby recorded this species on Inner Farne, but I could only locate a single plant on this island in 1971. This species has not been recorded on the islands since that date.

Glaux maritima **Sea Milkwort** **Plate 3**

A small prostrate pale green perennial. Flowers have a pale pink calyx 3-6mm in diameter but no petals.

Life form: hemicryptophyte; British distribution: maritime; habitat preference: maritime.

First recorded by Tate in 1857 for the Farne Islands. The next record was by Hull (1927) for

Inner Farne. It was present in 1931 when it was collected by Goddard (Watt, 1951) probably from Inner Farne. In 1971, I recorded this species on Inner Farne, the Wideopens, Brownsman, Staple Island and Longstone. It was recorded again from all these islands by the wardens in 1983. On Inner Farne, this plant can be found not far from the path leading up to the chapel and on Brownsman thrives on the south-east edge of the soil cap.

Anagallis arvensis **Scarlet Pimpernel**

An annual, usually prostrate with vermilion flowers with a purple eye. Stems quadrangular and the leaves are dotted with black glands on the underside. Often occurs on disturbed ground.

Life form: therophyte/chamaephyte; British distribution: ubiquitous; habitat preference: ruderal.

The only records for the Farne Islands are from Inner Farne and the Wideopens when the wardens made their survey in 1983.

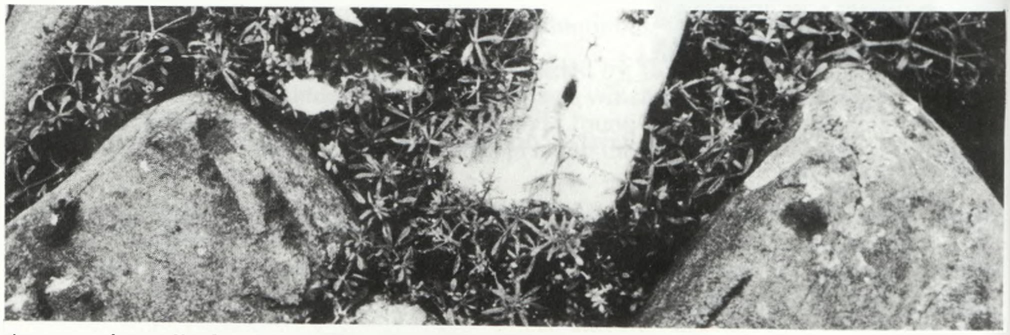
Armeria maritima **Thrift, Sea Pink** **Plate 3**

One of the most beautiful plants of the Farne Islands. A perennial with a much branched woody rootstock. It forms a cushion of densely bunched leaves when growing on the cliff face but the leaves of plants in the turf near the lighthouse cottages on Inner Farne form a flat rosette. The leaves are fleshy, long, narrow and with a single vein. Flower stalks are leafless and up to 15cm on this island with a head of closely packed flowers of various shades of pink. Each flower has a funnel shaped calyx and five petals.

Life form: hemicryptophyte/chamaephyte; British distribution: maritime; habitat preference: maritime.

It was recorded by Tate (1857) on Inner Farne and Brownsman and on the south side of Brownsman by Cordeaux (1892): "A thrift with dense clusters of pink flowers". Goddard (1924-48) noted in 1947 that the south side of Inner Farne near the lighthouse was covered with campion and thrift because the area had not been trampled by visitors during the war years. This species was also recorded on Staple Island by the British Ecological Society in 1948. There are now only a few plants near the cliff edge adjacent to the lighthouse cottages on Inner Farne. There was a drift of this plant covering a considerable area above these cliffs along with *Trifolium repens* and *Festuca ovina*. These two species were heavily grazed by rabbits but after the demise of the rabbits the thrift practically disappeared.

Galium aparine **Goosegrass**



An annual usually found straggling in hedge bottoms but it also occurs on waste ground and coastal shingle. Stems are four-angled, rough with down curved prickles which are also present on the whorls of six to eight narrow leaves. Flowers are small, white and inconspicuous and the fruits which may be up to 6mm in diameter are also covered in hooked bristles.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

Tate recorded this species on Brownsman and South Wamses in 1857. Watt (1951) included it in a list of plants which had disappeared since 1857, but Sowerby (1953-62) recorded it on Inner Farne, Knoxes Reef and South Wamses. It was present on these islands and also on Brownsman and Staple Island when the wardens made their survey in 1983.

Anchusa arvensis **Bugloss**

A very bristly annual to biennial up to 20cm. The hairs on the wavy, irregularly toothed lanceolate leaves have swollen bulbous bases. Flowers are small, bright blue with the corolla tubes swollen at the base.

Life form: therophyte/hemicryptophyte; British distribution: ubiquitous; habitat preference: ruderal.

First recorded by Tate (1857) on Inner Farne. All subsequent records are from this island except one in 1983 when it was found on the Wideopens by the wardens. Only a very minor component of the vegetation on Inner Farne but in some years it is much more common than in others.

Amsinckia lycopsoides **Scarce Fiddleneck**

Annual up to 30cm with coarse hairy leaves and stems, and a deep yellow corolla. It occurs only on Inner Farne.

Life form: therophyte; British distribution: ?; habitat preference: ruderal.

It was first reported by Hull (1927), and Goddard (1924-48) noted it in 1930 and later years. Watt pointed out in 1951 "it is a native of Lower California and was probably introduced accidentally many years ago when the lightkeepers kept poultry here. In 1925 there was a small patch of it on the grass bank just outside the enclosure gate, but recently it has spread rapidly and now covers a considerable area". In 1992 it still occupied a considerable area and was very common adjacent to the chapel.

Myosotis arvensis **Field Forget-me-not**

An erect biennial, our most common Forget-me-not growing up to 15cm on Inner Farne. A softly hairy plant with lanceolate leaves and blue flowers.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: ruderal.

First recorded on Inner Farne by Tate (1857) and all subsequent records are from this island, except for one from the Wideopens where I found it in several areas in 1971. It was still locally frequent there when this island was surveyed by the wardens in 1983.

Cynoglossum officinale **Hound's Tongue**

A soft, grey, down perennial up to 70cm with small maroon flowers. Occurs along the coast of Northumberland.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

Only one record for the Farne Islands by Sowerby (1953-62).

Callitriche stagnalis **Common Water Starwort**

Annual to perennial, if growing in water with dense floating rosettes of leaves, but if on wet mud the plant is prostrate. Flowers green, minute without petals.

Life form: therophyte/hydrophyte; British distribution: ubiquitous; habitat preference: aquatic.

It was present in 1931 when it was collected by Goddard (Watt, 1951). The record is probably from Inner Farne where Sowerby recorded it (1953-62). It had disappeared from Inner Farne by 1971 but I found it in a small pool on the exposed rocks on Staple Island and it was still extant in the same pool in 1983 when it was recorded by the wardens. It appeared on the pond on Brownsman in 1988 but has not been found since due to the pond being dry during the spring and summer months.

Lamium purpureum **Red Dead-nettle**

A very common downy annual weed in cultivated land and on waste ground throughout the British Isles. Distinguished by its square stems with leafy flower spikes of pinkish-purple flowers.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

The only record is that of Sowerby (1953-62) on Inner Farne.

Prunella vulgaris **Selfheal**

A creeping perennial up to 20cm with pointed, oval leaves and purple flowers.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland/ruderal.

All records are from Inner Farne. Tate (1857) first recorded it and it was present in 1931 when it was collected by Goddard (Watt, 1951). It was seen by Sowerby (1953-62) but it has not been recorded since then.

Hyoscyamus niger **Henbane** **Plate 4**

Life form: hemicryptophyte; British distribution: ubiquitous/maritime; habitat preference: ruderal.

A single plant was discovered on Inner Farne by the wardens in 1991.

A native, poisonous annual plant on disturbed ground and sandy places especially by the sea. The seed may have been transferred to the island by a bird or even a visitor. It appeared to produce typical capsules full of seeds but no other plants have subsequently been found.

Veronica chamaedrys **Birdseye Speedwell, Germander Speedwell**

A weak, hairy perennial with brilliant blue flowers with a white eye. A common plant throughout the British Isles.

Life form: chamaeophyte; British distribution: ubiquitous; habitat preference: grassland/woodland

The only record on the Farne Islands is of a large plant I found growing at the high tide line on the Northern Hares in 1972.

[*Veronica montana* **Wood Speedwell**

Life form: chamaeophyte; British distribution: ubiquitous; habitat preference: woodland

This perennial was recorded by Sowerby (1953-62) but it is a plant of damp woods and it is doubtful if it occurred on the Farne Islands.]

Plantago major **Ratstail Plantain**

A widespread common plantain especially in well-trodden open habitats. Flowers in greenish spikes up to 15cm; the flowers are minute, pale yellow with conspicuous purple anthers. The broad oval leaves have very prominent veins on their undersides.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: ruderal.

I first recorded this perennial on Staple Island in 1971 and it was again recorded on this island by the wardens in their survey in 1983.

Plantago coronopus **Buck's-horn Plantain**

A low downy biennial, sometimes annual or perennial found on sandy and gravelly soil not far from the sea and also in cracks in maritime rocks. Some plants are extremely small. They all have very variable leaves in a rosette, usually pinnately lobed, but sometimes they are linear and almost entire but invariably shorter and more prostrate than the sea plantain.

Life form: therophyte/hemicryptophyte; British distribution: maritime; habitat preference: maritime.

Recorded by Tate (1857). It was present in 1931 when it was collected by Goddard (Watt, 1951). The British Ecological Society recorded it on Inner Farne in 1948 and Sowerby recorded it from the same island in 1953-62. In 1971 I found it on the Wideopens as well as on Inner Farne and it is still to be found on these two islands.

Plantago maritima **Sea Plantain**

A low hairless perennial from 10-20cm high with thick fleshy leaves which are sometimes slightly toothed. Flowers are in dense spikes with prominent pale yellow anthers.

Life form: hemicryptophyte; British distribution: maritime; habitat preference: maritime.

First recorded by Tate (1857) on Longstone. Hull found this plant on Inner Farne in 1927. It was present in 1931 when it was collected by Goddard (Watt, 1951). This appears to be the last record of this widespread and common plant of sea-shores and salt-marshes. I have searched for this plant without success but it may well survive on some of the islands.

Sambucus nigra **Elder**

A common shrub, sometimes a small tree, found throughout the British Isles.

Life form: phanerophyte; British distribution: ubiquitous; habitat preference: ruderal.

It was collected by Goddard in 1931 (Watt, 1951). This specimen almost certainly came from

Inner Farne where it had been planted. Elders have since been recorded on Inner Farne by Sowerby (1953-62), Hirons (1971), by the wardens in 1983, and they are still present. These elders are typical of the specimens found in exposed positions around our coasts. New growth is often killed by exposure at the end of the growing season but the twigs provide some protection for the new shoots which arise the following year. Elders are characteristic of nitrogen-rich soils and they are very resistant to rabbits.

Bellis perennis **Daisy**

An abundant perennial plant in short grassland throughout the British Isles and flowering throughout the year.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

Recorded by Tate (1857) on Inner Farne and the Wideopens. Goddard collected it in 1931 (Watt, 1951) and noted that it was in flower on Inner Farne in June 1947 (Goddard, 1924-48). Sowerby's (1953-62) record is from this island. It was present in 1971 on Inner Farne and the Wideopens, and in 1983 the wardens found a single plant in flower on Longstone.

Achillea millefolium **Yarrow**

A downy dark green perennial with lanceolate leaves, two to three pinnate with small linear leaflets. Flower heads white or pink in flat terminal umbels.

Life form: chamaephyte; British distribution: ubiquitous; habitat preference: grassland.

The only record is that of Sowerby (1953-62).

Tripleurospermum maritimum **Sea Mayweed** **Plate 3**

An annual or perennial maritime species often half-prostrate with branching stems up to 50cm and two to three pinnate leaves. The large flower heads, up to 5cm in diameter, are daisy-like with yellow disc florets and white ray florets. A plant of the drift-line, shingle beaches, coastal rocks and at the foot of sand dunes.

Life form: hemicryptophyte/chamaephyte; British distribution: maritime; habitat preference: maritime.

It was collected by Goddard in 1931 (Watt, 1951) and he recorded it on Knoxes Reef in 1947 (Goddard, 1924-48). Sowerby (1953-62) recorded it growing on Inner Farne. I failed to find it on this island in 1971 but it was then in flower on Staple Island. In 1980, it flowered on the Wideopens and Knoxes Reef. In 1983, the wardens recorded it on Brownsman and Staple Island and four years later I again found it on Knoxes Reef; there had been a considerable increase in its abundance on Brownsman.

Matricaria discoidea **Pineapple Weed, Rayless Mayweed**

An introduced species and now widespread and increasing, especially in well trodden areas. Dark green, bushy and up to 30cm high. Leaves two or three pinnate, with thread-like segments. Flower heads have yellow-green disc florets but they are without ray florets.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

First recorded by Sowerby (1953-62). This appears to be the only record until 1971 when I found it on the Wideopens and Brownsman. It was still on these two islands when the wardens made their survey in 1983.

Senecio jacobaea **Ragwort** **Plate 4**

A biennial or sometimes perennial with deeply pinnately lobed leaves with the basal ones forming a rosette. It has an erect stem up to 140cm high bearing a flat-topped terminal cluster of yellow daisy-like flowers. An abundant plant of dry grassland and sand dunes.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: ruderal.

It was recorded by Tate (1857) on Inner Farne and the Wideopens. All subsequent records are from these two islands where it is still common. Hull (1927) reported that "sea campion and ragwort have taken possession". Goddard (1924-48) recorded ragwort on West Wideopen in 1946. In 1991 there was a pure stand of this species adjacent to the stand of Hemlock, *Conium maculatum*, on West Wideopen.

On Inner Farne the terminal clusters of flowers provide shade for tern chicks and protection from inclement weather. This plant is not eaten by rabbits.

Senecio viscosus **Stinking Groundsel, Sticky Groundsel**

A dark grey-green bushy annual. The whole plant is covered with sticky hairs. Occurs in waste and bare places especially by the sea.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

Only once recorded for the Farne Islands by Hull (1927).

Senecio vulgaris **Groundsel**

A ubiquitous annual or overwintering herb which can be found flowering throughout the year.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

It does not appear to have been recorded until I found it in flower in 1971 on Inner Farne, the Wideopens and Brownsman. In 1983 the wardens could find only a few plants on Brownsman.

[***Arctium lappa***

This was recorded by Tate (1857) and Hull (1927), but almost certainly refers to *A. nemorosum* recorded by Goddard (Watt, 1951) and subsequent observers. *A. lappa* has not been reported north of Yorkshire (Perring & Walters, 1976).]

Arctium minus **subsp.** ***nemorosum*** **Lesser Burdock**

A stout downy biennial up to 100cm high on the Farne Islands. The lower leaf stalks are hollow and furrowed above. The flower heads are globular, 25mm across, on short stalks forming loose spikes. The florets almost equal the purple-tipped sepal-like bracts. All the bracts have hooked tips. It is a plant of woodland clearings, waysides and waste places.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: ruderal.

Recorded from Inner Farne and the Wideopens by Tate (1857). Hull recorded it from Inner Farne in 1927 and Goddard (1924-48) found it on numerous occasions on Inner Farne, Brownsman and the Wideopens in 1946 and 1947. He included it in his collection made in 1931 (Watt, 1951). Sowerby (1953-62) found it on Inner Farne, and it was thriving there in 1971 and also on West Wideopens. It was recorded on both islands by the wardens in 1983. On West Wideopens it is common at the eastern end where the soil has a sand content of almost 80%.

Carduus nutans **Musk Thistle**

A grey, cottony, downy thistle, usually biennial growing up to 100cm. The large reddish-purple drooping flower heads bear florets which are distinctly two lipped. Usually found in pastures, waysides and waste places on calcareous soils.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland/ruderal.

It was was collected by Goddard in 1931 (Watt, 1951). The last record is that of Sowerby (1953-62).

***Carduus crispus* Welted Thistle**

Biennial up to 120cm high with erect cottony stems and flower heads in dense clusters. A plant of stream-sides, hedgerows and waste places.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland/ruderal.

It was collected by Goddard in 1931 (Watt, 1951). The last record was made by Sowerby (1953-62).

***Cirsium vulgare* Spear Thistle** **Plate 4**

Our commonest large thistle. A stout downy biennial plant which may reach 150cm but those growing on the Farne Islands have not exceeded 100cm. Leaves pinnately lobed, spiny above and these spines continue downwards onto the stem forming long spiny wings. Flower heads may be solitary or two or three together, reddish-purple and more than 25mm in diameter. The sepal-like bracts have yellow topped spines. A common plant of grassland and waste places.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: ruderal.

First recorded by Tate (1857). Hall recorded it on Inner Farne in 1927 and Goddard (1924-48) recorded it on Knoxes Reef in 1947. In 1971 I found it in flower on the Wideopens and Staple Island as well as on Inner Farne, and in 1983 there was an additional new record from Brownsman made by the wardens.

***Cirsium arvense* Creeping Thistle**

Perennial with fairly small pale lilac flower heads. May grow up to 140cm high and the male and female flowers are on different plants. An abundant species throughout the British Isles and a difficult plant to eradicate because of its capacity to produce new plants from fragments of its roots.

Life form: geophyte; British distribution: ubiquitous; habitat preference: ruderal.

It was recorded on the Farne Islands by Tate (1857) and on Inner Farne by the British Ecological Society (1948) but Watt (1951) included this species in her list of plants which had disappeared since 1857. I recorded Creeping Thistles in flower in 1971 on Inner Farne, the Wideopens, Brownsman and Staple Island. By 1988 there was a large stand on the drift deposit on Staple Island and at the foot of the drift deposit on Brownsman. I recorded a small increase in both stands in 1988 but by 1991 both stands had completely disappeared, although no spraying of herbicides had taken place. It still occurs on Inner Farne, the Wideopens, by the cottage garden on Brownsman, and on Staple Island.

***Sonchus asper* Spiny Milk- or Sow-Thistle**

A common, annual weed, sometimes overwintering which can be distinguished from *S. oleraceus* by its leaves which are less pinnafied with the terminal lobe much smaller. They are spine-toothed with wavy edges and they clasp the stem with rounded auricles.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

It was collected by Goddard in 1931 (Watt, 1951) and was recorded on Inner Farne by Sowerby (1953-62). It was present on this island in 1971 and I also found it on the Wideopens and Brownsman. The wardens recorded it in 1983 on the same islands plus several plants on Knoxes Reef.

Sonchus oleraceus **Sow-Thistle, Milk-Thistle, Smooth Sow-Thistle**

An annual, sometimes overwintering and widespread weed of disturbed and waste ground. The leaves are very variable, pinnately lobed with the terminal lobe the largest. The stem is stout, hollow, up to 150cm high and contains latex. The flowers in terminal clusters resemble small pale dandelions.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: ruderal.

The first record is by Tate (1857) on Inner Farne. It was collected by Goddard in 1931 (Watt, 1951), probably also on Inner Farne. Since then it has spread: in 1971 it was on the Wideopens, Knoxes Reef and Staple Island. In 1973, I also found a plant in flower on Harcar. In their survey of 1983, the wardens recorded it on Inner Farne, Brownsman, Staple Island, Harcar and Longstone.

Hypochaeris radicata **Common Catsear**

A perennial in grassy areas, found throughout the British Isles. The leaves are in a basal rosette, narrow oblong, pinnately lobed or broadly toothed and are covered with rough hairs. Main stem up to 30cm, with dandelion-like flowers up to 25mm in diameter.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

I found this species in flower on South Wamses in 1973 and the wardens, in their survey of 1983, recorded it from the same island and also on Brownsman.

Taraxacum officinale **Dandelion** **Plate 4**

A well known perennial, abundant and widespread in waste and grassy places.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland/ruderal.

Tate (1857) found it growing on Inner Farne, Brownsman and Staple Island. Philipson's (1880) record is for Brownsman and/or Staple Island in 1876. It was collected by Goddard in 1931 (Watt, 1951), probably from Inner Farne. I found it in 1971 on Inner Farne and also on Knoxes Reef. I failed to locate it on Brownsman or Staple Island.

Crepis capillaris **Smooth Hawksbeard**

A widespread annual with dandelion-like leaves. The stem is up to 45cm, branched above with dandelion-like flowers 12mm in diameter. The bright outer yellow florets are usually reddish beneath.

Life form: therophyte/hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland/ruderal.

The only record is that of Sowerby (1953-62) from Inner Farne.

Iris pseudacorus **Yellow Iris**

The common wild iris. An erect perennial up to 150cm with a stout rhizome, stiff broad leaves with a prominent midrib and a well branched flowering stem bearing yellow flowers varying from pale yellow to almost orange. Typically found in marshes and shallow water.

Life form: helophyte; British distribution: ubiquitous; habitat preference: aquatic.

All records are from Inner Farne (Tate, 1857; Watt, 1951; Sowerby, 1953-62) and I found it there in 1971. The plant is still found not far from the track leading up to the chapel.

Juncus gerardii **Saltmarsh Rush**

A perennial, slender rush about 30cm tall which is widespread and often common in brackish marshes. Flowering stems triangular in the upper part. Flowers are dark brown in lax clusters.

Life form: geophyte; British distribution: maritime; habitat preference: maritime.

All records from Tate (1857) onwards are from Inner Farne. In 1971, I recorded a stand of this plant 2m in diameter, close to the pond, but it now appears that this plant is no longer extant.

Juncus bufonius **Toad Rush**

An annual 5-30cm tall but appears unrush-like with a thin branched hollow stem and with grass-like leaves at its base. The flowers are pale green in branched clusters and at the base of each cluster is a long leaf-like bract. Often common in moist sandy and muddy places especially around ponds.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

First recorded by Sowerby (1953-62) on Inner Farne. In 1971, I recorded it around the pond on Inner Farne, and around the ponds on the Wideopens and Brownsman. The pond on West Wideopen has now disappeared but the wardens found this species growing on Inner Farne and Brownsman in 1983.

Juncus bulbosus **Bulbous Rush**

A very variable perennial rush like a densely tufted grass up to 12cm high. The stems are slightly swollen at the base and it does not form a creeping rhizome.

Life form: hemicryptophyte/helophyte/hydrophyte; British distribution: ubiquitous; habitat preference: aquatic/woodland

It was recorded by Tate (1857) on Brownsman. Watt (1951) included it in her list of plants which had disappeared since 1857, but Sowerby (1953-62) recorded it on Inner Farne. It has not been recorded since then.

Luzula campestris **Field Woodrush, Sweep's Brush, Good Friday Grass**

A short creeping perennial up to 20cm with grass-like leaves and creeping stolons. The flowers are very dark brown with long anthers up to six times longer than their filaments. Common throughout the British Isles.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

Recorded by Tate (1857) on Inner Farne. Watt (1951) included it in her list of plants which had disappeared since 1857.

Festuca rubra **Red Fescue**

A variable perennial grass up to 35cm. The leaves on non-flowering stems tend to be inrolled and pointed whereas those on the flowering stems are flat and blunt. Flower heads are branched and the spikelets may be green-purple or reddish. Found in all kinds of grassy places.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

The first record is Tate (1857) and it was collected by Goddard in 1931 (Watt, 1951). Sowerby

(1953-62) recorded it on Inner Farne. In 1971, I recorded it on Inner Farne, the Wideopens, Brownsman, Staple Island, South and North Wamses. The wardens, in their survey of 1983, recorded it on all of these islands except the Wideopens and North Wamses.

Festuca ovina **Sheep's Fescue**

A very common, hairless perennial grass up to 30cm high. It is a tufted species with very short, narrow, inrolled leaves with the leaf sheaths split more than half way to the base.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

Recorded by Tate (1857) and it was collected by Goddard in 1931 (Watt, 1951). Sowerby (1953-62) recorded it on Inner Farne and in 1971 I found it to be common on this island and 'occasional' on the Wideopens.

[*Festuca lemanii*

This was recorded by Tate (1857) from the Farne Islands, but has not been observed there since then. The species is not otherwise known north of Yorkshire (Perring & Walters, 1976) and Tate's record is therefore probably erroneous.]

Lolium perenne **Perennial Rye-grass**

Another common and widespread grass. A perennial which is often cultivated. It is a tall species up to 40cm, hairless with dark green, narrow, shiny leaves. Flower heads are in unbranched spikes with the spikelets unstalked on either side of the stem.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

First recorded from Inner Farne by Sowerby (1953-62). In 1971, I found it on Inner Farne, the Wideopens, Knoxes Reef and Staple Island but in 1982 the wardens found it only on the first two of these islands.

Poa annua **Annual Meadow-Grass**

A very abundant and widespread species, 5-25cm tall, found on bare, waste and cultivated ground. The leaves are flat and hooded at their tips. The flower heads are triangular in outline and branched.

Life form: therophyte/hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland/ruderal.

Recorded from the Wideopens by Tate (1857). The next record appears to be 1971 when I found it on Inner Farne, the Wideopens, Brownsman and Staple Island. In 1983, the wardens did not record this species on the Wideopens but found it on four more islands: South Wamses, Harcar, Longstone and Northern Hares. It was quite common on West Wideopen in 1986.

Poa trivialis **Rough Meadow-Grass**

Widely distributed and common in meadows and rich moist soils but is also found on waste and cultivated ground. It is a loosely tufted perennial 20-100cm high with creeping stolons. The leaves may be green or purplish, hairless but the sheaths are rough which distinguishes it from the Smooth Meadow-Grass.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland/ruderal.

Recorded by Tate in 1857 on Inner Farne and the Wideopens. The British Ecological Society found it on Inner Farne in 1948, and Sowerby (1953-62) recorded it on the same island. Watt (1951), however, included it in her list of species no longer present that had disappeared since 1857. This species was 'frequent' on Inner Farne and Brownsman in 1971.

***Poa pratensis* Smooth Meadow-Grass**

A widespread and perennial grass of drier areas. A very variable species from 5-50cm, with creeping, slender rhizomes and hooded and blunt leaves. The flower heads are branched and often have purplish spikelets.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

Tate recorded this grass on the Wideopens in 1857. It was collected by Goddard in 1931 (Watt, 1951). I found it on Inner Farne and the Wideopens in 1971 and the wardens recorded it on Brownsman and Staple Island in 1983.

***Puccinellia maritima* Common Saltmarsh Grass**

Perennial 10-80cm high. A densely tufted grass with creeping stolons and roots produced from the nodes which form a compact turf. The leaves are hairless with the sheaths smooth and rounded on the back.

Life form: hemicryptophyte; British distribution: maritime; habitat preference: maritime.

This plant had been either under-recorded for the islands or has increased its range in recent years. Recorded by Tate (1857), Hull (1927) for Longstone, and it was collected by Goddard in 1931 (Watt, 1951). Sowerby's (1953-62) record is for Inner Farne, but in 1971 I recorded it from all the islands except the Wideopens and Brownsman, and in 1983 the wardens in their survey found it on all the islands.

***Dactylis glomerata* Cock's-foot**

A coarse densely tufted perennial 15-140cm high. The leaves are flat keeled, only slightly rough-edged but with rough sheaths. Flower heads are branched. Single-sided with egg-shaped clusters of green or purplish spikelets. A widespread and abundant species in grassy and waste places.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland/ruderal.

There are only three records, all from Inner Farne: by Tate (1857), in 1931 when it was collected by Goddard (Watt, 1951) and by Sowerby (1953-62).

***Leymus arenarius* Lyme-grass** **Plate 2**

A bluish-grey robust grass usually found on sand dunes. This perennial species forms large tufts up to 1-2m high. The leaves are broad, sharply-pointed and sometimes inrolled. The flower heads are large, unbranched with stalkless spikelets in pairs alternating on opposite sides of the stem.

Life form: hemicryptophyte; British distribution: maritime; habitat preference: maritime.

This huge grass was not recorded before I found it on Knoxes Reef in 1971. It still occurs on this reef but the extent of its cover varies from year to year according to the severity of the winter storms. Fulmars nest among this grass and in 1992 it held twenty-seven pairs. It was recorded on Staple Island in 1988 and appeared to be well established there in 1991.

***Elytrigia repens* Couch-grass, Twitch**

A coarse, tenacious perennial which spreads by means of creeping wiry rhizomes. The stems may attain a height of 120cm, with unbranched flower stalks.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: ruderal.

Recorded by Tate (1857) and although listed as absent by Watt in 1951, it was again recorded from Inner Farne by Sowerby (1953-62). There have been no further records since then. It is perhaps rather surprising that this tenacious species has disappeared.

Elytrigia juncea **Sand Couch-grass**

A grey perennial grass up to 60cm high found on young dunes and sandy coasts. The leaves have downy ribs with overlapping sheaths and brittle flowering stems which bear large flower heads with very large spikelets.

Life form: hemicryptophyte; British distribution: maritime; habitat preference: maritime.

It does not appear to have been recorded on the Farne Islands until I found it on Knoxes Reef in 1971. It still flourishes there among the shingle.

Triticum aestivum **Wheat**

Tate recorded this plant on Brownsman and South Wamses in 1857 and I found ten plants on Staple Island in 1971.

Hordeum murinum **Wall Barley**

An annual, common on waste land. A coarse, pale green tufted plant prostrate at the base but with flowering stems up to 25cm tall. The flower head is the typical barley-like spike. Spikelets arranged in alternating groups of three up the stem, each one with three stiff, rough awns up to 2.5cm long.

Life form: therophyte; British distribution: maritime; habitat preference: ruderal.

I found thirty or more plants close to the garden wall on Brownsman in 1971. It still grows on the same site.

Hordeum vulgare **Barley**

I found several plants on Knoxes Reef and Staple Island in 1971 and the wardens recorded it on Harcar in 1983.

Avena fatua **Wild Oat**

An introduced, tufted, stout annual up to 100cm high, with broad rough leaves and large flower heads spreading with characteristically oat-like spikelets.

Life form: therophyte; British distribution: ubiquitous; habitat preference: ruderal.

It was recorded on the Wideopens and Brownsman by the wardens in their survey of 1983.

Trisetum flavescens **Yellow Oat-grass**

A pale, slender perennial up to 45cm high with narrow flat leaves and flower heads resembling dainty oat-like flowers. Common in calcareous grassy places.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

First recorded by Tate (1857). Watt (1951) included it in her list of species which had disappeared since 1857, but Sowerby (1953-62) recorded it on Inner Farne. It has not been recorded since then.

Holcus lanatus **Yorkshire Fog**

A very common grass in a great variety of habitats and in a wide range of soils. A very soft downy perennial up to 100cm high. The leaves are finely pointed and downy and the flower heads branched and spreading with two flowered spikelets. Each flower has a short awn. A study of these plants on South Wamses showed that the leaves were significantly shorter than those of mainland plants (mean 169.9mm against 188.4mm) and significantly broader (13.2mm against 8.9mm).

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland/ruderal.

It was recorded by Tate (1857) on Brownsman, Staple Island and South Wamses. It was collected by Goddard in 1931 (Watt, 1951), probably on Inner Farne, and it was again recorded for Inner Farne by the British Ecological Society in 1948 and by Sowerby (1953-62). In 1971, it was still on Inner Farne and also on the Wideopens, North and South Wamses. It was recorded from these four islands and also from Brownsman by the wardens in 1983.

Agrostis capillaris **Common Bent-grass, Brown Top**

A tufted perennial 10-70cm high spreading by means of rhizomes. The leaves are usually flat up to 4mm wide. The flower heads are whorl-branched, loose and spreading; the flowers very rarely have awns.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

There are three records: Tate (1857) recorded this species on Staple Island, it was collected by Goddard in 1931 (Watt, 1951), and it was recorded by Sowerby (1953-62) on Inner Farne.

Agrostis stolonifera **Fiorin, White Bent**

Abundant in established grassland, damp ground and waste places. A variable, tufted, hairy perennial 15-40cm high, which spreads by leafy stolons. Leaves may be green, greyish or bluish, rolled when young but afterwards becoming flat and finely pointed. The flower heads are in branched whorls which spread in the flowering stage but contract in fruit. The spikelets are single flowered, straw-coloured and very small.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

It was recorded by Tate (1857), but included in a list of plants which had disappeared since 1857 by Watt (1951). However, Sowerby (1953-62) recorded it from Inner Farne, and I found it to be 'frequent' on this island in 1971.

Alopecurus pratensis **Meadow Foxtail**

A very common plant of meadows which occurs throughout the British Isles. A hairless tufted perennial 30-100cm high with roughish leaves and inflated sheaths.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

There is only one record: the wardens found this species on Brownsman in 1983.

Alopecurus geniculatus **Marsh Foxtail**

A perennial plant of wet meadows and the edges of ponds and ditches, 15-45cm high. The rooting stems are markedly bent at the base, the leaves are without hairs, and the upper sheaths are distinctly inflated. The panicles are narrowly cylindrical, dense and often tinged blue or purplish.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: aquatic.

I found a small area of this plant growing adjacent to the pond on Brownsman in 1989, and this appears to be the only record. The pond was dug out later that year and the plant disappeared.

Carex otrubae **False Fox-sedge**

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

Recorded (as *C. vulpina*) by Tate (1857) on Inner Farne. Watt (1951) included it in her list of species that had disappeared since 1857. It occurs in maritime habitats on Lindisfarne.

Carex flacca **Glaucous Sedge, Carnation Grass**

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: grassland.

Recorded (as *C. diversicolor*) by Tate (1857) on Inner Farne. Watt (1951) included it in her list of plants that had disappeared since 1857.

Carex distans **Distant Sedge**

A densely tufted perennial found in marshes and also in wet cracks in rocks.

Life form: hemicryptophyte; British distribution: ubiquitous; habitat preference: aquatic.

This is another sedge recorded by Tate in 1857 on Inner Farne. Watt (1951) included it in her list of plants that had disappeared since 1857, but Sowerby (1953-62) recorded it on Inner Farne. There appear to have been no subsequent records.

Dactylorhiza incarnata **Early Marsh Orchid**

Life form: geophyte; British distribution: ubiquitous; habitat preference: aquatic.

This orchid grows in peaty marshes and fens and was recorded from Brownsman by Tate (1857). Watt (1951) included it in her list of plants that had disappeared since 1857.

ACKNOWLEDGEMENTS

I wish to thank the Management Committee of the Farne Islands and the then Regional Director of the National Trust, Mr Oliver C. Maurice, for permission to carry out my studies of the vegetation of the islands during the last twenty or more years.

The help given to me by the Warden Naturalists, Mr Peter Hawkey and subsequently Mr John Walton, as well as all the wardens on the islands is gratefully acknowledged. Mr Hawkey and Mr Walton have also been most helpful in providing information on some matters of detail during the preparation of this report.

During 1971 I received much help and encouragement from my supervisor, Professor David Bellamy, and I must also express my appreciation of the late Mrs Grace Hickling who supplied me with unpublished data and gave me every help and encouragement during my early studies of the vegetation. I am also grateful to Professor Clark for his help during the preparation of this paper.

English Nature kindly provided grant aid to allow the inclusion of coloured photographs.

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BIRDS ON THE FARNE ISLANDS IN 1993

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INTRODUCTION

Calm seas on 27 March enabled the wardens to occupy Inner Farne and Brownsman, both islands then being manned until 4 December. Twenty-four species bred with the total population estimated at a record 67,902 pairs. The auk species were mainly responsible for this increase with rises in guillemot, razorbill and puffin populations. The puffin colonies were last censused in 1989 when it was estimated that 26,329 pairs were present. The sample counts this season would suggest that the population now stands at 34,710 pairs. On the negative side, eiders suffered their poorest season for many years. Not only did the number of breeding ducks drop by over 450 but both clutch and brood sizes were well below the recent Farne Island average. The situation will be closely monitored in 1994 although it is worth remembering that a similar situation in 1975 saw a return to 'usual' numbers in 1976. Roseate terns maintained their tenuous toe-hold on the islands with three pairs on Inner Farne, swallows bred in the chapel for the fourth succesive year, and a carrion crow attempted to breed on West Wideopen.

Passage birds, excluding the 'exotica', were represented by 150 species. Five of these were new to the island list: soft-plumaged petrel, Mediterranean shearwater, Richard's pipit (2), marsh warbler (2), and rose-coloured starling. Second appearances were made by mandarin duck, Sabine's gull and rustic bunting, a magpie was recorded for only the third time, hen harrier and quail for the fourth, with spotted crake making its fifth appearance. A yellow-breasted bunting was recorded for the sixth time, as was garganey. A hoopoe in April was the eighth record and the first since 1976. Other species to quicken the pulse included bluethroat (a record year with at least forty-two birds recorded), icterine warbler, yellow-browed warbler (at least five, plus one showing some characteristics of the race *humei* from central Asia), red-breasted flycatcher, red-backed shrike, common rosefinch and little bunting. A very exciting year for migrants is perhaps best summed up by the scenario on Brownsman where, in mid-September, the wardens could watch Richard's pipit, red-breasted flycatcher and yellow-breasted bunting feeding within feet of each other!

Two passage seabirds broke records this season. 626 sooty shearwaters on 4 September, with 700+ on 14 September, rather overshadowed the previous maxima of 291 in September 1991. The previous 'best' season for storm petrel was 1991 when five birds were recorded, but this season 14+ were noted. The most impressive movements were those of guillemot during the morning of 20 November when it was estimated that 9,000+ an hour were flying south through Staple Sound - an unprecedented passage in Northumberland.

Thanks go to the 1993 wardening team of Wayne Clynes, Bob Elliot, Jim Hickling, Bill Makin, Jon Riley, Jarrod Sneyd, Andy Snowball, Graeme Stringer and Dan Wiseman, as well as to various boatmen, for supplying the records which make up this report.

Details of all the birds are given in the following list: this follows the order and scientific nomenclature of Professor Dr K H Voous' list of recent holarctic species (1977), except for the Manx shearwater and gannet which adopt the new changes recommended by *Ibis* **133**, p438. Where appropriate, the figures for 1992 breeding birds are included, for comparison, in brackets.

SYSTEMATIC LIST

Unidentified Divers *Gavia* spp.

Eighteen sightings of 1-3 birds between 30 March and 21 May, and forty-five records of 1-14 from 21 August-26 November.

Red-throated Diver *Gavia stellata*

Seven spring records of 1-3 birds from 28 March-29 April, with 1-12 on thirty-one days from 24 August-2 December.

Black-throated Diver *G. arctica*

Three records of 1-5 from 7 April-8 May, and 1-6 on eighteen days from 18 September-2 December.

Great Northern Diver *G. immer*

Single birds past the islands on 19 May and 4 June - the latter bird in summer plumage. Then singles on eight days from 12 September-16 November. Twelve were recorded on 22 November, eleven flying north and one south.

Great Crested Grebe *Podiceps cristatus*

Two on Inner Sound on 20 October, two through Staple Sound on 23 October, then singles on 13, 20 and 22 November.

Red-necked Grebe *P. grisegena*

One summer-plumaged bird seen on the sea off Crumstone on 26 August, then 1-2 regularly from 8 September-26 November.

Fulmar *Fulmarus glacialis*

Birds were present on 27 March with those on Inner Farne already occupying nest sites. First eggs were laid on Brownsman on 15 May with first young on the same island on 5 July. 248 (223) pairs nested as follows: Inner Farne 40 (31), Knoxes Reef 26 (27), West Wideopen 19 (20), East Wideopen 9 (13), Skeney Scar 1 (2), Staple Island 32 (36), Brownsman 63 (52), North Wamses 20 (9), South Wamses 25 (22), Big Harcar 6 (7), Little Harcar 1 (0), Northern Hares 2 (1), Longstone End 4 (3). First young fledged on Inner Farne and Brownsman on 26 August, the last on 9 September. The largest movement of the year occurred on 13 September with 1,000+ an hour passing north. A blue phase bird was on East Wideopen on 14 July with one north on 5 September and three flying north on 13 September. A pure white/albino bird flew south through Staple Sound on 4 September and north past Crumstone on 7 September. After the usual desertion period numbers increased to *ca* 250 by mid-November.

Soft-plumaged Petrel *Pterodroma* sp.

One seen flying north past Crumstone on 5 September. First record for the islands.

Sooty Shearwater *Puffinus griseus*

Birds recorded almost daily from 2 August-21 October. Most records related to 1-80 but 626 flying north on 4 September and 700+ flying north on 13 September broke all previous island records.

Manx Shearwater *P. puffinus*

1-89 recorded from 13 April-21 October, peak movements occurring from late August to September.

Mediterranean Shearwater *P. yelkouan*

Singles recorded on six days from 18 August-14 September, with three flying north on 25 August and two north on 26 August. First acceptable records for the islands.

Storm Petrel *Hydrobates pelagicus*

At least fourteen birds were recorded on nine days from 11 July-12 September. They included one in a feeding group of seabirds associating with Minke whales on 15 August, and seven flying north on 23 August. It was not possible to identify the particular species of four small petrels.

Gannet *Morus bassanus*

Seen almost daily throughout the season although becoming very scarce from mid-October onwards. Peak passage occurred on 5 September with 1,500+ an hour moving north throughout the day.

Cormorant *Phalacrocorax carbo*

Birds present at the breeding sites on 27 March and nest material collection noted on 3 April. First eggs located on 12 May but were probably laid prior to this date. 268 (262) pairs nested as follows: East Wideopen 142 (150), North Wamses 126 (88), Big Harcar 0 (24). Most young had fledged by mid-July. Few birds were recorded from mid-November onwards.

Shag *P. aristotelis*

A late start to the season with the first eggs not seen until 30 April. First young recorded on 10 June. 1,948 (1,871) pairs nested as follows: Megstone 9 (10), Inner Farne 293 (283), West Wideopen 132 (190), East Wideopen 154 (150), Skeney Scar 108 (20), Staple Island 594 (673), Brownsman 284 (279), North Wamses 36 (38), South Wamses 173 (98), Roddam and Green 14 (6), Big Harcar 122 (109), Longstone End 29 (15). Many pairs failed to breed and deserted well-built or complete nests. The first birds fledged on 27 July and the last on 1 October. 2,000-3,000 were present around the islands from October onwards.

Grey Heron *Ardea cinerea*

1-2 seen regularly throughout the season, the majority of records being from August onwards.

Mute Swan *Cygnus olor*

1-6 recorded on seven days from 27 March-2 November.

Whooper Swan *C. cygnus*

Two flying north on 28 March, one north on 6 May, one north on 23 October, eight south on 26 October and four north on 1 November.

Pink-footed Goose *Anser brachyrhynchus*

Eight flying north over Staple Island on 22 June may have been feral birds. One with a flock of greylag geese on 11 November.

Greylag Goose *A. anser*

Four records of 2-18 in June, then 2-13 on six days from 18 July-22 October. 140 flying south on 11 November and 500+ south on 21 November.

Canada Goose *Branta canadensis*

Singles on 1-2 June and eight flying north on 7 June. The remains of a bird found on East Wideopen at the start of the season were presumed to be those of the injured bird resident since 1987.

Barnacle Goose *B. leucopsis*

Eight flying north through Inner Sound on 23 October with two present on Brownsman on 3 and 4 November.

Brent Goose *B. bernicla*

1-48 recorded on fourteen days from 18 September-20 November.

Shelduck *Tadorna tadorna*

Pairs present on Inner Farne and Brownsman/Staple Island throughout April, May and early June but no evidence of breeding. Twenty west of Inner Farne on 1 July and thirteen flying north through Inner Sound were the only large groups. One flying over Brownsman on 1 December was the final record.

Mandarin Duck *Aix galericulata*

One male on West Wideopen on 30 November associating with a flock of mallards. Second record for the islands and last recorded in May 1988.

Wigeon *Anas penelope*

Spring records of 1-6 on four days from 28 March-26 April. Then seen regularly from 23 August onwards with a maximum count of 310 on 23 October.

Teal *A. crecca*

Ten spring records of 2-10, then seen regularly from 8 August onwards. Maximum count of *ca* seventy roosting on Knoxes Reef on 30 November.

Mallard *A. platyrhynchos*

Birds seen regularly throughout the season with a maximum count of 150+ on Knoxes Reef on 1 December. 2 (4) pairs bred as follows: Staple Island 2 (0), Brownsman 0 (2), North Wamses 0 (1), South Wamses 0 (1). One nest was presumed predated whilst the other produced eight ducklings, seen on the sea with an adult on 20 July.

Pintail *A. acuta*

A female was flushed from Brownsman pond on 26 July, a male flew south through Staple Sound on 30 September, and a male was present on Knoxes Reef from 22-26 November.

Garganey *A. querquedula*

One on Staple Island pools on 10 May, two on rock pools on Inner Farne on 27 May, then singles on 14 September and 2 October. The fifth and last record was in May 1992 and there have thus now been ten records for the islands.

Shoveler *A. clypeata*

One male and one female flying south on 13 April then records of 1-2 birds on seven days from 24 October-1 December.

Pochard *Aythya ferina*

One spring record of a bird flying south on 16 April. Four with an eider flock, plus one moving north, on 21 November, and one south on 24 November.

Tufted Duck *A. fuligula*

Five on 21 May, then 1-3 on fifteen days from 11 August-1 December.

Scaup *A. marila*

1-9 on five days from 15 August-21 November.

Eider *Somateria mollissima*

Birds started moving on to the islands on 24 April, with the first egg found on 28 April. 744 (1,202) females nested as follows: Inner Farne 532 (789), Knoxes Reef 5 (8), West Wideopen 12 (48), East Wideopen 5 (13), Staple Island 29 (39), Brownsman 118 (264), North Wamses 12 (16), South Wamses 16 (16), Big Harcar 8 (4), Longstone main rock 3 (0), Longstone End 4 (5). Most birds laid smaller clutches than usual and only small numbers of young were noted. *Ca* 1,600 were on the sea from mid-October onwards.

Long-tailed Duck *Clangula hyemalis*

1-4 on eight days from 30 March-22 April. 1-4 on nineteen days from 9 October-1 December.

Common Scoter *Melanitta nigra*

Singles and small flocks seen on fifty-five days throughout the season. Maximum day count of 230 flying north on 23 October.

Velvet Scoter *M. fusca*

1-5 on fourteen days from 6 August-24 November.

Goldeneye *Bucephala clangula*

Four on 29 March and one on 12 April then 1-6 on eleven days between 10 September and 1 December. On 23 October thirty-two were logged flying past the islands.

Red-breasted Merganser *Mergus serrator*

1-2 on five days from 10 April-18 May, then 1-2 on five days from 25 September-25 October.

Goosander *M. merganser*

1-4 on eight days between 10 September and 28 November.

Hen Harrier *Circus cyaneus*

One flew over Inner Farne, heading for the mainland, on 7 April. Fourth record for the islands and last recorded in October 1990.

Sparrowhawk *Accipiter nisus*

Singles on five days between late March and early April, then seen on nineteen days from 15 August-13 November.

Kestrel *Falco tinnunculus*

One on 30 March and 15 April, with 1-2 on twenty-two days from 1 August-30 October.

Merlin *F. columbarius*

A female was resident from 29 March-14 April, then 1-2 were seen on twenty-seven days between 23 August and 1 December. Kills included turnstone, blackbird and starling.

Peregrine *F. peregrinus*

A female was present on 5 and 15 April: on the latter date it was seen catching, but dropping, three puffins. 1-2 birds on twenty-six days from 21 September-3 December.

Quail *Coturnix coturnix*

A female was present on Brownsman from 11-15 May. Fourth record for the islands and last recorded in May 1992.

Water Rail *Rallus aquaticus*

Singles present on 16 and 30 September, 3, 14, 22 and 24 October and 1 November.

Spotted Crake *Porzana porzana*

One flushed from the vegetation around Brownsman pond on 10 September. Fifth record for the islands and last recorded in November 1985.

Moorhen *Gallinula chloropus*

A dead adult was found on Northern Hares on 22 May; live juveniles on Brownsman on 9 September and 20 November.

Oystercatcher *Haematopus ostralegus*

Ca sixty around the islands in early spring. First eggs on Inner Farne on 10 May, with first young on 9 June. 25 (27) pairs nested as follows: Inner Farne 5 (6), Knoxes Reef 3 (2), West Wideopen 2 (2), East Wideopen 1 (1), Staple Island 4 (2), Brownsman 6 (7), North Wamses 1 (1), South Wamses 1 (1), Big Harcar 0 (1), Northern Hares 0 (2), Longstone main rock 2 (2). Maximum count of 220+ on 4 September.

Ringed Plover *Charadrius hiaticula*

First eggs were located on Brownsman on 26 April, with first young on 27 May. 10 (12) pairs nested as follows: Inner Farne 4 (2), Knoxes Reef 1 (1), West Wideopen 1 (1), Staple Island 1 (3), Brownsman 2 (4), Longstone main rock 1 (1). Forty-three on 4 September was the largest count, with numbers reducing to 4-5 from mid-November.

Golden Plover *Pluvialis apricaria*

Three records of 1-3 on 11, 12 and 14 April. Two flying south on 30 July, then 1-9 regularly from early September. Forty-one over Inner Farne on 2 September was the largest count.

Grey Plover *P. squatarola*

Two May records of 1-3 and one in July, then 1-12 regularly from 12 August until end of season.

Lapwing *Vanellus vanellus*

1-8 on twelve days from March-early May, one in August, then 1-17 regularly from early September onwards. Fifty-eight flying north through Inner Sound on 10 November was the maximum count.

Knot *Calidris canutus*

Regular sightings of 1-10 from 14 May-25 November, with twenty-three recorded on 21 August and twenty on 29 August.

Sanderling *C. alba*

Two flying south over Brownsman on 30 August and one flying north through Staple Sound on 24 October.

Little Stint *C. minuta*

Records of single birds on fourteen days from 8 September-1 December, with two on 17 September and 4 October.

Curlew Sandpiper *C. ferruginea*

One, amongst a flock of dunlin, flying west past Staple Island on 13 September.

Purple Sandpiper *C. maritima*

Recorded every month throughout the season, with just one record of a single bird in June. Spring numbers peaked at *ca* 330 in late April-early May, with an autumn maxima of *ca* 250 from mid-October onwards.

Dunlin *C. alpina*

Spring records of 1-3 on eight days from 10 April-21 May. Returning birds were noted from 4 July onwards and seen regularly until 1 December. Maximum count of 35+ in mid-September.

Ruff *Philomachus pugnax*

All records came from the outer group and related to single birds on eighteen days from 11 August-28 September. These records possibly involved only six birds.

Jack Snipe *Lymnocryptes minimus*

1-2 recorded on fifteen days from 9 September-1 December.

Snipe *Gallinago gallinago*

Singles on eleven days from 28 March-28 April, then 1-3 regularly from 17 August-1 December. Peak count of ten on 24 November.

Woodcock *Scolopax rusticola*

1-2 on 9-12 April, then 1-4 from 30 September regularly until the end of the season.

Black-tailed Godwit *Limosa limosa*

Two flying north through Staple Sound on 20 July with four flying south past Crumstone on 25 July, and a single on Knoxes Reef on 4 October.

Bar-tailed Godwit *L. lapponica*

1-7 on six days from 17 September-1 December.

Whimbrel *Numenius phaeopus*

An early bird on 28 March, then 1-6 seen regularly from 2 May-13 October, with one flying east over Inner Farne on 1 November. Thirteen flying west over the Inner Farne lighthouse on 15 August was the only large group.

Curlew *N. arquata*

Seen almost daily throughout the season. *Ca* 1,000 on Knoxes Reef on 19 October was the maximum count.

Spotted Redshank *Tringa erythropus*

Singles on Brownsman on 18 August and Inner Farne on 27 September.

Redshank *T. totanus*

Recorded almost daily throughout the season. Maximum counts of 50-60 in late August and September.

Greenshank *T. nebularia*

Singles on 10 May and 30 June, then 1-2 on ten days between 16 July and 15 November.

Green Sandpiper *T. ochropus*

One present on Brownsman and Staple Island from 12-15 April, then 1-2 on nine days from 25 July-11 September. Records probably related to just five birds.

Common Sandpiper *Actitis hypoleucos*

Spring records of 1-4 on eleven days from 23 April-12 June, then singles on fifteen days from 10 July-14 September.

Turnstone *Arenaria interpres*

Seen daily during the season with 1-6 present during the summer months. Peak count of *ca* 100 in the spring, with *ca* 480 from late September.

Phalarope sp.

One bird on the sea and flying around just south of the Knivestone on 7 September appeared to be an adult in winter plumage, but was too distant for specific identification.

Pomarine Skua *Stercorarius pomarinus*

1-31 recorded on forty days from 26 July-21 November. The peak count of thirty-one occurred on 5 September, with double figures noted on only two other days in October.

Arctic Skua *S. parasiticus*

Two singles in April, two singles in May, one in June, then small numbers regularly from 10 July-24 October. A late individual flew south on 13 November. Peak counts logged throughout late August with 20-40 on a daily basis. 109 on 24 August and eighty-six on 25 August were the largest day-totals.

Long-tailed Skua *S. longicaudus*

Singles on 12 and 14 August were recorded from the inner group. One flying north on 30 August, two (adult and juvenile) north on 8 September and one south on 19 September were recorded from the outer group.

Great Skua *S. skua*

One record in March, one in April, one in May, then becoming regular from late July until 1 November. Generally recorded in single figures, although into double figures on eight days. Peak counts of forty-three on 24 August and ninety-nine on 13 September.

Little Gull *Larus minutus*

An adult was on Brownsman on 18 and 19 April and an immature over Brownsman on 19 May, then records of single birds on seven days from 7 September-19 October. Four adults and a first winter bird flew north past Crumstone on 9 October.

Sabine's Gull *L. sabini*

A juvenile flying north through Staple Sound on 22 August, with another north past Crumstone on 14 September. Second and third records for the islands and last recorded in August 1991.

Black-headed Gull *L. ridibundus*

Birds present when the wardens arrived and display evident from 3 April onwards. First eggs were found on 11 May. 68 (107) pairs nested as follows: Inner Farne 49 (131), Brownsman 19 (55). Birds were few in number throughout August and early September with a winter build-up of 200+ from late September onwards.

Common Gull *L. canus*

1-50 around the islands throughout April and May. Two records in June, one in July, one in August, then becoming regular and increasing to 150+ from mid-November onwards.

Lesser Black-backed Gull *L. fuscus* and **Herring Gull** *L. argentatus*

1,181 (820) pairs nested as follows: Megstone 2 (2), Inner Farne 4 (5), Knoxes Reef 35 (30), West Wideopen 152 (109), East Wideopen 108 (96), Skeney Scar 13 (0), Staple Island 16 (21), Brownsman 39 (8), North Wamses 321 (255), South Wamses 161 (87), Roddam and Green 35 (0), Big Harcar 176 (128), Little Harcar 22 (22), Northern Hares 81 (34), Longstone main rock 6 (4), Longstone End 10 (19). One lesser black-blacked gull on Brownsman appeared to specialize in killing adult Arctic terns. The last record of lesser black-backed gulls occurred on 2 November while large roosts of herring gulls built up from early October onwards with an estimated 3,000+ an hour flying in to roost on the Wideopens on 12 October.

Iceland Gull *L. glaucoides*

An adult flying over Inner Farne on 5 April.

Glaucous Gull *L. hyperboreus*

A second or third year bird passed through Staple Sound on 3 October, with a first winter bird south over Staple Island on 6 October.

Great Black-backed Gull *L. marinus*

Small numbers daily from late March with a gradual increase from late July onwards. 2 (2) pairs nested as follows: West Wideopen 1 (1), East Wideopen 0 (1), South Wamses 1 (0). *Ca* 1,500 birds roosted on the islands from mid-November onwards.

Kittiwake *Rissa tridactyla*

Birds present around the islands when the wardens arrived and nest building noted from 3 April. First eggs on Inner Farne on 5 May with first young on 30 May. 5,889 (6,178) pairs nested as follows: Megstone 45 (42), Inner Farne 1,654 (2,012), West Wideopen 342 (380), East Wideopen 457 (380), Skeney Scar 108 (198), Staple Island 1,511 (1,632), Brownsman 1,506 (1,126), North Wamses 69 (42), South Wamses 67 (28), Roddam and Green 41 (31), Big Harcar 89 (90). First young fledged on 5 July and the last on 14 August. 6,000+ roosting on Longstone and the sea on 16 September was the peak autumn count. With the exception of 200 flying north on 13 November only small numbers were seen during October-December.

Lesser Crested Tern *Sterna bengalensis*

Back for its tenth season, the bird was seen on both Brownsman and Inner Farne on 3 May. Seen on six further days in May and observed copulating with a Sandwich tern on 31 May. Having looked 'settled' on 1 June it then vanished, only to reappear on three days in July and intermittently between 1 and 8 August.

Sandwich Tern *S. sandvicensis*

Two on 28 March gradually increased to *ca* 5,000 by 1 May. First eggs on Inner Farne on 9 May and on Brownsman on 29 May, with first young on 8 June. 2,349 (2,730) pairs nested as follows: Inner Farne 2200 (0), Brownsman 149 (2,730). First chicks fledged on 16 July. Small numbers present throughout August with three flying south on 25 September the final record.

Roseate Tern *S. dougallii*

One over Brownsman on 4 May heralded the arrival. 3 (4) pairs nested as follows: Inner Farne 3 (1), Brownsman 0 (3). Despite birds being seen over Brownsman regularly throughout May-July it would appear that this was the first year on record when no birds bred on the outer group. The final record was of a single bird off Brownsman on 14 September.

The young on Inner Farne used the nest boxes for shelter and this possibly helped towards the three pairs rearing six young. Nest boxes were first pioneered in the United States and the RSPB introduced them to Anglesey in 1988. They are now used at most colonies and their success can be judged by the 1992 season at Rockabill, Co. Dublin where out of 378 nesting pairs, 114 pairs used them. The remainder of the boxes were used by the chicks for shelter. Nest boxes put out on Brownsman and Inner Farne in 1988 and 1989 were not used by the birds and another attempt in 1991 had similar results. In 1993 the wardens waited until the birds had nested and then placed the boxes close to the nests; the chicks took to them like the proverbial ducks to water!

Common Tern *S. hirundo*

Two through Inner Sound on 21 April was the first record of the season. First eggs located on 23 May with first chick on 16 June. 291 (260) pairs nested as follows: Inner Farne 289 (244), Brownsman 2 (16). First fledgling noted on 15 July. Two flying north on 25 September was the final record.

Arctic Tern *S. paradisaea*

Two on Inner Farne on 23 April was the first sighting. First eggs were located on 18 May on both Inner Farne and Brownsman. 3,138 (3,437) pairs nested as follows: Inner Farne 2,007 (2,140), Knoxes Reef 0 (3), Staple Island 19 (22), Brownsman 1,111 (1,272), Longstone main rock 1 (0). First young on 11 June with first fledging on 4 July. The last record was three flying north through Staple Sound on 12 October.

Little Tern *S. albifrons*

The best season on record for this species. Eleven birds roosting on the beach in St Cuthbert's Cove on 9 May increased nightly to thirty-nine on 23 May, then decreased gradually to one by 31 May. One bird feeding in Crawford's Gut in the outer group on 26 June was the only other record.

Guillemot *Uria aalge*

Birds present on the breeding ledges when the wardens arrived on 27 March. First eggs located on 14 April, but first young not seen until 29 May. Last young left the cliffs on 2 August. 16,873 (12,912) pairs nested as follows: Megstone 140 (120), Inner Farne 968 (1,294), West Wideopen 529 (629), East Wideopen 906 (1,410), Skeney Scar 710 (340), Staple Island 8,530 (6,624), Brownsman 3,990 (1,977), North Wamses 955 (450), South Wamses 145 (68). Small numbers recorded daily throughout August-September with *ca* 1,000 back on the Pinnacles from 9 November onwards. Southerly passsage throughout the morning of 20 November was estimated at a staggering 9,000+ an hour.

Razorbill *Alca torda*

Birds present on the ledges on 27 March. 132 (84) pairs nested as follows: Inner Farne 49 (31), West Wideopen 25 (14), East Wideopen 20 (8), Skeney Scar 3 (3), Staple Island 18 (18), Brownsman 3 (3), North Wamses 5 (6), South Wamses 3 (0), Big Harcar 6 (1). First young seen on 4 June on South Wamses, with all breeding areas deserted by late July. Small numbers of between one and ten from then until the end of the season.

Black Guillemot *Cepphus grylle*

An excellent year for this species with almost daily records throughout late March and April. There were single sightings in May, July and August, then birds were seen regularly from 6 September-2 December. Records generally related to 1-4 birds with six seen on 21 and 30 October. A summer-plumaged bird roosting with shags on the west face of Staple Island on four days in April was an unusual record.

Little Auk *Alle alle*

Two birds flying north through Inner Sound on 2 October and three flying north past Crumstone on 12 October.

Puffin *Fratercula arctica*

'Many thousands' ashore and around the islands on 27 March. First eggs noted from 16-20 April with first evidence of young on 27 May. Sample counts of occupied burrows were carried out on the breeding islands and the population was an estimated 34,710 pairs compared with 26,329 pairs in the 1989 count. Individual island totals as follows: Inner Farne 8,226 (4,950), West Wideopen 5,795 (5,859), East Wideopen 1,474 (1,097), Staple Island 8,334 (7,113), Brownsman 9,392 (6,815), North Wamses 288 (104), South Wamses 1,038 (305), Big Harcar 101 (44), Longstone End 62 (42). With the last young presumed fledged around the end of August birds became very scarce thereafter.

Woodpigeon *Columba palumbus*

Two on 30 March, singles on four days in April, one on 11 May, two on 12 May and a single on 17 May. One was noted in October and two in November, the last on 25 November.

Collared Dove *Streptopelia decaocto*

Singles on three days in April, 17 May, 12 and 26 June.

Turtle Dove *S. turtur*

One on Staple Island on 18 May, one on Northern Hares on 21 May, and a 'resident' on Brownsman and Staple Island from 2-5 June. A juvenile was on Brownsman on 7 October.

Long-eared Owl *Asio otus*

One sitting on the south-west rocks of Inner Farne on 2 November, one flushed from behind the Fishe House on Inner Farne on 17 November and one flying over Brownsman towards the mainland on 24 November.

Short-eared Owl *A. flammeus*

A bird present on Brownsman on 10 April killed a female wheatear. Then singles on 11 April, 7 May, 27 September and four days in October, and a single on Brownsman from 22-23 November.

Swift *Apus apus*

Singles over both Staple Island and Inner Farne on 7 May were the first of the season. Then 1-6 on nineteen days with the last record on 20 August. On 25 June fifty-eight were over Brownsman and Staple Island, apparently driven down by heavy rain.

Hoopoe *Upupa epops*

One on Inner Farne on the morning of 12 April could, considering its colouring and bold markings, be surprisingly elusive. Eighth record for the islands and last seen in September 1976.

Wryneck *Jynx torquilla*

One was present on Brownsman on 10 May, with possibly a different bird from 11-18 May. The records could, however, refer to the same bird.

Skylark *Alauda arvensis*

1-6 seen regularly throughout April and May, one record in August, then almost daily from 4 September. Peak count occurred on 30 September with *ca* ninety on the inner and outer groups.

Sand Martin *Riparia riparia*

First recorded on 30 March, then one record in April, one in May, and two in September, the last being 21 September. All records relate to single birds.

Swallow *Hirundo rustica*

For the fourth year in succession a pair nested in St Cuthbert's chapel, fledging two broods of six and three. 1-10 seen almost daily from 20 April-11 October.

House Martin *Delichon urbica*

1-2 on eight days from 17 May-10 September.

Richard's Pipit *Anthus novaeseelandiae*

One first winter bird present on Brownsman from 14-20 September, followed by another first winter bird from 1-9 October. First and second records for the islands. (A large pipit on 16 October 1984 may have been of this species.)

Tree Pipit *A. trivialis*

First spring record was on 26 April and this was followed by sightings of 1-3 birds on three days in April, ten days in May, six days in June, twelve days in September and nine days in October, with the last sighting on 9 October. Ten on 2 October was the only double-figure count.

Meadow Pipit *A. pratensis*

Almost daily records of 1-60 between April and early May, one record in June, then 1-60 from 3 September-3 December.

Rock Pipit *A. spinoletta*

Recorded throughout the season. 13 (15) pairs nested as follows: Inner Farne 5 (5), West Wideopen 1 (2), Staple Island 2 (4), Brownsman 5 (4). *Ca* forty were present from mid-September onwards.

Yellow Wagtail *Motacilla flava*

Singles on four days in April, two days in May, one day in August and six days in September, with the last bird on 3 October. One on 11 May was possibly a grey headed wagtail *M. f. thunbergi* whilst that on 13 September was a male blue-headed wagtail *M. f. flava.*

Grey Wagtail *M. cinerea*

One on Inner Farne on 30 September and one on 8 October on the same island.

Pied Wagtail *M. alba*

Birds present from 27 March until late September, then singles on 19 October and 24 November. 5 (3) pairs bred: Inner Farne 2 (2), Staple Island 1 (0), Brownsman 1 (0), Longstone main rock 1 (1). Unlike 1991 and 1992 there was no evidence that white wagtails *M. a. alba* bred, although they were seen regularly from 11 April-22 July with a late bird on 8 September.

Wren *Troglodytes troglodytes*

1-6 throughout April and early May, then 1-15 regularly from 15 September until the end of the season.

Dunnock *Prunella modularis*

1-4 from 12 April-15 May, then 1-7 almost daily from 13 September-7 November.

Robin *Erithacus rubecula*

1-12 almost daily from 3 April-17 May, a juvenile on Brownsman on 22 July, then 1-120 from 28 August-29 November. Highest day count was on 3 October with *ca* eighty on the outer group and *ca* forty on the inner group.

Bluethroat *Luscinia svecica*

An amazing year with a minimum of forty in spring and two in October. They started arriving on 9 May and were present continuously until 21 May with a maximum day count of at least thirty-four on 11 May, of which twenty-six were males. Then a male on 27 May, a female/immature on 28 May, a female on 1 June, a female on 13 October and a male on 22 October.

Black Redstart *Phoenicurus ochruros*

1-2 regularly from 3 April-28 May, then singles on seven days from 9 September-4 November.

Redstart *P. phoenicurus*

Spring records of 1-30+ on fourteen days from 9 April-20 May, then 1-50+ on twenty-three days from 8 September-11 October. Largest spring count of 30+ on 11 May and autumn count of 50+ on 16 September.

Whinchat *Saxicola rubetra*

1-14+ on twelve days from 24 April-24 May, then 1-4 on nine days from 9 September-9 October.

Wheatear *Oenanthe oenanthe*

Almost daily records of 1-20 until late May, with a maximum of over seventy-five on 11 May. Two records in early June, juveniles on 4 and 24 July, then 1-30+ from 11 August-18 October.

Ring Ouzel *Turdus torquatus*

1-2 recorded on nine days from 25 April-20 May with autumn birds appearing from 14 September-10 October. Numbers generally 1-3 but thirty on Brownsman and Staple Island on 9 October included one flock of twenty-five which landed briefly before flying on.

Blackbird *T. merula*

1-10 almost daily from 27 March-25 April, then 1-110+ from 24 September-3 December. No large movements noted with the maximum count being 110+ on 27 October.

Fieldfare *T. pilaris*

Regular spring records of 1-50 until 1 May with *ca* 350 brought in by fog on 11 April. Returning birds noted from 7 September onwards with a maximum count of 650+ on 10 October.

Song Thrush *T. philomelos*

1-20+ almost daily until 17 May with autumn records from 10 September onwards. Largest count of 450+ on 30 September, with 100+ on five days in early October.

Redwing *T. iliacus*

1-40+ almost daily from 29 March-27 April. Singles on 1 and 14 May, then noted regularly from 14 September. Early October saw regular counts of 300+ with *ca* 2,500 forced low over the islands by persistent drizzle and rain on the morning of 10 October.

Mistle Thrush *T. viscivorus*

One heard calling over Staple Island on 14 April, then singles on 19 and 30 September and 9-10 October.

Grasshopper Warbler *Locustella naevia*

Singles on 30 April, with 1-2 on four days between 1 and 13 May. Then 1-5 on sixteen days from 8 September-7 October. These records possibly relate to just fourteen birds.

Sedge Warbler *Acrocephalus schoenobaenus*

1-5 almost daily from 10-26 May, one on 4 June, then 1-7+ on twelve days from 1 August-3 October.

Marsh Warbler *A. palustris*

Two birds present on Brownsman on the afternoon of 2 June and all day 3 June. They were in the company of a single reed warbler *Acrocephalus scirpaceus* which gave good comparative views. First and second records for the islands.

Reed Warbler *A. scirpaceus*

One on 26-27 May and a single on 2 June were the only spring records. 'Unstreaked

Acrocephalus' were present on thirteen days from 14 September-10 October. Numbering generally 1-4, there was a count of at least twenty-five on 1 October - an island record.

Icterine Warbler *Hippolais icterina*

One present on Brownsman on 1 and 2 October.

Lesser Whitethroat *Sylvia curruca*

Recorded on 29-30 April, almost daily from 9-21 May, then on 9, 11, 13 September and 7 and 9 October. Normally 1-2 but a minimum of twenty-one on 11 May set a new island record.

Whitethroat *S. communis*

1-8 on twelve days from 27 April-22 May, one on 2 June, then 1-10 on fourteen days from 20 August-9 October. Largest day count was sixteen on 13 May.

Garden Warbler *S. borin*

1-3 recorded regularly from 10-30 May, with 1-6 from 9 August-9 October.

Blackcap *S. atricapilla*

1-4 on sixteen days from 12 April-19 May, two singles in June, and 1-35+ almost daily from 10 September-6 November.

Yellow-browed Warbler *Phylloscopus inornatus*

Singles on 23 and 29 September, two on 3 October and singles on 4 and 7 October. A bird present on Brownsman on 2 November showed some, but not all, of the characteristics of the race *P. i. humei* from Central Asia.

Wood Warbler *P. sibilatrix*

Present on Inner Farne, Brownsman and Staple Island from 10-14 May. Possibly just two birds account for this spread of records.

Chiffchaff *P. collybita*

1-40+ almost daily from 1 April-27 May, singles on 2 and 6 June, one on 16 August, then 1-8 from 9 September-2 November with a late bird on 21 November. Peak spring counts occurred between 10 and 13 May. Eleven of the birds recorded during October were of the eastern grey type.

Willow Warbler *P. trochilus*

First recorded on 9 April then 1-20+ until 21 May. One on 2 June, then 1-60 almost daily from 5 August-13 October. Peak autumn count on 16 September with 45+ on the outer group and 12+ on Inner Farne. Several of the birds present on 14 September were of the grey northern type and a very pale bird on 26 September may have been the northern form *P. t. acredula*.

Goldcrest *Regulus regulus*

1-10 on nine days from 3-22 April with 1-110 from 19 August-5 November. Peak passage recorded in the first ten days of October.

Spotted Flycatcher *Muscicapa striata*

1-2 on twelve days from 10 May-9 June, then 1-2 on thirteen days from 7-30 September with a final record on 31 October.

Red-breasted Flycatcher *Ficedula parva*

One first winter bird on Brownsman from 13-17 September, then singles on Inner Farne on 29 September and 19 October.

Pied Flycatcher *F. hypoleuca*

1-8 on seven days from 10-22 May, singles on 12-13 and 15-16 August, then 1-10 on eighteen days between 7 September and 7 October.

Red-backed Shrike *Lanius collurio*

One male on Inner Farne during the afternoon of 3 June.

Magpie *Pica pica*

One flew past the lighthouse cliffs on Inner Farne heading towards the mainland on 28 September. Third record for the islands and last recorded in May 1983.

Jackdaw *Corvus monedula*

One on 30 March, 1-2 on 15, 17 and 20 April, one on 11, 12 and 28 May, two on 5 June, one 'resident' on Brownsman from 21-24 September and again on 3-5 October, and two over Inner Farne on the latter date.

Rook *C. frugilegus*

Four over Brownsman and Inner Farne on 1 April with singles on 5, 13, 20 and 21 April. Singles on 14 and 18 May, with two over Brownsman and Inner Farne on 2 October.

Carrion Crow *C. corone*

1-16 seen regularly throughout the season. A nest containing three eggs was found on West Wideopen on 12 May; only one egg remained by 20 May and this later vanished. The adult bird was never seen in attendance. This is the first breeding attempt since 1988.

Starling *Sturnus vulgaris*

A pair nested in a crevice in the 14th century window in St Cuthbert's Chapel. Small numbers, up to fifty, recorded almost daily until mid-July, then a gradual increase to *ca* 100. Incoming flocks of 200-400 from mid-September onwards.

Rose-coloured Starling *S. roseus*

First seen around midday on 9 September, but brief views and elusive nature meant that positive identification was not possible until 10 September when this juvenile was watched feeding with *ca* forty-five starlings. The bird commuted between Brownsman and Staple Island during its two day stay. First record for the islands.

Chaffinch *Fringilla coelebs*

1-4 almost daily from 1-16 April, a single female on Brownsman on 8 and 9 June, and 1-8 daily from 9 September-3 December. Forty-three on 10 September was the peak count.

Brambling *F. montifringilla*

1-7 almost daily from 3-30 April, a male on Inner Farne on 10 and 11 May, then seen regularly from 29 September with a maximum count of *ca* forty-five on 10 October.

Greenfinch *Carduelis chloris*

Singles on Brownsman on 2-3 and 8 April and 30 September.

Goldfinch *C. carduelis*

Singles on 10-11 and 23-24 April, 1 and 7 May and 4 and 15 October.

Siskin *C. spinus*

First recorded on 8 September then regularly until 17 November, with two over Staple Island on 2 December. Generally 1-20 birds involved but passage on 7 October saw *ca* 350 over the island in the space of thirty minutes.

Linnet *C. cannabina*

Regular spring sightings of 1-20 until 8 June, then 1-50 from 8 August-3 December.

Twite *C. flavirostris*

One on Inner Farne on 21 October.

Redpoll *C. flammea*

Singles on 25 April, 22 and 29 September.

Scarlet Rosefinch *Carpodacus erythrinus*

One female/immature present on Brownsman on 3 June, and a female/immature on 14 September.

Lapland Bunting *Calcarius lapponicus*

1-4 on twenty-three days from 9 September-24 November.

Snow Bunting *Plectrophenax nivalis*

1-5 on twenty-one days from 14 September-13 November.

Yellowhammer *Emberiza citrinella*

One on Brownsman from 24-25 October, with another on four days from 4-11 November.

Rustic Bunting *E. rustica*

A male was watched for approximately thirty minutes around the pond area on Brownsman on the afternoon of 9 May. Second record for the islands and last recorded in October 1992.

Little Bunting *E. pusilla*

One on Brownsman during the afternoon of 29 September.

Yellow-breasted Bunting *E. aureola*

An immature/female found on Staple Island flew to Brownsman and was present on 15 and 16 September. The lucky observers could watch it feeding around the pond area in the company of Richard's pipit and red-breasted flycatcher. Sixth record for the islands and last recorded in September 1992.

Reed Bunting *E. schoeniclus*

1-7 on eleven days from 31 March-17 May, with 1-12 on seventeen days from 16 September-6 November.

Feral Pigeon

Ca 100 present at the start of the season rising to *ca* 300 by late September. A rough estimate suggested that about twenty pairs nested.

EXOTICA

Chilean Flamingo *Phoenicopterus chilensis*

Two flew over Inner Farne at 0800 on 14 April. They spent the rest of that day between North and South Wamses before flying south at 1600.

Lanner Falcon *Falco biarmicus*

One bird, complete with jesses, spent the morning of 13 August on Inner Farne. Having killed a fledgling Sandwich tern attempts were made by one of the wardens to catch it with the use of a lure. The bird wanted nothing to do with this and was last seen flying off towards the mainland.

Budgerigar *Melopsittacus undulatus*

A white 'budgie' with blue flecks was resident on Brownsman from 20-27 August. A pile of feathers found on 5 September would suggest it provided a snack for a passing sparrowhawk.

BIRD RINGING

During the year 424 birds were recovered; this compares with 167 in 1992. They included 379 retrapped, controlled or identified by colour rings, and in addition to numerous recoveries in the British Isles, Farne ringed birds were found in places as far apart as Norway, Sweden, Germany, France, Portugal and Africa.

Two cormorants were found dead, one at Berwick-upon-Tweed and one at Wraysbury in Buckinghamshire: their ages were seven and eleven years respectively. There were sight records of 223 shags, thirty-eight of which had been seen on various islands on more than one occasion between March and September. Twenty-nine were from the Isle of May colony and one had been ringed at Craigleith. Areas where they were found dead included Bamburgh, Tayside and the Fife and Grampian Regions of Scotland. The oldest bird was aged twenty-two years.

Eider ducks were found dead in areas between the Farne Islands, Holy Island and Seaton Sluice, while twenty-six ringed between 1981 and 1986 were retrapped on Inner Farne and Brownsman. An unidentified colour marked lesser black-backed gull was seen in June and two were found dead, one of which had been ringed on the islands in 1961 and is the oldest recorded lesser black-backed gull: a fourth bird was recovered at Agadir in Morocco. Ten alien herring gulls were sighted and one twenty-eight year old Farne ringed gull was recovered on West Wideopen.

A kittiwake ringed in 1964, which the British Trust for Ornithology has confirmed as the oldest recorded kittiwake, was a victim of the *Braer* oil tanker spill in Shetland in January and other birds were recovered in Craster, Druridge Bay, the Faeroes, Norway, Sweden, Germany and France. There were fourteen sight records of birds ringed between 1975 and 1976.

Nine Sandwich terns were found in Africa: these included two in Ghana, five in Senegal and one in Nigeria and a bird with ring number XS09241 reported as 'caught and kept in captivity' near Nuba in Ghana in 1978 has now been reported as 'alive captive' in Abidjan on the Ivory Coast. Other birds were found on the Farne Islands, Druridge Bay, Coquet Island, Sunderland in Tyne and Wear, the Grampian Region in Scotland, Germany and Portugal. Once again colour rings have proved their value and there were sight records of at least twenty-six marked birds ringed between 1974 and 1986. One was ringed at the Sands of Forvie and eleven have not yet been identified, while one was controlled at Seal Sands in Cleveland. Information has been received of birds controlled in August 1992: ten at Tentsmuir Point, Fife and five at the mouth of the Eden estuary, also in Fife. A common tern ringed in 1985 was controlled on Coquet Island in 1992 while a roseate tern marked with a royal blue ring was seen on Brownsman in June and on Longstone in August. Six Arctic terns were found dead, five on the islands and one on Coquet Island, while sight records of five colour ringed birds were reported from this island. Sightings of seven colour marked birds, two of which were aliens. were reported from the Farne Islands.

Twelve guillemots were seen between April and July. Three were ringed at Sule Skerry, Orkney, one on the Isle of May, Fife Region, one at Great Saltee Island, Wexford, Eire, and two in the Highland Region at Nigg and Helmsdale. It is interesting to note that the birds from the Isle of May and Wexford were also on the Farne Islands in 1992, while a further five colour ringed birds have not yet been identified. Puffins were found at Druridge Bay, Amble, Whitley Bay and Saltburn in Cleveland while thirteen birds ringed between 1973 and 1982 were present on the islands. The oldest bird was aged twenty years.

Two purple sandpipers were seen and a razorbill ringed on the Isle of May was on the islands in April. A ringed plover marked at Long Nanny, Beadnell was present in July and a blackcap from Stavanger in Norway was found dead on Inner Farne in October.

Trans. nat. Hist. Soc. Northumb. **57**, 135-152 (1994)

THE STATUS OF THE WALL BROWN BUTTERFLY, *LASIOMMATA MEGERA*, IN NORTHUMBERLAND, 1965-91, IN RELATION TO LOCAL WEATHER

by

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SUMMARY

The Wall Brown butterfly (*Lasiommata megera* L.) was once common and widely distributed throughout north-east England. Towards the end of the last century it disappeared from Northumberland and became uncommon in County Durham.

During the early 1970s it spread once again throughout County Durham and reappeared north of the River Tyne at Tynemouth in summer 1976.

Observations of the occurrence of this butterfly in the north-east during the period 1965-91, and comparison with monthly weather records, suggest that improvements in the climate during 1970-76 with less rainfall, less snow, less ground frost and higher average temperatures played an important role in the improved fortunes of the Wall Brown in the north-east of England.

INTRODUCTION

Until the early 1860s the Wall Brown butterfly, *Lasiommata megera* L., was apparently abundant and widely distributed throughout north-east England (Dunn & Parrack, 1986) and in Scotland as far north as Aberdeen in the east and at least as far as Glasgow in the west (Thomson, 1980). In the late nineteenth and early twentieth centuries there was a contraction of the range southwards (Emmet & Heath, 1989).

Subsequently there were relatively few and isolated records in Scotland and in north-east England. At the beginning of the 1970s *Lasiommata megera* was regarded as a rarity in County Durham (VC 66) and its occasional appearance in some years at Crimdon Dene or Seaton Carew represented the extent of its distribution in the north-east, north of the River Tees (Dunn, 1974). Dunn (1974) has documented the remarkable increase and spread of the Wall Brown in County Durham throughout the early 1970s and since (Dunn & Parrack, 1986).

From 1976 onwards there has been a similar spread of the Wall Brown north of the River Tyne, especially in the east of the region. I have kept records of all butterflies encountered in the area since the 1965 season, and here review my experience of the Wall Brown during the last quarter of a century, and compare its reappearance in the north-east with changes in climate.

METHODS

Butterfly Records

Information on the occurrence of the Wall Brown has been extracted from a wider survey relating to twenty-three species of local butterflies recorded in personal diaries from 1965 onwards. Recorded notes provided information with regard to dates of sightings, locations, habitat and some indication of the numbers of individuals.

Weather Records

Monthly records for the period 1965-89 plus the early months of 1990 were kindly provided, on request, by Professor M. D. Newson, Department of Geography, University of Newcastle upon Tyne. The observations included the amounts of rainfall, ground frost, snow, sunshine, and ground and air temperatures. Recordings were made at the University until September 1987 and subsequently within one mile at a similar site in Jesmond.

Weather data are summarized with particular reference to differences between the periods 1965-69, 1970-76 (when the Wall Brown spread throughout County Durham and first appeared in North Tyneside) and 1977-89 (when the butterfly became more widespread and established in Northumberland VCs 67 and 68). Since particular stages of the butterfly's life-cycle may be more vulnerable to adverse weather conditions, analyses have also been made of the seasonal and sometimes the monthly data.

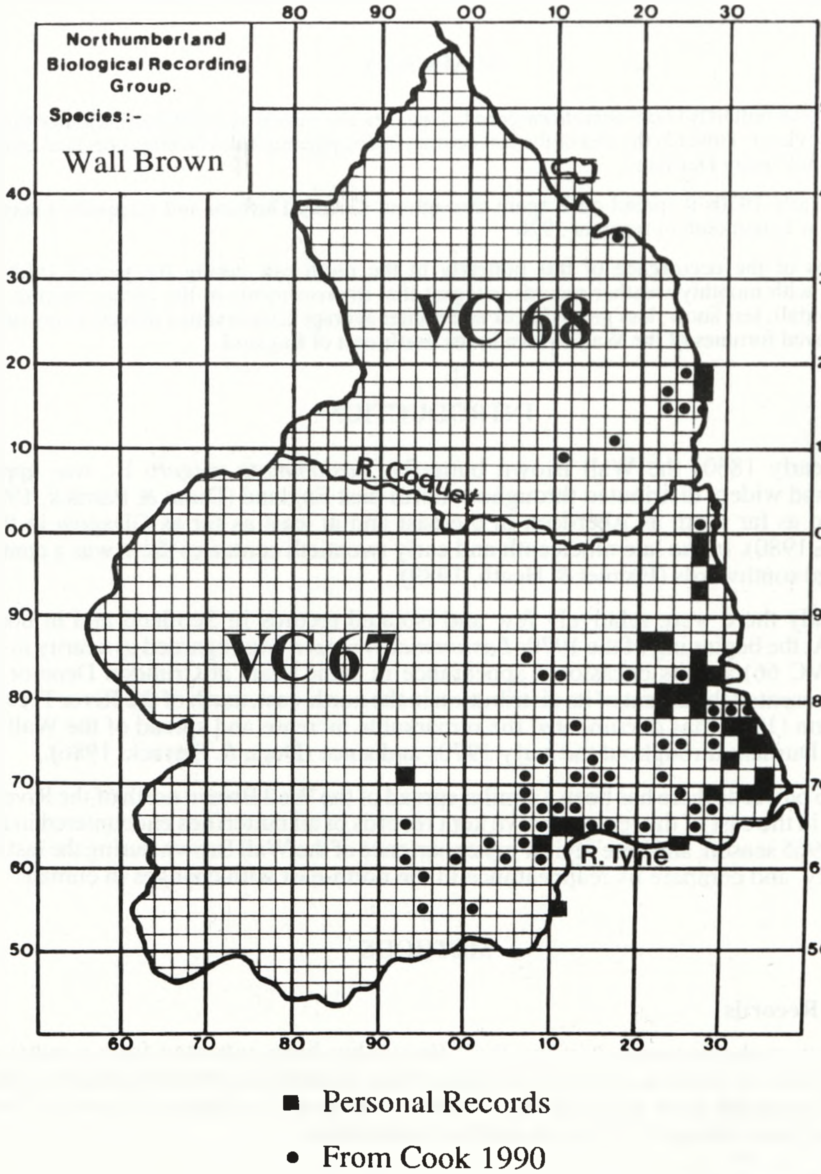
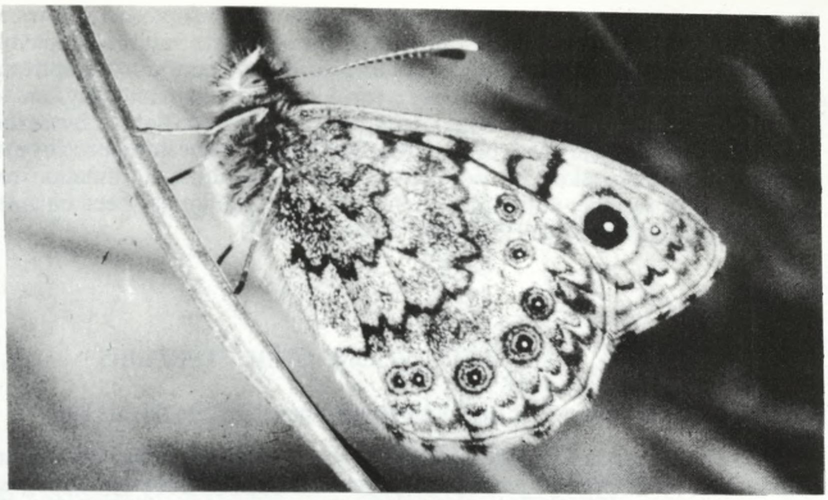


Fig. 1 Distribution map of the Wall Brown butterfly in the Watsonian Vice-counties 67 (South Northumberland) and 68 (North Northumberland).

(i) underside



(ii) male

(iii) female

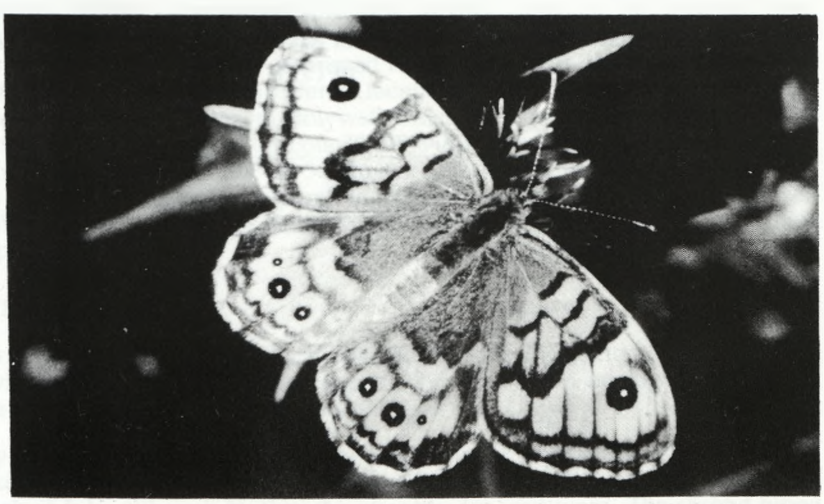


Plate 1 Wall Brown butterflies photographed by H. A. Ellis

Standard meteorological 3-monthly seasons have been adopted as follows: winter, December-February; spring, March-May; summer, June-August; autumn, September-November. In addition, it has sometimes been useful to consider the period from April to August since this is the time that the larvae, which have over-wintered, feed to maturity, and following pupation give rise to the first flight, and their offspring, the second flight of butterflies. Also, since the well-being (or even survival) of the butterflies is likely to be influenced by extremes of weather, account has been taken of isolated adverse conditions. Information regarding past and contemporary weather conditions in the United Kingdom has been obtained from the works of Lamb (1982), Holford (1982), and Stirling (1982).

OBSERVATIONS OF BUTTERFLIES

Appearance and spread of the Wall Brown north of the River Tyne

In spite of visiting numerous suitable locations in Northumberland (VCs 67 and 68) from 1965, it was not until 1976 that I came across the Wall Brown, when on 15 August three were seen flying on the grassy banks overlooking the Tyne estuary between Knott's Flats and Collingwood Monument (NZ 368691). Three were seen on revisiting this location on 17 August.

I did not encounter any Wall Brown butterflies north of the River Tyne in the 1977 season but in the subsequent three years I noted thirteen individuals in Tynemouth, North Shields, Whitley Bay, Seaton Delaval and further north near Cresswell.

During the years 1981-91 the Wall Brown has become relatively common in the north-east, and north of the River Tyne I have seen it in greater numbers (total 370-400 individuals) than before and in many additional sites (Table 1, Fig. 1), predominantly in the east of the region. New locations included those in the valleys of the River Blyth (from 1981), and Wansbeck (from 1985) and at the coast near Cresswell and Druridge Bay and as far north as Howick (1986). My observations further inland have been limited, but I saw the Wall Brown in Newcastle in 1981 and at Brunton Bank near Chollerford in 1984. Overall, butterflies were seen at thirty-seven different locations, with eleven different sites in 1990 and thirteen in 1991. A complete list of the various locations is given in Appendix 1.

Table 1

Number of locations and butterflies north of River Tyne in five successive quinquennia and in 1991

Period	Locations	Butterflies
1966-70	0	0
1971-75	0	0
1976-80	7	16
1981-85	19	170-180
1986-90	16	100-110
1991	13	86

Total number of butterflies 370-400 in thirty-seven different locations.

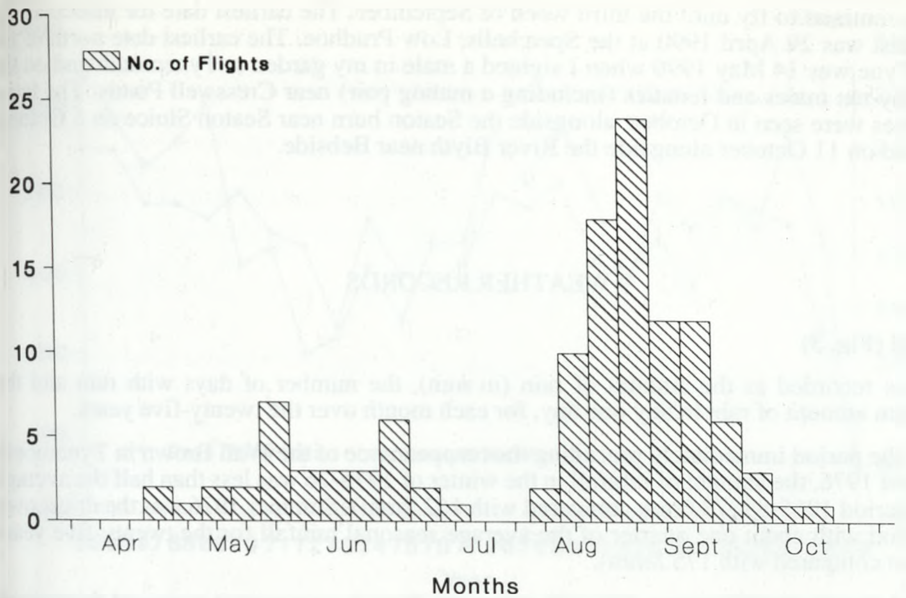


Fig. 2 Diagram to show the times of the two flight periods of the Wall Brown butterfly based on personal records over the period 1976 to 1991.

Numbers of Butterflies

There were 125 card entries over the twenty-seven years of which a hundred related to locations north of the River Tyne. On about one half (47%) of the occasions only one butterfly was encountered in a given location. On 35% of occasions there were two to five individuals, on 11%, six to ten individuals and only on 5% of occasions were more than twenty butterflies noted. The maximum number encountered was forty to fifty alongside the footpath from Hartley to St Mary's Island, in the protection of the old firing range embankments, in August 1982. It was this local abundance which accounted for the unusually large total number of butterflies (seventy to eighty) seen at nine different locations in 1982. Examples of other good locations were alongside the footpath from Holywell Village to East Holywell (thirty to forty seen on 30 August 1983), and on part of the course of the old dismantled railway near Middle Engine Lane, North Shields (twenty-one on 30 August 1991). South of the River Tyne, the Wall Brown was found in spring and/or summer in locations such as those at Waldridge Fell (nineteen on 29 August 1991) and alongside the Spetchells (old chalk tips) near Low Prudhoe (twelve on 29 April 1990).

Flight Periods (Fig. 2)

There was evidence of breeding at several locations, such as those in Tynemouth, Whitley Bay and Cresswell, where both spring and summer broods occurred or where mating couples and/or ovipositing were observed. Larvae were not encountered.

According to my records, butterflies generally appear during the first or second week in May. Numbers peak in the last week of May and insects continue on the wing until the last week of June or first week of July, although by then the majority are well-worn. The second brood appears during the first week in August, numbers peak in the last week of that month and insects continue to fly until the third week of September. The earliest date for insects in the north-east was 29 April 1990 at the Spetchells, Low Prudhoe. The earliest date north of the River Tyne was 14 May 1990 when I sighted a male in my garden at Tynemouth and on the same day ten males and females (including a mating pair) near Cresswell Ponds. The latest butterflies were seen in October: alongside the Seaton burn near Seaton Sluice on 5 October 1985 and on 11 October alongside the River Blyth near Bebside.

WEATHER RECORDS

Rainfall (Fig. 3)

This was recorded as the amount of rain (in mm), the number of days with rain and the maximum amount of rain in any one day, for each month over the twenty-five years.

During the period immediately preceding the reappearance of the Wall Brown in Tynemouth in August 1976, the amount of rainfall in the winter of 1975-76 was less than half the average for the period 1965-89 (73.6mm compared with 162.2mm). Summer 1976 was the driest over this period with about one quarter of the average seasonal rainfall for the twenty-five years (43.5mm compared with 175.8mm).

The total annual rainfall during 1971-76, when the Wall Brown started to spread throughout County Durham and first appeared in North Tyneside, was significantly less ($P<0.01$)[1] than in the previous period from 1965-70. Indeed, 1972, 1973 and 1975 were amongst the five years with the lowest annual rainfall over twenty-five years, whereas 1965, 1966 and 1969 were amongst the five years with the highest rainfall.

Seasonally, the winters of 1972-73, 1974-75 and 1975-76, the spring of 1974, the summers of 1972 and 1976 and the autumns of 1971, 1972 and 1973, were all amongst the five driest in twenty-five years. The autumn of 1976, after the appearance of the Wall Brown in Tynemouth, was one of the wettest, with September of that year the wettest over the twenty-five years.

1973 and 1976 were amongst the five years with the least number of days with rain and during 1965-70 there were significantly more days with rain (mean 190.8 days) in comparison with either of the two subsequent periods 1971-76 (mean 161 days, $P<0.01$) and 1977-89 (mean 166.1 days, $P<0.05$). This difference affected all seasons during the year in which the Wall Brown was spreading throughout County Durham and appeared in Tynemouth. Thus the winters of 1972-73, 1974-75 and 1975-76, the springs of 1973 and 1974, the summers of 1975 and 1976 and the autumns of 1971, 1972 and 1973 were all amongst the years with the fewest number of days with any rain in the corresponding seasons.

Snow (Fig. 4)

Over the whole period snowfall, recorded as the number of days with lying snow for each month, was variable. The mean annual number of days with lying snow during the period 1971-76 (6.3 days) was significantly less than the corresponding values for the previous period 1965-70 (25.2 days, $P<0.01$) or the previous and subsequent periods combined ($P<0.05$).

Seasonally, during the winters of 1965-66 to 1969-70, before the revival of the Wall Brown occurred, snow lay for nine to twenty-nine days with more than average in four of the five years. The worst was 1965-66 with twenty-nine days of lying snow. During the period of recovery of the Wall Brown from 1970 to 1976 snow lay for only none to five days. During the winters of 1970-71 to 1975-76 the mean value for the number of days with lying snow (2.8 days) was significantly less than the corresponding value for the earlier period 1965-66 to 1969-70 (18.4 days, $P<0.01$).

1 A P value of 0.01 means that the probability that the difference is due to chance is 1 in 100. A P value below 0.05 is regarded as significant.

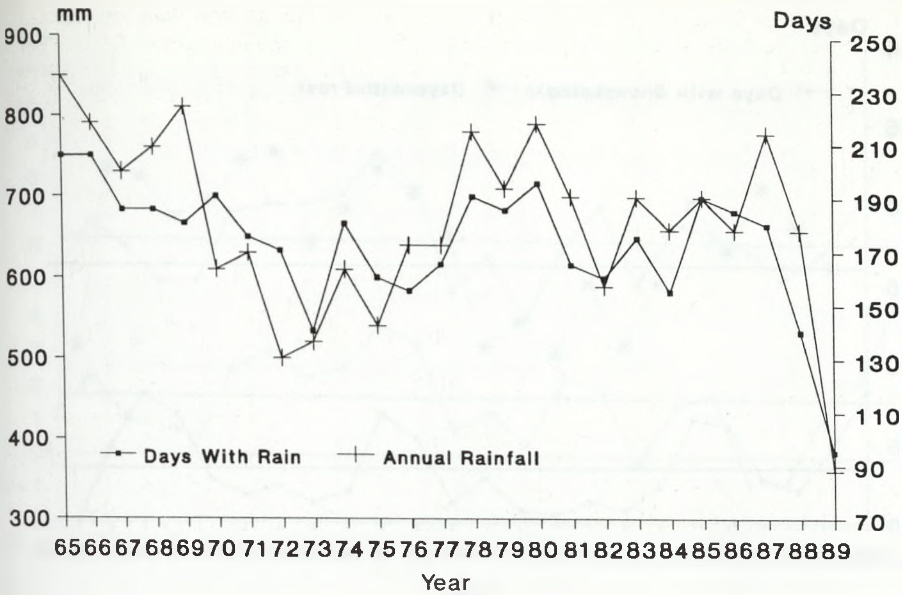


Fig. 3 Annual rainfall (mean 667.3mm) and number of days with rain (mean 171.2 days) at Newcastle over the period 1965 to 1989.

Ground Frost

Frost occurred during the period October to May and there were significantly (P<0.01) fewer days with ground frost in the years 1970-71 to 1975-76 (mean 62.5 days) in comparison with 1965-66 to 1969-70 (mean 92.6 days). The three winters of 1971-72, 1974-75 and 1975-76, and the springs of 1972 and 1974 were amongst the first five with the fewest days of ground frost over twenty-five years. Comparable or lower amounts of ground frost did not occur for a further twelve years in 1987-88 and 1988-89.

Minimum Ground Temperature

Winter and spring values for 1965-70 were below average for the twenty-five years. In winter values were lower during 1965-70 (mean -9.4°C) than in 1971-76 (mean -6.6°C, P<0.001) and 1977-90 (mean -6.5°C, P<0.01). Particularly low temperatures occurred in December 1965 (-11°C), February 1969 (-12°C), January 1970 (-14°C) and February 1972 (-11°C). That for January 1970 was the lowest minimum temperature since 1953. In contrast, values were amongst the highest recorded over twenty-five years in December 1970 (-4°C), 1974 (-3.5°C), 1975 (-4.5°C); in January 1975 (-5.1°C) and 1976 (-5.4°C); and in February 1974 (-5.1°C) and 1976 (-3.7°C), over the period when the Wall Brown was spreading throughout County Durham.

In spring the minimum ground temperature values for 1965-70 (mean -6.4°C) were significantly lower (P<0.01) than those for 1971-76 (mean -3.4°C) and 1977-89 (mean -3.2°C).

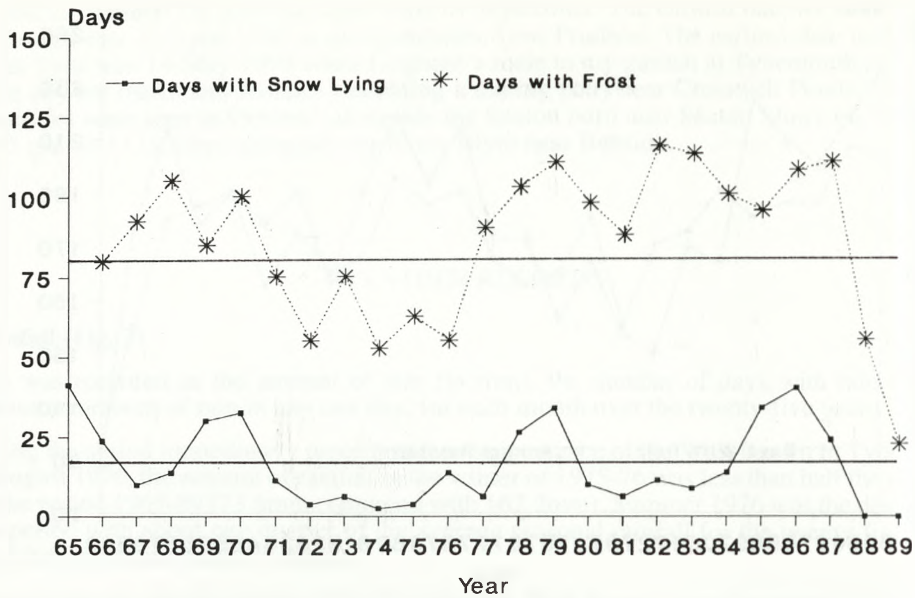


Fig. 4 Number of days with lying snow (mean 16 days) and with ground frost (mean 85 days) at Newcastle over the period 1965 to 1989 (for ground frost, the year indicated is the one in which the months of January to May occurred).

Air Temperatures (Fig. 5)

Data were analysed for monthly mean maximum and minimum temperatures, mean temperatures and for absolute maximum and absolute minimum temperatures. A summary only is given here.

Absolute minimum air temperature

During the period 1965-70 the mean value for each of the three spring months (-1.5°C) was significantly lower than the corresponding values for 1971-76 (0.1°C, $P<0.05$) and for 1977-89 (-0.3°C, $P<0.01$). In four of the years during the period 1965-70, spring values were amongst the first four of the six lowest temperatures over twenty-five years. In contrast, corresponding values for the period 1971-76 were amongst the first four of the highest values.

Absolute maximum temperature

During the winters, the highest value (15°C) over twenty-five years was recorded in January and December 1971 and the mean values were significantly higher ($P<0.05$) during 1970-71 to 1975-76 (12.4°C) compared with 1965-66 to 1969-70 (10.9°C). During summers, the second highest value over twenty-five years was recorded in June 1976 (30°C) and notably high values occurred also in July 1969 (28°C), July 1971 (28°C), and the August of 1973 (28°C) and 1975 (28.4°C). In autumn, high temperatures (24°C) occurred in September 1970 and 1971, and the second highest value over twenty-five years was recorded in September 1973 (24.5°C). Highest autumnal values for each year were lower in 1965-69 in comparison with 1976-89 ($P<0.05$). Also values for the single month of September were significantly lower in the period 1965-69

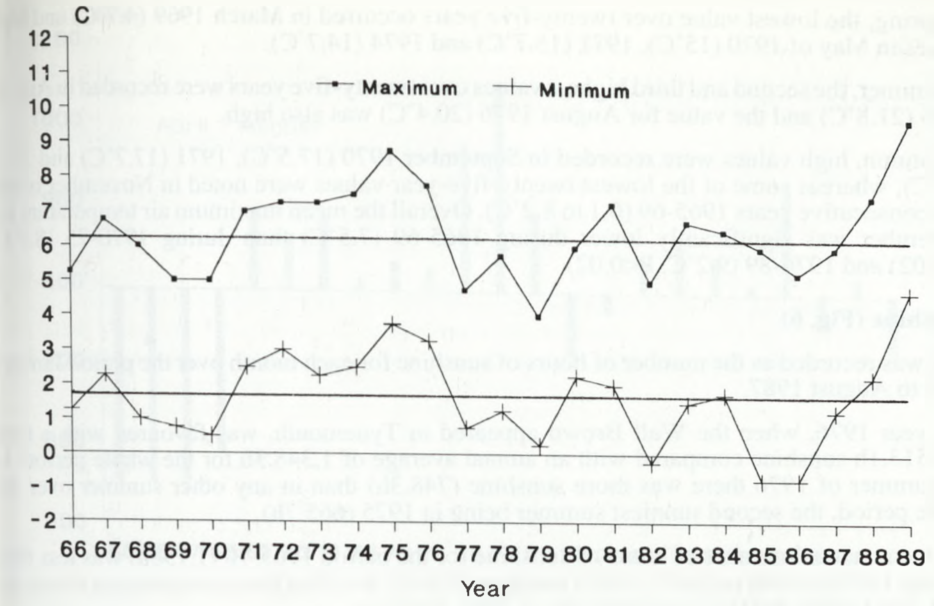


Fig. 5 Winter mean maximum (overall mean 6.5°C) and minimum (overall mean1.9°C) air temperatures at Newcastle over the period 1965-66 to 1988-89 (the year indicated relates to the one in which the January and February and the preceding December occurred).

(mean 20.4°C) in comparison with 1970-75 (mean 22.7°C, P<0.05) and 1976-89 (mean 22.4°C, P<0.02).

Mean minimum air temperature

During winter, some of the lowest values over twenty-five years were recorded in February 1968 (-0.6°C) and 1969 (-1.6°C), whereas the two highest values occurred in December 1971 (5.4°C) and 1974 (5.2°C). The mean seasonal values were significantly higher during 1970-71 to 1975-76 (2.9°C) than in either of the periods 1965-66 to 1969-70 (1.2°C, P<0.001) and 1976-77 to 1989-90 (1.5°C, P<0.01). During spring the lowest values over twenty-five years occurred in March in 1965 (0.8°C), 1969 (0.4°C) and 1970 (0.8°C), and the second highest value in May 1976 (7.8°C). In the summer particularly high values were recorded in July (13.2°C) and August (14.1°C) of 1975 and in July 1976 (13°C). During autumn, some of the lowest values over twenty-five years were recorded in November of 1965 (2°C), 1967 (2.5°C), 1969 (1.7°C) and 1973 (2.7°C). Mean values for October were significantly higher (P<0.05) during 1965-69 (8.2°C) compared with 1970-75 (6.6°C). This resulted from the exceptionally high minimum air temperature during October 1968 (9.3°C) and 1969 (9.6°C) in comparison with the twenty-five-year mean (7.3 ± 0.3, range 4.1 to 9.6°C).

Mean maximum air temperature

During winter, some of the highest values over twenty-five years were recorded in 1971, 1974 and 1975. That for December 1974 (9.9°C) was the highest value over the twenty-five years. The seasonal mean value for 1970-71 to 1975-76 (7.6°C) was significantly higher than those for 1965-66 to 1969-70 (5.6°C, P<0.001) and for 1976-77 to 1989-90 (6.3°C, P<0.02).

In spring, the lowest value over twenty-five years occurred in March 1969 (4.7°C) and high values in May of 1970 (15°C), 1971 (15.7°C) and 1974 (14.7°C).

In summer, the second and third highest values over twenty-five years were recorded in August 1975 (21.8°C) and the value for August 1976 (20.4°C) was also high.

In autumn, high values were recorded in September 1970 (17.5°C), 1971 (17.7°C) and 1973 (17°C), whereas some of the lowest twenty-five-year values were noted in November of the five consecutive years 1965-69 (6.1 to 8.2°C). Overall the mean maximum air temperature for November was significantly lower during 1965-69 (7.5°C) than during 1970-75 (8.7°C, $P<0.02$) and 1976-89 (9.2°C, $P<0.02$).

Sunshine (Fig. 6)

This was recorded as the number of hours of sunshine for each month over the period January 1965 to August 1987.

The year 1976, when the Wall Brown appeared in Tynemouth, was favoured with a total of 1,513.1h sunshine compared with an annual average of 1,348.3h for the whole period. In the summer of 1976 there was more sunshine (748.3h) than in any other summer over the whole period, the second sunniest summer being in 1975 (665.7h).

The mean annual number of hours of sunshine for the period 1965-70 (1,158h) was less than average for the whole period (1,348h) and significantly less than the corresponding values for 1971-76 (1,437h, $P<0.02$), and 1977-86 (1,409h, $P<0.01$).

The autumns of 1965, 1966 and 1968 (194-221h) were the first three years with least sunshine, whereas the years 1971 and 1975 (each 331h) were amongst the first five sunniest years. The mean autumn value for 1965-69 (230h) was significantly less than that for 1970-75 (291h) and 1976-86 (309h), ($P<0.01$ in each case).

In spring, the five years 1965-69 were well-represented amongst those with the least sunshine over the twenty-two years, and the mean value for 1965-70 (338h) was significantly less than those for 1971-76 (408h, $P<0.02$), and 1977-87 (437h, $P<0.01$).

The summers of 1965-68 were also prominent amongst those with least sunshine, whereas 1975 and 1976 headed the list of the five sunniest summers with 135.4% and 152.2% respectively of the mean hours of sunshine for June to August over the entire period. The mean value for the summers of 1971-76 (578h) was significantly higher than the values for 1965-70 (433h, $P<0.05$) and for 1977-87 (478h, $P<0.01$).

During the main breeding season from April to August there were below average amounts of sunshine from 1965 to 1968 inclusive. Thereafter the number of hours increased and remained more or less the same throughout the remainder of the period to 1987. The mean value for the five month period April to August for 1965-70 (669h) was significantly less than the corresponding values for 1971-76 (888h, $P<0.02$), and 1977-87 (809h, $P<0.05$).

DISCUSSION

Butterfly Records

Dunn (1974) has described the spread of the Wall Brown throughout County Durham (VC 66) since the early 1970s. The present account documents its reappearance north of the River Tyne and subsequent spread into Northumberland (VCs 67 and 68). After its disappearance towards the end of the last century, the Wall Brown made an unexpected and welcome appearance in North Tyneside during August 1976. Subsequently it has become established in Northumberland, particularly in the east, in the coastal region and along the major river valleys.

The numbers of butterflies have varied from year to year in individual sites and sometimes butterflies seemed to have disappeared altogether from one location whilst additional sites were identified elsewhere. For example, a few butterflies were seen at Knott's Flats, Tyne-

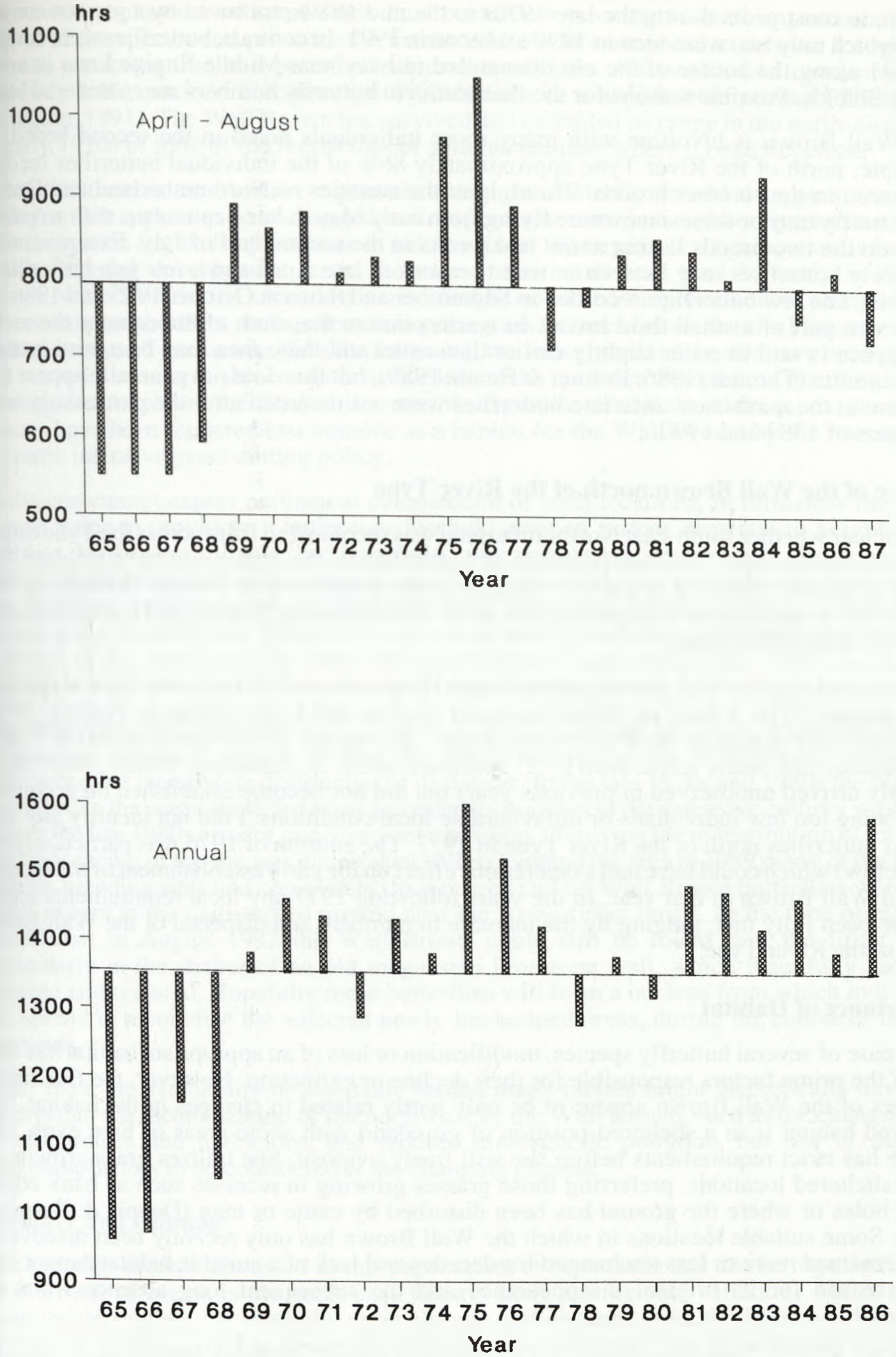


Fig. 6 Hours of sunshine during the months April to August (mean 793 hours) and for each year (mean 1348 hours) at Newcastle over the period 1965 to 1987.

mouth, in most years during the late 1970s to the mid 1980s, followed by a gap for six years after which only two were seen in 1990 and none in 1991. In contrast, butterflies were common in 1991 along the course of the old dismantled railway near Middle Engine Lane in nearby North Shields. Possible reasons for the fluctuation in butterfly numbers are considered below.

The Wall Brown is bivoltine with many more individuals noted in the second brood. For example, north of the River Tyne approximately 86% of the individual butterflies recorded were seen in the summer broods. Throughout the counties of Northumberland and Durham the butterfly may be seen somewhere flying from early May to late September, with an interval between the two broods lasting about two weeks in the second half of July. Exceptionally, a few early butterflies may be seen in some seasons in late April and a few late butterflies in October. The few butterflies recorded in September and those in October 1985 and 1986 may have been part of a small third brood. In warm years in the south of the country the second emergence is said to occur slightly earlier than usual and there then may be a third brood in early autumn (Thomas, 1986; Emmet & Heath, 1989), but this does not generally appear to be the case in the north-east since late butterflies were not recorded after the particularly warm summers of 1989 and 1990.

Source of the Wall Brown north of the River Tyne

It is unclear whether south-east Northumberland was recolonized from across the Tyne estuary and/or from the west. The reappearance of butterflies in the area could have resulted from active dispersal following a marked increase in the population in County Durham, or been merely the result of passive dispersal from more or less random straying and transportation by wind or some other means.

It is assumed that the Wall Brown did not begin its spread north of the River Tyne at the coast until August 1976. I have no earlier personal records and Dunn (Dunn & Parrack, 1986), referring to the spread of the Wall Brown, states "By August 1976 it had crossed the Tyne in Northumberland where it was seen by T. Swinburn and J. D. Parrack at Whitley Bay". Some possibly arrived unobserved in previous years but did not become established on account of there being too few individuals or unfavourable local conditions. I did not identify any Wall Brown butterflies north of the River Tyne in 1977. The autumn of 1976 was particularly wet (see below) which could have had a deleterious effect on the early establishment of the recently arrived Wall Brown in that year. In the years following 1977 any local requirements appear to have been fully met, judging by the increase in numbers and dispersal of the Wall Brown north of the River Tyne.

Importance of Habitat

In the case of several butterfly species, modification or loss of an appropriate habitat has been one of the prime factors responsible for their decline or extinction. However, the fluctuating fortunes of the Wall Brown appear to be only partly related to changes in the habitat. The favoured habitat is in a sheltered position of grassland with some areas of bare earth. The female has strict requirements before she will freely oviposit. She utilizes grass growing in warm sheltered locations, preferring those grasses growing in recesses such as bank edges, rabbit holes or where the ground has been disturbed by cattle or man (Dennis & Bramley, 1985). Some suitable locations in which the Wall Brown has only recently been discovered have remained more or less unchanged for decades and lack of a suitable habitat cannot be a major reason for its original disappearance and the subsequent long absence from the north-east.

The chalk waste mounds (Spetchells) at Low Prudhoe and the old firing range mounds of earth at Hartley, Whitley Bay, are good examples of a suitable habitat. The course of dismantled railways, as at Whitley Bay and near Middle Engine Lane, North Shields, provide excellent habitats, especially if sheltered by accompanying hedgerows or up-slopes of shallow cuttings. Disused railway lines are of considerable ecological importance in the north-east and support a wide range of plants (Mitchell & Cooke, 1991) and a number of species of butterflies, including the uncommon Small Skipper (Ellis, 1991).

The nomadic behaviour of some individual butterflies must be of vital importance to the survival of the species and provides the means whereby it can spread to recover lost ground after any retraction due to a period of adverse conditions. Although often encountered in apparently self-contained colonies, the Wall Brown is a well known nomad (Thomas & Lewington, 1991). The Wall Brown has survived and extended its range in the north-east since the early 1970s in spite of the recent loss of suitable habitats where it once occurred.

Sometimes there is no obvious explanation why the butterfly should disappear from one locality, which appears to be unchanged, and reappears in a similar neighbouring habitat. Other times the reason for its disappearance is only too clear. For example, (i) a location is lost to a building/housing development, as in the case of the small boat yard formerly in Preston Village, North Shields; (ii) a location is modified by so-called 'improvements', carried out by well-meaning authorities, such as occurred at the grass terraces below Knott's Flats, overlooking the estuary at Tynemouth. Here the terraces at the western end of the site have been planted with various trees and shrubs such as willow, alder and sea buckthorn, resulting in the 'shading-out' of about one third of the suitable available habitat. In addition, the remaining terraces have been rendered less suitable as a habitat for the Wall Brown by the introduction of a more intensive grass-cutting policy.

Whilst one cannot expect permanent colonization of such locations, nevertheless they have been of value in providing a temporary foothold prior to further dispersal to neighbouring locations providing a suitable, and hopefully more permanent, environment. However, even some of these apparently safe locations may be under threat, for example, the Spetchells at Low Prudhoe, which support an important flora and many different species of butterflies, including the Wall Brown. Publicity has recently been given to the possibility that hundreds of tonnes of the chalk could be removed for commercial gain (Jamieson, 1991). Such an act could have a devastating effect on the local butterfly population.

That strip of land alongside the coastal path from Marsden, South Shields to Whitburn provides an excellent location in which to study the future fortunes of the Wall Brown, following a widespread but incomplete destruction of its habitat. In the late 1970s and 1980s the butterfly flourished in the warm sheltered areas provided by hollows in the extensive colliery waste tips. During the late 1980s a major improvement operation, involving the redistribution of the waste and landscaping of the site was undertaken. When I visited the area in 1989 many of the former suitable breeding sites had completely disappeared and no Wall Brown butterflies were to be found except in the undisturbed ground near the Army firing range. At the time of my most recent visit in August 1992 the Wall Brown could still be found near the firing range, particularly in the shelter of an old magnesian limestone wall, which thankfully had been repaired and restored. Hopefully these butterflies will form a nucleus from which individuals can spread to recolonize the adjacent newly-landscaped areas, during the course of the next few years.

Apart from the availability of a suitable habitat many factors might theoretically have been involved in the recolonization of the north-east by the Wall Brown, such as the changing uses of insecticides and herbicides, and reduced atmospheric pollution, but one of the most important factors to be considered is the changing climate.

Weather and Climate

The monthly records discussed in this paper relate to Newcastle and can be regarded only as an indicator of events in the north-east. Clearly there are regional variations within the two counties depending, for example, upon altitude and distance from the influences of the sea (Wheeler, 1992) and, furthermore, the particular microclimate of a given habitat is of major importance to the well-being of the Wall Brown.

Although it is well known that swings of climate from one year to the next, or from one group of years to those immediately following make it difficult to assess any long-term effects on the ecosystem, there have been such striking changes in climate throughout the period under consideration that it is difficult not to believe that they have played a pivotal role in the Wall Brown's success in the north-east. It is possible, too, that climatic changes were of importance in bringing about the decline and extinction of the Wall Brown in the north at the end of the last century.

Long-term changes in climate are thought to influence the fortunes of several species of butterflies (Chinery, 1989). We all associate butterflies with warm sunny days and most butterflies increase their numbers during good summers and decline in years with low temperatures and/or high rainfall. However, the weather has important effects during other seasons. The overwintering larvae of the Wall Brown do not enter a state of complete hibernation but feed intermittently during mild spells. Severe cold and wet winters adversely affect the larvae whereas in less severe winters the opportunities to feed are increased and their growth speeded up. Low rainfall would be expected to increase the chances of survival of the larvae especially of those in their early instars. Apart from any physical effects of the rain, wet seasons at any time of the year can adversely effect larvae and/or pupae by encouraging the growth of parasitic fungi. During spring and summer, when breeding takes place, dull, wet weather restricts the time available for the adults to fly, feed, mate and oviposit. Warm, sunny, breeding seasons avoid these limitations and in addition speed up growth and development of larvae and pupae and so reduce the time available for predators to find them (Chinery, 1989).

Apart from changes in climate there are no clear reasons why the Wall Brown should have contracted its range in Scotland and north-east England during the last quarter of the 19th century. There were exceptionally cold and wet summers in the 1860s and in England and Wales the summer of 1872 was very wet (Holford, 1982). From 1875 onwards most of the summers were wet. The winter of 1878-79 was very snowy and was followed by a cold spring and summer and the summer was one of the seven coldest and wettest on record. This cold weather must have had a deleterious effect on the reproductive cycle of some butterflies, especially those on the edge of their northern range.

More recently there was a run of severe winters in the 1940s and 1950s, culminating in the notorious freeze-up of 1962-63. The average annual rainfall was high (676mm) in Newcastle between 1941 and 1970 and in northern England there was serious flooding in January 1948. At Tynemouth the month's total rainfall was three times average at 170mm, which exceeded the previous record by 41mm (Stirling, 1982).

The data presented here relating to events in Newcastle over twenty-five years show that there was above average annual rainfall over the period 1965 to 1969 and below average rainfall from 1970 to 1976 when the Wall Brown spread throughout County Durham and reappeared north of the River Tyne. Indeed, the month of October 1967 was one of the wettest over England and Wales as a whole since 1903 (Stirling, 1982). Local data for the individual seasons also show less than average rainfall from 1971 to 1976 with particularly low values in the spring of 1974, the summers of 1972 and 1976 and the autumns of 1971 to 1973. It is noteworthy that the rainfall between April and August in 1976 was the second lowest (at 147.4mm) over twenty-five years. This dry period affected England and Wales generally and culminated in the drought of 1975-76, which will long be remembered.

In England and Wales 1971-75 was the driest five year period since the 1850s. The worst drought since rainfall records began occurred during 1975 and 1976 and in those years we had the driest twelve, sixteen and eighteen month periods since 1820. The year 1975 was the fifth driest of this century with rainless spells commencing in May and continuing through to August. The excellent summers of 1975 and 1976 followed the favourable winter of 1975-76, which was the mildest in England since the winter of 1833-34 (Holford, 1982). Some comment is necessary with regard to the autumn of 1976, immediately after the appearance of the Wall Brown in North Tyneside. Locally this was the second wettest over twenty-five years and in England and Wales September of that year was the second wettest since 1873 (Holford, 1982). This extremely wet autumn may have temporarily interrupted the colonization of North Tyneside by the Wall Brown.

The period 1970-76 was favoured with less ground frost, higher minimal ground temperatures and less snow in comparison with the immediately preceding years and all these features might be expected to have improved the chances of survival of the overwintering larvae. The milder and sunnier springs and summers of 1970-76 would have been ideal for the larvae and the breeding adults.

One is led to the conclusion that climatic change has played a significant role in the improved fortunes of the Wall Brown in the north-east during the past ten to fifteen years. Although not as widespread or as frequent as the Meadow Brown (*Maniola jurtina*), the Wall Brown can now be regarded as one of the commoner butterflies in the north-east. Its future survival, at least in the short-term, appears to be assured provided we can preserve as many of its present habitats as possible. Hopefully the current proposals for extending the Green Belt and measures to expand nature conservation projects in North Tyneside (1991) will safeguard the remaining countryside from further encroachment, at least in the forthcoming quarter of a century. Any improvements to existing open spaces and waste land should be undertaken with caution and full understanding of the implications for any existing butterfly population. So often attempts to tidy up and improve an area to make it more attractive and accessible to the public have involved landscaping, tree planting and/or intensive grass cutting programmes which can prove detrimental to the local flora and butterfly population.

ACKNOWLEDGEMENTS

I wish to thank Professor M. D. Newson for the weather records, my wife Christine for her companionship and help on the field outings, and Dr P. Davis for permission to use the official recording card of the Northumberland Biological Records Centre.

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APPENDIX

PERSONAL RECORDS OF WALL BROWN BUTTERFLY, 1976-1991

Records marked by an asterisk (*) have been notified to the Biological Records Centre, Institute of Terrestrial Ecology, Monk's Wood Experimental Station, Huntingdon.

NORTH OF RIVER TYNE

Tynemouth, North Shields and Wallsend (VC 67)

Grass terraces below Knott's Flats to Tynemouth Pier

Bank between Knott's Flats and Collingwood Monument, overlooking estuary. (NZ 368691). 15 Aug 1976 (3)*; 17 Aug 1976 (3)*; 13 Aug 1990 (1F).

Footpath west end of Knott's Flats upper terrace leading to Riverview Estate (NZ 363688). 5 Sept 1979 (6)*; 30 May 1981 (2); 14 June 1981 (1); 23 Aug 1981 (5); 31 May 1982 (4); 1 June 1982 (several); 28 Aug 1982 (6); 31 Aug 1982 (several); 4 Sept 1982 (2); 11 Sept 1982 (several F); 1 July 1983 (1F); 23 June 1984 1F); 25 Aug 1990 (1F).

On Tynemouth dyke, below Priory, foot of pier (NZ 373692). 15 Aug 1981 (1M).

Garden, Southlands, Tynemouth (NZ 358701)

2 Sept 1978 (1F); late Sept 1978 (1); 5 Sept 1979 (1); 22 Aug 1982 (1); 28 Aug 1982 (1); 26 Aug 1983 (1M); 27 Aug 1984 (1); 11 Sept 1986 (1); 11 Aug 1989 (1); 19 Aug 1989 (1F); 14 May 1990 (1M); 12 Aug 1990 (1); 16 Aug 1990 (1); 23 Aug 1990 (1F).

Preston Village, Beach Road, Rake Lane, Middle Engine Lane

Near Preston Cemetery, Billy Mill (NZ 344696) 10 June 1978 (1F)*; (NZ 348694) 24 Aug 1990 (1).

Preston Village Boat Yard (now housing development) (NZ 349698) 30 May 1982 (1F).

Footpath in field off Beach Road (NZ 342693) 15 Aug 1982 (2).

Rake Lane (NZ 342706) 31 May 1982 (1).

Dismantled rail track near Middle Engine Lane (NZ 322694) 30 Aug 1991 (21 M & F).

Wallsend

Rising Sun Country Park (NZ 299696) 31 Aug 1991 (6 M & F).

Whitley Bay, Holywell, Seaton Delaval, Seaton Sluice (VC 67)

Coastal footpath from Old Hartley to St Mary's Island (especially near old firing range earth embankments) (NZ 344756).

3 June 1978 (1M)*; 16 Aug 1981 (1M); 28 Aug 1982 (40-50 M & F); 16 June 1984 (4); 6 Sept 1991 (1M & 1F); 15 Sept 1991 (1M).

Footpath from Holywell to East Holywell (NZ 311737).

30 Aug 1983 (30-40 M & F).

On and near course of dismantled railway from near Seaton Delaval Hall to Seaton Wood, Holywell Ponds, Brierdene Farm, Crow Hall Farm

(NZ 316762) 7 Sept 1980 (1F)*; 2 June 1985 (2F).

(NZ 322752) 16 Aug 1981 (2); 4 Sept 1982 (1); 27 May 1989 (1); 7 Aug 1990 (16 M & F); 28 Aug 1990 (4 M & F).

Near Brierdene Farm (NZ 330742-332741) 18 Aug 1991 (5).

Field opposite Crow Hall Farm (NZ 328747) 12 Aug 1991 (1M); 18 Aug 1991 (1).

Holywell Dene near Hartley West Farm (NZ 333751) 12 Aug 1991 (1F).

Burnside near Starlight Castle ruins, Seaton Sluice

(NZ 335763) 5 Oct 1985 (several); 11 Sept 1984 (24 M & F).

Blyth Valley (VC 67)

Plessey Woods Country Park

(NZ 238802) 31 May 1984 (1); 1 Sept 1990 (1M). (NZ 240800 12 Aug 1990 (1F). (NZ 235797) 21 Sept 1991 (1M).

Near Hartford Hall

(NZ 251802) 'Cowslip' bank adjacent to riverside footpath 27 Aug 1990 (5 M & F); 1 Sept 1991 (28 M & F).

Riverside footpath in wood near weir, Humford Mill

(NZ 262 797) 8 Aug 1990 (1M & 1F).

Reclaimed old opencast site near Humford

(NZ 265804) 10 Sept 1987 (1M); 11 Sept 1991 (2M).

Attlee Park near Bedlington

(NZ 266814) 14 Aug 1982 (2); 7 Sept 1987 (1M); 31 Aug 1990 (2).

Riverside path and grassland near Furnace Bridge, Bedlington Station, Bebside

(NZ 276821) 19 Sept 1985 (6 M & F); 28 Sept 1985 (several); 10 Sept 1986 (5M & 1F); 11 Oct 1986 (1); 26 Aug 1988 (1M); 7 Aug 1989 (2M & 1F); 23 May 1990 (3).

Wasteland east of Furnace Bridge near A189

(NZ 282824) 18 Aug 1981 (1M); 27 Aug 1984 (10 M & F); 1 June 1985 (1).

Wansbeck Valley (VC 67)

Riverside and woodland paths

Riverside footpath near Jubilee Well (NZ 211866) 26 June 1985 (several).
Riverside path near weir (NZ 232862) 22 Aug 1989 (6M & F).
Riverside path, Wansbeck Country Park near Cambois Rowing Club hut (NZ 276859) 12 Sept 1987 (several).

Cresswell and Druridge Bay (VC 67)

Sandy grassland near Blakemoor Farm 0.6 miles NE of Cresswell Village (NZ 288942) 9 Sept 1980 (1F)*

Cresswell Ponds

Car park to sand dunes (NZ 280954) 29 Sept 1988 (1); 4 Sept 1989 (5M & F).
Hedge-lined inland footpath from Cresswell Ponds to caravan site (NZ 276936) 14 Sept 1982 (several); 13 Sept 1987 (9 M & F); 12 Aug 1989 (12 M & F); 14 May 1990 (10 M & F); 20 Aug 1991 (3 M & F).

Druridge Bay Ponds

Footpath to derelict church (NZ 275965-266965) 21 Aug 1991 (5M &3F).
Dunes to Chevington Drift (NZ 273971-271981) 21 Aug 1991 (6 M & F).

Howick (VC 68)

Coastal footpath, Howick to Craster near Cullernose Point (NU 260187) 8 Sept 1986 (1M &1F).

Coastal footpath near Rumbling Kern (NU 262172) 18 Sept 1987 (several)

Newcastle upon Tyne (VC 67)

Waste ground in Railway Street (NZ 241634) 24 Aug 1981 (1).

Chollerford (VC 67)

Brunton Bank disused limestone quarry (NY 929701) 29 May 1984 (1M).

SOUTH OF RIVER TYNE

Castle Eden Denemouth (VC 66)

On undercliff, boulder clay and magnesium limestone outcrops (NZ 452414) 12 July 1979 (1); 29 June 1981 (1F); 1 July 1984 (3M & 1F).

South Shields (VC 66)

Coastal footpath from Marsden to Whitburn

Cliff top Marsden Bay (NZ 405645) 17 Sept 1987 (2).

Cliff top Lizard Point to Souter Point (NZ 409642-415628, especially near firing range NZ 413632). 17 Sept 1979 (10 M & F*); 16 Aug 1980 (2M & 1F); 21 Aug 1982 (30-40 M & F); 31 Aug 1989 (6 M & F); 14 Aug 1991 (9M).

Whitburn, Cleadon Hill above Welland Farm (NZ 392630) 20 June 1985 (numerous M & F).

Lower Prudhoe (VC 67)

Alongside old chalk waste tips (Spetchells) (NZ 092639-101641) 7 May 1988 (1M); 4 Sept 1988 (10 M & F); 21 May 1989 (10 M & F); 21 Aug 1989 (10); 29 April 1990 (12M & 1F); 20 May 1990 (1); 29 June 1991 (1).

Clara Vale, near Crawcrook (VC 67)
(NZ 131648) 13 June 1988 (1).

Penshaw Monument (VC66)
(NZ 335544) 30 June 1984 (2).

Derwentside, Ebchester, course of dismantled railway (VC 67)
(NZ 109552) 24 Aug 1981 (1).

Waldridge Fell, near Chester-le-Street (VC 66)
Open Fell (NZ 251498) 29 Aug 1991 (5M&F).

Alongside footpath (NZ 248503-253511) 23 June 1981 (2F); 30 April 1984 (several); 19 June 1985 (2M & 1F); 29 Aug 1991 (14 M & F).

Trans. nat. Hist. Soc. Northumb. **57**, 153-175 (1994)

THE FLORA AND VEGETATION OF MAGNESIAN LIMESTONE SEA CLIFFS, COUNTY DURHAM

by

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SUMMARY

An extensive ecological survey of the magnesian limestone sea cliffs on the Durham coast was conducted to describe their vegetation-habitat heterogeneity. Calcicolous and mesotrophic grassland habitats were dominant and graded into a complex mosaic of smaller, isolated habitats. Abundant and constantly distributed species consisted mainly of common grassland perennials. Species rare in County Durham were often restricted to the smaller, isolated habitats, particularly calcareous flushes and marshy cliff hollows. Here rare species of contrasting phytogeographic distributions were observed growing together forming unusual, species-rich communities. Several very rare species not recorded previously on the cliffs are described. A number of rare species were not recorded from their known locations suggesting that some important and unique wetland assemblages may have been lost from the local flora. It is suggested that such losses represent the most serious threat to the conservation interest of the cliffs and that monitoring of these assemblages will be required for future conservation management options to be assessed and implemented.

INTRODUCTION

Magnesian limestone in the British Isles is represented by a narrow belt only several kilometres wide which runs from the Midlands to the north east of England (Lousley, 1950). Its largest outcrops occur in County Durham where it is exposed most extensively on the east coast forming sea cliffs which are capped with dry banks and damp hollows of calcareous glacial drift (Doody, 1981). Of national importance, the area is ecologically distinct, possessing the only paramaritime magnesian limestone cliffs in Britain (Ratcliffe, 1977). The cliffs are characterized by mainly inland vegetation types (Graham, 1988) with some plant assemblages apparently unique to the area (Doody, 1980; Wheeler, 1980). Despite its importance, few intensive studies of the Durham sea cliff vegetation have been conducted. Most of the existing literature consists of descriptive accounts of the species-rich flora (Bradshaw, 1965; Heslop-Harrison, 1923, 1943; Heslop-Harrison & Richardson, 1953; Preston, 1915) or its celebrated rarities (Heslop-Harrison, 1917, 1953). Considerable attention has also been directed towards the threats to the flora. These include the cessation of colliery waste tipping on the beaches (a practice that has been conducted for over a century) which may lead to vastly increased erosion rates of the cliffs behind with the resultant loss of important communities (Cooke & Gray, 1984). In addition, the improvement of the quality of the beaches may increase recreational pressures (Durham County Council, 1982) and agricultural activities inland from the cliffs may be causing habitat modification through fertilizer runoff (Wheeler, 1980). Other threats include rubbish dumping, deliberate fires, inappropriate landscaping schemes and general misuse, abuse and mismanagement (Doody, 1980, 1981). Given the unique and species-rich plant assemblages found on these sea cliffs and the apparent threats to their continued existence, there is an urgent need to investigate these communities. The main aims of this study were:

i) to describe and assess the vegetation-habitat heterogeneity of the cliffs.

ii) to produce an accurate and up to date inventory of the distribution and abundance of species on the cliffs and a description of their habitat preferences.

iii) to examine the composition of the flora in a European context.

iv) to determine which locations are important in terms of species richness and rarity.

v) to discuss the results of i-iv in relation to work previously conducted on the cliffs.

THE SITE

The coastline of County Durham (VC66) extends for over 40km between the Rivers Tyne and Tees in north-east England. The site investigated in this study consisted of a 15km section of coastline between the industrial ports of Seaham and Hartlepool (Fig. 1) and is covered by Ordnance Survey maps NZ 44 and NZ 43/53 (1:25,000 series). Most of the cliffs have been designated as a Site of Special Scientific Interest (Doody, 1980) on account of their floral and geological interest. Sections of cliffs and cliff tops at Hawthorn Hive and Horden are owned by the National Trust, the mouth of Castle Eden Dene forms part of a National Nature Reserve and the cliffs at Blackhall Rocks are managed as a county Conservation Trust reserve. Other botanically interesting magnesian limestone sea cliffs in VC 66 to the north of Sunderland are not covered in the present paper.

The rocks which now constitute the sea cliffs were formed during the upper Permian some 240 million years ago. A large desert was flooded by a shallow tropical sea, the Zechstein sea, and was followed by a complex series of deposition and sea level fluctuations (Pettigrew, 1980). This has resulted in a varied geology along the coast. The cliffs to the north of Horden consist of reef dolomite with interbedded evaporites whilst towards the south at Blackhall rocks the cliffs consist of Hartlepool and Roker dolomites (Smith & Francis, 1967). In between these two areas the cliffs have slumped considerably to form extensive sea banks which in places almost reach high water mark (Doody, 1980). The height of the cliffs and sea banks generally varies between 15m and 40m. In a number of locations drainage channels have eroded deeply into the soft bedrock to form the well known denes and gills which dissect the coastline.

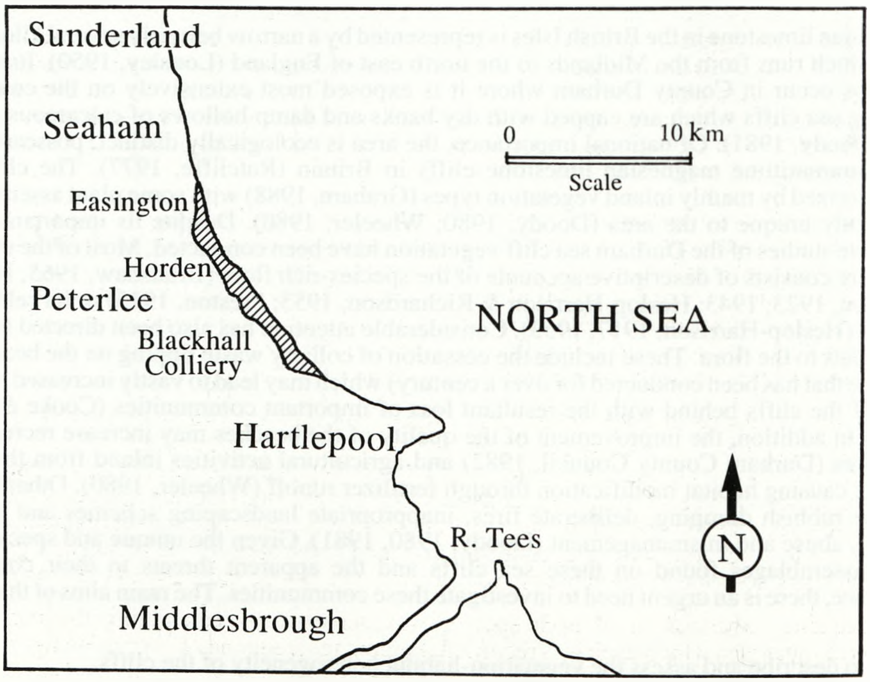

Fig. 1. Sketch map showing location of study area in North East England.

The cliffs and sea banks are capped with Pleistocene clays, sands and gravels resulting in a complex pattern of dry banks and damp hollows and variable soils (Doody, 1981). Brown earths of the Escrick2 association have developed in locally well drained areas at Easington whilst generally poor drainage has resulted in gleyed soils of the Dunkeswick association over much of the area (Jarvis *et al.*, 1984). Wind blown sand up to two metres in depth has accumulated in some cliff hollows (Smith & Francis, 1967).

The North Sea has an ameliorating effect on the climate of the area with sea mists depreciating the total hours of sunshine over the immediate coastal belt (Smith, 1970). Mean temperatures (1906 - 33) were 16 °C in July and August and 2 °C in January (Harris, 1982). Approximately 220 days per annum are suitable for plant growth in lowland areas of the county compared with 150-180 days in the uplands (Graham, 1988). The area is one of the driest in Britain with an average precipitation of 670mm per year, but rainfall patterns vary monthly and annually (Smith, 1970).

The early history of the area, as with much of the county, was characterized by pastoral and arable farming (Graham, 1988). The main human influence has undoubtedly been the development of large deep coal mines at Blackhall, Horden, Easington and Dawdon, near Seaham over the last 150 years (Doody, 1981). Tipping of colliery wastes began in 1858 and since then it has been calculated that some 40 million tonnes have been dumped directly into the sea (Hydraulics Research Station, 1970). Longshore drift has carried the wastes along the coast where it has accumulated in long submarine mounds (Forster & Cooke, 1984), fractions of which are continually washed onto the beaches by the incoming tide. This has resulted in the formation of steep, artificial raised beaches which have forced the highwater mark seawards, sometimes by as much as 120 m (Hydraulics Research Station, 1970). In recent years increased erosion of these raised beaches has commenced (Hydraulics Research Station, 1977) and this may result in increased erosion of the soft limestone cliffs behind.

METHODS

The survey reported here was conducted during the summer months of 1990-1992. It included the semi-natural vegetation of the cliffs from their southern extremity near Crimdon Dene (Grid ref. NZ 483373) to the mouth of Hawthorn Dene (Grid ref. NZ 443460) some 10 Km, or thirteen 1km Ordnance Survey grid squares, to the north (see Fig. 2). All cliff tops and accessible slopes were surveyed on foot whilst dangerous areas were surveyed with binoculars. The seaward 30m of gill and dene mouths were included in the survey but their inland areas were omitted and any foreshore communities were ignored.

Nature Conservancy Council phase 1 survey maps of the area at a scale of 1:10, 000 (Nature Conservancy Council, 1988) were used as the basis of the survey work. Vascular plant species were recorded on standard botanical recording cards (Tyne and Wear Museums Service, undated) and habitats were recorded as recommended in the Phase 1 habitat survey manual (Nature Conservancy Council, 1990). As far as possible the time allocated for the initial survey of every 100m section of cliff during the summer of 1990 was restricted to 20 min. so that a uniform sampling intensity was maintained throughout the study area.

The cover abundance of each habitat and species within each ordnance survey kilometre section of the cliffs was recorded by using the five point scale adopted in *The Flora and Vegetation of County Durham* (Graham, 1988). Published plant records (Doody, 1980, 1981; Graham, 1988; Wheeler, 1980) were consulted for the locations of rare species which were specifically searched for during the survey. For each species the mean cover abundance score over the thirteen sections was calculated and assigned to the appropriate abundance category. A record was also made of the habitat in which each species was most abundantly represented.

The frequency distribution of each species was achieved by calculating the number of kilometre squares in which each was recorded. Percentage frequency distribution figures were then assigned to categories as defined by Graham (1988). The data were compiled into a simple tabular database or inventory for analysis (Appendix 1). Notes regarding the frequency distribution of each species within the County (Graham, 1988) and their European distribution,

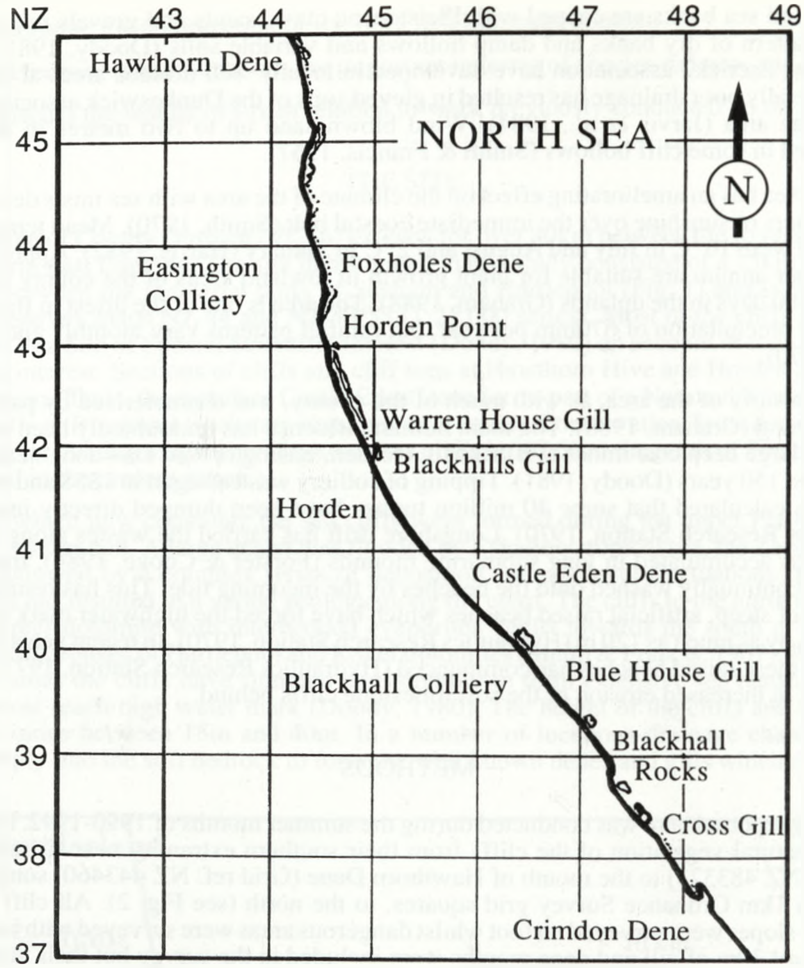

Fig. 2. Sketch map of study area with Ordnance Survey 1km grid overlaid.

based on Matthews (1955) and modified by Ratcliffe (1968), Birks (1973) and Jermy & Crabbe (1978), were included for discussion. Nomenclature of species follows that of Stace (1991).

RESULTS AND DISCUSSION

The study area (Fig. 2) was found to consist of three visually distinct topographic coastal sections which relate to the main geological areas described by Smith & Francis (1967). These were:

i) Crimdon Dene to Blue House Gill. This area consisted of fragmentary clifftop grassland and extensive grassy cliff slopes and sheer unvegetated cliffs of approximately 40m height.

ii) Blue House Gill to Horden Point. This area was characterized by fragmentary clifftop grassland and steep, grassy sea banks of approximately 30m height.

iii) Horden Point to Hawthorn Dene. This area consisted of extensive clifftop grassland and sheer cliffs which were partially vegetated.

Table 1.

Maximum area (ha) covered by each habitat in each 1km section of cliff on the Durham Coast

Dimensions				Area (ha) of main habitat types							
1km grid	Length (km)	Width (m)	Area (Ha)	Scrub	Meso-trophic grass	Calcic-olous grass	Marsh	Tall herb	Flush	Marit-ime cliff	Other
4837	0.4	50	2.0	0.5	1.8	0.1		0.1			
4737	0.3	50	1.5	0.3	1.1	0.1					
4738	1.2	50	6.0	0.1	1.5	5.4	0.3	0.3	0.3	0.1	0.1
4739	0.4	50	2.0	0.1	1.6	0.1					
4639	1.0	60	6.0	0.1	1.5	5.4	0.3		0.3		
4640	0.4	60	2.4	0.1	1.2	1.2					0.1
4540	1.0	60	6.0	0.3	0.3	5.4		0.1	0.1		
4541	0.7	60	4.2	0.2	1.0	3.8					
4441	0.4	60	2.4	0.1		1.9		0.1			
4442	0.9	60	5.4			2.6		1.3			
4443	1.0	60	6.0	0.3	1.5	4.6		1.5	0.1		
4444	1.2	60	7.2	0.4	1.8	6.5		0.4	0.1		
4445	1.2	100	12.0	0.6	0.1	10.8		0.6	0.1		
TOTAL	10.1		63.1	3.1	13.4	47.9	0.6	4.7	1.0	0.1	0.2

Measurements were taken on site and from 1:10,000 Ordnance Survey maps of the width and length of vegetated cliffs, clifftops and banks within each 1km recording unit. Total areas of vegetated cliff for each unit were then calculated (Table 1). These ranged from 1.5 ha in grid square 4737, which was represented by steep cliffs adjacent to Crimdon caravan park, to 12 ha in grid square 4445, which was represented by extensive clifftop grassland at Hive Point adjacent to Hawthorn Dene. The total area of vegetated cliff within the study area was calculated at 63.1 ha. In simple terms the study area was characterized generally by a 60m x 10km band of vegetated cliffs.

Eight visually distinguishable habitats as defined by the Nature Conservancy Council (1990) were recorded on the cliffs (Table 1). Conversion of the cover abundance scores on the recording cards allowed the calculation of the maximum possible area covered by each habitat within each 1km sampling unit. The largest maximum possible areas were covered by calcicolous grassland (47.9ha) and mesotrophic grassland (13.4ha). Smaller areas were covered by tall herb (4.7ha), scrub (3.1ha), calcareous flush (1.0ha) and marshy grassland (0.6ha). Maritime cliff grassland and disturbed habitats accounted for very small areas of the vegetated cliffs (<0.5ha).

Most habitats were of constant distribution within the study area although maritime cliff grassland and disturbed habitats were of occasional distribution. These were recorded mainly from the Blackhall rocks area (grid squares 4738, 4739) where small cliff headlands were exposed directly to sea spray or to notable human disturbances at access points to the foreshore. Calcareous flush and marshy grasslands had their main stations at Blackhall rocks, due to the presence of numerous damp cliff hollows in this area. In addition habitat diversity was greatest at Blackhall rocks where all eight habitat types were represented, presumably due to the complex topography of these cliffs.

A total of 246 vascular plant species and hybrids was recorded from the study area (Appendix 1). Table 2 summarizes the species-habitat composition and indicates that although marshy grassland and calcareous flush accounted for only a small area of the cliffs (1.6 ha maximum) they represented the main habitats for almost 20% (46 species) of the flora. In contrast mesotrophic and calcicolous grassland habitats accounted for most of the vegetation cover of the cliffs (i.e. possible maximum cover exceeding 60 ha) but represented the main habitats for

Table 2

Summary of species - habitat composition of the Durham sea cliffs

Habitat	Approximate Area (ha)	Number of Species	Percentage of Total Species	Examples
Scrub (A2)	3.1	16	6.5	*Crataegus monogyna* *Prunus spinosa* *Ligustrum vulgare* *Salix caprea*
Mesotrophic Grassland (B2)	13.4	51	20.7	*Arrhenatherum elatius* *Dactylis glomerata* *Elytrigia repens*
Calcicolous Grassland (B3)	47.9	67	27.2	*Briza media* *Carex flacca* *Leontodon hispidus* *Succisa pratensis*
Marshy Grassland (B5)	0.6	25	10.2	*Angelica sylvestris* *Eupatorium cannabinum* *Filipendula ulmaria* *Molinea caerulea*
Tall Herb &Fern (C1)	4.7	34	13.8	*Heracleum sphondylium* *Chamerion angustifolium* *Pteridium aquilinum*
Calcareous Flush (E2)	1.0	21	8.5	*Carex panicea* *Juncus articulatus* *Pinguicula vulgaris* *Triglochin palustris*
Maritime Cliff (H8)	<1	4	1.6	*Armeria maritima* *Plantago coronopus*
Disturbed & Miscellaneous (J)	<1	28	11.4	*Anisantha sterilis* *Hordeum murinum* *Tripleurospermum inodorum*
TOTAL		246	100	

less than half of the recorded species (118 species). This indicates that although most of the habitats are small and scattered they are important in determining the floristic composition of the area. Species representative of each habitat are shown in Table 2 and reference can be made to Appendix 1 for other examples.

The frequency distribution and cover abundance characteristics of the flora are summarized

Table 3

Summary of species frequency distribution and abundance on the Durham sea cliffs

Frequency Distribution Category	Cover Abundance Category	Number of Species	Percentage of Total Species	Examples
Constant	Dominant	1	0.4	*Festuca rubra*
Constant	Profuse	3	1.2	*Agrostis stolonifera* *Carex flacca* *Tussilago farfara*
Constant	Abundant	21	8.2	*Arrhenatherum elatius* *Briza media* *Leontodon hispidus* *Plantago maritima* *Succisa pratensis*
Constant	Sparse	65	26.4	*Angelica sylvestris* *Cirsium palustre* *Dactylis glomerata* *Eupatorium cannabinum* *Filipendula ulmaria* *Linum catharticum* *Pteridium aquilinum* *Stachys officinalis*
Constant	Very Sparse	11	4.5	*Arctium nemorosum* *Ligustrum vulgare* *Triglochin palustris* *Tripleurospermum inodorum*
Frequent	Sparse	19	7.7	*Anisantha sterilis* *Blackstonia perfoliata* *Cochleria officinalis* *Molinea caerulea* *Thalictrum minus*
Frequent	Very Sparse	11	4.5	*Calluna vulgaris* *Carex panicea* *Pinguicula vulgaris*
Occasional-Very Rare	Abundant	4	1.6	*Conopodium majus* *Phragmites australis*
Occasional-Very Rare	Sparse	23	9.3	*Ammophila arenaria* *Bromopsis ramosa* *Cynosurus cristatus* *Fallopia japonica*
Occasional-Very Rare	Very Sparse	88	35.8	*Armeria maritima* *Astragalus danicus* *Astragalus glycyphyllos* *Juncus subnodulosis* *Juniperus communis* *Primula farinosa* *Pyrola rotundifolia* *Samolus valerandi*
TOTAL		246	100	

See Appendix 1 for frequency distribution and cover abundance categories.

Table 4

Composition of the Durham sea cliff flora

Floristic Element	Durham coast: Number of species	Durham coast: % Total species	County Durham: Number of species	County Durham: % Total species	Examples
Continental	14	5.7	109	9.5	*Astragalus glycyphyllos* *Hypericum montanum* *Serratula tinctoria* *Genista tinctoria*
Continental Northern	16	6.5	111	9.7	*Astragalus danicus* *Pinguicula vulgaris* *Parnassia palustris* *Pyrola rotundifolia*
Continental Southern	20	8.1	162	14.2	*Blackstonia perfoliata* *Lithospermum officinale* *Samolus valerandi* *Carlina vulgaris*
Northern Montane	2	0.8	32	2.8	*Dactylorhiza traunsteineri* *Primula farinosa*
Oceanic Northern	1	0.4	18	1.6	*Cochleria officinalis*
Oceanic West European	8	3.2	35	3.1	*Armeria maritima* *Ammophila arenaria* *Ulex europaeus*
Northern Sub Atlantic	1	0.4	13	1.1	*Dactylorhiza purpurella*
Southern Sub Atlantic	8	3.2	28	2.4	*Bromopsis ramosa* *Equisetum telmateia* *Tamis communis*
Widespread Sub Atlantic	29	11.8	95	8.3	*Carex flacca* *Centaurea nigra* *Heracleum sphondylium* *Plantago maritima*
Widespread	135	54.9	387	33.9	*Agrostis stolonifera* *Arrhenatherum elatius* *Eupatorium cannabinum* *Festuca rubra* *Leontodon hispidus* *Molinea caerulea* *Pteridium aquilinum* *Tripleurospermum inodorum* *Tussilago farfara*
Other	12	4.9	153	13.4	*Impatiens glandulifera*
TOTAL	246	100	1143	100	

in Table 3 which shows that ten distinct categories can be defined. Almost 90% of the species were of sparse or very sparse cover (<5% cover) and of these over half were of occasional to very rare frequency distribution (recorded from less than three 1km grid squares). Examples included species restricted to small habitats such as maritime grassland (e.g. *Armeria maritima*) and calcareous flushes (e.g. *Primula farinosa, Samolus valerandi*). The cliff vegetation was dominated by less than 10% of the total flora and included a number of representatives of the grass family (e.g. *Festuca rubra, Agrostis stolonifera, Briza media, Arrhenatherum elatius*) and members of the Compositae (e.g. *Tussilago farfara, Leontodon hispidus*). Together these two families accounted for over 25% of the total number of species recorded (55 species listed in Appendix 1). A few species were of rare frequency distribution along the coast but where present were of abundant cover. Examples included *Phragmites australis*, a prominent component of waterlogged cliff hollows at Blackhall Rocks (grid squares 4837, 4838, 4839), and *Conopodium majus* which was abundant on the extensive cliff top grassland at Hive Point (grid squares 4444, 4445).

An interpretation of the composition of the cliff flora in terms of the European distribution of its constituent species is shown in Table 4. Ten distinctive floristic elements were represented on the coast with over 50% of species being of Widespread European distribution.This included most species of dominant, profuse and abundant cover in the study area as listed in Table 3(e.g. *Festuca rubra, Agrostis stolonifera, Tussilago farfara, Leontodon hispidus*). Almost 12% of species were grouped within the Widespread Sub Atlantic element and included other profuse or abundant species (e.g. *Carex flacca, Plantago maritima*). Of the remaining species recorded on the cliffs most were grouped into the Continental (5.7%), Continental Northern (6.5%) and Continental Southern (8.1%) floristic elements. Notable species included here were *Astragalus glycyphyllos, Hypericum montanum, Serratula tinctoria* and *Genista tinctoria* (Continental), *Astragalus danicus, Pinguicula vulgaris, Parnassia palustris* and *Pyrola rotundifolia* (Continental Northern), *Lithospermum officinale and Samolus valerandi* (Continental Southern). Other elements of the flora included maritime species such as *Armeria maritima* and *Ammophila arenaria* (Oceanic West European) and species obviously introduced by human activity such as *Impatiens glandulifera* (grouped into 'Other' category). A few elements were represented by one or two species including *Primula farinosa, Dactylorhiza traunsteineri* (Northern Montane) and *Dactylorhiza purpurella* (Northern Sub Atlantic) in damp cliff hollows and *Cochlearia officinalis* (Oceanic Northern) on exposed headlands.

A comparison of the floristic composition of the cliff flora with that of the county (Graham, 1988) is also presented in Table 4. Over 20% of the total number of vascular plants recorded within the county (1143 species) were recorded from the study area which occupies less than 0.5% of all 1km grid squares in the County. Most elements were not as well represented at the coast as within the county as a whole, presumably due to the smaller area and reduced diversity of habitats of the sea cliffs. Poorly represented elements included the Continental, Continental Northern and Continental Southern groups which together accounted for 20.3% of the cliff flora compared to 33.4% of the county flora. Such species have their headquarters in central and eastern Europe and are well adapted to severe frosts experienced in these regions (Fitter, 1978). It is likely that the moderating influence of the North Sea on the Durham coast benefits other elements of the flora to the detriment of the continental groups. For example the Sub-Atlantic species, which are typically sensitive to severe winters, are better represented at the coast than in the county as a whole.

Despite their proximity to the sea, the maritime species of the Oceanic West European element are no better represented on the cliffs (3.2% of flora) than elsewhere in the county (3.1% of county flora). It has been suggested that the effect of the artificial raised beaches, formed by wastes from the local collieries, has been to reduce the influence of salt spray on the cliffs (Cooke & Gray, 1984). This has been shown as the major environmental factor determining the vegetation composition of sea cliffs elsewhere in Britain (Goldsmith, 1973; Malloch, 1972; Malloch *et al*, 1985). Inland species are directly inhibited by the sea spray and saline soils to the advantage of halophytes on many British cliffs. However on the Durham coast inland species are not inhibited and a unique paramaritime magnesian limestone flora of national importance has developed (Ratcliffe, 1977).

Of interest, *Sesleria albicans*, a species which is common on most of the inland outcrops of magnesian limestone in County Durham, was not recorded on the cliffs.

The area represents the most thermophilous example of calcicolous grassland in the county (Doody, 1981; Shimwell, 1968) and on a continental scale has been classified as intermediate between the limestone grasslands of western Ireland and the Arctic-alpine grasslands of Europe (Shimwell, 1971a; 1971b). The Durham coast is thus of phytogeographical significance and is ecologically distinct (Doody, 1980) and represents a meeting place for species with predominantly northern or southern British distributions (Perring & Walters, 1962). A northern, montane species uncommon in lowland County Durham was *Primula farinosa*, whilst a number of generally southern species, such as *Blackstonia perfoliata, Viola reichenbachiana* and *Hypericum montanum*, were at or near the northern limits of their British range. Of particular interest these cliffs also support populations of several rare insects, including the local race of the Mountain Argus butterfly, *Aricia artaxerxes salamacis* (foodplant *Helianthemum nummularium*).

Table 5 shows the total number of species recorded within each 1km section of cliff (see Fig. 2 for locations) as well as the number of county rarities. Species richness was greatest on the northern and southern cliffs of the study area and generally less on the slumped sea banks in between. At Blackhall Rocks 129 and 130 species were recorded from grid squares 4738 and 4639 respectively and on the cliffs adjacent to Foxholes Dene (grid square 4443) 130 species were recorded. Each of these grid squares thus possessed over 50% of the total number of vascular plants recorded along the coast. Other species-rich grid squares were at Hive Point (grid squares 4444 and 4445; 45.5% and 48.4% of total flora respectively) and cliffs adjacent to the mouth of Castle Eden Dene (grid square 4540; 47.5% of total flora).

In general, species-rich locations possessed the highest numbers of species recorded as rare or very rare in the county (Graham, 1988). Of the twelve county rarities observed, eight were recorded from Blackhall rocks (grid squares 4738 and 4639). These areas represented the main stations of rare habitats such as calcareous flush, marshy grassland and maritime cliff grassland and habitat diversity was also greatest in these areas (see Table 2). Rare species here included isolated, prostrate bushes of *Juniperus communis*, small populations of *Samolus valerandi* (several hundred individual plants), large populations of *Juncus subnodulosus*, a single plant of *Dactylorhiza traunsteineri* in wet cliff hollows, and small areas (20 m^2) of *Astragalus danicus* on a dry ridge. In a small flush at the mouth of Blue House Gill (grid square 4639) over a hundred individual plants of *Pyrola rotundifolia* were observed. The extensive cliff top grasslands at Hive Point (grid square 4445) represented the only station on the coast for several other county rarities. These included scattered individuals of *Hypericum montanum* and *Genista tinctoria*. Although rare in the county, *Geranium sanguineum* was distributed throughout the study area in some abundance.

Several county rarities were recorded on the coast for the first time. These included a large population of *Astragalus glycyphyllos* in a bracken dominated cliff hollow near Hive Point (grid square 4444), and four individual plants of *Lithospermum officinale* on a south facing bankside at the mouth of Foxholes Dene (grid square 4443). In addition a previously unknown population of *Samolus valerandi* (approximately fifty plants) was found in a slump flush near Blackhills Gill (grid square 4541).

A number of other species rare to the county have been described in the literature (Doody, 1980, 1981; Graham, 1988; Wheeler, 1980) but these were not observed during the survey. These included *Anacamptis pyramidalis, Cochlearia danica, Epipactis palustris* and *Ophrys apifera*. Other notable species not observed included *Blysmus compressus, Dactylorhiza incarnata, Menyanthes trifoliata* and *Scutellaria galericulata*. Most of these species have considerable fluctuations in above-ground populations and may be extant on the Durham cliffs. However a number of these species were previously recorded in calcareous flushes (Wheeler, 1980) and it is possible that some of these small and isolated habitats may have been lost in recent years, resulting in the extinction of some of these rarities from the coast. Wheeler (1980) has noted that several of the rare flush species had become less abundant since earlier records were made (Heslop-Harrison, 1917; Heslop-Harrison & Richardson, 1953). For example the

Table 5

Summary of species richness and presence of county rarieties in 1km sections of the Durham sea cliffs

1 km section of cliffs (4 figure grid reference)	Area (ha)	Number of species	% of total species on cliffs	Number of County Durham rarities	County rarities
4837	2.0	103	41.9	3	*Cochlearia officinalis* *Geranium sanguineum* *Juniperus communis*
4737	1.5	59	24.0	1	*Geranium sanguineum*
4738	6.0	129	52.4	5	*Cochlearia officinalis* *Dactylorhiza traunsteineri* *Geranium sanguineum* *Juniperus communis* *Samolus valerandi*
4739	2.0	94	38.2	2	*Cochlearia officinalis* *Geranium sanguineum*
4639	6.0	130	52.8	5	*Astragalus danicus* *Cochlearia officinalis* *Geranium sanguineum* *Juncus subnodulosus* *Pyrola rotundifolia*
4640	2.4	87	35.4	1	*Geranium sanguineum*
4540	6.0	117	47.5	1	*Geranium sanguineum*
4541	4.2	96	39.0	2	*Geranium sanguineum* *Samolus valerandi*
4441	2.4	90	36.6	1	*Geranium sanguineum*
4442	5.4	98	39.8	1	*Geranium sanguineum*
4443	6.0	130	52.8	2	*Geranium sanguineum* *Lithospermum officinale*
4444	7.2	112	45.5	3	*Astragalus glycyphyllos* *Geranium sanguineum* *Hypericum montanum*
4445	12.0	119	48.4	3	*Geranium sanguineum* *Genista tinctoria* *Hypericum montanum*
TOTAL	63.1	246	100	12	

only British report for the European *Gymnadenia odoratissima* belongs here (Heslop-Harrison, 1917), although this record has never been confirmed (Stace, 1991) and has never been recorded since (Wheeler, 1980). The continued survival of other flush species is uncertain.

It has been suggested that a combination of slippage (which creates new sites for colonization), low nutrient levels (to suppress potential competitors) and a permanently wet substratum (for the successful establishment seeds) have been vital in the maintenance of isolated communities in the flushes and wet hollows (Cooper, undated). However in recent years these regulatory factors have been affected in a number of ways (Cooper, undated; Wheeler, 1980). As the raised beach formed by the dumping of colliery wastes is eroded (Hydraulics Research Station, 1977) this affords less protection to the cliffs behind and increased undercutting has begun (Cooke & Gray, 1984). This has caused increased localized slippage of glacial materials and changes in the water table. Some flushes have thus dried out and have been grown over by grassy vegetation or covered by slipped materials.

Rubbish dumping on the cliffs and leaching of fertilizers from adjacent agricultural fields may have caused eutrophication of some flushes to the detriment of the rare, slow growing species and in favour of more competitive species. Such a process has been described for species-rich cliffs in South Wales (Etherington & Clarke, 1987) and may be well advanced in some of the important Durham coast flushes. For example survey observations suggested that tall, competitive species such as *Equisetum telmateia, Eupatorium cannabinum* and *Phragmites australis* were prominent components of several flushes and Wheeler (1980) has suggested that their abundance has increased in recent years.

The processes described above probably represent the most serious threats to the conservation interest of the Durham sea cliffs at present, as the communities in these flushes are of a type not observed elsewhere in Britain (Cooper, undated; Wheeler, 1980). The best examples occur on the steep sea cliffs at Blackhall Rocks (Doody, 1981). It is here that species of a predominantly northern or southern British distribution, such as *Pinguicula vulgaris* and *Blackstonia perfoliata* grow together in a number of isolated skeletal flushes (Cooper, undated). This may help to explain the high species diversity of these habitats. The data in this study suggests that monitoring of these small and unique habitats is imperative for future conservation management options to be assessed and successfully implemented.

ACKNOWLEDGEMENT

The authors wish to acknowledge the helpful advice and constructive comments received from Rev. G. G. Graham, County Recorder for County Durham (VC66), during the preparation of the manuscript for this paper.

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Appendix 1

Distribution, abundance and habitat characteristics of vascular plants on the sea cliffs of County Durham, summer 1990 to 1992

1 km Grid squares Species	4837	4737	4738	4739	4639	4640	4540	4541	4441	4442	4443	4444	4445	%Fq Dist.	Fq. Dist. cliffs	Mean abund.	Abun. cliffs	Fq. Dist. County	Cont. dist.	Main hab.
Acer pseudoplatanus	1						1			1	1		1	38.5	frequent	1.0	V.sparse	frequent	cs	b3
Achillea millefolium	2	2	3	2	3	2	3	2	3	2	3	3	3	100.0	constant	2.5	Abundant	frequent	w	b2
Aegopodium podagraria				1										7.7	occ-vrare	1.0	V.sparse	frequent	w	b2
Agrimonia eupatoria			2		2		2	2	1		2	2	2	61.5	constant	1.9	Sparse	frequent	w	b3
Agrostis capillaris				3	2	3	2	2		2	2	3	2	69.2	constant	2.3	Sparse	constant	w	b2
Agrostis stolonifera	4	4	4	4	4	5	4	5	4	4	5	4	4	100.0	constant	4.2	Profuse	frequent	w	b3
Ajuga reptans			1	1								1	2	30.8	frequent	1.3	Vsparse	frequent	saw	b3
Alchemilla xanthochlora													1	7.7	occ-vrare	1.0	Vsparse	frequent	saw	b3
Allium triquetrum													1	7.7	occ-vrare	1.0	Vsparse	v.rare	m	b3
Allium vineale													1	7.7	occ-vrare	1.0	Vsparse	occasional	c	c1
Ammophila arenaria	2									1				15.4	occ-vrare	1.5	Sparse	occasional	owe	j
Angelica sylvestris	2		2	2	2	2	3	3	2	2	2	2	3	92.3	constant	2.3	Sparse	frequent	w	b5
Anisantha sterilis	2	2		1							1			30.8	frequent	1.5	Sparse	frequent	saw	j
Anthoxanthum odoratum	3		2	2		2	3	2	1	2	2	2	3	84.6	constant	2.2	Sparse	frequent	w	b2
Anthyllis vulneraria	1	1	1	2	2	3	1	2	2	2	1	2	1	100.0	constant	1.6	Sparse	frequent	saw	b3
Arctium nemorosum			1	1	1	1	2	1			1	1		61.5	constant	1.1	Vsparse	frequent	w	c1
Armeria maritima			1	1										15.4	occ-vrare	1.0	Vsparse	occasional	owe	h8
Arrhenatherum elatius	4	3	3	3	3	3	2	4	2	2	2	2	2	100.0	constant	2.7	Abundant	constant	w	b2
Artemisia vulgaris					1				1		1	1		30.8	frequent	1.0	Vsparse	frequent	c	j
Arum maculatum												1		7.7	occ-vrare	1.0	Vsparse	frequent	cs	b2
Aster novi-belgii			2								1	1		23.1	occ-vrare	1.3	Vsparse	frequent	other	b5
Astragalus danicus					1									7.7	occ-vrare	1.0	Vsparse	vrare	cn	b3
Astragalus glycyphyllos												1		7.7	occ-vrare	1.0	Vsparse	vrare	c	c1
Bellis perennis	3		2	2	2		2	2					2	53.8	constant	2.1	Sparse	constant	saw	e2
Betula pendula							2	1	1					23.1	occ-vrare	1.3	Vsparse	frequent	cn	e2

1 km Grid squares Species	4837	4737	4738	4739	4639	4640	4540	4541	4441	4442	4443	4444	4445	%Fq Dist.	Fq. Dist. cliffs	Mean abund.	Abun. cliffs	Fq. Dist. County	Cont. dist.	Main hab.
Blackstonia perfoliata			2							2		2	2	30.8	frequent	2.0	Sparse	occasional	cs	b3
Brachypodium sylvaticum	3	3	3	2	3		3	4	3	3	3	3	3	92.3	constant	3.0	Abundant	frequent	w	b3
Brassica napus								1	2					15.4	occ-vrare	1.5	Sparse	occasional	other	j
Briza media	3		3	3	3	3	3	4	4	4	4	3	4	92.3	constant	3.4	Abundant	constant	c	b3
Bromopsis ramosa	2													7.7	occ-vrare	2.0	Sparse	frequent	sas	c1
Bromus hordeaceus		1												7.7	occ-vrare	1.0	Vsparse	frequent	w	b2
Calluna vulgaris					1		1				1	1	1	38.5	frequent	1.0	Vsparse	frequent	w	b2
Caltha palustris				1										7.7	occ-vrare	1.0	Vsparse	frequent	w	b5
Campanula rotundifolia	3		2		3		2	2	3	1	2	2		69.2	constant	2.2	Sparse	frequent	w	b3
Carex flacca	4	4	4	3	4	2	4	4	4	3	4	4	4	100.0	constant	3.7	Profuse	frequent	saw	b3
Carex hostiana			1											7.7	occ-vrare	1.0	Vsparse	occasional	saw	e2
Carex otrubae					1									7.7	occ-vrare	1.0	Vsparse	frequent	sas	b5
Carex panicea	2			1	1			1						30.8	frequent	1.3	Vsparse	frequent	w	e2
Carlina vulgaris	2		1	1	2	2	1	2	2	2	2	2	1	92.3	constant	1.7	Sparse	frequent	cs	b3
Centaurea nigra	3	3	3	3	3	2	3	3	3	3	3	3	3	100.0	constant	2.9	Abundant	frequent	saw	b2
Centaurea scabiosa	3		2	1	2		2	2	4	2	2	2	3	84.6	constant	2.3	Sparse	frequent	w	b3
Centaurium erythraea	3		2		2		2	1	1	1	3	2	2	76.9	constant	1.9	Sparse	frequent	saw	b3
Cerastium fontanum	3		1	3	2		2				2	2	2	61.5	constant	2.1	Sparse	frequent	w	b2
Cerastium tomentosum	1	1												15.4	occ-vrare	1.0	Vsparse	occasional	other	j
Chaerophyllum temelentum			1											7.7	occ-vrare	1.0	Vsparse	frequent	c	b2
Chamerion angustifolium					2	2	1	2		2	2	2	1	61.5	constant	1.8	Sparse	frequent	w	c1
Chenopodium album									1					7.7	occ-vrare	1.0	Vsparse	frequent	w	j
Cirsium arvense	2	2		2	3	4	2	3	2	2	3	3	1	92.3	constant	2.4	Sparse	frequent	w	c1
Cirsium palustre	2	2		1	2	1	2	2	1		1			69.2	constant	1.6	Sparse	frequent	w	b5
Cirsium vulgare	2			1	2	1	1	1		1	1	2		69.2	constant	1.3	Vsparse	frequent	w	c1
Cochlearia officinalis	1		3	2	2									30.8	frequent	2.0	Sparse	rare	on	h8
Conium maculatum			1											7.7	occ-vrare	1.0	Vsparse	frequent	w	c1
Conopodium majus												2	3	15.4	occ-vrare	2.5	Abundant	constant	owe	b3
Convolvulus arvensis					2								2	15.4	occ-vrare	2.0	Sparse	occasional	w	c1
Corylus avellana									1	1			1	23.1	occ-vrare	1.0	Vsparse	frequent	saw	a2

1 km Grid squares Species	4837	4737	4738	4739	4639	4640	4540	4541	4441	4442	4443	4444	4445	%Fq Dist.	Fq. Dist. cliffs	Mean abund.	Abun. cliffs	Fq. Dist. County	Cont. dist.	Main hab.
Crataegus monogyna	1		2	1	1	1	1		2	1	2	2	2	84.6	constant	1.5	Vsparse	frequent	w	a2
Crocosmia x crocosmiiflora	1	1					1							23.1	occ-vrare	1.0	Vsparse	occasional	other	b5
Cruciata laevipes	3					1								15.4	occ-vrare	2.0	Sparse	frequent	cs	b2
Cynosurus cristatus											1	1	3	23.1	occ-vrare	1.7	Sparse	frequent	w	b2
Dactylis glomerata	2	2	2	2	2	3	2	3	2	2	2	2	3	100.0	constant	2.2	Sparse	frequent	w	b2
Dactylorhiza fuchsii	2	2	1	2	3	3	3	3	2	2	2	2	3	100.0	constant	2.3	Sparse	frequent	cn	e2
Dactylorhiza purpurella						2	2							15.4	occ-vrare	2.0	Sparse	frequent	san	e2
Dactylorhiza traunsteineri			1											7.7	occ-vrare	1.0	Vsparse	vrare	nm	e2
Danthonia decumbens					2		2	2	2	2	2	2	2	61.5	constant	2.0	Sparse	frequent	w	e2
Daucus carota			2	2	2								2	30.8	frequent	2.0	Sparse	occasional	w	h8
Deschampsia cespitosa	2	2	2	2	2		2	2		1			2	69.2	constant	1.9	Sparse	frequent	w	b5
Diplotaxis tenuifolia			1											7.7	occ-vrare	1.0	Vsparse	frequent	cs	j
Dryopteris dilitata							1							7.7	occ-vrare	1.0	Vsparse	constant	w	c1
Dryopteris filix-mas			1			1	1							23.1	occ-vrare	1.0	Vsparse	constant	w	c1
Echium vulgare					1									7.7	occ-vrare	1.0	Vsparse	occasional	w	b3
Elymus caninus											1			7.7	occ-vrare	1.0	Vsparse	occasional	w	c1
Elytrigia juncea					1									7.7	occ-vrare	1.0	Vsparse	frequent	owe	j
Elytrigia repens	3	3	2	2	3	3	1	3	2	2	2	2	3	100.0	constant	2.4	Sparse	frequent	w	b2
Epilobium hirsutum					2				1					15.4	occ-vrare	1.5	Sparse	frequent	w	b5
Epilobium parviflorum							1							7.7	occ-vrare	1.0	Vsparse	frequent	cs	b5
Equisetum arvense	3	3	2	2	3	3	3	3	2	2	3	2	4	100.0	constant	2.7	Abundant	frequent	w	b3
Equisetum telmateia			3		2			1	1	1	2	2	1	61.5	constant	1.6	Sparse	frequent	sas	b5
Eriophorum angustifolium			1				1							15.4	occ-vrare	1.0	Vsparse	frequent	cn	e2
Eupatorium cannabinum	2	2	2	2	3	3	3	3	2	2	3	3	1	100.0	constant	2.4	Sparse	occasional	w	b5
Euphrasia nemorosa					2		2	2	2	2	2	2	1	61.5	constant	1.9	Sparse	frequent	cn	b3
Fallopia japonica			2											7.7	occ-vrare	2.0	Sparse	?	other	c1
Festuca arundinacea	2	3	3		3	2	2	3	3	3	3	3	3	92.3	constant	2.8	Abundant	occasional	w	b2
Festuca ovina			2										1	15.4	occ-vrare	1.5	Sparse	frequent	cn	b3
Festuca rubra	5	5	5	5	5	5	5	5	5	5	5	5	5	100.0	constant	5.0	Dominant	constant	w	b3

1 km Grid squares Species	4837	4737	4738	4739	4639	4640	4540	4541	4441	4442	4443	4444	4445	%Fq Dist.	Fq. Dist. cliffs	Mean abund.	Abun. cliffs	Fq. Dist. County	Cont. dist.	Main hab.
Filipendula ulmaria			2	2	3	2	2	3	2	1	2	2	3	84.6	constant	2.2	Sparse	frequent	cn	b5
Fragaria vesca			1			1	1							23.1	occ-vrare	1.0	Vsparse	frequent	w	b2
Fraxinus excelsior	1						1			1	1			30.8	frequent	1.0	Vsparse	frequent	w	a2
Galeopsis tetrahit											1			7.7	occ-vrare	1.0	Vsparse	frequent	w	b2
Galium aparine	2	3	2	2	1			2			2			53.8	constant	2.0	Sparse	frequent	w	c1
Galium verum	2	2	2	2	3		3	3	2	2	3	3	3	92.3	constant	2.5	Abundant	frequent	w	b3
Genista tinctoria													1	7.7	occ-vrare	1.0	Vsparse	rare	c	b3
Gentianella amarella													1	7.7	occ-vrare	1.0	Vsparse	frequent	cn	e2
Geranium pratense							1			1	1			23.1	occ-vrare	1.0	Vsparse	frequent	w	c1
Geranium robertianum			1											7.7	occ-vrare	1.0	Vsparse	frequent	w	c1
Geranium sanguineum	4	4	3	3	3	3	4	3	4	3	3	3	4	100.0	constant	3.4	Abundant	rare	w	b3
Glechoma hederacea	1													7.7	occ-vrare	1.0	Vsparse	frequent	w	b2
Gymnadenia conopsea					2		2	3	2	2	2	2		53.8	constant	2.1	Sparse	occasional	w	b3
Hedera helix											1	1		15.4	occ-vrare	1.0	Vsparse	frequent	saw	a2
Helianthemum nummularium	4	3	2	2	2	2	3	2	4	3	3	1	2	100.0	constant	2.5	Abundant	frequent	w	b3
Helictotrichon pratense	2		1		2	1	3	1	2	2	2		3	76.9	constant	1.9	Sparse	occasional	saw	b3
Helictotrichon pubescens									1				2	15.4	occ-vrare	1.5	Sparse	occasional	cn	b3
Heracleum sphondylium	2	2	2	1	2	2	3	2	1	1		2	2	92.3	constant	1.8	Sparse	frequent	saw	c1
Hesperis matronalis	1		1											15.4	occ-vrare	1.0	Vsparse	frequent	other	b5
Hieracium perpropinquium	1				2	2	2	1	2	1	1	2	2	76.9	constant	1.6	sparse	frequent	other	b3
Holcus lanatus	3		2		3	3	2	4		1	2	2	2	76.9	constant	2.4	Sparse	frequent	w	b2
Hordeum murinum	2	2		1	2									30.8	frequent	1.8	Sparse	frequent	cs	j
Hyacinthoides non - scripta												1	1	15.4	occ-vrare	1.0	Vsparse	frequent	owe	c1
Hypericum montanum												1	1	15.4	occ-vrare	1.0	Vsparse	rare	c	b3
Hypericum pulchrum	2		1		2		2				2	3	2	53.8	constant	2.0	Sparse	occasional	saw	b3
Hypericum tetrapterum					1									7.7	occ-vrare	1.0	Vsparse	frequent	saw	b5
Hypochaeris radicata		2	2	2	2	3	3	3		3	2	2	3	84.6	constant	2.5	Sparse	frequent	w	b2

1 km Grid squares Species	4837	4737	4738	4739	4639	4640	4540	4541	4441	4442	4443	4444	4445	%Fq Dist.	Fq. Dist. cliffs	Mean abund.	Abun. cliffs	Fq. Dist. County	Cont. dist.	Main hab.
Impatiens glandulifera											1			7.7	occ-vrare	1.0	Vsparse	frequent	other	b5
Iris pseudacorus			2	1	1									23.1	occ-vrare	1.3	Vsparse	frequent	w	b5
Juncus acutiflorus					1									7.7	occ-vrare	1.0	Vsparse	frequent	saw	b5
Juncus articulatus	2		2	1	2	1	2	2	1	1	2	2	1	92.3	constant	1.6	Sparse	frequent	w	e2
Juncus effusus					1									7.7	occ-vrare	1.0	Vsparse	frequent	w	b5
Juncus inflexus	2	2	2	2	2	2	2	1	1	1	2	2	1	100.0	constant	1.7	Sparse	frequent	cs	b5
Juncus subnodulosus					1									7.7	occ-vrare	1.0	Vsparse	vrare	saw	b5
Juniperus communis	1		1											15.4	occ-vrare	1.0	Vsparse	rare	w	b3
Knautia arvensis			1		2			1			1		3	38.5	frequent	1.6	Sparse	frequent	w	b2
Kniphofia spp	1	1												15.4	occ-vrare	1.0	Vsparse	?	other	j
Koeleria macrantha	2			2			2		3					30.8	frequent	2.3	Sparse	occasional	cs	b3
Lamium album				1							1			15.4	occ-vrare	1.0	Vsparse	frequent	w	c1
Lamium purpureum												1		7.7	occ-vrare	1.0	Vsparse	constant	w	j
Lapsana communis			1											7.7	occ-vrare	1.0	Vsparse	frequent	w	c1
Lathyris pratensis			2		3		2	2			2		3	46.2	frequent	2.3	Sparse	frequent	w	b2
Lathyrus montanus													1	7.7	occ-vrare	1.0	Vsparse	frequent	saw	b2
Leontodon autumnalis											2	2		15.4	occ-vrare	2.0	Sparse	frequent	w	b2
Leontodon hispidus	2		2	3	3	2	3	3	4	3	3	3	3	92.3	constant	2.8	Abundant	frequent	w	b3
Leucanthemum vulgare												2	3	15.4	occ-vrare	2.5	Abundant	frequent	w	b2
Ligustrum vulgare					1	1	1		1		1	1	2	53.8	constant	1.1	Vsparse	frequent	cs	a2
Linaria vulgaris			1							1				15.4	occ-vrare	1.0	Vsparse	frequent	w	j
Linum catharticum			2		3	2	2	3	2	2	2	2	3	76.9	constant	2.3	Sparse	frequent	w	b3
Listera ovata	2		2		1		1	1					2	46.2	frequent	1.5	Sparse	frequent	w	b3
Lithospermum officinale											1			7.7	occ-vrare	1.0	Vsparse	vrare	cs	b3
Lolium perenne	2		1	2	2	2	2		1	3	2		1	76.9	constant	1.8	Sparse	frequent	w	b2
Lonicera periclymenum											1			7.7	occ-vrare	1.0	Vsparse	frequent	saw	a2
Lotus corniculatus	3	3	3	3	3	3	4	3	2	3	3	3	3	100.0	constant	3.0	Abundant	constant	w	b3
Luzula campestris											1			7.7	occ-vrare	1.0	Vsparse	frequent	w	b2
Lycopersicon esculentum											1			7.7	occ-vrare	1.0	Vsparse	occasional	other	j
Medicago lupulina						2						1	1	23.1	occ-vrare	1.3	Vsparse	frequent	w	b2

1 km Grid squares Species	4837	4737	4738	4739	4639	4640	4540	4541	4441	4442	4443	4444	4445	%Fq Dist.	Fq. Dist. cliffs	Mean abund.	Abun. cliffs	Fq. Dist. County	Cont. dist.	Main hab.
Melilotus officinalis												1		7.7	occ-vrare	1.0	Vsparse	occasional	w	j
Mentha aquatica	1			1	1									23.1	occ-vrare	1.0	Vsparse	frequent	w	b5
Mercurialis perennis											1			7.7	occ-vrare	1.0	Vsparse	frequent	w	c1
Molinea caerulea			2	1	3					1	1		2	46.2	frequent	1.7	Sparse	frequent	w	b5
Ononis repens	3	3	2	3	3	3	2	3	3	2	2	3	3	100.0	constant	2.7	Abundant	frequent	saw	b3
Orchis mascula	2	2	2		2		2				1		3	53.8	constant	2.0	Sparse	frequent	w	e2
Origanum vulgare			2		1		2		2		2	2	3	53.8	constant	2.0	Sparse	occasional	w	b3
Papaver rhoeas										1				7.7	occ-vrare	1.0	Vsparse	frequent	w	j
Parnassia palustris	1		1	1			1							30.8	frequent	1.0	Vsparse	occasional	cn	e2
Petasites hybridus											2			7.7	occ-vrare	2.0	Sparse	frequent	cs	b5
Phleum pratense										1				7.7	occ-vrare	1.0	Vsparse	frequent	w	b2
Phragmites australis	3		3	2										23.1	occ-vrare	2.7	Abundant	frequent	w	b5
Pilosella officinarum	2		2	2	2	2	2	2	3	2	1	2	2	92.3	constant	2.0	Sparse	frequent	w	b3
Pimpinella saxifraga	2	2	1	2	3	2	2	2	3	2	2	2	2	100.0	constant	2.1	Sparse	frequent	w	b3
Pinguicula vulgaris	2		1		1	1		1						38.5	frequent	1.2	Vsparse	occasional	cn	e2
Plantago coronopus			1											7.7	occ-vrare	1.0	Vsparse	frequent	saw	h8
Plantago lanceolata	3	3	3	3	3	3	3	3	3	2	3	3	3	100.0	constant	2.9	Abundant	frequent	w	b3
Plantago major							2							7.7	occ-vrare	2.0	Sparse	constant	w	j
Plantago maritima	3	3	3	3	3	4	4	3	3	3	2	3	3	100.0	constant	3.1	Abundant	frequent	saw	b3
Plantago media	3		2	2	2	1	2	1	1	1	1	1	2	92.3	constant	1.6	Sparse	frequent	w	b3
Poa pratensis	3	2	3	3	2	3	2					2	2	69.2	constant	2.4	Sparse	frequent	w	b2
Poa trivialis			3	2										15.4	occ-vrare	2.5	Abundant	frequent	w	b2
Polygala vulgaris	2		1	2		2	3	3	2	2	2		3	76.9	constant	2.2	Sparse	frequent	saw	b3
Polygonum aviculare											1			7.7	occ-vrare	1.0	Vsparse	frequent	w	j
Populus tremula											1			7.7	occ-vrare	1.0	Vsparse	occasional	w	a2
Potentilla anserina			2	1										15.4	occ-vrare	1.5	Sparse	frequent	w	b2
Potentilla erecta	1		1	1	1	1	2	1		2	2	2	2	84.6	constant	1.5	Vsparse	frequent	w	b2
Potentilla reptans	3	3	2	2	3	3	3	2			2	3	3	84.6	constant	2.6	Abundant	frequent	w	b2
Potentilla sterilis											1			7.7	occ-vrare	1.0	Vsparse	frequent	saw	b2
Potentilla x mixta												1		7.7	occ-vrare	1.0	Vsparse	?	w	b2

1 km Grid squares Species	4837	4737	4738	4739	4639	4640	4540	4541	4441	4442	4443	4444	4445	%Fq Dist.	Fq. Dist. cliffs	Mean abund.	Abun. cliffs	Fq. Dist. County	Cont. dist.	Main hab.
Primula farinosa			1	1										15.4	occ-vrare	1.0	Vsparse	occasional	nm	e2
Primula veris	2	3	1	2	2	1	2		2	1	2	2	3	92.3	constant	1.9	Sparse	frequent	cs	b3
Primula x polyantha			1											7.7	occ-vrare	1.0	Vsparse	occasional	other	b3
Primula vulgaris	2	1	3	3	3		2		2	1	2	2	2	84.6	constant	2.1	Sparse	frequent	saw	b3
Prunella vulgaris	2		2		2	1			2		2		2	53.8	constant	1.9	Sparse	frequent	w	e2
Prunus spinosa	1				1	1	2		1	1	2	3	1	69.2	constant	1.4	Vsparse	frequent	w	a2
Pteridium aquilinum			3		1		2	2	2	3	3	2	3	69.2	constant	2.3	Sparse	frequent	w	c1
Pulicaria dysenterica	2	2	1	1	3	1	1	2	2	1	3	2		92.3	constant	1.8	Sparse	occasional	saw	b5
Pyrola rotundifolia					1									7.7	occ-vrare	1.0	Vsparse	vrare	cn	e2
Quercus robur							1							7.7	occ-vrare	1.0	Vsparse	frequent	c	a2
Ranunculis acris					2									7.7	occ-vrare	2.0	Sparse	constant	w	b2
Ranunculus bulbosus			2											7.7	occ-vrare	2.0	Sparse	frequent	w	b2
Ranunculus ficaria	2	2	2	1	3					1		1		53.8	constant	1.7	Sparse	frequent	w	b2
Ranunculus repens				2										7.7	occ-vrare	2.0	Sparse	frequent	w	b2
Reseda lutea	2		1							2				23.1	occ-vrare	1.7	Sparse	frequent	sas	j
Reseda luteola											1	1		15.4	occ-vrare	1.0	Vsparse	frequent	sas	j
Rhinanthus minor				1			2	2	2	2	2		2	53.8	constant	1.9	Sparse	frequent	w	b2
Rosa canina		1	3		1	2	1	1	1	1	2	2	2	84.6	constant	1.5	Sparse	frequent	w	a2
Rosa mollis	1	1				2	2		1		2	2	2	61.5	constant	1.6	Sparse	frequent	cn	a2
Rosa pimpinellifolia	2	1			1	1			2	2			2	53.8	constant	1.6	Sparse	occasional	c	b3
Rubus caesius											1			7.7	occ-vrare	1.0	Vsparse	frequent	w	a2
Rubus Sect. Rubus	3	3	3	2	3	2	3	3	1	2	3	2	3	100.0	constant	2.5	Abundant	constant	w	a2
Rumex acetosa	2				2		1						3	30.8	frequent	2.0	Sparse	frequent	cn	b2
Rumex acetosella						3	1				1	1		30.8	frequent	1.5	Sparse	frequent	w	b2
Rumex crispus	2		1	3	2	2	1	2	1	1	2	2		84.6	constant	1.7	Sparse	frequent	w	c1
Rumex obtusifolius		1	2	2	1						1			38.5	frequent	1.4	Vsparse	frequent	saw	c1
Salix caprea					1		3	2	1	1	2		1	53.8	constant	1.6	Sparse	frequent	cn	a2
Salix repens			2		3	1	2		3	2	2		2	61.5	constant	2.1	Sparse	occasional	cn	b3
Sambucus nigra										1	1	1		23.1	occ-vrare	1.0	Vsparse	frequent	saw	a2
Samolus valerandi			1					1						15.4	occ-vrare	1.0	Vsparse	vrare	cs	e2

1 km Grid squares Species	4837	4737	4738	4739	4639	4640	4540	4541	4441	4442	4443	4444	4445	%Fq Dist.	Fq. Dist. cliffs	Mean abund.	Abun. cliffs	Fq. Dist. County	Cont. dist.	Main hab.
Sanguisorba minor	3	3	2	3	3	2	3	2	3	2	2	2	3	100.0	constant	2.5	Abundant	frequent	cs	b3
Sanguisorba officinalis													1	7.7	occ-vrare	1.0	Vsparse	frequent	w	e2
Scabiosa columbaria			1						2	1				23.1	occ-vrare	1.3	Vsparse	frequent	cs	b3
Scirpus maritimus					1									7.7	occ-vrare	1.0	Vsparse	occasional	owe	j
Senecio erucifolius	2		3	1	2		1				2	3	3	61.5	constant	2.1	Sparse	occasional	cs	b3
Senecio jacobaea	1					1	2	1			2	2		46.2	frequent	1.5	Sparse	constant	w	c1
Senecio squalidus			1		1	2			1	1	1	1		53.8	constant	1.1	Vsparse	frequent	cs	j
Senecio vulgaris			1								1			15.4	occ-vrare	1.0	Vsparse	constant	w	j
Serratula tinctoria			2	2	1	1	1	2					4	53.8	constant	1.9	Sparse	occasional	c	b3
Silaum silaus			1					1			1		1	30.8	frequent	1.0	Vsparse	frequent	c	b3
Silene dioica						2	2					1	1	30.8	frequent	1.5	Sparse	constant	w	c1
Silene vulgaris					1				1	2				23.1	occ-vrare	1.3	Vsparse	occasional	w	j
Sinapsis arvensis			1		1							1		23.1	occ-vrare	1.0	Vsparse	frequent	w	j
Sisymbrium officinale	2	2		1										23.1	occ-vrare	1.7	Sparse	frequent	w	j
Sonchus arvensis		1	2	2	2	2	1	1	2			1		69.2	constant	1.6	Sparse	frequent	w	c1
Sonchus asper	2	1	2		2	2		2				1		53.8	constant	1.7	Sparse	frequent	w	c1
Sonchus oleraceus	1		2	1	2	2		2	1	1	2	1	1	84.6	constant	1.5	Vsparse	frequent	w	c1
Stachys officinalis	2	2	1	2	2	1	2	3		1	2	2	3	92.3	constant	1.9	Sparse	frequent	w	b3
Stachys sylvatica						1					1			15.4	occ-vrare	1.0	Vsparse	frequent	w	c1
Stellaria holostea												2	2	15.4	occ-vrare	2.0	Sparse	frequent	w	c1
Stellaria media	3		1	1	1									30.8	frequent	1.5	Sparse	constant	w	j
Succisa pratensis	3	3	2	3	3	2	3	3	3	3	3	3	3	100.0	constant	2.8	Abundant	frequent	w	b3
Tamis communis						2	1				2		1	30.8	frequent	1.5	Sparse	occasional	sas	c1
Taraxacum agg	3	2	2	2	1		2	2	2	2	2		2	84.6	constant	2.0	Sparse	constant	w	b2
Teucrium scorodonia													2	7.7	occ-vrare	2.0	Sparse	frequent	sas	c1
Thalictrum minus	2				1				2	2				30.8	frequent	1.8	Sparse	occasional	saw	b3
Thymus polytrichus	1		1		1		1		3	1	1		1	61.5	constant	1.3	Vsparse	frequent	owe	b3
Torilis japonica										1				7.7	occ-vrare	1.0	Vsparse	frequent	c	b2
Tragopogon pratensis					1	1	1	1				1	1	46.2	frequent	1.0	Vsparse	frequent	w	b2
Trifolium medium	3		2	2	3	2	3	3	2	3	3	3	3	92.3	constant	2.7	Abundant	frequent	c	b3

1 km Grid squares Species	4837	4737	4738	4739	4639	4640	4540	4541	4441	4442	4443	4444	4445	%Fq Dist.	Fq. Dist. cliffs	Mean abund.	Abun. cliffs	Fq. Dist. County	Cont. dist.	Main hab.
Trifolium pratense	3		3	2	3	2	3	2	2	2	3	3	3	92.3	constant	2.6	Abundant	constant	w	b3
Trifolium repens					2	2		2			2	2		38.5	frequent	2.0	Sparse	constant	w	b2
Triglochin palustre	1		1	1		1	1	1		1				53.8	constant	1.0	Vsparse	frequent	w	e2
Tripleurospermum inodorum				1		1	1	1	2	2		2		53.8	constant	1.4	Vsparse	frequent	w	j
Trisetum flavescens							2				2	2	2	30.8	frequent	2.0	Sparse	frequent	cs	b2
Tussilago farfara	4	4	3	3	4	4	4	4	3	4	4	4	2	100.0	constant	3.6	Profuse	frequent	w	b3
Ulex europaeus	2		2	1	2	1	2	1		1	1	2		76.9	constant	1.5	Sparse	frequent	owe	a2
Urtica dioica		2	2	1	2			2			1	1		53.8	constant	1.6	Sparse	frequent	w	c1
Valeriana dioica			1	1										15.4	occ-vrare	1.0	Vsparse	occasional	c	e2
Veronica persica								1						7.7	occ-vrare	1.0	Vsparse	constant	w	j
Vicia cracca	3		2	3	3	2		3	2	2	2	2	3	84.6	constant	2.5	Sparse	frequent	w	b2
Vicia sativa			2								1			15.4	occ-vrare	1.5	Sparse	occasional	w	b2
Viola hirta					1									7.7	occ-vrare	1.0	Vsparse	frequent	w	b3
Viola reichenbachiana							1	1	1					23.1	occ-vrare	1.0	Vsparse	occasional	sas	b3
Viola riviniana	2		1	2	2	2	2	2	1	2	2	2	2	92.3	constant	1.8	Sparse	frequent	w	b3

Habitat codes:

a2 Scrub
b2 Mesotrophic grassland
b3 Calcicolous grassland
b5 Marshy grassland
c1 Tall Herb & Fern
e2 Calcareous Flush
h8 Maritime Cliff
j Miscellaneous/disturbed

Frequency distribution codes on cliffs:

Constant (50 - 90%) = >6 Grid squares
Frequent (25 - 50%) = 4-6 Grid squares
Occ - Vrare(25%) = <4 Grid squares

County frequency distribution codes:

Constant (50-90%)
Frequent (25-50%)
Occasional (5-25%)
Rare (< 5%)
Very Rare (negligible)

Cover abundance on cliffs:

Dominant (50-90%)
Profuse (25-50%)
Abundant (5-25%)
Sparse (<5%)
Very Sparse (negligible)

Continental distribution:

c Continental
cn Continental Northern
cs Continental Southern
nm Northern Montane
on Oceanic Northern
owe Oceanic West European
san Northern Sub Atlantic
sas Southern Sub Atlantic
saw Widespread Sub Atlantic
other

NOTICE TO CONTRIBUTORS

Original contributions relating to the geology, flora, fauna and ecology of the north-east of England and connected historical studies will be considered for publication in the *Transactions*. These may take the form of extended articles or short notes. Papers (which should be sent to the Editor, The Natural History Society of Northumbria, The Hancock Museum, Newcastle upon Tyne NE2 4PT) are accepted on the understanding that they are not being offered in whole or in part to any other journal. All submissions must conform to the style of the journal and will be subject to expert review which may require revision of the manuscript.

TEXT Manuscripts should be concise and the title of the paper as short as possible. The author's name appears at the beginning of the paper together with the full name and address of the institution in which the research has been carried out or the author's postal address. If the author has subsequently moved to another institution, the name and address of this institution should also be given in the footnote.

Manuscripts must be typed, double-spaced on one side of good quality A4 paper with ample margins and with the sheets numbered. If possible, authors should supply a word processor disc of the paper on an IBM-compatible machine. Latin names of genera and species should be underlined or if possible put in italics. The first mention of a species should include both the scientific name with authority and, where appropriate, the English name, but thereafter only one of the names should be used. Footnotes should be avoided as far as possible. Dates should be in the form '1 January 1991'. Text-figures should be referred to as 'Fig.1' *etc.* Figures 1 to 100 should be written out in full *i.e.* one, two, *etc.*, except when referring to measurements *i.e.* 5m.

Metric units should be used, or, if other units are used, metric equivalents should be inserted in parentheses. The Royal Society's *General notes on the preparation of scientific papers* should be followed on points not mentioned here.

STRUCTURE The text will normally be divided by headings, starting with a summary of no more than 200 words in continuous prose in which the main conclusions are set out. The main paper should consist of a minimum number of sub-divisions, including introduction, methods, results, discussion and conclusions, as appropriate to the individual paper.

REFERENCES References should be listed in alphabetical order at the end of the paper in the form:

COULSON, J. C. (1959). The growth of grey seal calves on the Farne Islands, Northumberland. *Trans. nat. Hist. Soc. Northumb.*, **13**,151.

HUXLEY, J. S. (1932). *Problems of relative growth.* London: Methuen.

Titles of journals should be abbreviated according to the *World List of Scientific Periodicals* and references to books should include both the publisher and place of publication. In the text, references will be either in the form 'Smith (1973)...' or '...(Smith, 1973)' and authors must ensure that the references are accurately cited; they will not be checked by the editor.

TABLES Tables should be set out on separate sheets, numbered in Arabic numerals and given a concise heading. Their approximate position (and that of illustrations) should be indicated on the typescript. All captions should be self-explanatory and should include a key to any symbols used.

FIGURES AND PLATES Originals of line drawings are needed for high quality reproductions; photographs must be of good quality, on glossy paper, with, if necessary, a transparent overlay showing the position of any lettering or scale to be inserted. Where several photographs are to form one plate this should be indicated on the prints. Photocopies can be supplied with the manuscript. Captions must not be incorporated in the illustrations, but should be listed on a separate sheet of paper in double spacing. The identity and top of each figure should be given on the back.

PROOFS Galley proofs will be sent to authors. They should be carefully checked with the original MS and returned with the least possible delay; only essential corrections should be made.

SEPARATES A number of free copies of each paper will be provided. If authors require a specific number of offprints of their contribution, they should contact the editor before the issue goes to print.

Trans. nat. Hist. Soc. Northumb. **56**, 177-204 (1994)

ANNUAL REPORT
OF THE
COUNCIL
FOR THE
YEAR ENDED 31 JULY 1994

THE NATURAL HISTORY SOCIETY OF NORTHUMBRIA

PRESIDENT

His Grace the Duke of Northumberland

VICE PRESIDENTS

The Viscount Ridley
A H Dickinson
R W T Thorp
Sir James Steel
M J Hudson
J Alder
Dr G A L Johnson
D F McGuire
D R Shannon
D P Walton
I D Moorhouse
Mrs M A Patterson
Dr A G Lunn
A M Tynan

COUNCIL

(1) **Elected by members**:
1991 - Dr P Garson, Mrs P Hammock, Mrs A Newson
1992 - Mrs S Chambers, Mrs J Holmes, Dr T G Walker
1993 - H Baird, Dr J M Jones

(2) **Nominated by sections:**
Dr A G Lunn (botany), L Jessop (entomology), Dr G A L Johnson (geology), E Slack (Gosforth Park), Dr D Gardner-Medwin (library), D C Noble-Rollin (ornithology), Professor R B Clark (publications)

(3) **University representatives:**
Dr A J Richards, Dr B J Selman, P S Davis

TRUSTEES

A H Dickinson, R M Gledson, I D Moorhouse, Mrs M A Patterson, The Viscount Ridley, D R Shannon, E Slack, D C Souter, R F Walker

HONORARY TREASURER
E Slack

SECRETARY
D C Noble-Rollin

GENERAL PURPOSES COMMITTEE
P S Davis, Dr A G Lunn, Dr D Gardner-Medwin, D R Shannon, E Slack

SOCIETY REPRESENTATIVES

Coquet Island Advisory Management Committee: I D Moorhouse, D C Noble-Rollin

Fontburn Reservoir Wildlife Advisory Group: I S Davidson

Lindisfarne National Nature Reserve:
  Advisory Committee: D G Bell
  Wildfowl Panel: D C Noble-Rollin

Museum Management Committee: Dr D Gardner-Medwin, D C Noble-Rollin, E Slack, Dr R Stobbart

STAFF:
Mrs S K Carter, Mrs M A Patterson, Mrs J Shannon, Mrs R Wolland

GOSFORTH PARK NATURE RESERVE
Warden: P Drummond

THE HANCOCK MUSEUM
Principal Keeper: A Coles

ANNUAL REPORT OF THE COUNCIL FOR THE YEAR ENDED 31 JULY 1994

The year under review will forever be remembered by the many people who were involved with it as the year the *Flora of Northumberland* was published. It was an extraordinary and extremely ambitious task that was undertaken in 1983 but Professor George Swan, Mr David Noble-Rollin and the production team have produced for the Society an exceptionally professional, admirable and diligently researched publication which will be constantly referred to beyond our lifetimes. It is without doubt one of the Society's most prestigious publications since our first paper was published in 1831 though any proposal to build on this success with a similar follow-up volume on another subject will be coolly received for some time.

Council is pleased to report that the very happy working relationship with Tyne and Wear Museums reported last year continues in close co-operation with Mr Alec Coles the resident Principal Keeper. As managers of the museum their imaginative blockbuster exhibitions continue to attract the public and in one twelve month period covering the 'Dinosaurs Alive!' exhibition, over a quarter of a million people visited the museum.

This is all most encouraging for the future and with all that follows in this report and in the healthy financial statements it is evident that the Society is thriving and enjoying enviable success after a worrying and difficult period three years ago. After all the other good news from the Hancock Museum sales of the *Flora* have been better than anticipated and the Society is in a buoyant mood.

Disabled visitors are now able to use a platform lift to reach the first floor galleries. The original toilets of 1880 have been modernised within the strictures of the Grade II* listing which places the museum in the top six per cent of listed buildings in the country. The works included a completely new disabled persons toilet and a unisex baby-changing room and the University is warmly thanked for carrying out these improvements.

MEMBERSHIP

The total membership (with 1993 figures in brackets) on 31 July 1994 was 900 (921), 21 less than a year earlier. This was made up of 7 (7) honorary members, 42 (40) life members, 580 (638) members who receive *Transactions*, 239 (191) members who do not receive publications, 20 (23) associate members, 3 (1) schools and 9 (21) complimentary members. Several people make payments under long-standing bankers' orders ranging from £1 to £9, when these sums were the current subscription rates, and they are regarded as donors and not members.

The Council reports with much regret the death of six members, Mrs I M Catterall (1982), Miss B McDonald (1988), Mr J McGovern (1978), Mr J Parker (1990), Mr J D Price (1993) and Captain J Smith (1980). The dates in brackets are the year in which they joined the Society.

COUNCIL

At the annual meeting in November 1993 Mr H G Baird and Dr J M Jones were elected to Council and Miss R B Harbottle retired by rotation.

Mr Hugh Baird is a long standing member of the Society and previously represented the membership on Council in 1978. Dr Mick Jones has served as a University representative on Council for many years and is chairman of the geology section of the Society, introducing the lecturers during the winter and often leading interesting and informative field meetings each year. After the business of the meeting Mr Tony Tynan gave a short talk on Gosforth Park.

General Purposes Committee this year has lost two of its most respected members, both we are pleased to say through retirement. Mr Tony Dickinson has been associated with the Society since he joined in 1927 and was a founder member of the committee in 1961. He is the Society's solicitor and a Vice President. His active concern for the Society, particularly during the recent problems, has been greatly appreciated by both the Chairman and Council. However, as he remains a Vice President we can be assured that his wisdom will still be available. The Council also wishes to thank Mr Don McGuire for his long service on the committee. His advice and suggestions have been invaluable in dealing with the day to day running of the Society and in formulating the policies to be presented to Council. He asked to retire mainly due to his other extensive commitments but will continue as a Vice President.

PUBLICATIONS

The most important event of the year was undoubtedly the publication of the *Flora of Northumberland* by Professor George A Swan. The first twelve copies arrived at the Society office in November in time for the annual meeting. There was also a telephone message from the printer saying the die for the gold embossing on the cloth cover was damaged and that it was possible that the rest of the production would have to be without the drawing. There was some very undignified discussion as to who should get the rare twelve copies with the embossing! However, as the next delivery arrived it became clear that the problem had been solved and that all the copies would be the same.

The official launch of the book took place on Thursday 6 January 1994 and with it a ten year project finally came to fruition. It was very gratifying that everyone involved in the production was able to attend and the Society would like to thank them for contributing to this prestigious publication. The photograph of the production team was taken at the launch. They are as follows, from left to right: Mrs Tricia Hammock, typesetting and preparation of the computer programme to enable the page layout design to work; Mrs Margaret Patterson, who typed the flora drafts three times and was involved from the beginning of the project; Mrs Joyce E Webster who prepared the cover drawing and title page illustration; Mrs Margaret Swan who carried out much of the field work with her husband and supported him over the long period of the preparation of the book; Dr Angus G Lunn, author of the environment section, the biography of Professor Swan and one of the editors of the whole book; Professor George A Swan, the author and editor; Mr David Noble-Rollin, typesetting and in charge of overall production of the book; Mrs Joan Holding who prepared the colour plates to camera ready copy; Mrs Jean Lunn who prepared all the complex maps, designed the cover and page layouts and the overlays; Dr John Richards, author of the *Taraxacum* section and one of the editors; and finally Dr Brian J Selman who wrote the account of Dutch Elm disease. At this point it should be said that one other person's contribution needs to be mentioned. The late Mrs Grace Hickling worked on the *Flora* from 1983 until her sudden death in 1986 and during this period she prepared much of the basic layout of the species entries and the other preliminary work involved in any major publication.

There were also two issues of the *Transactions* during the year. Volume 56 part 1 was dated September 1993 and contained the following papers: 'Ore genetics in the Northern Pennines, 1948-1990' by Sir Kingsley Dunham, a transcript of the Pybus Memorial Lecture given by the author in 1991; 'Gosforth Park Nature Reserve annual report 1991' by Mrs Tricia Hammock and Mr David Noble-Rollin, the second report based on the members' logbook; 'A small collection of fishes from Madeira Island deposited in the Hancock Museum' by Dr A J Edwards: the material includes a number of rare and interesting specimens that came from the late Lord Richard Percy's collection which is stored at Newcastle University; an entomology paper 'Quantitative sampling of coleoptera in north-east woodlands using flight interception traps' by Mr Les Jessop and Mr P M Hammond, which consisted of a comparison of insect catches from Gosforth Park Nature Reserve and Lockhaugh Bank Wood: this was discussed in relation to previous knowledge of beetle assemblages in the north-east of England. Finally, Dr Brian Young had two contributions to the issue, firstly a paper on 'Some new occurrences of barytocalcite in the Northern Pennine orefield' and a short communication 'Vivianite of post-Roman origin from Vindolanda, Northumberland' with co-author Mr Robin Birley.

The second issue of the *Transactions* which was dated April 1994 was the largest part produced by the Society for many years and contained coloured plates. The first paper was 'The Flora of the Farne Islands' by Mr Mont J D Hirons describing the work done by the author on the vegetation of the islands over the last twenty years. It contained four coloured plates and a number of black and white pictures. The Society would like to thank English Nature for its

The production team for the *Flora of Northumberland*.
1) Mrs Tricia Hammock, 2) Mrs Margaret Patterson, 3) Mrs Joyce Webster, 4) Mrs Margaret Swan, 5) Dr Angus Lunn, 6) Professor George Swan, 7) Mr David Noble-Rollin, 8) Mrs Joan Holding, 9) Mrs Jean Lunn, 10) Dr John Richards, 11) Dr Brian Selman.

generous grant to this project and also the National Trust for its support. Both this paper and the next were also produced in booklet form to be sold by the National Trust in their Seahouses shop. The second paper was 'Birds on the Farne Islands in 1993' by Mr John Walton and Mrs Rita Wolland (ringing report) and edited by Mrs Margaret Patterson. This is the first time that this annual report has been included in the *Transactions* since 1972 and it is hoped that this practice will be continued in future with off-prints being sold to the public at Seahouses. The third paper was 'The status of the Wall Brown Butterfly, *Lasiommata megera*, in Northumberland, 1965-91, in relation to local weather' by Dr Hew A Ellis. In this contribution Dr Ellis shows that the recent re-establishing of the species north of the Tyne has been helped by weather patterns during the early 1970s. The final paper in this issue was 'The flora and vegetation of magnesian limestone sea cliffs, County Durham' by Mr D N Mitchell, Mr A W Davison and Mr J A Cooke. The work covered extensive vegetation surveys of the Durham sea cliffs showing a number of varied plant communities.

This year has been one of the most productive for scientific works in the Society's history with the publication of two issues of the *Transactions* and the *Flora of Northumberland*. In addition the Society is assisting in the production of the *Vasculum* and helping the museum with a user guide and the yet to be published fossil catalogue.

STAFF AND MANAGEMENT

The first part of the year was again dominated by the production of the *Flora of Northumberland* which reached the crucial stage of being printed in late August/September with the usual last minute mistakes and panics. To keep the office from getting bored during this time an issue of the *Transactions,* volume 56 part 1, was being printed and was distributed separately from the bulletin later in the year. We are again fortunate that the staff has not changed during the past year and during this difficult time they have supported the Secretary, maintained the continuity of information to members and undertaken their office duties willingly and efficiently. Mrs Margaret Patterson continues her secretarial work and is assistant editor of the *Transactions.* Mrs Sue Carter has the important role of looking after the membership and particularly banker's orders and covenant forms. Mrs Joan Shannon maintains the Society's exchange publications and sales of *Transactions.* Mrs Rita Wolland looks after the day-to-day accounting, the field meeting bookings and the continued ringing returns from the Farne Islands, and during this year she also took on the sales of the *Flora of Northumberland,* particularly the pre-publication orders which were complicated by the late production of the overlays.

During the autumn many of the volunteers, who devote so much of their time to the Society, assisted in innumerable ways to reduce the pressure on the Secretary. Council would particularly like to thank Mrs Tricia Hammock who worked long hours typesetting corrections to the *Flora* while helping Mrs Jean Lunn with the production of the text for the many maps and the overlays, while at the same time taking on much of the difficult work on the issue of the *Transactions.* This left the Secretary free to organise and oversee the production of both works. Mr and Mrs Chambers took on all the enquiries to the library and helped with any task that they were asked to do.

Mrs Joan Holding's contribution to the success of the Society's publications cannot be over estimated. She not only produced the front covers for the last two issues of the *Transactions* but also prepared often difficult and complex diagrams from authors' sketches. To add to her work pressure she illustrated the bulletins throughout the year and had to produce a new cover for the off-print of 'Birds on the Farne Islands in 1993'.

Mrs June Holmes has continued her research into Bewick's foreign bird drawings, and is now also answering the correspondence and helping with outside researchers interested in the collection both for the Society and the museum. Mrs Anna Newson has worked throughout the year to catalogue the rest of the Bewick water colours and drawings and assisted Mrs Holmes with visitors and enquiries relevant to her specialisation in the vignettes and tail-pieces.

Mrs Janet Angel offered to help and was given the unenviable job of transcribing the Gosforth Park logbooks to help Mrs Hammock prepare the yearly results for the reserve. She was so efficient at the work that the Secretary also asked her to look at some of the older records that had recently been found in the museum, including 1966 which is the only systematic recording during that decade. The Council would like to thank them all for their hard work.

In April work began on the decoration of the Society office. This lasted approximately a month and entailed the staff having to camp temporarily in the library and Council room, which gave everyone lots of exercise in running up and down the stairs between the two rooms. It confirmed that having the staff in one room is much more efficient. On completion everyone moved back into an attractive, carpeted and calming atmosphere which, when the staff can remember where everything has been put, will also be more efficient. The Council would like to thank Mr Derek Shannon for his design work and for overseeing the project.

HANCOCK MUSEUM

A Year of Plenty There is little doubt that 1993-4 has been an exceptional year for the Hancock Museum. The unprecedented numbers of visitors reflect a range of new developments, although possibly the dinosaurs must take much of the credit.

Between 1 April 1993 and 31 March 1994 the museum received over 257,000 visitors. This compared with a previous highest total of just under 100,000 which is a feat unlikely to be repeated in the near future. The challenge is to build on this 'year of plenty', and to ensure that full future benefit is derived from the increased profile of the Hancock.

The most visible change to the museum over the year is the new 'Land of the Pharaohs Gallery' that opened on 6 October. Particular thanks are due to the British Museum, not only for the generous loan of thirty-eight items for an initial three-year period, but for the great help and encouragement that was received from their Department of Egyptian Antiquities. The results are clear for all to see, and the level of use of the gallery by schools has been extremely encouraging.

Temporary Exhibitions 'Dinosaurs Alive!' (13 October-2 April). It now seems hard to believe that it was only last 14 October that saw 'Dinosaurs Alive!' open to an expectant audience. That it was possible to market the exhibition so extensively and effectively owes much to the generous sponsorship of the exhibition by Tyne and Wear Metro. This was recognised by a matching award under the Government's Business Sponsorship Incentive Scheme. It also received an award from the North-East's Sponsors Club. As a result of these additional sums, Metro's sponsorship was worth £22,000 to the museum.

The fact that over a quarter of a million apparently satisfied visitors saw the exhibition is testimony not only to the quality of the exhibition and effective marketing, but to the way in which the 'front-of-house' staff coped with a completely new experience. There is probably no other exhibition that has captured the imagination of the region's public and press to a similar extent. From the spectacular arrival and procession through the city centre, to the footprint trail and the 'Metro-saurus', to the seven record-breaking months, this was the exhibition that really brought the Hancock to the attention of the north-east.

'Books, Brains and Lightbulbs' (21 August-9 January). Amongst the 'dinomania' it is easy to forget about some of the smaller exhibitions that have visited the Hancock this year. 'Books, Brains and Lightbulbs' was produced by the history department at Newcastle Discovery, and initially shown there. It celebrated 200 years of the Newcastle Literary and Philosophical Society, and was therefore particularly relevant to the Hancock's (and of course, the Natural History Society's) history.

'Between the Sheets' (28 March-2 October). This is a temporary exhibition about paper making and paper media put together by students from the University of Newcastle upon Tyne's Museums Studies Course. It is a great credit to their endeavours, especially as this was the first time that most of the team had mounted an exhibition.

'British Gas Wildlife Photographer of the Year - 1992 Competition' (13 May-20 June). This ever-popular exhibition occupied the 'Green Room' between May and June. Our thanks are due to British Gas, and especially their staff in the Killingworth offices for the opening.

'Claws!' A large proportion of staff time has been devoted to producing our own block-buster exhibition about cats, from tigers to tabbies and sabre-tooths to Siamese. The exhibition was opened on 25 July by Councillor Roy Burgess, Chairman of Tyne and Wear Passenger

Transport Association. On account of its date of opening, this exhibition will be reviewed in next year's annual report; however, it is appropriate to thank all the lenders of mounted specimens, especially the Natural History Museum, National Museums of Scotland, the National Museum of Wales and National Museums on Merseyside. In addition, thanks are due to Laury Redman and Sarah Doyle of Redman Design Associates, who designed the exhibition.

Education Projects It could be misleading to consider education as a separate operational area. In actual fact, the museum's education officer, Ms Gillian Mason, has a substantial input into all their public activities, particularly the preparation of exhibition and display briefs. This, we hope, is borne out by the quality of interpretation in new projects. This being said, the number of visits by organised groups, and the range of special events, are the two most tangible measures of education provision. Over 36,000 children visited the Hancock with school parties. Regular 'twilight' in-service sessions are held for teachers, focusing on different areas of the National Curriculum, and these have been very well attended.

The 'Land of the Pharaohs' gallery is undoubtedly one of the major draws, and is invariably booked up by schools almost a term ahead. In April, a special three-week living history event was produced in association with the Time Travellers company. This in itself attracted over 1,600 visitors. A number of replica items have been purchased for handling sessions associated with 'Land of the Pharaohs', and a work pack and audio guide have also been produced, the latter with financial assistance from the North of England Museums Service. Similar resources have been produced for the 'Claws!' exhibition. Egyptian activities also included mask making and jewellery design, as well as a lecture about embalming and mummification by Ms Elizabeth Watson, entitled 'Perfect Preservation'.

A number of further education courses have utilised the facilities of the museum, the most obvious being undergraduate zoology and coastal management courses, and the postgraduate museums studies course within the University of Newcastle upon Tyne. Groups from other institutions (*e.g.* University of Northumbria at Newcastle, Newcastle College etc) have been looking at completely different areas such as media studies and the evolution of classification systems in art and science. Staff have also been involved in lecturing and presentations to the postgraduate museums studies students in the University of Newcastle upon Tyne.

Throughout the year there has been a variety of Family Fun Days, including the return of live snakes and spiders, and some of the animals saved by Creature Care at Throckley. In addition, performing arts students provided 'Jurassic Larks', whilst another weekend event invited children to write their own customised dinosaur stories. Arguably the most memorable of all were the much-publicised Dino-snore-ins, with over 270 visitors paying for the privilege to spend the night on the museum floor. 'Between the Sheets' inspired separate sessions on kite-making, paper collage and quilling.

Access The development of an Access Policy is well under way. In the meantime, a number of initiatives identified in the draft policy have already been completed or are in the process of development. The installation of the platform lift, thanks to financial assistance from the Museums and Galleries Improvement Fund, and the Tyne and Wear Museums Business Club, has provided much-needed access to the first floor for visitors with mobility difficulties. Large print and braille guides have been produced as part of the Active Access Strategy supported by the North of England Museums Service, and the same organisation has also provided financial assistance to train a member of staff in British Sign Language (level 1, currently progressing to level 2). A number of signed activities have taken place throughout the year.

Building Maintenance and Development The building has not been without its problems this year, and the roof has contributed its usual quota of leaks and frights. Investigations are still underway to assess the state of internal walls that have suffered inundation in the past. The poor state of the external paintwork led to a complete external redecoration in the spring. The most positive development has been the commencement of the long-awaited scheme to renew and improve the public toilet provision. New male and female toilets, a unisex toilet for disabled visitors and a separate baby changing room are all under construction and due to open in August. Great credit is due to Mr Derek Shannon for pursuing this project so tenaciously in the face of great odds, not to mention costs!

Collections Efforts have been made to improve the storage and documentation of the collections in a number of areas. This work puts into action the recommendations of a draft Collections Management Plan produced earlier in the year. Re-storage has concentrated on the following collections: removal of vertebrate material, especially trophy heads, from the unsuitable attic and basement areas, and re-location in the new biology stores at the rear of the building; removal of pyritised coal-balls and associated material from off-site storage in a damp basement to dry conditions in Newcastle Discovery; reorganisation of first floor Osteology/British Entomology store to increase space available for expansion of collections and for research and study. A conservation grant from the North of England Museums Service made possible the purchase of a sophisticated radio-telemetry temperature and humidity monitoring system. This allows the continuous monitoring of environments in galleries, stores, or individual cases by remote sensors. These transmit information to a radio receiver and all data is logged direct onto a computer programme. All data can be utilised to investigate the stability or otherwise of the museum's environment. The installation of collections databases on the University computer network has greatly improved the efficiency of data-retrieval.

Dr Roger Stobbart has completed curation on the important Trichoptera (caddis) collections. He is now working on the bird-wing butterflies, fulfilling a programme of curation drawn up by Mr Les Jessop, keeper of biology, with a view to the eventual re-storage of this collection in new purpose-built cabinets. The curation of the osteology collections proceeds thanks to the dedication of Mrs Paddy Cottam. Mr Eric Morton, assistant keeper of biology, has been supervising the cleaning and re-labelling of study skins and spirit collections.

The *Carex* (true sedges) component of the herbarium is developing as a result of continuing work by Mr Ron Cook. The phased re-storage of palaeontology collections continues as and when new cabinets can be purchased. Tyne and Wear Museums' keeper of archaeology, Mr Clive Hart, has been carrying out a survey of the non-Egypt archaeological holdings. The conservation of the John Hancock letters is now complete.

It would be inappropriate to include all new acquisitions here, so a selection of the most significant is listed, which in no way reflects complacency over the many other donations that we have received: a collection of three skulls (*Larus argentatus*, *Amia* sp. and *Lepisosteus*) donated by Dr A Panchen, University of Newcastle upon Tyne; a collection of Malaysian butterflies donated by Dr W R A Brown of Oxford; the fossil skull of a loxommatid amphibian from Whitley Bay, purchased from Leicester University (collected by Dr D Martill); a large fossil tree trunk (*Lepidodendron* sp.) collected by museum staff at Whorlton Hall Opencast, Westerhope; a large block of galena collected by D A C Mills; a selection of rare minerals donated by Mr B Young (including a slab of barytocalcite from Blaghill Mine, Alston, figured in volume 56 part 1 of the *Transactions*); a herbarium of vascular plants donated by Mr B Thompson of Lochgilphead, Argyll; a herbarium of vascular plants donated by Mr A Lacey of Brunel University.

It is hoped that the long-awaited catalogue of type and figured fossil vertebrates in the collections prepared by Mr Andrew Newman, Mr Steve Mclean and Mr Darren Hudson will be published soon.

Staff and Volunteers There have been a number of staff changes through the year: Mrs Fiona Fenwick took over as clerk/typist in August 1993. Mrs Fenwick's job title does no justice to the vital role that she plays at the Hancock in keeping the office functioning. Helen Fothergill is the new assistant keeper of geology, replacing Mr Andrew Newman who left last year (1993-4). The net result is that Mr Steve McLean, keeper of geology, is now based at the Hancock. Mr David Hall, the Hancock's in-house designer, left in April. Mr Hall has played a major part in the development of the Hancock over many years. He has been working part-time since 1992 and has left to devote all his time to his own design business. We thank him for his considerable efforts and wish him every success.

Partly as a result of the temporary requirements of 'Dinosaurs Alive!' there have been a number of changes in attendant staff over the year. We welcomed Mrs Kath Catherall and Ms Sarah Wylie and then said goodbye to Sarah and to Mrs Pat Jameson. We thank Ms Elizabeth Garland, Mr John Hogg, Ms Deirdre O'Brien and Ms Sharon Race, all of whom joined us temporarily for 'Dinosaurs Alive!' Mrs Christine Hughes started as part-time cleaner in August.

The Hancock has long been indebted to voluntary curators and assistants. Thanks are due to all the many people who have given their time over the year in various ways. The list below is not comprehensive, but includes those whose contributions have been particularly significant, and apologies are due to those who have been omitted; Mr Ron Cook, Botany/Oology curation; Mrs Paddy Cottam, Osteology curation; Mrs Susan Davison and Ms Rachel Edwards, Education materials; Miss Louise Hollingworth, Hancock Library; Dr Roger Stobbart, Entomology curation (and bee-keeping!); Ms Elizabeth Watson, Egyptology/Ethnography curation; Mr Darren Hudson and Mrs Elaine French, Geology; and Ms Melissa Murphy, Education.

At the end of a very busy and successful year, the Society would like to thank the University of Newcastle upon Tyne for its continued support. The Society is particularly grateful to the University for allowing the substantial surplus of income (generated by the 'Dinosaur's Alive!' exhibition) to be released to the museum for future development.

The Society is also grateful to the many private and statutory organisations who have provided assistance through grants, sponsorship and help in kind.

The work of the Hancock Museum Management Committee cannot be underestimated and the Society appreciates their support throughout the year. Special thanks must go to the Principal Keeper, Mr Alec Coles, and all the Tyne and Wear Museums' staff, both within and without the Hancock, for working so hard and so constantly towards the goal that we all share: to make the Hancock Museum the best of its kind, and to secure its future as a scientific and educational, and of course accessible, resource for current and future generations.

MUSEUM MANAGEMENT COMMITTEE

Since the last report the committee has met on three occasions on 30 November 1993 and 25 March and 9 June 1994. The main issues concerning the Society at the takeover by Tyne and Wear Museums was the curation and safety of its collections. It was pointed out that most of the committee's time would necessarily be used discussing financial matters such as the funding of projects and exhibitions, therefore leaving little time to discuss the conservation of collections. This was solved by Mr Alec Coles, Principal Keeper, agreeing to produce a report on collection management that would be circulated before each meeting. Added to this is the policy of informing the Secretary of any collections which are being loaned to museums or other organisations, so it is now possible for the Society to monitor the collections in its care.

The other matter of the safety of the specimens has also been addressed during the year with the production of a draft Disaster Plan for the Hancock Museum prepared by Mr Steve McLean, Keeper of Geology. This comprehensive document was presented at the June meeting and will be amended and discussed further during the coming year. However the museum has now at least the basic structure for dealing with the unthinkable. Most of the other matters discussed by the committee are dealt with under the Hancock Museum report above.

FINANCE

The surplus of income over expenditure for the year ended 31 July 1994 was £6,768 (1993 £387) after appropriations of £1,750 (1993 £3,250) and has been added to the general fund in order to cushion a fall in income and increased expenditure in future years.

As early as April 1993 it was forecast that the surplus for the year to 31 July 1994 would be only £2,150. This took into account the rise in subscription rates together with a reasonable estimate for the projected sales of the *Flora of Northumberland*.

However, the sales of the *Flora of Northumberland* exceeded all expectations and up to 31 July 1994 the number of copies sold was 579 compared with a budget of 450. This increase, with many copies at the full retail price, amounted to sales of £12,954 against a forecast of £9,500.

Prior to the publication of the *Flora of Northumberland* in December 1993 measures had been taken to improve the yields from the investment portfolio and to this end half of the Society's holding in the Charities Investment Fund was sold and reinvested at higher yields. This improved the income from this source by approximately £1,500 above budget, which more than counteracted the reduction of interest from bank deposits, after settling the cost of publication.

Other factors affecting the income of the Society were higher repayment of income tax from covenants with many more members responding to the request to pay their subscriptions under deed of covenant, an improved grant from the University of Newcastle upon Tyne and an increase in the level of donations. The Society greatly appreciates the continued support from the Percy Hedley Trust and Samares Investments.

Although there were variations in the level of budgeted individual expenses these were insignificant in total and therefore did not affect the result for the year.

A summary of the explanations given above is as follows:

	Budget 31.7.94	Actual 31.7.94	Surplus
Income	£	£	£
Subscriptions	13,000	13,546	546
Donations	1,000	1,398	398
University of Newcastle upon Tyne	7,000	7,200	200
Investment income	23,000	24,565	1,565
Sales of *Flora of Northumberland*	9,500	12,954	3,454
	53,500	59,663	6,163
Expenditure			
All headings	51,350	51,145	205
Excess of income over expenditure	£2,150	8,518	£6,368
Less: Appropriations		1,750	
		£6,758	

It is important to appreciate that the comparison between budgets and actual income and expenditure, not only for the current period but for future years, reflects the changes in the Society's activities and services to members. This comparison also gives advance warning of problems that may arise and the measures which should be taken to counteract them.

This is not, however, to assume that changes in levels of income and expenditure as compared with the previous year should be ignored. Whilst all of the changes in income have already been mentioned above, a general summary of movements over £200 in expenditure is as follows:

Salaries reflect not only inflationary increases to all staff, but also the effect of bringing the Secretary's salary in line with that of other conservation bodies together with the recognition of the efforts of David Noble-Rollin in the publication of the *Flora of Northumberland*, and major improvements in computerised systems and desktop publishing.

The cost of printing rather than photocopying the latest two bulletins wholly explains the increase under this heading whilst the ever increasing cost of postage particularly in relation to *Transactions* is the reason for the additional postal cost.

Membership of the London Zoological Society, including the subscription for the previous year in order to obtain its publications, reflect the increase in subscriptions.

Two parts of the *Transactions* were published during the year as opposed to one in the previous year and both contained more pages resulting in higher printing costs. The Society wishes to thank English Nature and the National Trust for their support towards publication of Volume 56 part 2 which included 'The Flora of the Farne Islands'.

Additional badger protection in the form of an artificial sett near Lake Lodge together with the cost of timber for a new boardwalk used by the ringing team represents the increased expenditure at Gosforth Park.

Depreciation is reduced because one of our computers was fully depreciated at 31 July 1993 and its replacement was not purchased until after the financial year end.

The reduction in the provision for deferred repairs of £4,000 was to finance the refurbishment of the Society's office and to provide a new light fitting in the Council room. This left £1,250 to which has been added the appropriation for this year of £1,750 making £3,000. This is required for our contribution to improving the lecture room and the external painting of Lake Lodge.

No major work was carried out at Gosforth Park Nature Reserve and the restoration fund remains at £5,000. This will be expended for further clearance of the lake area in order to regenerate and extend the reedbed.

Referring to the balance sheet and the Society's assets, the only addition to office furniture was the purchase from the leasing company of the photocopier for £295. This machine has been used mainly to produce the bulletins but will in future deal with general office work now that the bulletins are being printed and the additional cost of this will be entirely covered by the reduction in leasing charges.

There has been one significant change in the investment portfolio being the disposal referred to above of half of the Society's holding of shares in the Charities Investment Fund for £62,395, producing a surplus above cost of £52,395 which has been added to the general fund. The whole of the proceeds has been invested in higher yielding loan stocks and bonds in long established and top quality public companies. The benefit of this strategy has already been referred to in the form of considerably improved investment income.

The increase in amounts recoverable is represented mainly by the grant from English Nature and the sale of *The Flora of the Farne Islands* to the National Trust and bank balances reflect the eventual cost of the publication of the *Flora of Northumberland*.

The liabilities outstanding at 31 July are the Gosforth Park Nature Reserve Restoration Fund, the Provision for Deferred Repairs, both of which have been explained, and amounts owing or received in advance amounting to £8,539. This, of course, in 1993 included the amount set aside for the payment of the *Flora of Northumberland.*

Finally the wealth of the Society excluding unrealised surpluses on assets and investments is represented by the funds held at the financial year end amounting to £281,347, an extremely healthy position.

Since the year end £30,000 of the balance held in the Charities Deposit Fund has been invested in stocks and bonds in order to produce a greater return of income together with medium to long term capital appreciation.

The Society's day to day financial affairs will continue to be managed by the Council and the Honorary Treasurer, with the assistance of Mr K Patterson and our brokers Wise Speke on investment matters, for the benefit of the members. To this end the current year's surplus together with further improvements in income will be utilised to meet the increasing costs of improved services and members can be assured that no increase in subscriptions will be proposed unless this is absolutely necessary.

The financial statements were approved by Council on 7 October 1994 for presentation and approval by the members at the annual meeting.

LIBRARY

Dr Mike Cassidy resigned from the committee after having played a major part in discussions over the last several years, and the Council is grateful to him. We welcome as representative of the entomology section his successor, Mr Les Jessop, who immediately agreed to organise the library evening on 5 November. To a background of fireworks we were able to see many of the most important books in the history of entomology and hear accounts of their authors. The library made another contribution to the year's programme on 6 May when Mrs June Holmes, Mrs Anna Newson, Mr Hugh Chambers and Mrs Stella Chambers mounted an exhibition of Bewick watercolours and drawings and repeated the performance next day, with an introduction by Mr Peter Davis, for a visit of the Bewick Society.

Mr and Mrs Chambers made further progress with the computer-based catalogue. By 1995 we expect this to be complete and to include all the serial volumes and the separates (pamphlets and offprints) as well as the periodicals and books which have now been fully catalogued. Their contribution to the library has once again been a massive one.

In a special project for her MA at the University of Northumbria, Ms Michelle Bartlett very skilfully conserved four of our works from the Thomas Bewick studio and researched their background. We are delighted to have a copy of her thesis in the library. The University's conservation department also conserved some other damaged and frail drawings in the Bewick collection.

Sixty-five works have been added to the library this year, twenty-five of them donated, six by academic exchange, four by osmosis from the museum and the rest by purchase. We are grateful to Professor R B Clark, Mr Peter Davis, Mr Alistair Elliot, Dr Gavin Hardy, Mrs June Holmes, Mr Wylie Horne, Mr R Luggins, Dr Denys Smith, Mr John Steele, Professor George Swan, Mr Tony Tynan, Mr P Veitch, the Library of Congress, the Yorkshire Museum and anonymous donors for generous gifts of books, offprints and manuscripts. Those of local interest included *Bewick Gleanings* by Julia Boyd, *Thomas Bewick* by Montague Weekley (1953), *Northumbrian Nature Diary* by Wendy Dickson and illustrated by John Steele, an article on breeding terns on Coquet Island (W Horne), *The British Flora* by Stephen Robson of Darlington (1777), *Primula* by John Richards, 'Notes on the algal herbaria at Newcastle upon Tyne, Sunderland and Edinburgh' (F G Hardy) and, of course, the *Flora of Northumberland.* Dr David Gardner-Medwin also generously donated an original manuscript letter written in 1873 by Thomas Belt to Sir William Hooker, giving the first description of his discovery of the symbiosis between colonies of ants and the bull's horn acacia in Nicaragua.

ACTIVITIES

Ornithology section The indoor meetings for the ornithological section began on 1 October with a delightful talk and slides by Mr Eric Bird entitled 'The birds of the midnight sun'. These followed the adventures of Eric and some friends as they hunted the Arctic for bird species. Everyone enjoyed his sense of humour and the lecture was well attended. The programme continued with Dr Brian Nelson talking on 'Gannets and the Bass Rock' as the Pybus Memorial Lecture. Brian is the world's leading expert on the *Sulidae* and after the lecture none of the audience was in any doubt that this was the case. However the lasting impression is of the hardships that he and his wife had to endure while he completed his studies. Also he greatly increased our knowledge of the varied human history on the Bass itself. The 3 December meeting brought Mr Michael Leach, a professional wildlife photographer, to talk on 'The Complete Owl', which was the title of one of his books. The lecture, as one would have expected, was illustrated with excellent pictures, and a large audience was entertained to an enthralling talk on owl behaviour.

The new year began with 'Zimbabwe and the Okavango' by Mr Andrew Bielinski which was based on his six weeks in southern Africa in 1991. He managed to impress on the audience his great enthusiasm for the continent and the spectacular scenery and wildlife which is hard to equal anywhere in the world. The programme continued with Dr Tim Stowe of the Royal Society for the Protection of Birds talking on 'Corncrakes'. Tim managed to convey the serious conservation work that he and his colleagues are doing in Scotland into survival strategies for this endangered species. He described the painstaking research techniques used to study an almost invisible bird and the many false starts. However, with cooperation it should be possible to halt the decline and create areas for this interesting bird to survive. The final lecture was from Mr John Wilson who made a welcome return visit to the Society after a long absence. His subject was 'A naturalist down under' and he showed his great enthusiasm for Australia when he described his travels and the wildlife encountered by him and his wife on their two visits, and he also showed slides of some of the birds that they saw in New Zealand.

The outdoor programme began with the pelagic cruise on 14 August. This was not as spectacular as in previous years, although it was an excellent evening. The bird situation was saved for some members by our reciprocal agreement with the North Northumberland Bird Club which went out the following month and they had an amazing morning with superb sightings of most of the pelagic species that one would hope to see. On 11 September the section visited Fairburn Ings and Blacktoft Sands. The weather was excellent and the birds performed well with marvellous views of water rail, green sandpiper, greenshank, curlew sandpiper, little stint, marsh harrier, kingfisher and a ruddy duck with six rather late small ducklings.

The next meeting was on 3 October on Holy Island. Once again this proved to be an impressive field meeting with a number of sightings of interesting birds including yellow-browed warbler, lesser whitethroat, brambling, ring ouzel, siskin, brent goose and red-necked grebe. The group had to leave in mid-afternoon because of the tide and in consequence had a sighting of an unidentified gull. The markings were as follows: black legs, two coloured bill (black with light tip), white primaries, pale grey on wings and back and black spot behind the eye. Unfortunately no other groups saw the bird subsequently so it will probably remain a mystery.

On 22 January the section went to Musselburgh and Aberlady Bay; the conditions were fine but very windy which reduced the quality of the bird watching, particularly in the afternoon. However a good number of birds were seen including velvet scoter. The other winter meeting was on 19 February to south-west Scotland and on this occasion the group went first to Loch Ken to see the white-fronted geese and then back to the Wildfowl and Wetlands Trust at Caerlaverock. This proved less successful than expected with rather a lack of birds at the reserve in the afternoon, particularly birds of prey which are normally common.

The summer field meetings began on Sunday 1 May with the Northumberland Wildlife Trust and the Society holding a dawn chorus event in Gosforth Park Nature Reserve followed by a cooked breakfast, and for those who attended this was a very successful morning. Unfortunately the next two outdoor meetings had to be cancelled due to lack of support. We all hope that this is due to unusual circumstances and that the Society will be able to continue bus trips for members.

The North Northumberland Bird Club invited members to join their annual Farne Islands visit on 18 June which was led by Mr Graham Bell, and a number of Society members enjoyed their day amongst the terns.

The final outdoor meeting of the year on 19 July was with the Tynemouth Ringing Group to see storm petrels. Members congregated at 10.30pm in Tynemouth and made their way to the site. Anticipation was high with recent reports of the Swinhoe's petrel, although it had not been caught so far this year. Apart from members there was a subtle presence of Swinhoe's petrel devotees who sat on deck chairs or slept in sleeping bags awaiting the pelagic's return. On the night that the Society was there they remained disappointed although the group had an excellent time with a good number of storm petrels being caught. Most of the members returned to their beds by 1.00am on a beautiful warm moonlit night.

Botany section The winter lecture programme began with Dr Angus Lunn on 'The plants and vegetation of Alston Moor, North Pennines', when he described the influences of high altitude and a long history of lead and zinc mining on habitats in the area. For the subsequent meeting Dr Trevor Walker similarly had a high-altitude theme when, in 'A botanist in Venezuela', he discussed the altitudinal zonation of vegetation in the Andes. The members' night, after a film on Scottish gardens, very properly had a *Flora of Northumberland* theme, including portrait sketches of past Northumbrian botanists and a competition to name plants from their distribution maps. The final lecture was by Dr Clive Jermy, on 'The Killarney fern and other problems in fern conservation', centering on the very odd reproductive arrangements of some ferns, including the Killarney fern.

The summer excursions were all exceptionally well-attended. The first, in June, to Alston riverside following Dr Lunn's lecture, was to examine meadow and heavy-metal tolerant species. The second was in early July when Professor George Swan led members to the Scremerston shore where they saw a huge variety of plants including, on the edge of a barley field, some increasingly scarce arable weeds. Later in July, on a glorious day, the section made the long but worthwhile trip to Humphrey Head on Morecambe Bay and to nearby Whitbarrow Scar under the leadership of Dr John Richards; they were rewarded by a wealth of coastal and inland limestone species including several national rarities. The blue of *Veronica spicata* (spiked speedwell) against the white limestone at Humphrey Head was worth the trip alone.

Mammal section Dr Paul Bright's excellent 'A natural history of the dormouse' drew a large audience. Traffic problems meant the late arrival of the speaker but showing great composure he began to deliver his lecture immediately on entry into the lecture theatre. The talk covered a wide aspect of the dormouse's life style. From a common Victorian children's pet, its numbers have slipped to a very low ebb. Changes in farming and forestry practices appear to have contributed to this decline. The present dormouse survey was introduced and a number of survey sheets and information packs were handed out. It was a well presented and informative lecture and members showed great interest in the questions asked.

The programme continued with Mr Bob Elliot talking on 'Batwork in the 90s' on 28 January. His talk covered bat conservation issues as well as a few of the problems and solutions that have been faced by bat workers in Britain. Unfortunately the February speaker, Dr Martyn Gorman, was unable to come due to flu. At the last minute Mr John Steele, who was to introduce the speaker, had to take centre stage! He, as usual, gave an excellent talk on the National Park's work in Northumberland and showed some beautiful slides of the countryside that most of the audience was very familiar with. However, many of his pictures shed new light on the subject.

The mammal field meetings began on 23 October with a trip to the grey seals of the Farne Islands led by Mr John Walton. The weather was excellent and they saw the young seals and a first class selection of birds both at Seahouses and on the islands.

In May, Mr Paul Drummond took a small number of members to see badgers in Gosforth Park reserve and they were rewarded with views of a number of animals. The final meeting of this section was a batwatch on 6 July at Close House near Wylam led by Mr Allan Watson. They saw a number of species of bat and heard their notes interpreted by the bat detector.

Geology section There were six geology lectures during the winter beginning on 8 October with Dr Richard Swarbrick of Durham University Geological Sciences Department who gave an excellent lecture on 'Why there is oil and gas in the North Sea'. He began with a demonstration of what happens to shales from the Kimmeridge Clay when they are heated in a test tube. He showed specimens of different types of host rock and examples of source rocks around the world. His lecture was liberally illustrated with colour slides and he had even come prepared to answer expected questions by bringing transparencies with him. Over fifty members supported the lecture with lively questions.

During November, Dr Angela Coe, also from the Geological Sciences Department at Durham, gave a lecture attended by over forty members on 'New methods in stratigraphy' using examples from the Jurassic of Britain to illustrate her topic. She gave an excellent talk on sequence stratigraphy that was complementary to the lecture given by Professor Tucker the previous year. She explained the evolving principles which have changed the emphasis in research and teaching of sedimentary rocks and basins and which has rejuvenated the study of stratigraphy. She drew her examples from the rich Jurassic sequences in Yorkshire and Dorset.

Dr David Collinson from the Department of Physics at Newcastle University delivered the December lecture on 'Meteorites' and this proved to be a popular topic as over sixty members were present. He arrived with quite a few specimens of meteorites that were closely examined, and he explained the different types of meteorite and what they told us of the nature of the solar system. There was a very lively question time at the end of the lecture which lasted until 8.30pm, allowing members to look at the subject quite deeply.

On 14 January Dr John Senior from the Adult and Further Education Department at Durham made a return visit to the Society. This time he came to speak on 'The geology of Tenerife and the Canary Islands'. He has frequently led adult parties to the Canaries. Quite a large audience of over sixty-five was present and enjoyed his excellent colour slides of Tenerife. He also showed some of the flora of the islands explaining how the rich volcanic soils and extremes in elevation had created a wonderful nature reserve in the national park around Mount Teide. Unfortunately Dr Senior was not at all well at the time of his lecture and after being on his feet for over eighty minutes was grateful when questions terminated. The audience, however, was most appreciative that he had come.

Dr Eric Valentine from the Department of Civil Engineering at Newcastle University supplied a very topical lecture when he dealt with 'Coastal erosion along the North East coastline'. Memories of the Scarborough hotel collapsing into the sea were still vivid for most of the sixty members attending the lecture. They were surprised at the many problems that now beset our coastline and were impressed at the measures being undertaken to combat the worst excesses of nature. Dr Valentine, as well as being conversant with many of the problems and engineering solutions both good and bad around the world, is presently involved in studying problems in Cullercoats Bay. His illustrations and knowledge stood him in good stead when confronted with some of the questions from the audience.

The final lecture of the season was even more topical than the committee had envisaged when drawing up the winter programme, as this was given by Dr Paul Younger, Lecturer in Water Resources in the Department of Civil Engineering at Newcastle University. The title 'Environmental impact of coalfield closure in the north-east' looked particularly at the problems in the older parts of the Durham coalfield and the possible impact of future closures. His lecture, which was given to a large audience of over eighty, explained the problems of mine flooding with the minerals likely to contaminate mine waters and the difficulties encountered when the water table rose and drainage occurred at the surface. He was able to convince the audience on the inevitability of pollution and the time factors that were involved before this would occur in various parts of the north-east. His solution was not to turn off the pumps that prevented water rising into the upper mine workings where the main pollution comes from. His audience was very environmentally oriented and various questions at the end explored other ways of circumventing the problem. It is interesting to see now that since we have total closure of the coal mines in the north-east, British Coal has adopted Dr Younger's solution and plans to implement a continuous pumping scheme.

The September field meeting was well attended by over twenty members with Dr Mick Jones, our section Chairman, travelling by car to the coast near Amble and Hauxley where with an unusually low tide the group was able to examine some of the Coal Measure sedimentary sequences close to major faults. He was able to show the anomalous way in which the dip of the beds occurred in relation to the downthrow of the fault and explained that this was caused by faulting being contemporaneous with sedimentation. Domes and basins also occurred close to the fault system. The group visited the Hauxley peat beds which are rich in trees and other organic material. Dr Jones had time to show us the remains of the forest of upright trees in the cliffs east of Cresswell and the deformation of the beds close to the South Newbiggin fault system. This showed a similar pattern of deformation to the beds at Cullercoats and Hauxley.

At Cresswell a whisky bottle was picked up on the beach, regrettably without the liquid contents but enclosing a note from Master Bremner of Caithness, who was later contacted; it had taken only six weeks for the waves to carry the bottle to the pick-up point.

The visit planned for October was cancelled but on 28 May the next visit to Burnmouth and west of Belford was attended by fifteen members in cars with Dr Brian Turner of Durham

University leading the party. He demonstrated the sedimentology of the Fell Sandstones and Cementstones in Burnmouth Bay where on the foreshore the strata are inclined close to the vertical and where also the dominant features are the thick fluvial channel sandstones. He was able to show that there was sequence and order in the pattern of the succession. The party examined the sequence in the southern cliff near to Ross Point and found the beds near the top of the Cementstones are more calcareous and the channel sandstones increase in abundance and are thicker. The Fell Sandstone contact above was seen best at Maidenstone Stack where two erosively based fining upwards sequences occur.

After lunch the party examined the Fell Sandstone cliffs at Bowden Doors, a prominent crag over 400m long. The stratification is well seen in these outcrops with three facies visible. Water escape structures, current directions and channel positions could all be seen in the cliffs which proved to be a popular site for climbers as well as geologists. The party was blessed with unusually good clear weather and as well as being sunburnt had splendid views of the coastline from the top of the scarp.

Regretfully the June meeting had to be cancelled at the last moment due to a family bereavement of the leader, Dr Angela Coe.

Entomology section In general there seems to be a very low level of interest in entomology within the Society: the indoor meetings attract far fewer members than those of other sections and attendance at the field meetings is often less than half a dozen. With the hope of attracting more of the general naturalists to our meetings the aim this year has been to cover general topics in entomology rather than specialist subjects.

The first meeting of the section was on 24 September when Mr Les Jessop took members 'Behind the scenes' to see the Society's very extensive collection of insects, both foreign (mainly butterflies) and British (most groups). Members were given the opportunity to look over the collections and see the way in which they are stored.

On 21 January Dr Lewis Davies spoke on how some insects are faced with a very variable food supply and microclimate. Members were given a fascinating account of the way in which insects cope with these problems, with several 'case studies' taken from Dr Davies' own researches in the field.

On March 25 Dr Roger Stobbart spoke about the social behaviour of 'Bees', explaining that this is among the most complex in entomology: there are several levels of organisation, from totally solitary species through to the hives of honey bees. He provided a very clear and concise account of bee behaviour that, judging by the length of the question-and-answer session afterwards, clearly stirred the interest of the audience.

There has been a disappointingly low turn out for entomological field meetings in past years. In the hope of attracting non-specialists the Gosforth Park field meeting on 9 July led by Mr Les Jessop was advertised as an insect training session for beginners. In the event, the turnout of three was just as low as in previous years and consideration must be given as to whether it is justifiable to continue these outings.

GOSFORTH PARK NATURE RESERVE

Throughout the year under review there has been uncertainty as to the future of the High Gosforth Park Company Plc. The Secretary of State for the Environment reopened the enquiry into the planning application after the previous incumbent took the unusual step of making a split decision. The outcome of this was announced in May 1994 with a decision not to allow any development within the Park. The newspapers began speculation as to the future of the racecourse, suggesting that the Halls of Newcastle United fame might take an interest in the company. In July the newspapers reported that there was another party interested in the racecourse and by 2 August 1994 Northern Racing had taken a ninety-two per cent share in High Gosforth Park Plc. This company, under the ownership of Mr Stanley Clarke, already successfully runs Uttoxeter racecourse and it is hoped that they will be able to turn around the fortunes of the Newcastle course to the benefit of both the city and Gosforth Park. The Gosforth Park Nature Reserve Management Committee has arranged a meeting with the new management in September 1994 in order to establish a proper working relationship between the Society and the Company which will benefit both interests.

The wildlife news from the reserve is that most breeding species appear to be in good numbers although there is a growing concern for the water rail population (the only permanent breeding group in Northumberland) with the presence of mink in the area. Because of the difficulty of monitoring the rails the actual effect of this new predator will not be easy to assess. The most exciting visitor arrived in December just before Christmas - a bearded reedling, the first since 1966, was recorded in the *Phragmites* by Mr Michael Frankis and subsequently seen and heard by quite a number of members. The other interesting visitor was a marsh harrier first seen in April by Dr Mike Smith and subsequently seen in the second half of May by a number of members. This is the third year in succession that the reserve has attracted this species. Both the above 'rarities' are species that require reedbeds as a major part of their habitat. It is always dangerous to draw conclusions from a few sightings but perhaps in the future these reedbed birds may start to breed in the area if we can continue to increase the area of *Phragmites* both in the reserve and in other areas of the north-east.

There were no major work projects undertaken during the present year, although further desilting of the lake and better water control were necessary to continue the ten year management plan. The main reason was the reluctance of the High Gosforth Park Company to meet the Society to discuss any major improvements the Society had proposed to undertake this year. Consequently the only work carried out was maintenance. This included Society work parties run by the warden Mr Paul Drummond and also a substantial contribution by the Urban Fringe Area Management Scheme (UFAMS) under the direction of Mr Allen Creedy, Countryside Officer for the planning division of the development department at the Civic Centre. The Council would like to thank everyone involved for all their hard work throughout the year.

Trespass and poaching have been under control this year mainly due to the constant pressure of the wardening organised by Mr Paul Drummond and supported by his wife, Mary; he has made it a bad year for the less desirable elements in the reserve. This work has been assisted by a hard core of members who turn out night and day to help him chase any would-be poachers. The Council would like to thank them for their valuable contribution, and also Mr Dave Fuller of the Scout Camp for his active cooperation in wardening the racecourse end of the area.

RINGING STUDIES

During the period covered by this report, the Natural History Society Ringing Section pursued three main projects: continuation of the 'constant effort' ringing programme at Gosforth Park Nature Reserve, ringing at a coastal site, and studies of storm petrels at a Hebridean breeding colony. Interest in the Society's ringing activities continues to grow and there are now ten active participants.

The totals for birds ringed at Gosforth Park is shown in table 1. This site is operated as a 'flexible' constant-effort site. In addition to the six constant nets operated at least once in each of twelve ten-day periods during the spring and summer, additional nets are used in each session and additional ringing visits made to the reserve. The total ringed represents the total for all nets and visits, but the pattern of ringing activity was broadly similar to the previous year. There was a modest increase in the total number ringed, increasing from 405 during the period August 1992-July 1993 to 540 for August 1993-July 1994. While the numbers of some species ringed remained similar, such as blackbird, blackcap, great tit and wren, there were healthy increases in the numbers of blue tit, chiffchaff, reed bunting, reed warbler, sedge warbler and willow warbler. Only for long-tailed tits was there a substantial decrease in the numbers caught: seventeen compared with thirty-five in the same period last year.

A number of interesting recoveries or controls of Gosforth Park birds were reported during the current period. Two sedge warblers were reported: an adult male ringed in May 1993 was caught again (controlled) at Icklesham, Sussex, by Rye Bay Ringing Group and a juvenile, ringed on 22 August, was controlled only ten days later by the Stour Ringing Group at Poole Harbour, Dorset, a distance of 481km. Somewhat more unusual is the goldcrest ringed in the reserve on 5 September but later found 413km further south 'waterlogged after a storm' in Hampshire on 1 October. Our only previous recovery of a goldcrest was a bird ringed in October and later controlled, the same year, in Dungeness. The number of goldcrests in the reserve increases markedly during September into October and the origins and destinations of these birds merits further study. There continues to be an exchange of birds between Gosforth Park and Big Waters: three reed warblers controlled at Gosforth Park during the period were previously ringed at Big Waters, and one of our willow warblers has since moved there. At a time when the funding of the ringing scheme seems to be under increasing pressure, it is important that ringing is recognised as a worthwhile activity providing knowledge of our bird populations essential for adequate conservation. The constant effort scheme at Gosforth Park will continue to be the 'raison d'etre' of the Society's ringing group and we hope will be maintained for the foreseeable future.

Table 1

Ringing totals for Gosforth Park Nature reserve for August 1992-July 1993 ('1993') and August 1993-July 1994 ('1994').

	1993	1994		1993	1994
Blackbird	24	33	Lesser whitethroat	0	1
Blackcap	29	28	Long-tailed tit	35	17
Blue tit	59	88	Reed bunting	10	27
Bullfinch	7	11	Reed warbler	4	14
Chaffinch	3	2	Robin	43	35
Chiffchaff	3	15	Sedge warbler	53	99
Coal tit	3	5	Song thrush	7	5
Dunnock	8	14	Sparrowhawk	0	1
Garden warbler	4	3	Treecreeper	8	4
Goldcrest	2	4	Whitethroat	4	0
Great spotted woodpecker	2	3	Willow tit	4	8
Great tit	25	26	Willow warbler	36	66
Jay	1	4	Wren	31	27
			TOTAL	405	540

Ringing at coastal sites near Craster during the autumn of 1993 yielded eighty-one birds, consisting mainly of robins, blackbirds, goldcrests and blue tits, but with small numbers of other migrant species including blackcap, a redstart, spotted flycatcher, yellow-browed warbler and redwing. The most exiting bird was undoubtedly the robin caught wearing a German ring on 17 October. This bird, a first-year, had been ringed twenty-eight days previously in Heligoland, Germany. Ringing at one of these coastal sites started again in July this year, leading to a catch of thirty sedge warblers which provided further data to complement a study of sedge warbler moult at Gosforth Park. Ringing will be continued at these sites in future years.

An expedition to the Inner Hebrides in early July this year was made to continue a study of storm petrels at an island breeding colony. During a week-long trip, almost 200 storm petrels were caught and ringed. We also continued our search for tern colonies to provide data to compare with local breeding birds and identified breeding sites for black guillemot which may warrant more detailed study in future years. The Society's ringing activities on the west coast of Scotland represents a worthwhile extension to the range of the Society's activities and provides an opportunity to develop new research projects into seabird populations to complement the Society's interests in the north-east coast.

The first few months of 1994 saw a large scale mortality of seabirds along the east coast: great numbers of guillemots and shags were found dead on the beaches. These birds were in poor condition and had probably starved as a result of bad weather and consequent food shortages on their wintering grounds. Amongst a batch of recovery details for ringed birds picked up dead during this period were details of forty-two shags and only one guillemot, all ringed on the Farne Islands up to about seven years ago. The shags were all found along the east coast from Suffolk to Aberdeen: twenty-five were on the east coast of Scotland from Lothian Region to Aberdeen, six were from East Anglia and eleven were picked up locally. This suggests that Farne Islands shags may have been particularly badly hit. Since only 30% of guillemots survive to their fifth year, it is difficult to draw any certain conclusions from the lack of Farne Islands guillemot recoveries during this period. This highlights a factor which is of major concern: since the ringing of seabirds on the Farne Islands was stopped six years ago, soon after Grace Hickling's death, we are no longer in a position to assess with any confidence the risk of pollution incidents and food shortages of our breeding seabird populations. The ringing of seabirds at their colonies is of immense value in monitoring their populations and mortality for conservation purposes. Without such ringing of terns, for example, we would not be able to identify the risk to terns posed by indiscriminate trapping along the west coast of Africa. There is no doubt that the ringing programme on the Farne Islands in past years has had a major impact on the conservation of terns. We hope that it will be possible to reinstate the Society's ringing programme of Farne Islands seabirds as a major conservation priority.

THE FONTBURN RESERVOIR WILDLIFE ADVISORY GROUP

There were no meetings of the committee during the year.

COQUET ISLAND MANAGEMENT ADVISORY COMMITTEE

During the year the committee met on three occasions, in August, March and a site visit in July. The main concerns were the preparation of the next five year management plan for the island and assessing the successes and failures of the last five years. The reserve shows an increase in all the key species using a census done in 1984 as a base line, except for eider ducks. The latter are already part of the long term study being carried out by Dr John Coulson which has been mentioned in previous reports.

Probably the most important species on the island is the roseate tern which has shown a consistent increase from eighteen pairs in 1984 to thirty in 1993 (and again to greater numbers during the 1994 season). Coquet Island continues to be the reserve for this species in the United Kingdom and consequently the birds are being intensively studied to try to understand population changes. This is mostly being done by ringing the young birds with both British Trust for Ornithology rings and special RSPB rings that can be read using a telescope. The work is already beginning to help our understanding of their movements with the origins of adults being known and soon it should be possible to understand more of the age structure of the Coquet Island and other populations where this work is being carried out.

LINDISFARNE NATIONAL NATURE RESERVE

Lindisfarne Wildfowl Panel The main issues discussed at the Panel were the wildfowling management group report for the 1993-1994 season which is adequately discussed under the Lindisfarne Advisory Committee report. The other matter of importance was the report to the Panel of the public enquiry into bait digging in Budle Bay. Evidence was given by a wide range of interests: Dr S Percival, who is currently undertaking research into brent geese and wigeon, Mr P Davey and Mr W Symth of English Nature, the RSPB, Holy Island Parish Council, The British Association for Shooting and Conservation (BASC), Mr C Baker-Cresswell, the Northern Federation of Sea Anglers and the National Federation of Sea Anglers.

English Nature's aim at the enquiry was to gain the ability to manage bait digging on the National Nature Reserve in a positive way, in designated areas, taking into account the rights and wishes of the local community.

The conclusion of the enquiry in July 1994 was to confirm the ban on bait digging in Budle Bay. The Northern Federation of Sea Anglers has accepted the long standing invitation of English Nature to have a representative on the Lindisfarne Advisory Committee.

Lindisfarne Advisory Committee The committee met three times, in November, April and June. The main development has been the setting up of a Wildfowling Management Group (WMG) for the 1993-4 season, after consultation between English Nature and BASC. This effectively puts all administration and wardening of wildfowling on the reserve in the hands of the wildfowlers themselves, widely represented on the WMG committee. More specifically, the WMG issues and checks permits, appoints wardens, advises on management and represents the wildfowlers. The advantages of the new system have been more co-operation and support from the wildfowlers, English Nature wardens freed for other duties and lower overall cost to English Nature.

Some may feel that possibly too much control is now in the wildfowlers' hands, but the whole scheme is approved by, and accountable to, English Nature and is being carefully monitored.

Another important scheme, not yet finalised, is for the Longbridge End marsh, north of the causeway, to be divided into experimental plots to ascertain the best grazing/cutting conditions for brent geese and wigeon. This would ideally involve a temporary cessation of shooting there in the 1994-5 winter so as not to jeopardise the results of the experiment, but the idea of a voluntary ban was not favourably received by the wildfowlers at the June field meeting and requires more discussion.

The number of seasonal permits available was reduced to 400, of which 360 were issued, plus twenty-three weekly ones. A total of 1,889 duck and geese of eleven species was shot - just less than one bird per wildfowler per visit.

Other management included dune stabilisation, the control of horse-riding by permit and new NNR information notices.

DEREK R SHANNON

Chairman of Council

FINANCIAL STATEMENTS

31 JULY 1994

INCOME AND EXPENDITURE ACCOUNT

1993			
£		£	£
22,233	SALARIES, PENSION CONTRIBUTIONS AND NATIONAL INSURANCE		24,703
2,898	PRINTING AND STATIONERY		3,663
1,996	POSTAGE AND TELEPHONE		2,308
1,857	INSURANCE		1,894
889	REPAIRS AND RENEWALS	4958	
—	Less: Transfer from Provision for deferred repairs	4000	
889			958
1,400	REPAIRS TO LAKE LODGE		—
1,337	GENERAL EXPENSES		1,175
5	LICENCE FEE		5
740	AUDIT FEE		775
555	SUBSCRIPTIONS TO SOCIETIES		800
1,642	LECTURE AND FIELD MEETING EXPENSES		1,832
	TRANSACTIONS		
3,290	Expenditure	5,303	
1,027	Less: Proceeds of sale	1,048	
2,263			4,255
1,333	LIBRARY – Books	1,331	
1,245	– Rebinding and renovating	1,349	2,680
3,659	GOSFORTH PARK NATURE RESERVE	1,997	
2,300	Less: Transfer from Gosforth Park Nature Reserve Restoration Fund	—	
1,359			1,997
1,664	LEASE OF OFFICE MACHINERY		1,664
2,696	DEPRECIATION		2,436
	APPROPRIATIONS		
3,250	Gosforth Park Nature Reserve Restoration Fund		—
—	Provision for deferred repairs		1,750
387	EXCESS OF INCOME OVER EXPENDITURE FOR THE YEAR		6,768
£49,749			£59,663

SOCIETY OF NORTHUMBRIA

FOR THE YEAR ENDED 31 JULY 1994

1993			
£		£	£
	SUBSCRIPTIONS		
10,142	Annual subscriptions	13,325	
201	Add: Transfer from Life Members' Fund	221	
10,343			13,546
1,123	DONATIONS		1,398
6,750	UNIVERSITY OF NEWCASTLE UPON TYNE		7,200
23,884	INVESTMENT INCOME (GROSS)		24,565
—	SALES OF FLORA OF NORTHUMBERLAND		12,954
7,649	OVER PROVISION RELATING TO PUBLICATION OF FLORA OF NORTHUMBERLAND		—
£49,749			£59,663

1993			
£		£	£
	GENERAL FUND		
	Balance at 1 August 1993	47,515	
	Add: Excess of income over expenditure for the year (Note 4)	6,768	
47,515	Surplus on sale of investments	52,395	106,678
2,525	LIFE MEMBERS' FUND (Note 5)		2,704
	T B SHORT MEMORIAL FUND (Note 6)		
	Balance at 1 August 1993	93,588	
93,588	Less: Deficit on sale of investments	16	93,572
	GRACE HICKLING MEMORIAL FUND (Note 6)		
78,393	Balance at 1 August 1993 and 1994		78,393
	PROVISION FOR DEFERRED REPAIRS		
	Balance at 1 August 1993	5,250	
	Less: Transfer to income and expenditure account	4,000	
		1,250	
5,250	Add: Transfer from income and expenditure account	1,750	3,000
	GOSFORTH PARK NATURE RESERVE RESTORATION FUND		
5,000	Balance at 1 August 1993 and 1994		5,000
35,076	CREDITORS, ACCRUED CHARGES AND SUBSCRIPTIONS RECEIVED IN ADVANCE		8,539
£267,347			£297,886

Approved by Council on 7 October 1994

D R SHANNON – Chairman

E SLACK – Honorary Treasurer

SOCIETY OF NORTHUMBRIA

31 JULY 1994

1993 £		£	£
	FREEHOLD PROPERTY (Note 2)		
	Hancock Museum		Not valued
	Lake Lodge		
3,899	Cost	3,899	
5,300	Electrical installation	5,300	
9,199		9,199	
6,548	Less: Depreciation	6,626	
2,651			2,573
	HIDES, EQUIPMENT, OFFICE FURNITURE AND COMPUTERS (Note 3)		
16,651	Cost 1 August 1993	17,111	
460	Additions	295	
17,111		17,406	
10,466	Less: Depreciation	12,824	
6,645			4,582
	INVESTMENTS IN TRUSTEE SECURITIES, AT COST		
	Quoted		
67,567	Narrow range	138,350	
51,866	Wide range	51,866	
40,055	Special range	40,559	
	(Market value £332,405 – 1993 £258,950)		
	Unquoted		
	Charities Official Investment Fund		
20,000	9,750 shares of no par value	10,000	
	(Redemption value £60,115 – 1993 £117,894)		
179,488			240,775
	INCOME TAX RECOVERABLE, ACCRUED		
3,296	INCOME AND PAYMENTS IN ADVANCE		6,645
	CASH AT BANK		
72,069	Charities deposit fund	39,712	
2,143	Deposit account	1,337	
1,055	Current account	2,262	
75,267			43,311
£267,347			£297,886

STATEMENT OF TRUSTEES' RESPONSIBILITIES

The Trust deed, the Charities Act 1960 and the Charities (Statement of Account) Regulations 1960 require the trustees to prepare accounts for each financial year. In preparing these accounts, the trustees are encouraged to follow the recommendations outlined in Statement of Recommended Practice No. 2 - Accounting by Charities (issued by the Accounting Standards Committee in 1988).

The trustees consider that in preparing these accounts, they have used appropriate accounting policies, consistently applied and supported by reasonable and prudent judgements and estimates.

The trustees are responsible for keeping proper accounting records to enable them to ensure that the accounts comply with the Charities Act 1960. They are also responsible for safeguarding the assets of the charity and hence for taking reasonable steps for the prevention and detection of fraud and other irregularities.

ACCOUNTING POLICIES AND NOTES

1 Basis of accounting

The acounts have been prepared under the historical cost convention.

2. Freehold property including Library and Collections

(a) No value was attributed to the Hancock Museum at the date of its completion in 1884. The building is leased to the University of Newcastle upon Tyne which is normally responsible for all repairs and improvements.

(b) (i) The cost of Lake Lodge, less donations and grants received, of £3,899 is depreciated at 2% per annum.

(ii) The cost of installing mains electricity, less donations received, of £5,300 has been fully depreciated.

3. Hides, equipment, office furniture and computers.

The cost of the hides, equipment and office furniture is depreciated at 10% per annum and computers at 20% per annum.

4. Income and expenditure account

The excess of income over expenditure for the year is arrived at after appropriations to special funds for the purpose of setting aside temporary surpluses of income to meet future expenditure.

5. Life members' fund

Amounts received in payment of life subscriptions are taken to the life members' fund and are released to income and expenditure account over a period of 20 years in equal annual instalments.

6. T B Short and Grace Hickling Memorial Funds

The funds from these legacies are invested in accordance with the Trustee Investment Acts and are subject only to expenditure for special projects.

7. Capital commitments

	1994	1993
	£	£
Contracted	–	–
Authorised by Council	2,500	–

8. The Society is a registered charity, official number 526770.

AUDITORS' REPORT TO THE MEMBERS OF THE NATURAL HISTORY SOCIETY OF NORTHUMBRIA

We have audited the accounts on pages 200 to 204 which have been prepared under the accounting policies set out above.

Respective responsibilities of trustees and auditors

As described above the trustees are responsible for the preparation of accounts. It is our responsibility to form an independent opinion, based on our audit, on those accounts and to report our opinion to you.

Basis of opinion

We conducted our audit in accordance with Auditing Standards issued by the Auditing Practices Board. An audit includes examination, on a test basis, of evidence relevant to the amounts and disclosures in the accounts. It also includes an assessment of the significant estimates and judgements made by the trustees in the preparation of the accounts, and of whether the accounting policies are appropriate to the Society's circumstances, consistently applied and adequately disclosed.

We planned and performed our audit so as to obtain all the information and explanations which we considered necessary in order to provide us with sufficient evidence to give reasonable assurance that the accounts are free from material misstatement, whether caused by fraud or other irregularity or error. In forming our opinion we also evaluated the overall adequacy of the presentation of information in the accounts.

Opinion

In our opinion the accounts give a true and fair view of the state of affairs of the Society at 31 July 1994 and of its income and expenditure for the year then ended and have been properly prepared in accordance with the provisions of the Trust deed and the Charities Act 1960.

PRICE WATERHOUSE
Chartered Accountants

89 Sandyford Road
Newcastle upon Tyne
7 October 1994

Trans. nat. Hist. Soc. Northumb. **56**, 205-224 (1995)

BIRDS ON THE FARNE ISLANDS in 1994

compiled by

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INTRODUCTION

The wardens occupied both island bases, Inner Farne and Brownsman, from 30 March until 5 December. The question uppermost in everybody's minds in the early part of the season was how the guillemots and other birds had been affected by the seabird 'wreck' during February. Despite estimates of 20,000-50,000 guillemots found dead on the east coast, the breeding population on the islands showed no significant change. The shags, however, suffered a dramatic decline from 1,948 nesting pairs in 1993 to just 771 in 1994 - the lowest figure since 1982. A more positive note was struck by the eiders with 1,380 nests, after the poor showing of just 744 nests in 1993. Inner Farne again hosted three pairs of roseate terns. 'Elsie', the by now famous lesser-crested tern, returned for her eleventh summer on the islands. Paired with a Sandwich tern she laid one egg which hatched on 10 July, but the chick died within five days. There was a strong suspicion that one of her hybrid offspring, from 1989 or 1992, had returned and fledged a 'second generation' cross - further details in the report. Swallows bred in St Cuthbert's chapel for the fifth successive year and a carrion crow attempted to nest on Staple Island. Twenty-four species bred with the total population estimated at 66,557 pairs - this assumes that puffin populations were at a similar level to 1993.

Passage birds, excluding the 'exotica', were represented by 155 species - the overall total of 179 equals the record year of 1991. Two species were added to the island list: little egret and rough-legged buzzard. Third appearances were made by Alpine swift, Richard's pipit, Pallas's warbler and rustic bunting whilst short-toed lark (3) and Arctic warbler were recorded for the fourth time. Fifth records for hen harrier, quail and corncrake were logged whilst an exciting (!) house sparrow made its sixth appearance. Waxwing was recorded for just the eighth occasion with gadwall and great tit logged for the ninth time - the series of great tit records almost doubled the previous numbers. Other birds of note included Mediterranean shearwater, storm petrel, gadwall, garganey, curlew sandpiper, wryneck, shorelark, blue-headed and grey headed wagtails, bluethroat (maximum 10), barred warbler (4), yellow-browed warbler (7), firecrest, red-breasted flycatcher (2), common rosefinch, ortolan bunting (4) and little bunting.

Thanks go to the 1994 wardening team of Andy Baxter, Mat Cottam, Keith Gillon, Stef McElwee, Robert Smith, Jarrod Sneyd, Graeme Stringer, Andy Upton and Andy Wight, as well as to various boatmen, for supplying the records which make up this report.

Details of all the birds are given in the following list: this follows the order and scientific nomenclature of Professor Dr K H Voous' list of recent holarctic species (1977), except for the Manx shearwater and gannet which adopt the new changes recommended by *Ibis* **133**, p438. Where appropriate, the figures for 1993 breeding birds are included, for comparison, in brackets.

SYSTEMATIC LIST

Unidentified Diver spp. *Gavia* spp.

Ten sightings of 1-4 birds between 1 April and 19 May, with singles on four days between 10 September and 27 November.

Red-throated Diver *Gavia stellata*

Birds were seen virtually daily from 30 March until 9 May. Records relate mainly to 1-10 birds, with thirty flying north through Inner Sound and four noted on the sea on 18 April. Autumn records, again relating to 1-10 birds, regular from 10 September-25 November.

Black-throated Diver *G. arctica*

Two records of single birds from 25-27 April, and singles on four days from 11 October-10 November.

Great Northern Diver *G. immer*

There were no spring sightings. Six records between 5 October and 15 November all related to single birds, with the exception of three on 16 October.

Great Crested Grebe *Podiceps cristatus*

Single birds passed through Inner Sound on 15 April, 24 June, 2 September and 24 October.

Red-necked Grebe *P. grisegna*

Spring records from the inner group of singles on 7 and 14 April, with autumn records of singles flying north through Staple Sound on 4 and 5 October.

Slavonian Grebe *P. auritus*

One was off Gun rock (Staple Sound) on 22 October.

Fulmar *Fulmarus glacialis*

Birds were on site on 30 March when the wardens arrived. The first egg was laid on Brownsman on 13 May with first young on Brownsman on 4 July. 253 (248) pairs nested as follows: Inner Farne 41 (40), Knoxes Reef 31 (26), West Wideopen 20 (19), East Wideopen 12 (9), Skeney Scar 1 (1), Staple Island 34 (32), Brownsman 55 (63), North Wamses 24 (20), South Wamses 32 (25), Big Harcar 1 (6), Little Harcar 0 (1), Northern Hares 2 (2), Longstone End 0 (4). The first young fledged from Inner Farne and Brownsman on 26 August, and the last on 8 September. On 18 August a dead porpoise drifted through the Kettle with twelve fulmars in attendance - entrails were on the menu. Blue phase birds were recorded on 7, 8, 12 and 17 August and 14 September. After the usual desertion period in September/October numbers increased to *ca* 360 by late November.

Sooty Shearwater *Puffinus griseus*

Birds were recorded on nineteen days from 11 August-16 October. Numbers were generally 1-3, with 219 moving north on 14 September.

Manx Shearwater *P. puffinus*

One bird flew north on 15 April, there were five records of 1-10 in May, then almost daily sightings from 13 June-25 September. Records generally related to 1-56 birds with 317 moving north on 14 September. Two flying north past Crumstone on 5 October was the final record.

Mediterranean Shearwater *P. yelkouan*

During a five hour seawatch on 14 September one flew north between Brownsman and Crumstone.

Storm Petrel *Hydrobates pelagicus*

One flew north through Staple Sound on 17 September.

Gannet *Morus bassanus*

Recorded almost daily throughout much of the season, becoming scarce from early October onwards. The peak spring movement was on 13 April with *ca* 950 an hour moving north. The autumn peak was *ca* 1,700 an hour north past Crumstone on 5 October. A third or fourth year bird spent the afternoon of 15 August sitting on Inner Farne stack.

Cormorant *Phalacrocorax carbo*

Birds were present on the nesting islands on 30 March. First eggs were noted on 6 May but were probably laid prior to this date. 205 (268) pairs nested as follows: East Wideopen 105 (142), North Wamses 100 (126). The first chicks fledged on 21 June with the majority fledged by late August. Reports in mid-May suggest that lumpsuckers *Cyclopterus lumpus* were a major part of the diet amongst the outer group birds.

Shag *P. aristotelis*

Communications from the Isle of May had already alerted the wardens to the possibility that the shag population might be in trouble. Within days of arriving on the islands 225 corpses had been collected of which 90-95% were adult. The drop in breeding pairs was dramatic: 771 (1,948) pairs nested as follows: Megstone 7 (9), Inner Farne 156 (293), West Wideopen 84 (132), East Wideopen 38 (154), Skeney Scar 54 (108), Staple Island 174 (594), Brownsman 87 (284), North Wamses 12 (36), South Wamses 58 (173), Roddam and Green 14 (14), Big Harcar 55 (122), Longstone End 32 (29). This was the lowest number of nesting pairs recorded since 1982. First eggs were seen on 6 May, with the first young on 16 June and the last had fledged by early October. *Ca* 1,800 birds were present on 27 November.

Little Egret *Egretta garzetta*

One flew over the Wamses towards Longstone at 07.00 on 2 May. First record for the islands.

Grey Heron *Ardea cinerea*

1-3 were recorded regularly throughout the season with almost daily records from early September.

Mute Swan *Cygnus olor*

Six immatures flew north through Inner Sound on 6 May, with twelve south on 10 September, four south past Megstone on 23 September, ten south through Inner Sound on 9 September and six south on 1 November.

Whooper Swan *C. cygnus*

Seventeen moved north over the outer group on 5 April with fifteen north on 6 April.

Pink-footed Goose *Anser brachyrhynchus*

The best year on record for this species. Flocks of sixty-nine, seventeen and twenty-one on two dates in April, 130 and *ca* 500 on 6 May, seven, six, two, fifty-six and seventy-four on five dates in September, forty-nine in October and, finally, six and seventy-nine on two November dates.

Greylag Goose *A. anser*

A single flew north over Inner Farne on 8 April, with flocks of thirteen, nine and eleven on three further April dates. Nine through Staple Sound on 15 October were feral birds. The final record was of two birds south-west over Brownsman on 3 December.

Canada Goose *Branta canadensis*

Five flew north over the outer group on 25 May, with thirty-four north-east over Megstone on 3 June and nine observed in the same area on 10 June.

Barnacle Goose *B. leucopsis*

There was one spring record of eighteen north on 24 May, with six records of 2-7 between 3 September and 8 October. The seven birds on 4 October spent about twenty minutes on Brownsman.

Brent Goose *B. bernicla*

Eleven flew south through Staple Sound on 1 April, with four 'resident' on the outer group from 4 April-1 May. They were recorded during the autumn on seventeen dates from 15 September-15 November in flock sizes of 1-28. Four birds were 'resident' on Knoxes Reef between 26 and 29 September.

Shelduck *Tadorna tadorna*

Eight on 18 April, seven on 27 June and seven on 22 August were the only 'large' counts. Two pairs were present throughout the spring. A nest was located on Brownsman on 17 May but this contained one broken egg and another pressed into the soil and was considered to have been abandoned. 1 (0) pair nested on Staple Island and breeding was confirmed on 1 July when two adults with seven young chicks were found on the Staple Island pools. The brood had decreased to four by 23 July when they moved to the inner group, and was still four when they moved back to the outer group on 31 July. The female and four young commuted regularly between the island groups with the first young seen flying on 21 August.

Wigeon *Anas penelope*

Spring records were of 2-4 birds on five days between 8 and 22 April. One was on Knoxes Reef on 13 July with two there on 18 July. Seen regularly from late August onwards with peak movement of *ca* 400 north on 16-17 October. An injured bird discovered on Brownsman on 4 November was still present when the wardens left on 5 December.

Gadwall *A. strepera*

With just eight records up to 1992 this season set new standards with at least nine birds recorded: two north on 12 April, one north on 22 April, one on the Bridges on 13 September, one on Knoxes Reef on 26 September, two on Knoxes Reef on 6 October with singles on 12,18, and 28 October, two on 21 November and one on 27 November.

Teal *A. crecca*

Spring records involved 1-3 birds on seven days from 30 March-23 April. Noted regularly in small numbers from early August onwards with a maximum count of *ca* 200 in late November.

Mallard *A. platyrhynchos*

Birds were seen regularly throughout the season with a maximum count of *ca* 80 in early December. The birds on Knoxes Reef were joined by a white 'farmyard' type from 27 September-3 October. 1 (2) pair bred as follows: Staple Island 0 (2), Knoxes Reef 1 (0). The nest contained ten eggs all of which were presumed hatched in late June although no young were observed.

Pintail *A. acuta*

An eclipse female flew south through Staple Sound on 30 July, a female was present on Knoxes Reef from 19-26 September, then singles were seen on 10 and 31 October with three on 3 November. A male was on Knoxes Reef from 19-21 November and finally a male flew through the Kettle on 27 November.

Garganey *A. querquedula*

A female was flushed from the pools on Inner Farne on 13 May. This was the eleventh record for the islands.

Shoveler *A. clypeata*

A male and a female on Knoxes Reef on 23 April was the only spring record. A female flew through the Kettle on 3 August, then there were records of 1-6 on nineteen days from 13 September-4 December.

Pochard *Aythya ferina*

Seven were seen flying west over the Kettle on 22 September and a female was also in the Kettle on 4 November.

Tufted Duck *A. fuligula*

One was seen heading north through Inner Sound on 18 April, 1-3 on three days in May, 2-3 on three days in September, 1-2 on three days in October and finally two flew south over Knoxes Reef on 10 November.

Scaup *A. marila*

Records were all of birds flying north through Staple Sound: one on 25 September, thirteen on 16 October and one on 13 November.

Eider *Somateria mollissima*

Birds were exploring nesting areas on Inner Farne on 30 March, with the first eggs laid on 17 April. After the poor showing in 1993 a recovery to 'normal' numbers was welcome. 1,380 (744) females nested as follows: Inner Farne 919 (532), Knoxes Reef 6 (5), West Wideopen 47 (12), East Wideopen 11 (5), Staple Island 30 (29), Brownsman 323 (118), North Wamses 14 (12), South Wamses 14 (16), Big Harcar 7 (8), Northern Hares 2 (0), Longstone main rock 1 (3), Longstone End 6 (4). The first young were recorded on 16 May with the last leaving on 26 July. Autumn flocks were well dispersed with a maximum count from the islands of *ca* 1,000.

Long-tailed Duck *Clangula hyemalis*

1-8 were noted on ten days from 31 March-22 April. Autumn records involved 1-3 birds on nine days 13 from October-25 November.

Common Scoter *Melanitta nigra*

Birds were observed during every month of the season although they were scarce in May and June. Recorded on seventy-eight days from 31 March-1 December with a maximum count of *ca* 100 on 10 November.

Velvet Scoter *M. fusca*

One was present amongst an eider flock to the south of West Wideopen from 2-14 April, with another north through Staple Sound on 17 April. Autumn records of 1-9 birds on twelve days from 13 September-19 November.

Goldeneye *Bucephala clangula*

1-3 'resident' in the Kettle from 30 March-17 April. One flew south through Staple Sound on 4 July, seventy-five moved north on 16 October, then 1-15 were observed on fourteen days from 16 October-4 December.

Red-breasted Merganser *Mergus serrator*

1-2 were noted on four days between 12 and 18 April, two were in the Kettle on 3 July, one was seen on 16 September, then 1-39 on six days from 4-20 October.

Goosander *M. merganser*

One flew north through Staple Sound on 16 May. A female was off Brownsman east shore on 25 July whilst a male in eclipse plumage noted on Inner Farne on 26 July stayed around the inner group until 28 August. A juvenile first seen on 30 August was present until 30 September. A female flew south through Inner Sound on 25 November.

Hen Harrier *Circus cyaneus*

A juvenile female was present on Brownsman and Staple Island on 21-22 October - fifth record for the islands and last recorded in April 1993.

Sparrowhawk *Accipiter nisus*

A female present on Brownsman from 23-24 April was seen taking a fieldfare. An immature was on Brownsman and Inner Farne on 20 and 21 September and again on 28 September.

Rough-legged Buzzard *Buteo lagopus*

One of the Brownsman wardens, on an early morning 'round' of the island, flushed a bird from the vegetable garden on 20 October - as he had been hoping for a small passerine this came as something of a shock. First record for the islands.

Kestrel *Falco tinnunculus*

There were two records of single birds in April, two records in July, then singles on nineteen days from 1 September-4 December.

Merlin *F. columbarius*

A female was seen on both island groups on seven days between 30 March and 9 April, a female on 7 September, then 1-3 birds daily from 21 September-4 December. The bird on Brownsman on 21 September had an exotic taste in prey, pursuing both the Arctic warbler and little bunting - but failing to catch either species.

Peregrine *F. peregrinus*

Single birds were present around the inner group on five dates from 6-25 April, one was seen on 5 May, one on 31 August and then regularly from mid-September onwards. All records related to single birds with the exception of two high over Brownsman on 22 September

Quail *Coturnix coturnix*

A female was present on Inner Farne on 11 May with another, unsexed, on Brownsman from 23-27 May. Fifth and sixth records for the islands and last recorded in May 1993.

Corncrake *Crex crex*

One was on Brownsman and Staple Island on 22 May. Only the fifth record since 1970 and last recorded in September 1989.

Moorhen *Gallinula chloropus*

The log entry for the bird which spent the whole of the 27 April on Inner Farne reads: 'very tame and partial to custard creams'. The only other records involved an adult on Brownsman and a juvenile on Inner Farne on 3 November.

Oystercatcher *Haematopus ostralegus*

Ca seventy around the islands in early spring. First eggs were on Inner Farne on 8 May, with the first young on 5 June. 32 (25) pairs nested as follows: Inner Farne 6 (5), Knoxes Reef 4 (3), West Wideopen 3 (2), East Wideopen 2 (1), Staple Island 4 (4), Brownsman 7 (6), North Wamses 1 (1), South Wamses 2 (1), Big Harcar 1 (0), Northern Hares 1 (0), Longstone main rock 0 (2), Longstone End 1 (0). Maximum count was 200 on 12 August with numbers dwindling to twenty-five by the beginning of December.

Ringed Plover *Charadrius hiaticula*

First eggs were located on Staple Island on 23 April, with the first young on 25 May on Inner Farne. 12 (10) pairs nested as follows: Inner Farne 6 (4), Knoxes Reef 1 (1), West Wideopen 1 (1), East Wideopen 0 (0), Staple Island 1 (1), Brownsman 2 (2), Longstone main rock 1 (1). *Ca* sixty were around the islands in August and September but just one from October onwards.

Golden Plover *Pluvialis apricaria*

One spring record of a bird flying west over Inner Farne on 31 March. Recorded on seventeen days between 12 July and 2 December in parties of 1-30, with counts of eighty moving south on 26 September and 110 south on 19 November.

Grey Plover *P. squatarola*

1-2 on thirteen days in April, a single on Northern Hares on 6 May, singles on three dates in August and then 1-6 almost daily from 9 September onwards.

Lapwing *Vanellus vanellus*

Observed during every month of the season but just single records for May, June, and July. Largest counts were eighty-two on 3 November and *ca* ninety on 4 December.

Knot *Calidris canutus*

Regular sightings of 1-30 from 1 April-3 October with one on Inner Farne on 19 November. Largest counts were *ca* fifty on 30 April and *ca* sixty-five on 15 August.

Sanderling *C. alba*

One was present on Inner Farne beach on 8-9 August and one was on Brownsman on 23 August.

Little Stint *C. minuta*

A juvenile was on Staple Island on 26 August.

Curlew Sandpiper *C. ferruginea*

There was a surprisingly early record of a winter-plumaged bird on Big Harcar on 7 April.

Purple Sandpiper *C. maritima*

Birds were present from 30 March until 30 May with a maximum count of 307 on 1 May. Returning birds were present from 5 July with an autumn maximum of *ca* 220 in mid-August.

Dunlin *C. alpina*

Present throughout the season although there were just 1-2 during June and early July. The largest day count was thirty on Knoxes Reef on 13 July.

Ruff *Philomachus pugnax*

Singles on three days between 4 and 31 August, with one on 9 September and one, possibly two, on 11 September.

Jack Snipe *Lymnocryptes minimus*

1-2 were recorded on fifteen days from 22 September-4 December.

Snipe *Gallinago gallinago*

Spring records of 1-2 birds on eleven days from 30 March-24 April. Returning birds were noted from 10 August with almost daily records from mid-September onwards. Records generally related to 1-3 birds with six on 21 October and 3 November.

Woodcock *Scolopax rusticola*

1-10 were observed on twenty-six days from 21 September-3 December. The largest numbers ever recorded from the islands occurred on 5 November when *ca* ninety were present - fifty-three were flushed off Staple Island during one walk.

Bar-tailed Godwit *Limosa lapponica*

1-35 were recorded from the inner group on thirty-seven days from 2 April-6 November. Eight on Knoxes Reef on 26 May was the only record for that month. The largest count came from Roddam and Green, in the outer group, where fifty-two were present on 12 June. The only other outer group record was one on Longstone on 5 July.

Whimbrel *Numenius phaeopus*

Singles on two days in April, then 1-25 seen regularly during May. Return passage was noted from 11 July with parties of 1-25 until 6 September.

Curlew *N. arquata*

Seen daily throughout the season with a maximum count of 320 on Knoxes Reef on 12 July.

Redshank *Tringa totanus*

Present daily from 30 March-16 May, then daily from 3 June-4 December. Maximum *ca* eighty in late October.

Greenshank *T. nebularia*

Singles were noted on 8 May and 31 July, then 1-2 on ten days from 1 August-5 September.

Green Sandpiper *T. ochropus*

Singles were recorded from Brownsman and Staple Island on 23 and 31 August and 21 September.

Wood Sandpiper *T. glareola*

A juvenile was present on North Wamses on 4 August.

Common Sandpiper *Actitis hypoleucos*

1-3 were present on sixty days from 23 April-23 September, although none was noted during June. There were 15+ on 23 August.

Turnstone *Arenaria interpres*

Seen daily throughout the season with numbers never dropping below *ca* thirty. The maximum count was *ca* 530 in late August-early September.

Pomarine Skua *Stercorarius pomarinus*

1-23 were recorded on twenty-five days from 10 August-10 November. Counts only reached double figures twice - twenty-three on 27 September and eleven on 16 October.

Arctic Skua *S. parasiticus*

Singles were noted on 15 May and 14 June and six dates in July, then almost daily from 1 August until 30 November. The largest day count of sixty-three was on 1 September.

Long-tailed Skua *S. longicaudus*

1-3 were recorded on eighteen days from 8 August-26 October, with juveniles moving south on 12 and 13 November. Eight birds on 15 August was the largest count.

Great Skua *S. skua*

1-3 observed on twelve days from 13 April-24 July, becoming regular from 5 August-31 October with a late individual on 25 November. Numbers were generally 1-7 with a maximum of thirty on 14 September.

Little Gull *Larus minutus*

1-2 recorded on thirty days between 1 May and 3 November. A first-summer bird was 'resident' on Inner Farne from 2 June-2 July. The spread of records relates to a minimum of sixteen birds.

Black-headed Gull *L. ridibundus*

Birds were displaying when the wardens arrived on 30 March and first eggs were laid on 9 May on Inner Farne. 48 (68) pairs nested as follows: Inner Farne 27 (49), Brownsman 21 (19). Birds were scarce throughout August and September with a build-up to *ca* 200 in October.

Common Gull *L. canus*

1,200+ in mid-April decreased to none by mid-May. 1-2 birds were noted on five days in June and July, then small numbers from mid-August onwards with up to forty by early October and *ca* 200 by late November.

Lesser Black-backed Gull *L. fuscus* and **Herring Gull** *L. argentatus*

1,193 (1,181) pairs nested as follows: Megstone 4 (2), Inner Farne 6 (4), Knoxes Reef 29 (35), West Wideopen 243 (152), East Wideopen 119 (108), Skeney Scar 35 (13), Staple Island 46 (16), Brownsman 18 (39), North Wamses 251 (321), South Wamses 169 (161), Roddam and Green 15 (35), Big Harcar 202 (176), Little Harcar 13 (22), Northern Hares 33 (81), Longstone main rock 4 (6), Longstone End 6 (10). First eggs were noted on 20 April on Big Harcar. Counts on both island groups suggest that the population split is two thirds lesser black-backed gull, one third herring gull. A 'probable' yellow-legged gull was present on North Wamses on 16 and 22 April. An albino herring gull was on Knoxes Reef on 25 April. Lesser black-backed gulls had left by late October, with a single bird on West Wideopen on 2 December. Herring gulls numbered *ca* 1,200 by late November.

Glaucous Gull *L. hyperboreus*

Singles were observed on 1 and 12 April, 25 and 28 August and 18 October. An adult and a second winter bird were on Knoxes Reef on 20 November.

Great Black-backed Gull *L. marinus*

The maximum spring count was *ca* thirty. 3 (2) pairs nested as follows: West Wideopen 0 (1), East Wideopen 2 (0), South Wamses 1 (1). Autumn build-up began in mid-July with *ca* 2,040 by late November.

Kittiwake *Rissa tridactyla*

Birds were present on their breeding sites on 30 March and nest building throughout April. First eggs were noted on both Brownsman and Inner Farne on 16 May with first young on 12 June. 5,620 (5,889) pairs nested as follows: Megstone 31 (45), Inner Farne 1,561 (1,654), West Wideopen 280 (342), East Wideopen 380 (457), Skeney Scar 278 (108), Staple Island 1,515 (1,511), Brownsman 1,318 (1,506), North Wamses 77 (69), South Wamses 56 (67), Roddam and Green 35 (41), Big Harcar 89 (89). The first young fledged on 16 July with the majority having flown by late August. *Ca* 5,000 birds were roosting on the outer group on 27 September. A kittiwake with red legs, seen on Inner Farne on 24 April and 25 August, was **not** a red-legged kittiwake *R. brevirostris.*

Lesser Crested Tern *Sterna bengalensis*

Returning for her eleventh season, 'Elsie' appeared on Inner Farne on 29 April. Present intermittently from then on, with two morning excursions to Brownsman on 6 and 7 June, she was located nesting in the Inner Farne colony on 18 June, paired with a Sandwich tern. The one egg hatched on 10 July but the chick died on 15 July. She was then present almost daily until 24 August.

Amongst the hundreds of young, on 15 July, was one bird strongly reminiscent of Elsie's 1989 and 1992 hybrid offspring. A 'strange' adult Sandwich tern, with more yellow on the beak than is usual, was noted on 17 July. It was not until 25 July, however, that it became apparent that this adult was one of the parents of the 'hybrid-type' young. The bird fledged on 28 July and moved away from the islands on 7 August. The presumption is that the adult was the returning hybrid from 1989 or 1992, and the young was a second generation hybrid. The two birds in question were seen together at Musselburgh, Lothian, on 28 August.

Sandwich Tern *S. sandvicensis*

Five birds roosting on Inner Farne on 30 March increased to *ca* 4,000 by early May. First eggs were found on 26 May with first young on 23 June. 1,488 (2,349) pairs nested as follows: Inner Farne 1,232 (2,200), Brownsman 256 (149). The count was considered to be too low as additional breeding birds moved into the Farne colony from 25 June - nesting pairs were probably *ca* 2,000. The first young fledged on 15 July with the last in early September. The final record was one flying south on 6 October.

Roseate Tern *S. dougallii*

First recorded on 6 May. Three pairs nested on Inner Farne and fledged six young. A pair was present on Brownsman throughout mid-June and July but, despite making a scrape and defending a territory, never laid eggs. Three flying north past Crumstone on 14 September was the last record.

A short article in a spring issue of *BBC Wildlife* mentioned the use of tyres for nesting roseates on a reserve in Long Island Sound, North America. One of the wardens, prompted by this, placed a tyre out in the meadow and two pairs nested adjacent to it. Initially using the tyre as shelter the young of both pairs then moved into the nest boxes used in 1993.

Common Tern *S. hirundo*

First arrivals involved four birds on Inner Farne on 23 April. First eggs were seen on 29 May with first young on 18 June. 231 (291) pairs nested as follows: Inner Farne 230 (289), Brownsman 1 (2), with the first young fledging on 20 July. One off the south end of Brownsman on 6 October was the final record.

Arctic Tern *S. paradisaea*

The first record was of one over Brownsman on 22 April, with the first egg noted on 20 May and earliest young on 13 June: the first fledged on 8 July. 3,128 (3,138) pairs nested as follows: Inner Farne 1,826 (2,007), Staple Island 3 (19), Brownsman 1,299 (1,111). An unusual feature of the season was the large number of first summer birds present on Inner Farne in late May and July, reaching a peak of forty-one on 23 June. The final record was of two juveniles through Inner Sound on 28 October.

Little Tern *S. albifrons*

The best season ever. Thirty-one birds roosting on the Inner Farne beach on 4 May increased to seventy by 18 May, then declined to nil by 1 June. Two pairs were displaying and 'house-hunting' on 20 May, raising hopes of a new breeding species for the islands. There were three other records - singles in Staple Sound on 8 and 17 June, and three passing north on 24 June.

Guillemot *Uria aalge*

Birds were present in their thousands when the wardens arrived on 30 March. First eggs were located on 21 April with first young on 27 May. 17,316 (16,873) pairs nested as follows: Megstone 86 (140), Inner Farne 1,768 (968), West Wideopen 812 (529), East Wideopen 1,650 (906), Skeney Scar 726 (710), Staple Island 8,491 (8,530), Brownsman 3,201 (3,990), North Wamses 467 (955), South Wamses 115 (145). The first young were watched leaving the cliffs on 17 June with the last on 21 August. Small numbers were seen during September and October with a return to the Pinnacles from 3 November.

Razorbill *Alca torda*

Birds were present on 30 March, and first eggs found on 13 May with first young on 14 June. 141 (132) pairs nested as follows: Inner Farne 67 (49), West Wideopen 24 (25), East Wideopen 14 (20), Skeney Scar 4 (3), Staple Island 19 (18), Brownsman 1 (3), North Wamses 6 (5), South

Wamses 2 (3), Big Harcar 4 (6). The first young left its ledge on 3 July, with the last on 23 July. Small numbers were seen daily thereafter.

Black Guillemot *Cepphus grylle*

1-2 summer-plumaged birds seen on eight days between 31 March and 18 April, with single birds on 11, 13 and 14 August. Autumn records were of 1-2 on seventeen days from 4 October-23 November, with three in Inner Sound on 4 December.

Little Auk *Alle alle*

One flew through Staple Sound on 18 October.

Puffin *Fratercula arctica*

'Thousands' were ashore on islands of both the inner and outer groups on 30 March but still unsettled - landing regularly from 11 April. First eggs were noted around 30 April, with evidence of first young on 4 June. The vast majority of birds had left the islands by 21 August although one was still bringing fish into its burrow on Staple Island on 19 September. Individuals were seen 'at sea' almost daily until 12 October. No population count was carried out this year - the 1993 estimate was 34,710 pairs.

Woodpigeon *Columba palumbus*

1-3 birds seen on eight days from 30 March-1 June, with one on Staple Island on 4 November.

Collared Dove *Streptopelia decaocto*

Singles were noted on six days from 24 April-13 June with two over Brownsman on 30 April. Then singles were observed on Staple Island on 20 and 23 September.

Turtle Dove *S. turtur*

One on Longstone on 11 May was the only spring record, with an autumn bird on Brownsman on 20 September.

Cuckoo *Cuculus canorus*

One was present on Brownsman and Staple Island from 3-4 May. More surprising was a bird flushed on Inner Farne on, for the islands, the unusual date of 29 June.

Long-eared Owl *Asio otus*

1-2 birds seen on seven days between 17 October and 6 November.

Short-eared Owl *A. flammeus*

One flushed by Inner Farne jetty on 27 July was mobbed off the island by gulls and terns. Then singles were observed on 16 and 17 October and 18 November.

Swift *Apus apus*

1-5 birds were observed on twenty-one days from 7 May-10 September. The only large group was *ca* forty on 13 June.

Alpine Swift *A. melba*

One flew west over Inner Farne towards the mainland on 26 April. This is the third record for the islands and only previously recorded in 1882 and September 1972.

Wryneck *Jynx torquilla*

One was on Brownsman on 20 September.

Great Spotted Woodpecker *Dendrocops major*

One male on Brownsman on 13 September, with a different male on Staple Island from 14-16 September. The bird on Brownsman lived up to its name by attempting to demolish the wooden transect posts - provided with a 'washed-up' railway sleeper it did less damage!

Short-toed Lark *Calandrella brachydactyla*

The best year on record with three recorded: one on Brownsman from 18-26 May, one also on Brownsman on 3 November, and a different bird on Staple Island on 4 November. Fourth-sixth records for the islands and last recorded in November 1987.

Skylark *Alauda arvensis*

1-6 were seen regularly throughout April and May, singles on 30 July, 1 and 4 August, then 1-39 almost daily from 21 September-4 December.

Shore Lark *Eremophila alpestris*

A male was present on Brownsman on 6 November, with a 'fly-over' east over the Wamses on 25 November.

Sand Martin *Riparia riparia*

1-2 on nine days from 23 April-14 May, then singles on 23 and 31 August, with a last record on 2 September.

Swallow *Hirundo rustica*

For the fifth year in succession a pair nested in St Cuthbert's chapel fledging two broods. 1-14 were seen regularly between 22 April and 30 September although they were scarce during June and July. The largest count was twenty-two over Inner Farne on 24 August.

House Martin *Delichon urbica*

Singles observed on six days from 30 April-12 June, with three over Inner Farne on 9 May.

Richard's Pipit *Anthus novaeseelandiae*

A first winter bird was on Brownsman on 12 November. This is the third record for the islands and was last recorded in 1993.

Tree Pipit *A. trivialis*

Three were on Inner Farne meadow on 24 April, then singles were observed on four days in May, 23 August and five days in September - the last record was on 15 September.

Meadow Pipit *A. pratensis*

1-35 seen almost daily from 30 March-late May, one on 30 July, then 1-20 from 20 August-13 November.

Rock Pipit *A. spinoletta*

Present throughout the season. 16 (13) pairs nested as follows: Inner Farne 6 (5), West Wideopen 1 (1), Staple Island 2 (2), Brownsman 6 (5), Longstone 1 (0). A 'possible' Scandinavian race bird was present on Brownsman on 21 September.

Yellow Wagtail *Motacilla flava*

Singles seen on eight days from 24 April-29 May with four on Inner Farne on 29 April. A blue headed wagtail *M. f. flava* was present on Brownsman from 12-14 May with a grey-headed wagtail *M. f. thunbergi* from 22-25 May. A juvenile flew past Inner Farne on 29 August, with singles on 13 September and 15-16 September.

Grey Wagtail *M. cinerea*

Singles on five days from 22 September-3 November.

Pied Wagtail *M. alba*

Recorded from 30 March-23 October. 4 (5) pairs nested as follows: Inner Farne 2 (2), Staple Island 1 (1), Brownsman 1 (1), Longstone main rock 0 (1). The pair on Staple Island were a pied wagtail *M. a. yarrellii* and a white wagtail *M. a. alba*. Single white wagtails were recorded almost daily throughout May with two on 14 May.

Waxwing *Bombycilla garrulus*

One on Inner Farne on 12-13 November was heard calling on the latter date. Eighth record for the islands and last recorded in October 1990.

Wren *Troglodytes troglodytes*

1-6 were seen daily from 30 March-29 April, one was observed on Brownsman on 6 and 7 May, then 1-10 noted almost daily from 12 September until the end of the season.

Dunnock *Prunella modularis*

1-2 seen daily until 29 April, one on 24 September, then 1-10 daily from 1 October-4 December.

Robin *Erithacus rubecula*

1-2 were noted almost daily from 30 March-26 May, then 1-4 almost daily from 22 August until the end of the season. The maximum count was *ca* fifteen on 4 November. On that date a robin was discovered in a building on Inner Farne and released: it had been ringed at Sumburgh in Shetland on 24 October:

Bluethroat *Luscinia svecica*

Present on Brownsman and Inner Farne daily from 11-25 May with a maximum count of ten on 23 May. A bird on 14 May was singing in the Brownsman garden.

Black Redstart *Phoenicurus ochruros*

One on Inner Farne on 30 March was followed by singles on three days in April and two days in May. Then 1-4 seen regularly from 20 October-18 November with eight on 3 November.

Redstart *P. phoenicurus*

1-4 noted on eighteen days from 23 April-26 May. A female was on Inner Farne on 13 July and a male on Brownsman on 20 August, then 1-26 on ten days from 12 September-3 November. The day count of twenty-six occurred on 21 September with eighteen on the outer group and eight on the inner group.

Whinchat *Saxicola rubetra*

1-2 observed regularly from 23 April-22 May, then 1-7 almost daily from 23 August-24 September.

Wheatear *Oenanthe oenanthe*

1-40 seen daily from 30 March-30 May, two in June and three in July including a juvenile on West Wideopen on 14 July. Observed almost daily from 10 August-3 November with a peak count of forty-four on 29 August.

Ring Ouzel *Turdus torquatus*

Spring records of a female on 29 April and a male on 3 May. Autumn records of 1-2 birds on twelve days from 1 October-10 November probably related to just eight individuals.

Blackbird *T. merula*

1-6 seen almost daily from 30 March-7 May, with singles on Inner Farne on 13 June, and on Brownsman on 23 August and 21 September. 1-50 observed daily from 3 October, the largest movements being *ca* 200 on 10 October and similar numbers on 3 November.

Fieldfare *T. pilaris*

1-30+ on eleven days from 30 March-3 May. Three were on Brownsman on 23 August, one on 8 September, then 1-50 from 20 September-4 December. *Ca* 250 passed over on 10 October, with *ca* 230 moving through on 3 November.

Song Thrush *T. philomelos*

1-5 seen regularly throughout April and early May, then recorded almost daily from 15 September-4 December. Numbers were generally 1-50 with a passage of *ca* 1,300 on 10 October.

Redwing *T. iliacus*

1-15 observed on nine days from 30 March-25 April, then daily from 20 September onwards. Passage of *ca* 1,000 on 10 October was the largest day count.

Mistle Thrush *T. viscivorus*

One was on Inner Farne on 20 April, with a different bird on Brownsman and Staple Island from 20-23 April. Singles were seen on 5 and 31 October, 5-7 November, 12-13 November and 20 November.

Grasshopper Warbler *Locustella naevia*

Spring records of single birds on six days from 24 April-22 May. Two were on Brownsman on 20 September with one on 21 September.

Sedge Warbler *Acrocephalus schoenobaenus*

Singles were seen on Inner Farne on 29 April and 11-12 May, with 1-2 on Brownsman from 12-14 May. Returning birds, all on Brownsman, on 5, 21 and 25 August.

Reed Warbler *A. scirpaceus*

There were spring records of 1-3 from 22-24 May. 'Unstreaked *Acrocephalus*' were present on just three days from 20-22 September with a maximum of eight on the first date.

Barred Warbler *Sylvia nisoria*

The best year on record with four different birds, all in first-winter plumage: Brownsman from 10-13 August and 1-2 September, Inner Farne 9 September and Staple Island 15 September.

Lesser Whitethroat *S. curruca*

1-3 birds on ten days between 23 April and 21 May, with 1-2 on twelve days from 1 September-18 October.

Whitethroat *S. communis*

1-3 recorded regularly from 23 April-24 May, with 1-3 almost daily from 21 August-12 September. One was present on Inner Farne from 31 August-12 September.

Garden Warbler *S. borin*

1-3 noted on thirteen days from 4 May-24 May. Autumn records were of 1-8 on fourteen days from 14 August-22 September.

Blackcap *S. atricapilla*

One early bird, a male, was on Brownsman on 31 March, then 1-3 were recorded on ten days from 21 April-12 May. Returning birds, numbering 1-4, were seen on twenty days from 12 September-10 November.

Arctic Warbler *Phylloscopus borealis*

One, in first winter plumage, was on Staple Island and Brownsman on 21 September. Fourth record for the islands and last recorded in September 1992.

Pallas's Warbler *P. proregulus*

A 'rather tatty', though nonetheless welcome, bird was on Inner Farne on 3-4 November. Third record for the islands and last recorded in October 1982.

Yellow-browed Warbler *P. inornatus*

The best year on record with seven birds observed. Two were on Inner Farne, with one on Brownsman and Staple Island, on 21-22 October, two on Inner Farne on 25-26 October and two on Brownsman on 3 November.

Wood Warbler *P. sibilatrix*

One was on Inner Farne on 13 May.

Chiffchaff *P. collybita*

1-5 seen almost daily from 7 April-24 May. 1-2 were recorded on three days in mid-September, then 1-6 daily from 11 October-21 November.

Willow Warbler *P. trochilus*

1-21 present daily from 20 April-29 May. Returning birds were first recorded on 3 August with 1-17 seen almost daily until 7 November.

Goldcrest *Regulus regulus*

1-12 seen on eleven days from 11 April-29 April. Then recorded on thirty-six days from 3 September-9 November in numbers generally from 1-10 but with *ca* fifty on 21 October and *ca* forty on 3 November.

Firecrest *R. ignicapillus*

One male was present on Inner Farne on 6 and 7 November.

Spotted Flycatcher *Muscicapa striata*

1-3 recorded on nine days from 11-25 May. All autumn records related to Brownsman, with one on 11 and two on 21 September and one from 24-25 October.

Red-breasted Flycatcher *Ficedula parva*

First winter birds were on Inner Farne on 21 October and Brownsman on 7 November.

Pied Flycatcher *F. hypoleuca*

A young male, present on Staple Island on 12 May, was the only spring record. Autumn records were of 1-4 on twelve days from 4 August-1 October.

Great Tit *Parus major*

Between 1959-1993 this species had only been recorded on eight occasions. This year, with at least five birds involved, proved amazing. A male arrived on Brownsman on 19 October, with a male there on 20 October possibly a different individual. A male and a female present on 21 October were joined by another two birds on 22 October - one of these, a juvenile female, died overnight. One female remained on the island on 23 October. Not all the excitement was limited to the outer group: a female which arrived on Inner Farne on 20 October was still present when the wardens left on 5 December. The bird steadfastly refused to touch the peanuts provided, preferring the plentiful supply of moth caterpillars.

Jackdaw *Corvus monedula*

1-6 seen on ten days from 11 April-16 May, with 1-2 on four days between 2 and 27 October.

Rook *C. frugilegus*

1-8 were observed on fifteen days from 1 April-8 May. On 22 September there were twenty-two with 1-2 on 24 and 27-28 September. Two flying south through Inner Sound on 7 November was the final record.

Carrion Crow *C. corone*

Birds were seen regularly throughout April-June and September-December with the largest count of seven on 5 October. One, possibly two, hooded crows were present from 18-30 October. A nest was built on the remains of the light-tower on Staple Island - the last nesting attempt was in 1993.

Starling *Sturnus vulgaris*

A pair nested in the 14th century window in St Cuthbert's chapel, fledging four young on 12 June. Small numbers were seen almost daily throughout the season with the largest count of *ca* 180 on 3 November. One, flying through Staple Sound with a group of guillemots, was noted in the log as 'doing a little auk impression!'

House Sparrow *Passer domesticus*

Three records in one season is unprecedented: one male around Brownsman cottage on 8 April, another male calling on Inner Farne pele tower on 25 April, and a female on Inner Farne on 11 October. Sixth-ninth records for the islands and last recorded in April 1991.

Tree Sparrow *P. montanus*

One was on Brownsman from 3-7 May with two on the same island from 23-24 May.

Chaffinch *Fringilla coelebs*

Singles recorded on nine days from 30 March-29 April, with two on Brownsman on 24 April. Three were seen on 21-22 September, then 1-6 almost daily from 6 October-23 November.

Brambling *F. montifringilla*

There were spring records of 1-3 birds on 22-24 April. An adult female was noted on Brownsman on 21 September with another flying south over Inner Farne, followed by almost daily sightings from 1 October-13 November. Numbers were generally 1-25, the only large flocks being on 10 October with *ca* sixty-five on the islands and small parties moving overhead.

Greenfinch *Carduelis chloris*

Single birds were observed on four days from 3-19 April with 1-10 on seventeen days from 11 October-10 November. One bird present from 24-28 October took advantage of the nuts which had been provided for the great tits.

Goldfinch *C. carduelis*

1-7 were present daily from 30 March-13 May. The only autumn record was a bird on Inner Farne on 14 October.

Siskin *C. spinus*

1-3 seen on eight days from 11 April-14 May. A juvenile was on Brownsman on 3-4 August with another on Inner Farne from 31 August-3 September. Recorded daily from 20-25 September with a maximum of 25, then 1-2 noted from 21-24 October.

Linnet *C. cannabina*

1-17 seen daily from 30 March-16 May. One was on Brownsman on 7 July, with two on Inner Farne from 19-24 August, one on 9 September and then 1-50 daily from 21 September-5 December.

Twite *C. flavirostris*

One bird on Inner Farne on 7 November.

Redpoll *C. flammea*

One moving south over Inner Farne on 20 April, and a female with linnets on the same island on 23 April were the only spring records. 1-3 seen on fifteen days from 5 October-21 November. A mealy redpoll *C. f. flammea* was present on Inner Farne on 16-17 October.

Scarlet Rosefinch *Carpodacus erythrinus*

One 'female type' was on Brownsman on 22-23 May.

Bullfinch *Pyrrhula pyrrhula*

A male was seen on Inner Farne from 3-6 November and a female on Brownsman from 9-10 November. Both birds were considered to be of the northern race *P. p. pyrrhula*.

Lapland Bunting *Calcarius lapponicus*

A male was on Brownsman on 12 November.

Snow Bunting *Plectrophenax nivalis*

A female/first winter bird was on Staple Island on 24 September, then 1-2 were seen on seventeen days between 8 October and 3 December.

Yellowhammer *Emberiza citrinella*

A female, or immature, was present on Inner Farne on 20 October, with single males on Brownsman and Inner Farne on 21 October.

Ortolan Bunting *E. hortulana*

A record year for this species with four individuals involved: a female on Inner Farne for five minutes on 22 May, then first winter birds on Brownsman on 23-24 August, 8 September and 15 September.

Rustic Bunting *E. rustica*

A summer plumaged female was present on Brownsman from 21-23 May. Third record for the islands and last recorded in May 1993.

Little Bunting *E. pusilla*

One was on Brownsman on 13 September, with a first winter plumaged bird on 21 September.

Reed Bunting *E. schoeniclus*

Singles were recorded from 20-23 April, 24-25 May and 3 August. Then 1-4 were seen regularly from 10 October-13 November.

Feral Pigeon

Ca eighty birds were present on 30 March with numbers rising to *ca* 230 by mid-September. At least forty pairs nested on both island groups.

EXOTICA

Flamingo spp *Phoenicopterus* spp.

One flew north through through the Kettle at 19.55 on 7 April. No specific identification was made but it was possibly the Chilean bird that frequented the Northumberland coast.

Cockatiel *Nymphicus hollandicus*

One was on Brownsman and North Wamses on 25 April.

BIRD RINGING

by

R. Wolland[2]

During the year 410 birds were recovered compared with 424 in 1993. They included 179 retrapped, controlled or identified by colour rings as well as 102 originally ringed or colour marked away from the Farnes but found on the islands. Recovery places were as far apart as Orkney in the north and down through Europe to Africa. Fourteen birds (a guillemot, a cormorant and twelve shags) were described as being in an emaciated condition when found in February and early March. This was probably a result of the seabird wreck which occurred in the early part of the year.

Two cormorants were recovered, one at Dalgety Head, Fife Region and one near Coldstream: their ages were twelve and nine years respectively. Large numbers of shags were seen and fifty-eight Farne ringed birds were found dead between February and April, compared with six during the same period in 1993. Recovery areas ranged from Orkney and down the east coast of Scotland and England to the Pas-de-Calais in France. The oldest Farne ringed shag was thirty years old and was reported found in 'unknown circumstances' on the islands. The twenty-eight aliens, varying in age from three to fourteen years, were ringed at Craigleith and the Isle of May. A lesser black-backed gull marked in August 1962 was found dead at Powburn, while four herring gulls have not been identified. Kittiwakes were found on the islands, Beadnell, the Netherlands and France and among many that were sighted one has been identified as having been ringed on the Isle of May. The oldest bird was sixteen years.

Sandwich terns were recovered on the Farnes, Bamburgh, Warkworth and the Isle of Man, and there were three field records from Arnhem in the Netherlands. Other localities where birds were found included France, Spain, Morocco, Senegal and Ghana. Colour ringed birds marked between 1980 and 1984 were seen during June, July and August and the oldest was twenty-three years. Two common terns were reported: one ringed in 1973 was found 'sick and released' and a 1984 marked bird was seen in March at Seaforth on Merseyside. No roseate terns were recovered but Arctic terns were seen on the islands, at Low Newton-by-the-Sea and at Rockabill near Dublin, Eire. Five were found dead, four on the Farnes and one at Long Nanny nature reserve at Beadnell. The oldest bird was fifteen years.

There were sight records of twenty-five guillemots, many having been ringed and colour marked between 1988 and 1993 on the Isle of May. A bird seen on Staple Island in June was ringed at Fraserburgh and had been sighted on two previous occasions, in 1991 and 1993. A Farne bird ringed in 1966 was found in February in a 'starved and poor condition' at Torness in the Lothian Region. The fifteen puffins recovered included seven found dead. Recovery areas were the Farnes, Blyth, Newbiggin-by-the-Sea and Hartlepool in Cleveland. The oldest bird was fourteen years.

Three razorbills were sighted between May and July. A colour marked purple sandpiper was on Brownsman, while one ringed in 1993 at Hartlepool was seen in July.

TRANSACTIONS

OF THE

NATURAL HISTORY SOCIETY

OF

NORTHUMBRIA

ROBSON'S
GEOLOGY OF NORTH EAST ENGLAND

(Formerly 'The Geology of North East England')

Second Edition

Editor: G. A. L. Johnson

Volume 56
Part 5

The Natural History Society of Northumbria
The Hancock Museum
Newcastle upon Tyne NE2 4PT
1995

First published	*1980*
Second printing with revisions	*1982*
Second Edition	*1995*

Front cover: The Cheviot hills from south of Wandystead Farm by David Noble-Rollin

ISSN 0144-221X

Printed in Great Britain by Hindson Print, Newcastle upon Tyne.

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PREFACE
(First Edition)

In 1931, a series of contributions to the geology of Northumberland and Durham was written for the Summer Field Meeting of the Geologists' Association and was published as part of the *Proceedings* of the Association for that year.

This present volume has been compiled to supplement the contributions of 1931, by including accounts of the advances made in the geological knowledge of the region over the past forty-five years.

In view of the recent changes in the county boundaries, the region can perhaps better be described as North East England. It includes the administrative areas of Northumberland, Tyne and Wear, County Durham and Cleveland. Boundaries of geological systems seldom coincide with those of administrative regions and therefore, in order to present a more complete picture, contributors have sometimes included areas not strictly within the North East. The map (text-fig. 1) also embraces areas which lie beyond what may generally be described as north-east England, namely the Border country of Scotland, the Bewcastle Fells and the eastern margin of the Eden valley.

Since 1931, many geologists have added their contributions to the published literature of the region, to which the accompanying list of references bears witness. Not only has new information been documented but new concepts have been developed. Thus, while the basic geology remains unchanged, readers familiar with the 1931 publication will find revised concepts regarding, for example, stratigraphical correlation, structural patterns and the interpretation of glacial features.

Furthermore, technical improvements in the construction of geophysical instruments, and refinements in the interpretation of the data obtained by them, have led to the discovery of the deeply-buried Weardale granite. Advances in engineering have enabled that granite to be reached by the drill, to be cored and analysed. The developments within the field of geochemistry now make possible the reconstruction of the pattern of past events, including age-dating of igneous bodies; this is a technique which was only just being developed by investigators of forty years ago.

Offshore drilling, by the National Coal Board, has yielded much new information about the extent of the coalfields of Northumberland and Durham beyond the coastline. Seismic work by many oil companies, across the whole of the North Sea, has provided a vast amount of new structural and stratigraphical information, including the discovery of a central rift valley. The development of the new concept of plate tectonics has led to the re-assessment of the origins of fault patterns, not only in North East England, but throughout the world. Finally, refinements in colour-printing have simplified the reproduction of a coloured geological map of the region (text-fig. 1).

Some of the results of these advances are described in the chapters of this book, which has been compiled by a team of writers all closely associated in various ways with current geological research in North East England. The editor is very grateful to them for their co-operation and forbearance during the inevitable delays that afflict a compilation of this diversity. He is also indebted to Dr. G. A. L. Johnson for his assistance over the problems of editorship. The contributors record their thanks to Mr. J. W. Pallister and Dr. J. E. Robinson for constructive suggestions. In addition, Dr. D. B. Smith acknowledges the permission, received from the Director, the Institute of Geological Sciences, to publish the section on the Permian and Triassic; Dr. A. G. Lunn expresses his indebtedness to Dr. J. S. Cuming, Dr. D. W. Rhind and Mr. N. W. Riley for kindly allowing him to quote from their unpublished work in his contribution on the Quaternary. Also, Dr. B. A. O. Randall is much indebted to Dr. D. Magraw, a fellow contributor, for information from the archives of the National Coal Board, about the Great Whin Sill and the Tertiary dykes, which he has included in the section on the igneous rocks.

Thanks are also due to Mrs. Christine Cochrane, of the Geology Department in the University of Newcastle upon Tyne, for the draughting of all the figures, including the base for the colour map (text-fig. 1). For the production of the colour map itself, the contributors owe their thanks to members of the Geography Department in the University - to the late Mr. W. W. Anson and to Mr. John Knipe for advice at every stage, to Mr. Kenneth Crossley for the work of compilation upon which the map is based, to Mrs. Doreen Shanks for the photographic work and to Mr. Brian Allaker for the painstaking task of colour-printing. Mr. Peter Robson is thanked for the colour photograph. The contributors are most grateful to Mrs. Grace Hickling for her invaluable assistance in proof reading.

Acknowledgement is made to the Department of Geology in the University of Newcastle upon Tyne for the use of its facilities and, finally, the following oil companies are thanked for their financial help towards the costs of publication of this volume.

The British Petroleum Company Limited
Cluff Oil Limited
H. V. Dunnington and Associates
Esso Europe Inc.
Hamilton Brothers Oil and Gas Limited
The National Coal Board
Phillips Petroleum Company
Shell U. K. Exploration and Production Limited
Total Oil Marine Limited

PREFACE
(Second Edition)

When the last copies of the second printing of *The Geology of North East England* were sold during the summer of 1992, there was still a steady demand for the book and many enquiries for it after it was out of print. The publications committee of The Natural History Society of Northumbria recommended that the book should be thoroughly revised and published by the Society in a second edition. This was agreed by the Council who further recommended that the new second edition should be given a distinctive new title 'Robson's Geology of North East England'. This incorporates the name of the compiler and editor of the first edition, the late Dr Douglas Arthur Robson (1914-1992). Douglas devised and produced the first edition and persuaded experts in the geology of north-east England to write for him. Much of the text and many of the illustrations, including the coloured map, were prepared by him. It is most appropriate that his enthusiasm and industry should be remembered in the title of the new edition.

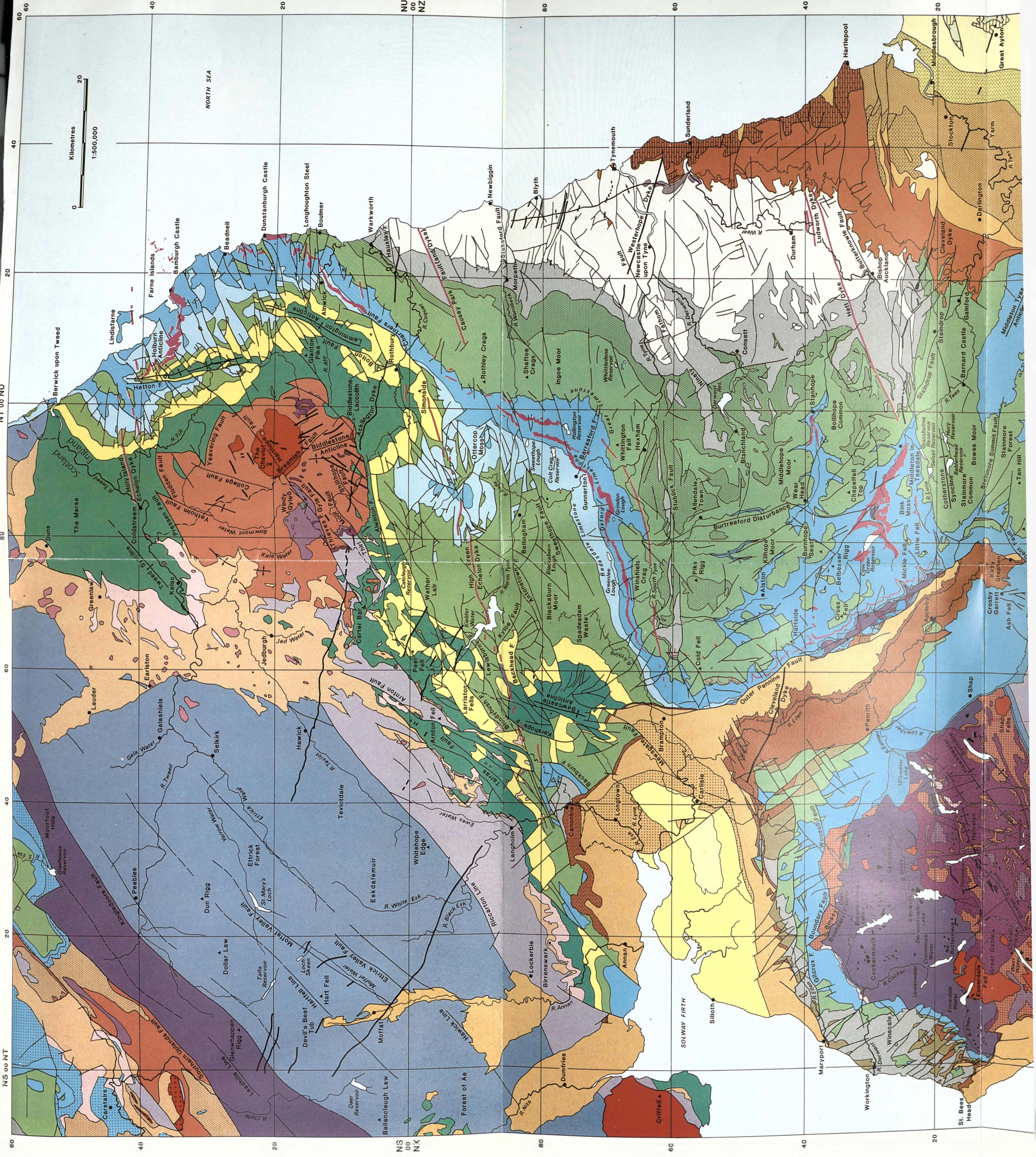
The opportunity has been taken in the preparation of the second edition to bring the text and illustrations up to date. Geology has advanced greatly in the fifteen years since the first edition was published and the current stratigraphical, structural and global tectonics interpretations are covered in the new book. A complex vocabulary of technical terms has been coined to describe recent geological advances in many fields. Technical terms used in the book will be found in up to date geological dictionaries which are readily available in bookshops.

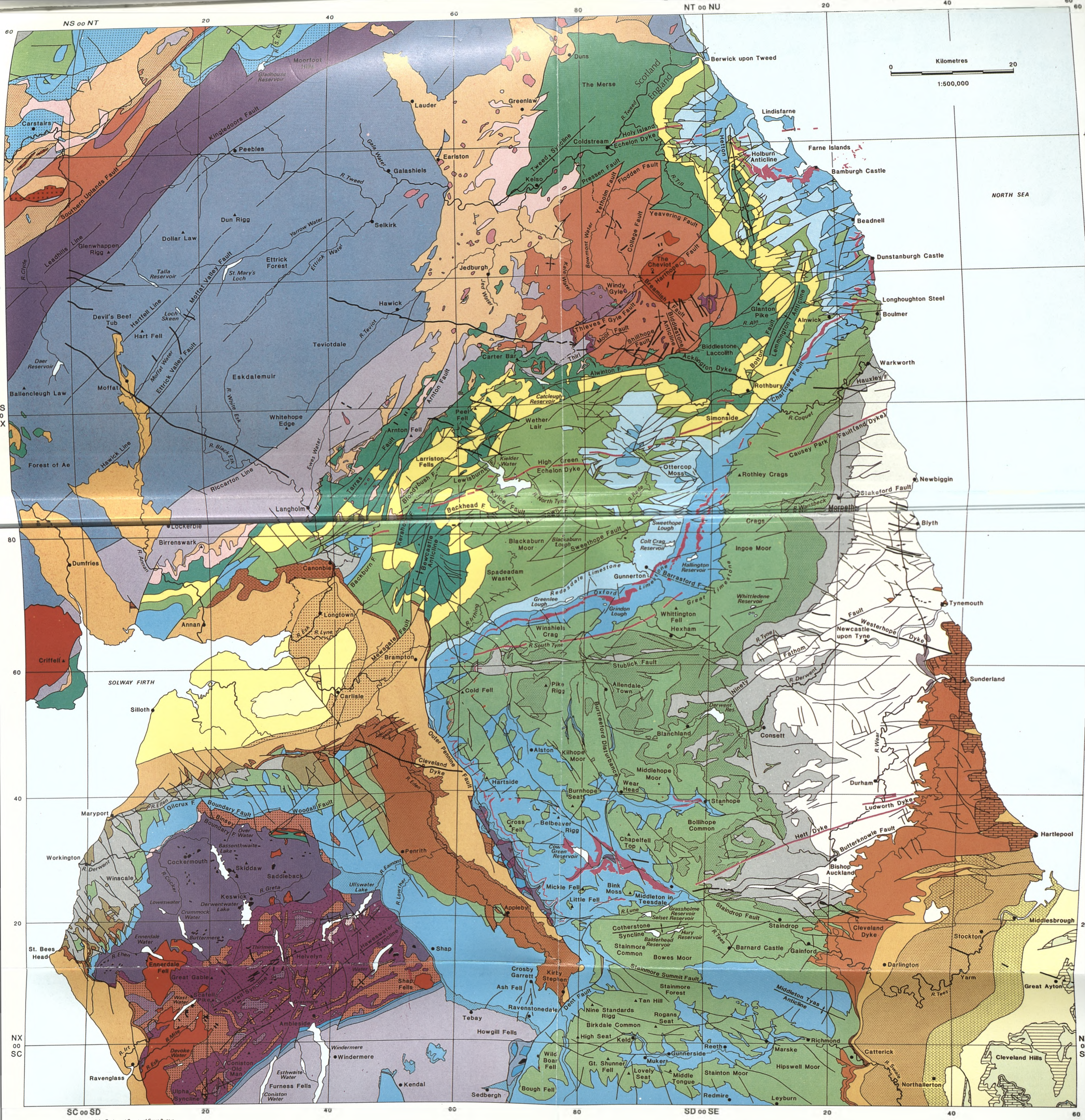
During the preparation of the new edition, all but one of the coal mines of the Northumberland and Durham coalfield have closed. After five hundred years of coal mining, reserves of good coal have contracted and production of saleable coal has declined for the last eighty years. All extractive industries have a finite life and the Great Northern Coalfield is no exception to this. Reference is made to closure of collieries in chapter 5 and a new problem, pollution by acid mine water discharge from abandoned mine workings when pumping ceases, is described in chapter 11. In this way we bid farewell to deep mining in the Great Northern Coalfield, cradle of the Industrial Revolution in Britain.

Publication of the new edition in the summer of 1995 was arranged to make it available for the British Association meeting in Newcastle upon Tyne in September. The Geologists' Association, also involved in this meeting, has given the Society much encouragement for the completion of the book and generous financial assistance towards publishing costs. This welcome co-operation is of much benefit to both societies and we look forward to working together in the future.

The new edition has been guided through the editorial stages and produced by computer-based technology by Mr David Noble-Rollin. Mrs Margaret Patterson has readily produced an accurate computer copy of the original edition and proof read the final text. The success of the project much depended on their skill and industry. I am also most grateful to Mrs Patricia Hammock who prepared the new tables and figures. Mrs Joan Holding who has redrawn and updated many of the figures and Professor R. B. Clark, the Society's editor, for his kindly supervision of the work and his invaluable proof reading. Finally, I acknowledge with thanks the assistance of the contributors who have willingly revised chapters and produced new text to a firm schedule. To all of these and others who have assisted in the compilation and production of the new edition, I tender most grateful thanks.

G. A. L. Johnson
July 1995





First published by the University of Newcastle upon Tyne 1977 Extended and reprinted 1982

STRATIGRAPHICAL SUCCESSION

Cartography Christine Cochrane

JURASSIC

WEST OF PENNINES
- Lower Lias

EAST OF PENNINES
- Corallian
- Kellaways Rock–Oxford Clay
- Ravenscar Formation
- Middle and Upper Lias
- Lower Lias

PERMIAN and TRIASSIC

TRIASSIC
- Stanwix Shale
- Kirklinton Sandstone
- St. Bees Sandstone
- Keuper Marl (Mercia Mudstones)
- Bunter Sandstone (Sherwood Sandstone)

PERMIAN
- Eden Shales
- Penrith Sandstone
- Upper Marls
- Seaham Beds etc.
- Hartlepool Dolomite etc.
- Middle Magnesian Limestone
- Lower Magnesian Limestone

CARBONIFEROUS

WEST OF PENNINES
- UPPER – Westphalian: Whitehaven Sandstone; Coal Measures (undifferentiated)
- Namurian: Upper Limestone Group
- LOWER – Dinantian: Lower and Middle Limestone Groups; Basement Beds; Upper Border Group; Middle Border Group; Lower Border Group

PENNINES
- Longhoughton Grits Upper Limestone Group
- Lower and Middle Limestone Groups
- Basement Beds

SCOTLAND (Midland Valley)
- Lower Limestone Group and Oil Shales
- Calciferous Sandstone Group

EAST OF PENNINES
- Upper Coal Measures
- Middle Coal Measures
- Lower Coal Measures
- Longhoughton Grits Upper Limestone Group
- Middle Limestone Group
- Lower Limestone Group
- Scremerston Coal Group
- Fell Sandstone Group
- Cementstone Group
- Conglomerates

OLD RED SANDSTONE (Devonian)
- Upper
- Lower

SILURIAN

SOUTHERN UPLANDS
- Wenlock–Ludlow
- Llandovery

LAKE DISTRICT
- Ludlow
- Wenlock–Llandovery

ORDOVICIAN
- Llandeilo–Caradoc
- Coniston Limestone–Ashgill
- Arenig–Llanvirn (Skiddaw Slates)

IGNEOUS ROCKS

Extrusions
- LOWER CARB.: Basalt
- LOWER O.R.S.: Andesite; Rhyolite; Pyroclast
- ORDOVICIAN (Borrowdale Volcanic Series): Pyroclast; Rhyolite; Andesite; Basalt

Minor Intrusions
- TERTIARY: Dykes
- PERMO-CARB.: Whin Sill and Dykes
- LOWER CARB.: Volcanic Vents etc.
- LOWER O.R.S.: Dykes; Felsite
- PRE-O.R.S.: Lake District

Major Intrusions
- LOWER O.R.S.: Granite/granophyre
- PRE-O.R.S.: Gabbro

- Anticline
- Syncline
- Fault
- Geological Boundary

GEOLOGICAL MAP of NORTH EAST ENGLAND

with the Scottish Borders and the Lake District

Based on a compilation carried out by K.R.Crossley in The University of Newcastle upon Tyne with later additions by G.A.L.Johnson and D.A.Robson

CHAPTER 1

INTRODUCTION

Geology and topography

North-east England lies on the margin of the North Sea Basin, a region of broad downwarping that has been active intermittently since the Devonian. The detailed knowledge of the basin dates from only the last three decades when exploration for natural gas and oil, backed up by new and elaborate offshore technology, allowed geologists first to complete a geophysical survey and later drill the basin and prove the stratigraphical succession. The lower part of this sequence outcrops in north-east England, namely the Devonian, Carboniferous, Permo-Trias and Jurassic systems. With the established economic potential of the North Sea Basin, these systems at outcrop have assumed a new importance. It is here, in north-east England, that some of the source rocks, reservoir rocks and trap rocks for hydrocarbon reserves can be studied in natural exposures. To this must be added the past and present economic wealth that has been won from the rocks of the region; coal, metals and stone, which made it pre-eminent during the industrial development of Britain.

The geological map (Fig. 1) illustrates the broad distribution of the Lower Palaeozoic rocks together with that of the Old Red Sandstone, the Carboniferous, the Permian, the Trias and part of the Jurassic. The Lower Palaeozoic sediments, strongly folded, fringe the region to the west and north-west and in the Lake District and Borders and are also present in the inliers of the western Cheviot area (NT 789095), the Pennine scarp (NY 700270) and upper Teesdale (NY 850295). The sediments of the Old Red Sandstone occur at surface mainly on the Scottish side of the Border, but the igneous rocks of that age form the great mass of the Cheviot Hills, two thirds of which lie on the English side. The Carboniferous rocks sweep in a great half-circle round the eastern perimeter of the Cheviot massif where, though broken by occasional folds and many faults, the regional dip swings from east to south-east and south. Erosion has removed all but the oldest of these rocks, the Cementstones, from the margin of the Cheviot massif (including the Tweed syncline) while the youngest, the Coal Measures, are preserved on land in an elongate triangle in the south-east, with its base in south Durham and its apex at the mouth of the River Coquet (NU 267050). South of the River Tyne, the broad arcuate structure of the Northumberland trough is terminated against the Stublick fault (NY 860610), and thereafter the Carboniferous rocks dip steadily eastwards from Cross Fell (NY 687344) to the coast, across the Alston Block. The northern, western and southern limits of the block are marked by major faults. In the south-east the Coal Measures are overlain by rocks of Permian and Triassic age and Jurassic rocks form the Cleveland Hills.

The topography of the region expresses the underlying geology, as has been described in Hickling *et al.* (1931). In northern Northumberland, the dominant feature is the mainly grass-covered range of the Cheviot Hills, with its winding valleys deeply dissecting the lava pile and the granite rocks, both of which are of Lower Old Red Sandstone age. On the eastern side of the massif, the streams and rivers pour out on to the Cementstone plain and, save for the Coquet and Aln, are diverted northwards by the unbroken line of the heather-clad Fell Sandstone scarp. The Fell Sandstones form a great barrier of crags facing west towards the Cheviot Hills, while their long dip slopes descend away east towards the sea. In the upper Coquet valley these rocks are brought by faulting very close to the Cheviot lavas (NT 900064) and at Carter Bar (NT 698068) they swing south to form the high waste of the Border line before they become divided by shale and limestone bands north of Brampton (NY 524613).

Mid-Northumberland is dominated by the succession of sandstones within the

Dinantian, Lower Limestone Group, which forms the heathery Ottercop Moss (NY 950900). Their great areal extent is due, in part, to the reversals in the regional south-east dip associated with the Otterburn basin (NY 890940). Another notable sandstone which affords strong scarp and dip features across mid-Northumberland is that of Rothley and Shaftoe (NZ 055825). However, this sandstone succession does not persist far along the strike for it is present neither in the Coquet area nor between the North and South Tyne. In the Coal Measure triangle between the rivers Tyne and Coquet, topographical features are few; much of the bedrock is below sea level and is covered by glacial till, pierced by outcrops of only the thicker Coal Measure sandstones.

The tilted plateau of the Alston Block, embracing the whole of Durham County, contrasts with the inner topographical dome and the concentric scarps of Northumberland. Cross Fell (NY 687344), like Cheviot Hill (NT 909205) 90km to the north, is a focal point, and the ground falls precipitously westwards to the Eden valley along the line of the Pennine fault scarp; northwards from Cross Fell, the high ground persists along the ridge of the block beyond Hartside (NY 648419) to Cold Fell (NY 606557) and southwards to Stainmore beyond Little Fell (NY 784217). However, to the east the ground falls gently, with the coarse sandstones near the top of the Namurian forming many a high, windswept bench, as far as Muggleswick Common (NZ 009500). The two consequent rivers, the Wear and the Tees, with their tributaries, form the main drainage of the Alston Block. In the extreme east the Magnesian Limestone, of Permian age, forms a persistent west-facing scarp and undulating plateau from Tynemouth (NZ 375695) to Hartlepool (NZ 535340).

Of those igneous rocks which postdate the Old Red Sandstone period, the Great Whin Sill is responsible for by far the most impressive topographical features. In the far north, the sill transgresses the succession from Fell Sandstones to Namurian over the eastern limb of the Holburn anticline (NU 050350) and culminates in a high scar on which Bamburgh Castle stands. Offshore, it forms the group of the Farne Islands (NU 218358). The sill then re-appears on the coast where it forms the noteworthy scarp-and-dip feature on which Dunstanburgh Castle was built (NU 259221). Across mid-Northumberland it is less in evidence until at Bavington it forms a double intrusion (NY 983803). However, the most prominent section of the sill lies between the North and the South Tyne, where it has been fashioned into an almost continuous succession of beetling crags, surmounted by the Roman Wall. South of the Tyne Gap (NY 685635), the sill is a much less conspicuous feature, but it occurs near the headwaters of the River Tees, to provide the rapids of Cauldron Snout (NY 814287) and the magnificent fall at High Force, near Middleton-in-Teesdale (NY 950254).

Many of the high points in north-east England provide wide panoramas. From the summit of the Cheviot (NT 909205) on a clear day, the blue ridge of Cross Fell may be seen while, in the east, 60 kilometres of Northumberland coast is spread out before the viewer. From the remote peak of Sighty Crag (NY 601809) among the Bewcastle Fells, both Cheviot, Cross Fell and Criffel, which rises beyond the Solway, are familiar landmarks. From Cross Fell itself the jagged peaks of the Lake District can be seen rising up beyond the Eden valley. To the east the heather moors of the Alston Block stretch away as far as the eye can see.

In the offshore region of north-east England, a broad Palaeozoic ridge trends east-west away from the coast and towards the North Sea Central Graben (Fig. 2). This Mid North Sea High separates the Southern North Sea Basin from the northern Forth Approaches Basin. Onshore the margins of the Mid North Sea High are at the connection with the Southern Uplands High in the north and along the Butterknowle line, the southern margin of the Alston Block, on the south. Geophysical survey of the High has proved three gravity lows that are best explained by buried batholith-shaped bodies with densities appropriate for granites (Fig. 2). These granites are comparable with the Devonian age plutons of Cheviot, Weardale and

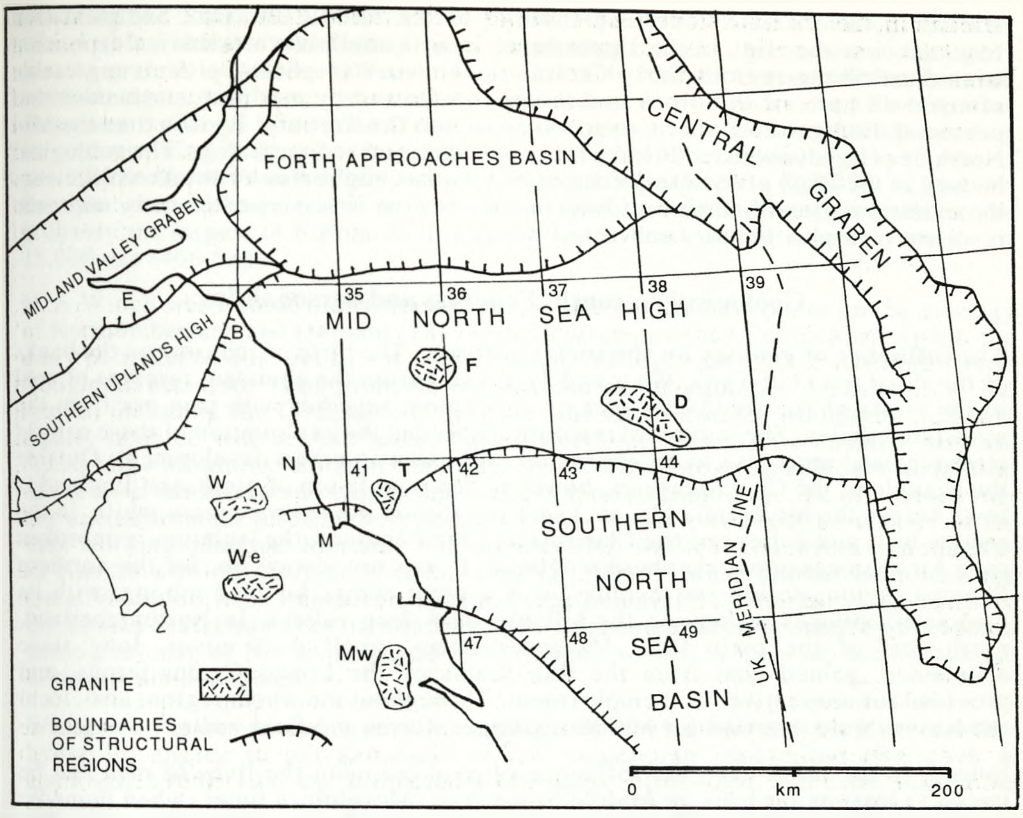


Fig. 2 Outline map of the North Sea off the coast of north-east England showing the major present day structural units. Subsurface granite plutons marked: D-Dogger, F-Farne, T-Teeside, Mw-Market Weighton, W-Weardale and We-Wensledale. Place names: E-Edinburgh, B-Berwick, N-Newcastle and M-Middlesbrough.

Wensleydale in the onshore area (Fig. 2). The positive structural influence of the buried granites could be partly responsible for the relative stability of the Mid North Sea High during the formation of the adjacent North Sea basins (Donato *et al.*, 1983).

Commercial wells drilled on the Mid North Sea High have given details of the geological succession and history of this block region. Some of this information is now available and the following notes are mainly derived from Donato *et al.* (1983), Besley (1988) and Leeder & Hardman (1990). The oldest strata proved on the High are probably Devonian (Old Red Sandstone) red beds and red bed deposition is thought to continue into the Carboniferous as it does in the onshore region. Over the High the Dinantian sediments are dominantly of clastic facies and similar to the sequence of onshore Northumberland. They thin towards the core of the High by onlap. During the Silesian, the block was probably covered by a relatively thin onlapping clastic sequence that was largely removed by later pre-Permian erosion. The Permian Rotliegend are patchy and probably derived by erosion of the underlying Devonian and Carboniferous sandstones and siltstones. Permian Zechstein marine deposits cover the High, but the lower part of the sequence is absent in some places suggesting that some topographic relief was present at this time probably owing to contemporary faulting. Faulting continued during the Triassic giving a patchy distribution in down-faulted regions. Non-deposition that started in the Triassic continued through to the Middle Jurassic. Sedimentation resumed over the High in the Upper Jurassic with shallow water marine deposition over most of the region. Early Cretaceous Cimmerian phase uplift or regression affected all parts of the block and this was followed by marine transgression that persisted through the Upper Cretaceous and into the Tertiary. By this time the Mid North Sea High had ceased to have much influence on sedimentation. The geological history of the High gives a sequence of events that might also have taken place over the onshore region of north-east England where post-Triassic sedimentary sequence is absent owing to Tertiary sub-aerial erosion.

Geological research: Progress and personalities

The influence of geology on the social pattern. The birth of industry on the banks of the three rivers of Tyne, Wear and Tees came from the abundant reserves of coal in the strata of the south-east part of the region, together with iron ore from the associated shales. The industrial revolution speeded the exploitation of these natural resources and gave rise to an enormous expansion in urban development. Outside the triangle of the Coal Measures, however, the population of north-east England is low. Across the broad uplands, enclosed farming is the main concern while, in the remote hills and valleys of the Cheviots and the Pennines, the isolation is unbroken save for the occasional shepherd's cottage. It was not always so, for the northern Pennine region, during last century, was a great centre for lead mining, with its associated villages occupying the hillsides and deep valleys. In Northumberland, north-west of the main Coal Measures, many small drift mines, long since abandoned, gained coal from the thin seams of the Lower Carboniferous, and provided for alternative rural employment. Throughout the whole region, also, local sandstones were quarried for building villages, farms and field walls.

Indeed, in the north-east, the influence of geology upon the lives of men can be traced at least as far back as Middle Stone Age (Mesolithic) times, when nomadic hunters used chert from the Pennines to fashion some of their stone implements. The Roman invaders, bringing with them their mining and building skills in the second century, are believed to have exploited lead in Weardale (certainly in north Yorkshire) and coal from the lowlands to the east. North of the River Tyne, the Romans used the natural rampart of the Great Whin Sill escarpment in the construction of Hadrian's Wall. In much later times, during the centuries of dispute between England and Scotland, many a crag of whinstone and sandstone became the site of a castle or fortified pele against the marauding clans from the far north.

The local development of the science. The scientific study of the materials of the earth's crust began in Europe towards the close of the eighteenth century; it is only within the past 160 years that investigators in the north-east of England, inspired by the work of the pioneering genius of men like Hutton, Playfair and William Smith in Britain, and Werner, Cuvier and Brogniart on the Continent, turned their attention to the rocks of Northumberland and Durham. These local pioneers were the first to set down the names of strata and mineral veins which, in the practice of quarrying and mining through the centuries, had hitherto only been handed down by word of mouth. The contributions of some of these men are considered below, but more detailed accounts of the pioneers of geology will be found in Robson (1986) and Lunn (1983).

Thomas Thompson, a medical doctor, provided one of the earliest accounts of local geology (1814). He identified the succession of limestones, shales, sandstones and coal seams which lie beneath the main Coal Measures and these he named the 'Independent Coal Formation'. Above them followed the 'Newcastle Coal Formation' and the 'Magnesian Limestone Formation'. The boundaries of these formations he delineated on an accompanying map. In his text, Thompson referred to some of the better-known limestones within the Independent Coal Formation, including the Scar, the Little and the Great. He explained such mining terms as 'plate' (clay-shale), 'whin' (any hard formation), 'hazle' (sandstone) and 'grit' (coarse-grained sandstone). He drew attention to the fact that, in the Pennine orefield, the metalliferous veins swell and become rich in galena and fluorspar as they enter the Great Limestone. Thompson also recorded some interesting statistics from the mining industry - that 540,000 cwts (27432t) of lead ore were mined annually from the Pennine field, which produced 345,375 cwts (17545t) of lead. At the time when Thompson was writing, the Beaumont-owned mines were claimed as probably the largest in Europe with, in addition to lead, an annual silver output of 15,000 ozs (466.5kg).

N. J. Winch was a most industrious observer. He published a paper on the geology of Northumberland and Durham (1817) which discussed the Cheviot porphyrites, the early Carboniferous rocks of the Tweed valley, even the Roddam Dene Conglomerate. Like Thompson, he listed some of the principal limestones of the region, including the Cockleshell, the Scar, the Great and the Melmerby Scar. He rightly doubted whether the beds of the Tweed valley could be equated with the 'Lead Mine Measures' south of the Tyne. He recorded the geographical distribution of the Coal Measures and the succeeding Magnesian Limestone; he also noted that the unconformable junction between these two formations could be viewed in the then working quarry at Marden, Whitley Bay (NZ 360715). He wrote that the coal in contact with the dyke at Westerhope (NZ 210655) was charred. He traced the Great Whin Sill from Bamburgh and the Farne Islands (NU 218358) in the north, to the Roman Wall country in the south. Winch's paper was accompanied by a coloured geological map of Northumberland and Durham, on which the main stratigraphical divisions are delineated.

Westgarth Forster senior, a mining engineer, in 1765 made and installed the first hydraulic engine in the Pennines, in the Coalcleugh lead mines (Raistrick & Jennings, 1965). His son followed in the same profession, but later turned his attention to geology. In 1809 the younger Westgarth Forster published his treatise on the section from Newcastle to Cross Fell, which contains a wealth of local information. In the edition of 1821, he quoted from Winch on the Coal Measures, but his own paper offered much more information on the limestone succession and the mineral veins of the Pennines. He described, for example, the 'rake' and the 'flat' or 'strata' veins and techniques adopted for tracing them overground, by observing subtle changes in topography, vegetation and the presence of ore-fragments on the surface. He referred to the practice of damming streams on the high ground, whose sudden release by 'hushing' scoured the hillsides clean to the bedrock. He recorded over 150 working mineral mines in the region. In his treatise, Forster made no mention of William Smith, but he devoted a section to the controversy between the Wernerians and the Huttonians. In the 1821 edition, he gave it as his opinion that Hutton's views had 'gradually sunk into disrepute'!

As the enthusiasm for the new science of geology grew, local naturalists increasingly turned their attention to the study of the rocks. One of the earliest of these was Henry Grey Bennet, a member of Parliament and a vice-president of the Geological Society; he was the second son of the fourth Earl of Tankerville, owner of the famous herd of white cattle at Chillingham, in north Northumberland. In the same volume as Winch's classic paper, Bennet (1817) contributed an account of the Beadnell dyke where it outcrops across the shore (NU 230270). Sir Walter Trevelyan, the progressive landowner at Wallington (NZ 022840) in mid-Northumberland, wrote numerous geological papers on both local and foreign geology. Interest in the past seems to have been handed down to his kinsmen, for a succeeding squire of Wallington, Sir George Otto Trevelyan, and the latter's son, George Macaulay Trevelyan, each in turn received the award of the Order of Merit, as distinguished historians.

Of the many early papers on the geology of north-east England, an important one was that by Nicholas Wood (1831) on a general survey of Northumberland's geology. Wood recorded that the main Coal Measures outcrop westwards along the northerly downthrow side of the Stublick fault and he demonstrated that the red sandstone of the Carlisle area belongs to what is today described as the New Red Sandstone. He also emphasized what Thompson had discovered over a decade earlier, that there are coal measures in association with the limestones and that they outcrop across Northumberland. He observed that the whin intrusion forms a double sill at Bavington (NY 983803) and that, in the Tweed valley, the red sandstone underlies the lowest Carboniferous strata.

In 1838, J. A. Knipe produced a geological map of England and Wales, which also included parts of Scotland, Ireland and France. The main divisions of the rocks of northern England are delineated, with the Old Red Sandstone of the Borders, the Mountain Limestone, Millstone Grit and Coal Measures of Northumberland and Durham and the New Red Sandstone of the Eden valley. On this map the extent of the Whin Sill is shown but there are no dykes except that at Westerhope. The outline of the Cheviot lavas is included, but the granite was as yet undiscovered.

George Tate of Alnwick was a naturalist of wide interests and an active member of the Berwickshire Naturalists' Club. He wrote prolifically for the Club's journal and for other local publications. He it was who established the main divisions of the rocks of the Carboniferous system of Northumberland as Tuedian and Bernician. Thomas Sopwith, who directed a cabinet and upholstery firm in Newcastle upon Tyne, grew sufficiently interested in geology to give up his business activities; he became manager of the Beaumont mines in the Allendale district (NY 840560), a post which he held from 1845 until 1871. He used his skill in cabinet-making to fashion models in wood (the well-known Sopwith models) to illustrate the lie of the strata in some of the mining areas. Many more northern investigators, during these years, contributed items of interest on local geology.

Contributions from Smith, Phillips and Sedgewick. William Smith had visited the north-east in 1794 and, among many other observations, recorded the presence of the Yellow Sands at Ferryhill (NZ 300329) which, as is known today, lie immediately south of the Butterknowle fault. Nearly thirty years later, when Smith journeyed north again, accompanied by his nephew, John Phillips, he approached the region from Keswick, across Alston Moor (NY 730400). John Phillips later described (1844) how his uncle posted him off to examine the cliffs of the Great Whin Sill in the Roman Wall area, before continuing to Carter Fell (NY 671033) and afterwards skirting the Cheviot Hills to Wooler (NT 995280). This led to the publication of the map of Northumberland, which bears a close resemblance to that of Winch, but with much greater emphasis upon the scarp features formed by the sandstones of the Carboniferous across the county.

Soon after his visit to the region with his nephew, William Smith met, in London, Colonel Braddyll, a Durham landowner with properties on the Magnesian Limestone. Smith persuaded the landowner that there was no truth in the dictum of the Newcastle coal-owners that there was 'no coal under Magnesian Limestone' (Phillips, 1844). Braddyll sunk a shaft at South Hetton with the result that a colliery grew up from which coal production rivalled that of any in the region.

Adam Sedgwick, the Woodwardian professor of geology at Cambridge, in a journey across the hills of west Durham, seems to have been the first observer to have recognized the significance, as a fault scarp, of the steep westerly slope below Cross Fell. In 1830, in one of his visits to the region, he examined the Cheviot Hills, staying at Alnwick Castle, the home of the Duke of Northumberland, another geological enthusiast. Sedgwick returned to the north-east a few years later and followed the course of the Magnesian Limestone. He described its outcrop through Durham to Tynemouth Castle (NZ 372698), recognizing the underlying Marl Slate and Yellow Sands, the brecciated limestones and the concretions at Fulwell

(Sedgewick, 1829). He noted that some igneous dykes penetrate the Permian formation, while others do not. Sedgwick was followed north a few years later by William Buckland, of Oxford, later to become Dean of Westminster, who, in 1838, described some of the moraines which lie east of the Cheviot Hills. John Phillips made a return visit to the south of the region, to describe the slate rocks which he had discovered beneath the red sandstones of the Lune valley.

The emergence of the specialist. By the middle of the nineteenth century, the main outlines of the geology of the north-east of England had become established and investigators began to turn their attention to geological detail. William Hutton of Hartlepool, after whom one of the main coal seams in the north-east is named, became a specialist in fossil botany and wrote numerous papers on the subject between 1830 and 1860. H. B. Brady, though in business in Newcastle as a pharmaceutical chemist, was more interested in zoology and he became a specialist in the identification and classification of the Foraminifera in the local limestones. In this work he aroused the enthusiasm of a young Methodist minister, Walter Howchin. The latter, however, was driven by ill-health to emigrate to Australia, where he recovered and later gained recognition as a geological authority on that country. In Adelaide, he joined the university department where Ralph, the son of George Tate of Alnwick, had recently been professor.

Undoubtedly the most distinguished geologist in the north of England during the second half of the nineteenth century was H. C. Sorby of Sheffield, a man of independent means who devoted his whole life to research. Sorby's interests ranged over not only the field of geology but also over those of metallurgy, chemistry, biology and geography. He may be said to have founded the study of sedimentary rocks, while his interest in the microscope led to the development of the technique for examining rocks in thin section. His field interests were mainly in Yorkshire, but by no means confined to that county; among his 200 publications, there were important papers on current directions in the Coal Measure sandstones of Northumberland (1852) and on aspects of the Magnesian Limestone of Durham.

J. J. H. Teall, later Director of the Geological Survey, was among the earliest petrologists to take advantage of the thin section technique developed by Sorby, and in 1888 he produced his 'British Petrography', a classical study of the igneous rocks. In this volume a number of the Cheviot rocks were first described, accompanied by accurate coloured drawings. Meanwhile C. T. Clough, an officer of the Geological Survey, together with W. Gunn, was responsible for the mapping of the Cheviot igneous succession where, for the first time, the main divisions of pyroclasts, lavas, major and minor intrusions were recognized (Clough, 1888). Another officer, the younger Hugh Miller, mapped the sediments south of the Cheviot massif. Others followed, both from the Survey and from the academic life; among the latter, David Page and G. A. Lebour, who each in turn held the chair of geology in Newcastle, made numerous and valuable contributions. Page is especially remembered for his introductory and advanced text-books of geology and for his popularization of the subject both in print and in lectures.

Towards the end of the century, the work of E. J. Garwood began to appear in geological literature. Garwood was one of the most colourful of geologists. Destined for the chemical industry, at least in the eyes of his guardian uncle, who was a director of the Jarrow Chemical Company, Garwood took rather the advice of the Curator of the Hancock Museum in Newcastle, and turned to geology. He became an authority on the faunal succession, especially the calcareous algae of the Lower Carboniferous of the north of England. He was also a noted Alpine climber and, with Gregory, he became the first explorer to cross Spitzbergen. He was a successful teacher both behind the lecture bench and in the field. In addition, he had wide cultural and political interests; among his friends he counted Edward Elgar the composer, A. E. Housman the poet and the formidable Margot, Countess of Oxford and Asquith, wife of the former Liberal prime minister.

After Garwood's death, his obituarist wrote of him as 'polished, witty and urbane' and it was said that he was wholly free of sarcasm and ridicule. His early life spanned the closing decade of three of the great pioneers in British geology (Adam Sedgwick, Roderick Impey Murchision and Charles Lyell), and he died in the era of the professional, in 1949, at the age of 85 years.

Other twentieth century geologists connected with the north-east of England include Dr C. T. Trechman, a gentleman of independent means who devoted his life to geology and travel. He had wide interests in geology and in particular made important contributions to knowledge of the Durham Permian rocks, the Quaternary glacial succession of east Durham and to studies of early man in northern England. He was a talented collector who amassed a large collection of fine geological and archaeological material from Britain and abroad in his home at Castle Eden. He regularly presented his best specimens to local and national museums.

The Coal Measures of Northumberland and Durham had only local divisions and no correlation of coal seams until the work of H. G. A. Hickling and William Hopkins working in Newcastle and Durham universities in the years shortly after the first world war. Using detailed lithological sections and nonmarine bivalve zones they produced correlations linking local coal seam names right across the coalfield.

R. G. Carruthers, district geologist in the Geological Survey office in Newcastle, supervised the revision of eight one-inch sheets of Northumberland during the 1920s and 1930s. In his early days in the Survey he mapped in the Highlands of Scotland and made his name by his independent interpretation of the Ballachulish area. His interests included Carboniferous rugose corals and his evolutionary study of *Zaphrentis delanouei*, published in 1910, has been quoted in almost every textbook of palaeontology since then. In later years Carruthers's radical reassessment of the Quaternary glacial deposits of northern England caused much opposition, but with passing years most of his views are now generally accepted. He was a geologist of vision whose findings were well ahead of his time.

A friend of Carruthers of very different disposition was Arthur Raistrick, a devout Quaker. A geologist in the University at Newcastle, Raistrick pioneered work on palynology, the study of fossil pollen and spores, and applied this technique to subdivision and dating of the Quaternary and Coal Measures rocks. He made his mark as a geologist, archaeologist, historian and author and he largely devised the pursuit of industrial archaeology. His work on the history of lead mining in the Pennines and the history of development of the north-east coalfield is particularly renowned. A prolific writer, Arthur Raistrick was equally at home producing technical papers for the specialist or more popular articles, to interest a wider public, many of which were published in the *Dalesman*.

The most celebrated geologist that north-east England has produced this century is probably Arthur Holmes. Born at Hebburn-on-Tyne in 1890, he was descended from Northumberland farming stock on both sides and had a great affection for the Northumbrian countryside. After training in London University and work as a geologist abroad, Arthur Holmes came to the University of Durham to found the Geology Department in 1924. Research and writing opportunities were considerable here and Holmes soon developed a great and growing reputation. He stayed in Durham until 1943 when he was appointed to the Regius Chair of Geology at Edinburgh. A very single minded research geologist, Arthur Holmes made significant advances in geological knowledge in many fields. He is particularly remembered for his work on radioactivity in geology, time scales and radiometric dating, the thermal history of the Earth, earth movements and continental drift, petrology and ore genesis. During the last years in Durham, Arthur Holmes found time to prepare the text *Principles of Physical Geology*, published in 1945. This is one of the most successful textbooks of geology ever written and it has been adopted widely over the past fifty years both in Britain and abroad.

CHAPTER 2

LOWER PALAEOZOIC ROCKS

In north-east England, rocks of Lower Palaeozoic age form a folded basement on which extensive later deposits were laid down. This basement is largely concealed by the younger rocks, but it is exposed in four regions: the Borders and the Southern Uplands of Scotland, the Lake District, the Cross Fell inlier and the Teesdale inlier (Fig. 1). Both the Southern Uplands and the Lake District are marginal to north-east England, but deserve mention because in both regions full successions of Lower Palaeozoic rocks are present. Both these areas are formed from rocks laid down on the margins of the Lower Palaeozoic Iapetus ocean (p331). Distinct faunal provinces in the Lake District Ordovician are similar to the rest of England and Wales, whereas the Ordovician faunas of the Southern Uplands are similar to North America; during the Ordovician the Iapetus ocean was wide enough to separate most benthic faunas (McKerrow & Cocks, 1976). The Southern Uplands rocks were laid down on the north side of the ocean while the Lake District succession was deposited on the south side.

The Southern Uplands of Scotland are formed of deep water oceanic sediments, graptolitic shales and thick greywacke sandstones overlying chert and basalt. There are ten or more distinct sequences of strata, each of which dips to the north, separated by major strike faults. The structure has been recognised as an accretionary prism of oceanic sediments adjacent to a subduction zone. It formed on an active continental margin where a sinking oceanic plate had a thick sedimentary cover (Leggett, McKerrow & Eales, 1979). A Lower Palaeozoic succession, from Arenig in the north through to the top of the Wenlock in the south, is present in the Southern Uplands. In the Border country, Lower Palaeozoic rocks outcrop on both sides of Cheviot, in the Berwick-upon-Tweed area (NU 000530) and near Carter Bar (NT 698068). These exposures are at the margin of the Southern Uplands and consist of Silurian, mainly Wenlock, greywackes and graptolitic mudstones.

The Lake District was close to another destructive plate boundary on the south side of the Iapetus ocean in the Ordovician. The region has been studied by many workers during the 19th and 20th centuries and a full account of the geology has been brought together by Moseley (1978). The earliest rocks are fossiliferous oceanic mudstones of Tremadoc age. They are followed by the Arenig and Llanvirn age Skiddaw Slates, graptolitic mudstones with siltstones, sandstones and conglomerates. The overlying Borrowdale Volcanic Series is believed to have formed in an island arc setting with basaltic, andesitic, and dacitic lavas and tuffs including ignimbrites totalling some 8000m in thickness. The volcanic pile built up to sea level and an erosional episode took place towards the end of the eruption of extrusive rocks. The following Caradoc age Coniston Limestone Group is a shallow water marine shelly facies of limestone and mudstone that is continued into the Ashgill when deepening seas allowed black graptolitic shales to form. During the Silurian a sedimentary basin developed in the southern Lake District in which some 5000m of mudstones and greywackes were laid down.

The Cross Fell inlier is a spindle-shaped area of Lower Palaeozoic rocks on the east side of the Vale of Eden and at the foot of the Pennine escarpment. The Lower Palaeozoic succession of the Lake District is repeated in the inlier except that the basal Tremadoc mudstones and the Silurian sequence above the Wenlock Brathay Flags are absent. Beds from the Arenig Skiddaw Slates through to the Wenlock are present in block faulted ground adjacent to the major Pennine faults. The Cross Fell inlier has been the subject of numerous papers and particularly Shotton (1935), Burgess & Wadge (1974) and Burgess & Holliday (1979).

The Teesdale Inlier in upper Teesdale, near the hamlet of Langdon Beck, is only seen in small outcrops of Skiddaw Slates and Borrowdale Volcanic Series. It lies on the western, upthrown side of the north-south trending Burtreeford Disturbance, an east facing faulted monocline. The rocks of the inlier are best seen in the banks of the Tees at Pencil Mill (NY 848296) where grey cleaved mudstones and phyllites are exposed on both sides of the river. Graptolites found on the right bank indicate Skiddaw Slates of the *Didymograptus bifidus* Zone, Llanvirn, Ordovician (Johnson, 1961; Burgess & Holliday, 1979). Small quarries on the right bank of the river near the remains of the mill were made when the mudstone was used to produce slate pencils. Several lamprophyre dykes cut the mudstones upstream of Pencil Mill. Volcanic rocks form small outcrops on the south side of the Tees opposite Widdybank Farm (NY 838296) and have been identified as rhyolitic tuffs forming part of the Ordovician Borrowdale Volcanic Series. Fairly numerous erratic boulders of volcanic rocks in boulder clay in the upper Tees valley suggests that the volcanic series occurs more widely in the floor of the valley than is suggested by the few small outcrops.

Other information on the lower Palaeozoic basement comes from the Roddymoor and Allenheads boreholes both of which reached slates below the Carboniferous succession. The Roddymoor Borehole at Crook (NZ 151363) reached the base of the Carboniferous at 862m from the surface and passed into slates believed to be the Skiddaw Slates (Woolacott, 1923). The Allenheads No. 1 Borehole (NY 860453) proved grey-green slates below the Carboniferous sequence at 467m below the surface and again these are regarded as Skiddaw Slates (Dunham, 1990). On this borehole evidence and the Teesdale Inlier, the Skiddaw Slates seem to be widespread below the Carboniferous in the region between Tyne and Stainmore.

CHAPTER 3

DEVONIAN OR OLD RED SANDSTONE

There was a long interval between the deposition of the highest Silurian rocks and the formation of the overlying Devonian. During this time strong north-west to south-east compression, generated by the final closure of the Iapetus Ocean, caused strong folding of the Lower Palaeozoic succession and it was uplifted to form a new mountainous continental land surface - the Old Red Sandstone continent (p331). Subsequently, sub-aerial erosion was active and sedimentary basins formed adjacent to the uplands and here thick sequences of sedimentary, extrusive and intrusive rocks were laid down. An angular landscape unconformity underlies the Devonian throughout the region. In north-east England the Devonian is divided into the Lower and Upper Old Red Sandstone, the Middle Old Red Sandstone, known in Ireland and northern Scotland, is absent and the two divisions are separated by a strong unconformity. Intrusion of vast amounts of igneous material accompanied the compression that formed the Old Red Sandstone continent. The emplacement of the Shap, Skiddaw and Weardale granites and the granophyre-gabbro complex of Carrock took place at the time (Fig. 5). Some of the igneous activity reached the surface in north-east England. The Cheviot Hills consist of Lower Devonian volcanic rocks intruded by the Cheviot granite.

Along the Scottish border, the Old Red Sandstone forms a wide outcrop with extensive Lower Devonian igneous rocks of the Cheviot region in England, but with the Old Red Sandstone sediments restricted to the Scottish side (Fig. 1). Lower Devonian extrusive and intrusive rocks are described elsewhere (p. 314) so in this section there is only an account of the sedimentary facies. Lower Old Red Sandstone sediments are relatively restricted in the Southern Uplands owing to pre-Upper Old Red Sandstone denudation. The rocks are exposed at Eyemouth, 12km north-west of Berwick (NT 948648). They consist of red feldspathic conglomerates, sandstones, cornstones and marls of lacustrine origin lying with strong unconformity on the Lower Palaeozoic basement. Andesitic lavas and tuffs are associated with the sediments and vents filled with agglomerate, mainly composed of andesite fragments, occur on the shore. Thin bands of sediment also occur intercalated among the lavas of the Cheviot igneous complex. A marked period of uplift and erosion separates the Lower and Upper Old Red Sandstone and is indicated by a strong unconformity. Again at Eyemouth the Upper Old Red Sandstone rests with marked discordance on the Lower Old Red Sandstone and in parts of the Cheviot Hills it lies on Lower Old Red Sandstone lavas and tuffs. Elsewhere these beds lie on the folded Lower Palaeozoic basement, such as the historically important localities of Hutton's unconformity best exposed at Siccar Point (NT 813709) where the gently inclined Upper Old Red Sandstone rests on an irregular surface of folded Llandovery mudstones. The Upper Old Red Sandstone consists of reddened conglomerates, sandstones and marls. They are a fluviatile succession produced by large rivers and palaocurrent evidence indicates a persistent stream flow from south-west to north-east (Leeder, 1973). Towards the end of Upper Old Red Sandstone times widespread carbonate palaeosols developed over the region and active soil forming processes took place over lengthy periods of time (Leeder, 1976).

Very similar red fluviatile conglomerates, sandstones and marls occur on the east side of the Lake District near Shap (NY 586088) and the Mell Fells (NY 397254) (Fig. 1). They rest on the Lower Palaeozoic basement and underly the marine Carboniferous and their age is believed to span the Devonian to Carboniferous boundary. The conglomerates and sandstones are devoid of fossils. Only the Pinskey Gill beds, marginal to the conglomerates at Shap, being of know Tournaisian (basal Carboniferous) age and thus they are the earliest dated Carboniferous rocks in the north of England (Johnson & Marshall, 1971). The Mell Fell conglomerates form coarse alluvial fan deposits close to the Lake District and grade to wide braided fluvial channel sediments away from the high ground. The total stratigraphic thickness is believed to be about 275m (Kimber & Johnson, 1986). On the other (east) side of the Vale of Eden the Polygenetic Conglomerate overlies the Lower Palaeozoic basement in the vicinity of Melmerby (NY 628370). It consists of pebbles of local origin with boulders of biotite-granite and is again believed to be an alluvial fan deposit of either Devonian or Lower Carboniferous age (Shotton, 1935; Burgess & Wadge, 1974). The overlying fluviatile quartz conglomerates and sandstones fill hollows in the basement and vary in thickness from 50m to over 200m along the Pennine escarpment (Burgess & Wadge, 1974). These are regarded as Lower Carboniferous in age. The conglomerates and sandstones thin eastwards and only 20m are found in the Teesdale inlier and 23m in the Rookhope Borehole (NY 937427).

CHAPTER 4

CARBONIFEROUS

Introduction

The Carboniferous geology of northern England has been described by many workers. Early epitomes by Westgarth Forster (1809, 1821) and Winch (1817) were followed by more detailed papers on the Carboniferous succession, its sub-division and correlation, by Tate (1867), Lebour (1875), Smith (1910) and Garwood (1913). From the latter part of the nineteenth century, regional memoirs of the Geological Survey have been published at intervals. The whole region is not covered by these memoirs, but they have made most significant contributions to geological understanding. Thus the Brampton memoir (Trotter & Hollingworth, 1932) gave the first detailed description of the Carboniferous succession in east Cumbria and this revision is continued eastwards in the Bellingham memoir (Frost & Holliday, 1980). The northern Pennine orefield memoir (Dunham, 1948, 1990) not only gives complete coverage of mines and mineralization, but is the source book for the stratigraphy of the Alston Block. The Bewcastle memoir (Day *et al.*, 1970) gives a revision of the stratigraphy of northern Cumbria and the Brough memoir (Burgess & Holliday, 1979) and the Barnard Castle memoir (Mills & Hull, 1976) cover south Durham and north Yorkshire. Other memoirs cover the Northumberland and Durham coalfield and north and central Northumberland. Important reviews of the geology of northern England such as Hickling *et al.* (1931) and Hickling & Robertson (1949), each in their day provided standard works of reference to the geology of the region and the Lower Carboniferous rocks received detailed description by Rayner (1953). Following the second world war numerous papers have been written on the Carboniferous rocks of the region, many of which are mentioned in the following text and listed in the accompanying references. With this extensive literature it is not necessary to describe the Carboniferous geology of north-east England in detail in this publication. Following the lead of Hedley (in Hickling *et al.*, 1931) it is proposed to cover those areas of the Carboniferous geology of the region where new information has significantly added to knowledge.

Divisions of the Carboniferous

The primary lithological division of the British Carboniferous into Carboniferous Limestone, Millstone Grit and Coal Measures is complicated in north-east England by the absence of thick marine limestones. The original classification in Northumberland divided the pre-Millstone Grit sequence into two major divisions, Tuedian Cementstones and Fell Sandstone groups, and Bernician Scremerston and Limestone groups. The group names have been retained to the present time, but Tuedian and Bernician have been dropped. The Lower and Middle Limestone groups of Northumberland are of Asbian and Brigantian age respectively, and lie at the top of the Dinantian (Table 1; Fig. 3). The Upper Limestone Group is Namurian and forms the lowest division of the Upper Carboniferous, between the base of the Great Limestone and the base of the Longhoughton Grits (Fig. 4). New lithostratigraphical divisions have been introduced in north-eastern Cumbria (Day *et al.*, 1970) and in south Cumbria (Taylor *et al.*, 1971; Burgess & Holliday, 1979) as are shown on Fig. 3.

The Millstone Grit division was recognized by Westgarth Forster (1821) in Durham and by Tate (1868) and others in Northumberland. It is a lithological division, restricted to the thick sandstones and grits between the top of the Limestone Group and the base of the Coal Measures. The limits were arbitrary and vary laterally across the region. More recent discoveries of Carboniferous zonal fossils in north-east England have proved that Westgarth Forster's 'Millstone Grit' division lies across the junction between the Namurian and the Westphalian. In Durham, the First and Second Grits are Namurian and the Third Grit is Westphalian. The name 'Millstone Grit' is unsatisfactory for this grit series, because it equates neither with, nor does it lie within the standard Millstone Grit Series (Fig. 4). For clarity's sake, the grits have been called the Longhoughton Grits in this work. The name is taken from Longhoughton, near the Northumberland coast, north of Alnwick (NU 185153), where the outcropping grits reach the North Sea. The overlying Coal Measures were originally separated into lithological divisions but have since been divided into zones using non-marine bivalves and miospores.

There are now international divisions of the Carboniferous that separate the period into two sub-periods, the Mississippian and the Pennsylvanian (Harland *et al.*, 1982). The junction lies within the Namurian between the H and R Zones and it coincides approximately with the Mississippian and Pennsylvanian boundary in Russia and USA. The international scheme uses mainly European divisions in the Mississippian and largely Russian divisions in the Pennsylvanian (Table 1). These divisions are of limited use in northern England owing to uncertainty in the correlation of the international boundaries in this area.

Correlation of the Carboniferous sequence over northern England was uncertain until recent biostratigraphical methods became available. In the absence of thick marine carbonates the Dinantian coral-brachiopod zones of Vaughan (1905) and Garwood (1913) are of limited value in the south and cannot be traced through to the north of the region. New correlation methods based on foraminiferal and conodont zones and palynology have given much assistance in correlation (Purnell, 1989; Armstrong & Purnell, 1993). New stages for the Dinantian proposed by George *et al.* (1976) are used in this paper (Fig. 3) though some revision of boundaries may be required in the future (Riley, 1993).

Detailed correlation and sub-division of the Namurian was made possible by the discovery of goniatites in the upper part of the Dinantian and in the Namurian succession. The base of the Upper Carboniferous (Namurian) was shown to be approximately at the base of the Great Limestone (Johnson *et al.*, 1962) and all the goniatite stages were later found to be present in the Namurian sequence (Hull, 1968). The base of the Coal Measures is now placed at the Quarterburn Marine Band on palaeontological evidence (Mills & Hull, 1968). A full account of the zones and divisions of the Carboniferous sequence in the north of England is given in Johnson & Hickling (1970) and the zonal scheme is shown on Table 1.

Palaeogeographical setting The Old Red Sandstone land surface over which the Carboniferous sea transgressed was not peneplained, but was a region of considerable topography. The high land lay to the north of Northumberland in the Southern Uplands of Scotland and, in the south, in the Pennine Alston Block of Durham County. Between them lay a wide sedimentary trough, divided by the Cheviot axis into a northern Tweed basin and a southern Northumberland basin (Fig. 5). Deposition in the basins began in Lower Old Red Sandstone times and the Upper Old Red Sandstone continued without break into the Carboniferous. To the south of the Alston Block, at the margin of the area, the east-west Stainmore basin was filled with a thick sequence of Carboniferous deposits (Fig. 3). The uplands were positive structural regions buoyed up by underlying, low density granitic intrusions of Caledonian age (Bott, 1967). They formed islands in the early Carboniferous which were progressively inundated by the sea as the Carboniferous period proceeded. The Alston Block island appears to have been submerged during the Asbian, which is confirmed by the Rookhope borehole section (Dunham *et al.*, 1965). The Carboniferous sea transgressed the Southern Uplands island as witnessed by the Sanquhar coalfield and Dumfries outliers, but the uplands of Galloway may have remained as islands throughout Carboniferous times.

Beyond the Southern Uplands island and across the Midland Valley of Scotland, which was another Carboniferous sedimentary basin, lay the northern shoreline of the Carboniferous sea in the vicinity of the Highland Boundary fault. The ancient Caledonian mountains of the Scottish Highlands provided a source area for the great volumes of clastic sediment that were laid down in the Carboniferous sedimentary basins. Though the island areas also provided a source of clastic sediments to the basins, they are only significant during the lower part of the Carboniferous (Leeder, 1974a). Sea connection with the wide southern ocean was by the North Sea basin to the east and across Ireland to the Solway on the west.

Dinantian and Namurian

Carboniferous sedimentation in Northumberland and Durham was primarily controlled by the inhomogeneous Lower Palaeozoic basement, composed of granites intruded into a varied succession of sedimentary and extrusive rocks (Johnson, 1967). The low-density granites are positive structurally and have been uplifted persistently such that the area above the granite, the Alston Block, is even today relatively high ground (Bott, 1967). On the margins of the uplifted Alston Block, hinge line faults developed, dropping down the adjacent Stainmore and Northumberland troughs (Fig. 5) which became profound sedimentary basins.

Two phases of deposition and a final phase of uplift and erosion have been recorded in the Carboniferous basins of northern England. Carboniferous deposition began in graben basins formed under north-south tension in the crust and lithosphere (Johnson, 1982). This was a period differential subsidence in northern England with structurally positive blocks, buoyed up by underlying low density Caledonian granites, forming islands while the intervening basins were submerged by the sea. This first phase of deposition continued into the Namurian or even later, but before this, in the upper Dinantian, the blocks separating the basins began to subside. In this way differential subsidence of blocks and basins became less pronounced and the second phase of deposition under widespread regional downwarping commenced. There is not a sharp break between the two phases of deposition, but rather a gradual transition towards the top of the Dinantian and the lower part of the Silesian. Uniform regional sinking over both blocks and basins continued through the Upper Carboniferous with the deposition of the Westphalian Coal Measures and possibly Stephanian deposits. Carboniferous deposition over northern England ceased as subsidence gradually came to an end.

During the Upper Carboniferous there seems to have been significant eustatic sea-level fall owing to continental accretion and the spread of southern hemisphere continental ice sheets (Johnson, 1982). An emergent land surface developed and slowly became raised as sea-level fell. Subaerial erosion of the Carboniferous deposits began. Late-Carboniferous earth movements contributed to the formation of an uplifted land surface and the old Carboniferous basins began to rise in a major inversion event (Leeder, 1988). In north-east England there is a regional unconformity at the top of the Carboniferous and the overlying Permian rests on either Westphalian, Namurian or Dinantian formations (Fig. 1). According to Leeder (1988) in certain areas up to 4km of erosion took place prior to Permian Rotliegend deposition.

There is general consensus that the first phase of Carboniferous deposition in northern England formed under north-south tensional stretching of the crust and lithosphere with the formation of graben and half graben basins. Most workers also agree that the tensional stress in the crust was caused by a subduction event to the south of Britain, (Bott, 1982; Dewey, 1982; Johnson, 1982; Leeder, 1982). Slab pull produced by down-going oceanic crust attached to the Carboniferous paralic shelf caused tensional stress to develop northwards right across the shelf (Bott *et al.*,

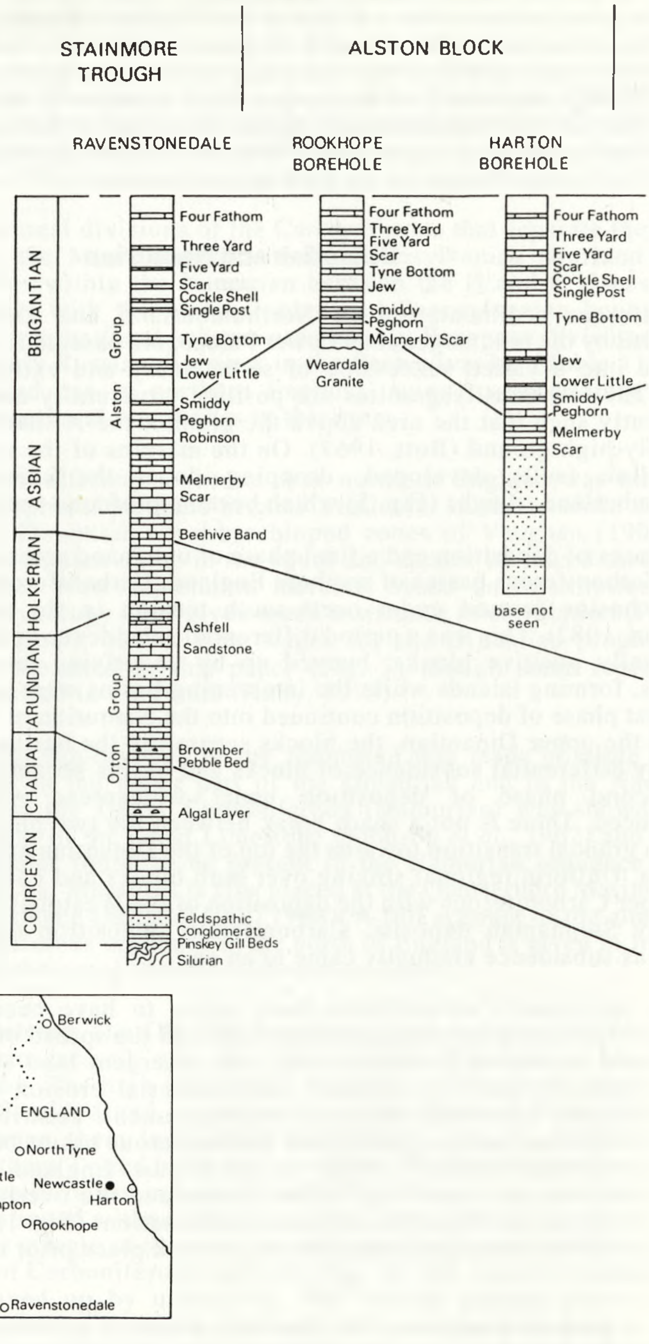
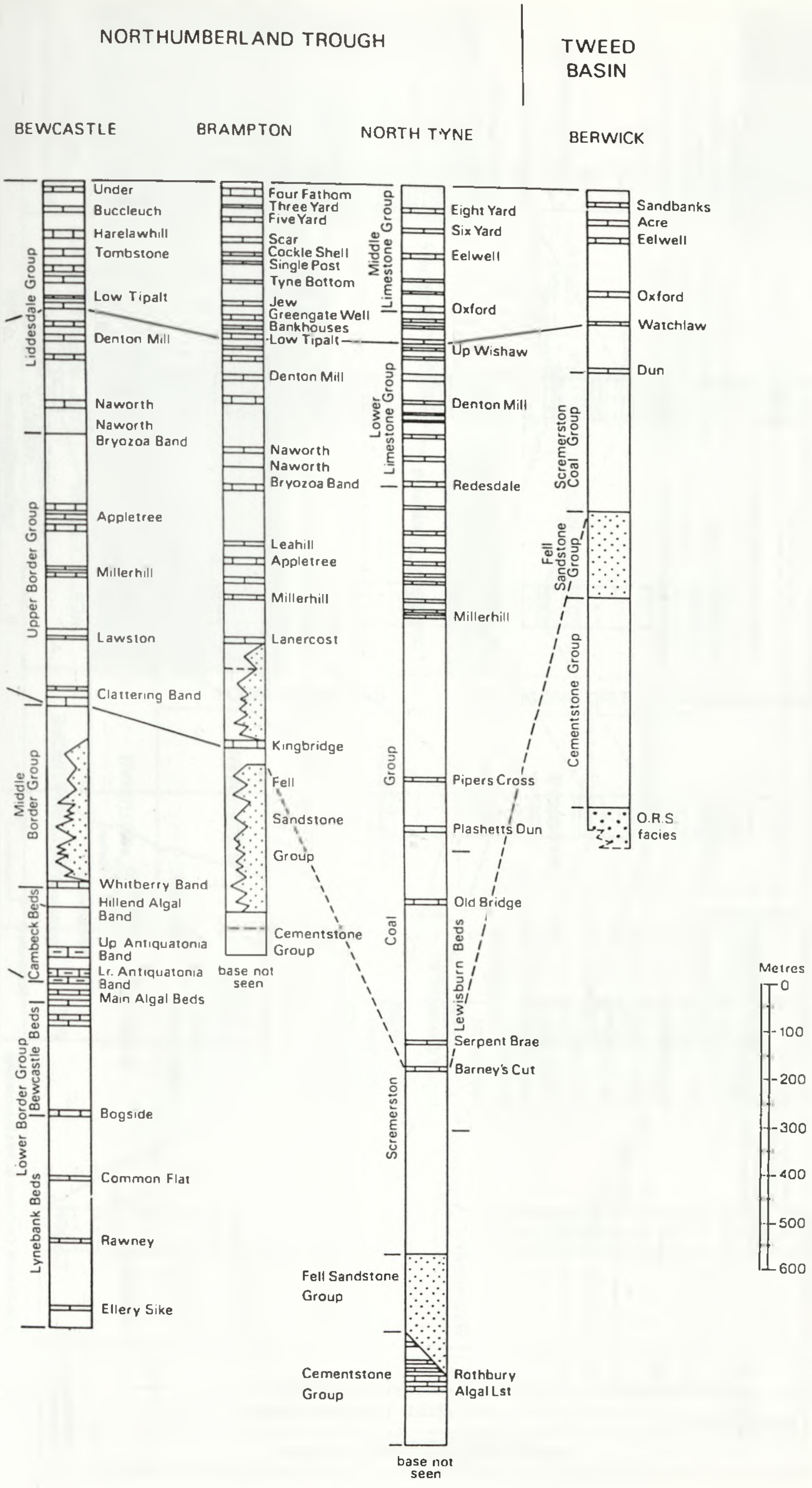


Fig. 3 Comparative vertical sections of Dinantian strata in north-east England.



NORTHUMBERLAND TROUGH
TWEED BASIN
BEWCASTLE
BRAMPTON
NORTH TYNE
BERWICK
Under
Buccleuch
Harelawhill
Tombstone
Low Tipalt
Denton Mill
Naworth
Naworth Bryozoa Band
Appletree
Millerhill
Lawston
Clattering Band
Whitberry Band
Hillend Algal Band
Up Antiquatonia Band
Lr. Antiquatonia Band
Main Algal Beds
Bogside
Common Flat
Rawney
Ellery Sike
Liddesdale Group
Upper Border Group
Middle Border Group
Cambeck Beds
Bewcastle Beds
Lower Border Group
Lynebank Beds
Four Fathom
Three Yard
Five Yard
Scar
Cockle Shell
Single Post
Tyne Bottom
Jew
Greengate Well
Bankhouses
Low Tipalt
Denton Mill
Naworth
Naworth
Bryozoa Band
Leahill
Appletree
Millerhill
Lanercost
Kingbridge
Fell
Sandstone
Group
Cementstone
Group
base not seen
Middle Limestone Group
Lower Limestone Group
Scremerston Coal Group
Eight Yard
Six Yard
Eelwell
Oxford
Up Wishaw
Denton Mill
Redesdale
Millerhill
Pipers Cross
Plashetts Dun
Old Bridge
Lewisburn Beds
Serpent Brae
Barney's Cut
Fell Sandstone Group
Cementstone Group
Rothbury Algal Lst
base not seen
Sandbanks
Acre
Eelwell
Oxford
Watchlaw
Dun
Scremerston Coal Group
Fell Sandstone Group
Cementstone Group
O.R.S. facies
Metres
0
100
200
300
400
500
600

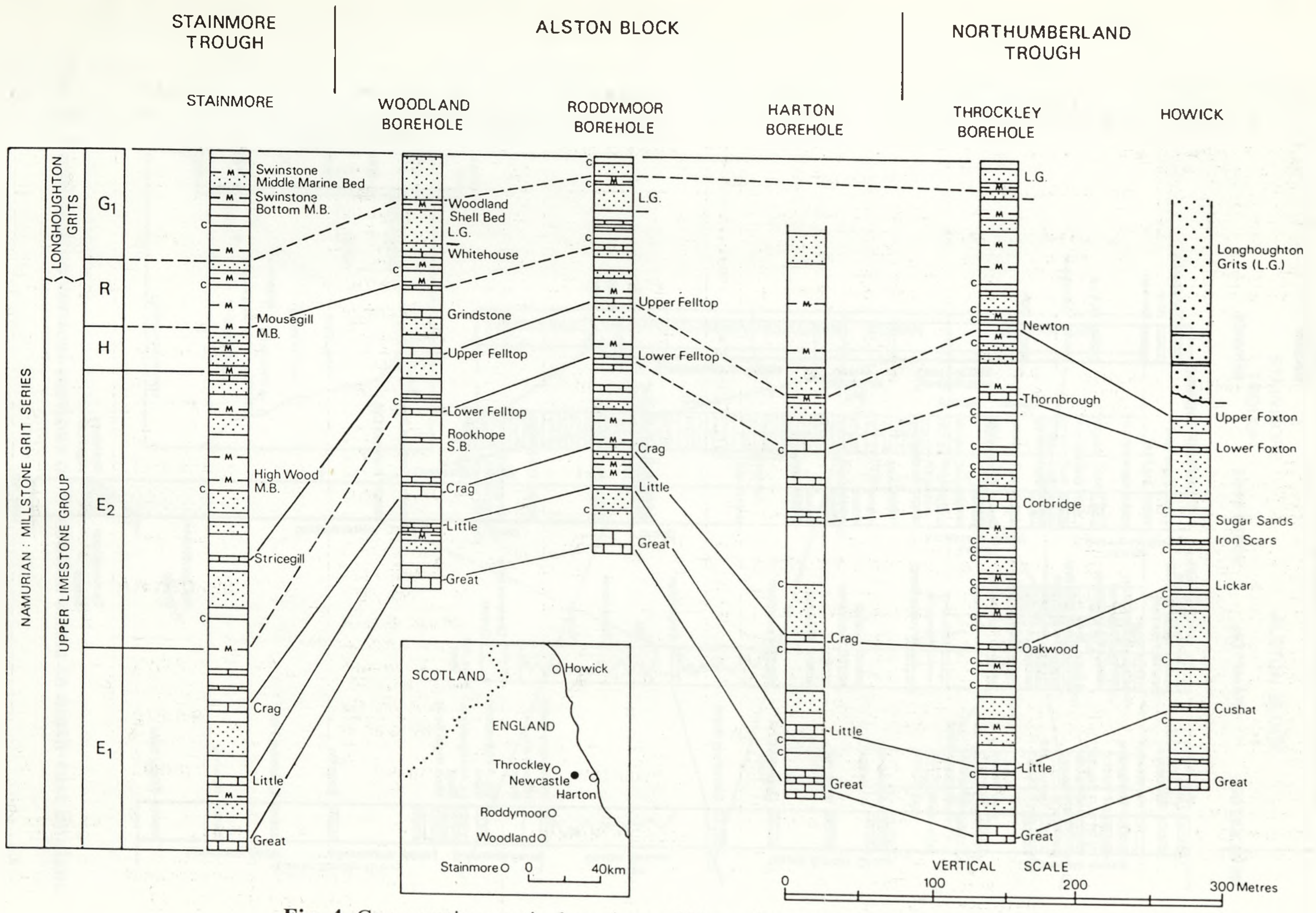


Fig. 4 Comparative vertical sections of Namurian strata in north-east England.

Table 1. Classification of Carboniferous rocks. Stipple indicates breaks in succession (partly after Harland *et al.*, 1982).

CARBONIFEROUS PERIOD (International Divisions in part provisional)				CARBONIFEROUS SYSTEM (Regional Divisions)					
PERIODS & SUBPERIODS		EPOCH	AGE	WESTERN EUROPE			NORTHUMBERLAND BASIN: WEST - CUMBRIA	NORTHUMBERLAND BASIN: EAST - NORTHUMBERLAND	NORTHERN PENNINES ALSTON BLOCK
PERMIAN			ASSELIAN	AUTUNIAN					
CARBONIFEROUS	PENNSYLVANIAN	GZELIAN	NOGINSKIAN	SILESIAN	STEPHANIAN	COAL MEASURES			
			KLAZMINSKIAN						
		KASIMOVIAN	DOROGOMILOVSKIAN						
			CHAMOVNICHESKIAN						
			KREVYAKINSKIAN						
		MOSCOVIAN	MYACHKOVSKIAN				UPPER COAL MEASURES	UPPER COAL MEASURES	
			PODOLSKIAN		WESTPHALIAN		MIDDLE COAL MEASURES	MIDDLE COAL MEASURES	
			KASHIRSKIAN						
			VEREISKIAN						
		BASHKIRIAN	MELEKESSKIAN				LOWER COAL MEASURES	LOWER COAL MEASURES	
			CHEREMSHANSKIAN						
			YEADONIAN		NAMURIAN	MILLSTONE GRIT			STAINMOOR GROUP
			MARSDENIAN				MILLSTONE GRIT SERIES	UPPER LIMESTONE GROUP / MILLSTONE GRIT SERIES	
			KINDERSCOUTIAN						
	MISSISSIPPIAN	SERPUKHOVIAN	ALPORTIAN						
			CHOKIERIAN						
			ARNSBERGIAN						
			PENDLEIAN						
		VISEAN	BRIGANTIAN	DINANTIAN	VISEAN	CARBONIFEROUS LIMESTONE	UPPER LIDDESDALE GROUP	MIDDLE LIMESTONE GROUP	UPPER ALSTON GROUP
			ASBIAN				UP BORDER GROUP / LR LIDDESDALE GROUP	LOWER LIMESTONE GROUP	LOWER ALSTON GROUP
			HOLKERIAN				MIDDLE BORDER GROUP	SCREMERSTON COAL GROUP	ORTON GROUP / BASEMENT GROUP
			ARUNDIAN					FELL SANDSTONE GROUP	
			CHADIAN				LOWER BORDER GROUP	CEMENTSTONE GROUP	
		TOURNAISIAN	IVORIAN		TOURNAISIAN				
			HASTARIAN					OLD RED SANDSTONE FACIES	
DEVONIAN			FAMENNIAN	STRUNIAN					

1984; Bott, 1987). The resulting extension of the upper crust caused the graben basins to form (Fig.17, p330).

Towards the end of the Dinantian, differential subsidence changed towards more uniform regional downwarping. This regional sinking has been referred to McKenzie's (1978) thermal subsidence hypothesis, that sinking caused by stretching of the crust leads to slow thermal subsidence and that the amount of subsidence in each case is comparable. Extensional thinning of the lithosphere caused rise in temperature at depth and subsequent cooling allowed thermal subsidence to take place. Thus the extension of the crust in the first phase of Carboniferous deposition led to a second phase of slow regional sinking owing to the thermal subsidence. This mechanism was modified by Bott *et al.* (1984) and Bott (1987) who emphasize the importance of tensional stress in the crust and lithosphere and suggest that thermal subsidence is a subordinate effect. There is uncertainty in our understanding of the subsidence mechanism forming the Carboniferous basins owing to lack of data, but the changes in subsidence pattern, from differential movement to regional sinking at the top of the Dinantian, is genuine.

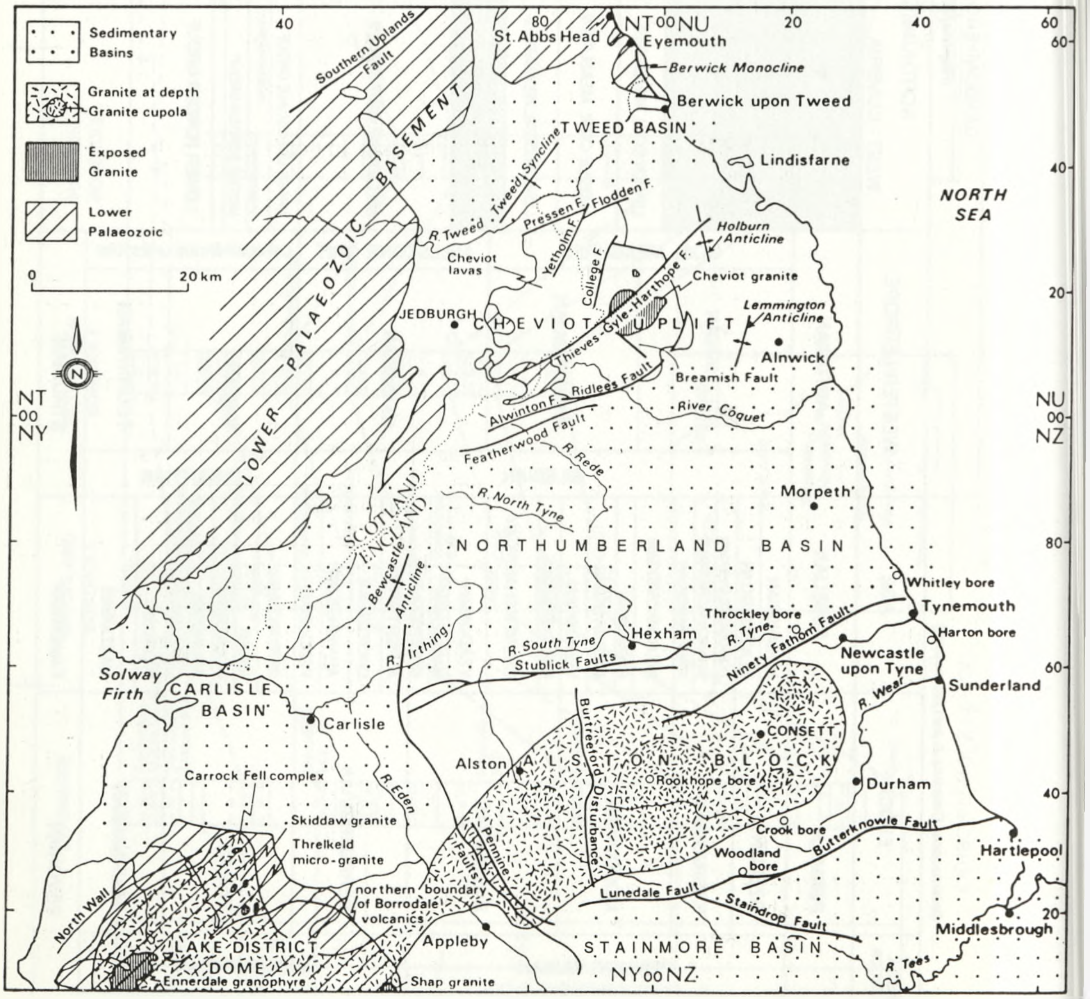


Fig. 5 Map showing the uplifted and basinal areas in north-east England and adjacent regions, in Carboniferous times (in part after Bott, 1967, 1974).

During most of the Dinantian, distribution of sediment in the graben basins of northern England was dependent on interplay of clastic detritus spreading from the north and east and marine deposits spreading from the south and west. The marine influence was only dominant in the upper Dinantian and lower Namurian when limestone was laid down throughout the region. Outside this interval the spread of clastic sediment from uplands to the north and east was the dominant influence with marine deposits tending to fail when traced northwards. Thus the massive Great Scar Limestone of Yorkshire divides into a sequence of clastic and carbonate bands in the Stainmore Basin (Burgess & Mitchell, 1976) and the massive Asbian Melmerby Scar Limestone of the Alston Block similarly divides northwards into a clastic-carbonate succession at the latitude of Cross Fell (Trotter & Hollingworth, 1932; Burgess & Wadge, 1974).

In the overlying Asbian and Brigantian the alternation of marine carbonates spreading northwards and clastic detritus spreading southwards continues and produces a sequence of widespread sedimentary cycles that occur throughout northern England (Fig. 3, Table 2). This cyclic succession was described by Forster (1809) and called the Yoredale Series by Phillips (1836). The individual cycles of limestone, shale and sandstone are repeated at least ten times before the top of the

Table 2 Correlation of the principal Brigantian limestones in north-east England

	Dunham & Wilson 1985	Burgess & Holliday 1979	Dunham 1990	Johnson 1959 Frost 1984	Frost 1969	Fowler1936	Carruthers *et al.* 1930	Carruthers *et al.* 1927	Gun & Clough1895	Fowler1926
	Askrigg Block	Stainmore	Alston Block	South Northumberland	Otterburn	Rothbury	Alnwick	Beadnell	Ford	Berwick
PENDLEIAN	Main	Great	Great	Great		Great	Great	Dryburn	Dryburn	Dryburn
BRIGANTIAN	Underset	Four Fathom	Four Fathom	Four Fathom		Eight Yard	Sandbanks or Eight Yard	Sandbanks	Lowdean	Sandbanks
	Three Yard	Three Yard	Three Yard	Three Yard		Six Yard	Acre or Six Yard	Acre	Acre	Acre
	Five Yard	Five Yard	Five Yard	Five Yard or Eelwell		Eelwell	Eelwell or Nine Yard	Eelwell	Eelwell	Eelwell
	Middle (upper part)	Scar	Scar	Scar or Shotto Wood, Up. & Lr. Bath House Wood		*strata with six or seven thin limestone bands*	*strata with thin limestone bands*	*strata with five or six thin limestone bands*	*strata with six thin limestone bands*	*strata with six thin limestone bands*
	Middle (central part)	Cockle Shell	Cockle Shell	Cockle Shell						
	Middle (lower part)	Single Post	Single Post	Single Post or Colwell and Dalla Bank						
	Simonstone	Tyne Bottom	Tyne Bottom	Tyne Bottom or Haughton & Barrasford						
	Hardrow Scar	Jew	Jew	Jew (Oxford)	Oxford	Oxford	Oxford	Oxford	Oxford	Oxford
	Gayle	Lower Little	Lower Little	Lower Little or Greengate Well	*limestone horizons absent*	*strata not exposed*	*strata not exposed*	*strata with two thin limestones*	*strata with one thin limestone*	*strata with one thin limestone*
	Hawes (upper part)	Smiddy	Smiddy (Up. Smiddy)	Bankhouses or Up.& Mid. Bankhouses						
	Hawes (lower part)	Peghorn	Peghorn (Lr. Smiddy)	Low Tipalt or Lr. Bankhouses	Watchlaw			Watchlaw	Watchlaw	*not seen*

Dinantian and were called cyclothems in the Pennines by Dunham (1948) following Wanless & Weller (1932). The origin and mode of formation of Yoredale cyclothems have received much attention with two main hypotheses being put forward, either sedimentary basin processes or major eustatic sea-level changes. Current understanding favours processes within the sedimentary basin with downwarping causing marine transgression followed by regression as prograding clastic sediment build up to sea-level and form delta flats (Dunham, 1950; Johnson, 1984; Leeder & Strudwick, 1987).

In detail the succession of Yoredale cyclothems is complicated by the presence of similar, but smaller minor cycles often towards the top of the major cycle units (Johnson, 1959, 1984). A standard correlation of major cycles has been established for many years throughout northern England and is shown on Fig. 3 and Table 2. However, the presence of minor cycle limestones gives potential for alternative correlations locally, particularly in south Northumberland where some of the limestones thin and split northwards towards the shoreline, making the standard sequence more difficult to decipher (Johnson, 1959). Thus the correlation of the sequence between the Tynebottom and Three Yard cyclothems from the Alston Block northwards to the Northumberland Trough was revised by Holliday *et al*, (1975) and Frost & Holliday (1980, Fig. 15). This led to confusion in terminology and in establishing the standard sequence of cyclothems, but it was further revised by Frost (1984) who showed that the original pattern of correlation of cyclothems should be adhered to in this region. The alternative correlations have recently been reviewed by Dunham (1990, p37) who recommended that the traditional correlation of cyclothems (Table 2) should be maintained.

Interpretation of the environment of deposition of Yoredale cyclothems has advanced in recent years with the recognition of river dominated prograding delta lobes with mouth bar, bay, levée, crevasse, lake and distributary channel facies (Elliott, 1974, 1975). A coarsening upwards siliclastic sequence is developed in each cycle. Main river channels and distributary channels that carried clastic sediment into the Carboniferous basins have been recognized particularly at the base of the Namurian (Dunham, 1990; Hodge & Dunham, 1991). Yoredale limestone bands are normally open offshore shallow deposits rich in fossils and the debris of fossils. Light grey coloured limestones characterize the Dinantian succession below the upper Asbian, but above this dark grey and black limestones enter and, with exceptions, tend to persist until the end of limestone deposition high in the Namurian. Special environments of deposition have been reported such as storm and wave dominated cycles adjacent to the Cheviot and Southern Uplands shore lines (Reynolds, 1992). Carboniferous deposition in the basins and on the blocks in north-east England is briefly described in the following paragraphs.

(a) **In the Stainmore Basin** (Fig. 5) initial deposition was composed of shallow marine shales, dolomitic limestones and fluviatile red sandstones and shales. This was followed by shallow marine carbonates which continue from the Chadian to the top of the Asbian, with a few horizons of interbedded sandstone and shale. Cyclic limestone, shale and sandstone of Yoredale facies begin in the Brigantian stage and persist through much of the Namurian with increasing dominance of shale and sandstone in upward succession (Figs 3, 4). Characteristic delta-lobe sediments and a barrier island sandstone body have been recognized in the clastic sequence above the Great Limestone of the Alston Block-Stainmore region (Elliott, 1975). With decrease of the marine element and increase in the development of terrestrial delta-flat conditions, the Coal Measures with productive coal seams were developed.

(b) **On the Alston Block**, divided from the Stainmore Basin by the Lunedale-Staindrop hinge line (NY 900202), the Carboniferous succession is thinner and deposition did not commence over the central region until the

Asbian, though the margins of the block were submerged rather earlier (Dunham *et al.*, 1965; Johnson & Dunham, 1963; Burgess & Harrison, 1967; Ridd *et al.*, 1970). The initial transgressive phase fills hollows in the uneven topography of the block with conglomerate, sandstone, shale and limestone bands. Above this the sequence is similar to the Stainmore trough except that the massive Melmerby Scar Limestone (Asbian) tends to be split by bands of sandstone and shale towards the north and centre of the Alston Block. Massive carbonates are not traced nearer to the northern shore line than about the latitude of Cross Fell (NY 687344). Yoredale facies deposition is well developed on the Alston Block and has been described in Johnson & Hickling (1970). The Longhoughton Grits are also well developed over the Alston Block and have been divided into the First, Second and Third grit bands over a large part of the region.

(c) **The Vale of Eden and Lake District**, lying to the west, are connected to the Alston Block by a basement ridge (Fig. 5). This was called the Ullswater anticline by George (1958) and has been shown to be underlain, in part, by a subsurface granite connection between the Lake District and Weardale batholiths (Bott, 1974). The Lake District and the Alston Block appear to have behaved as one structural unit during the deposition of the exposed Carboniferous succession and movement on the Pennine faults, which separate the two blocks at the present day, is late or post Carboniferous (Rowley, 1969; Bott, 1974). Apart from the basement beds, which are partly Devonian and thicken to 275m of sandstone and conglomerate about Mell Fell (Kimber & Johnson, 1986), the Carboniferous sequence of the Vale of Eden is much the same as that of the Alston Block and marker horizons are continuous. The Lake District is surrounded by Carboniferous sediments that dip off the block in all directions. It is possible that the block has been unroofed of Carboniferous deposits, but more likely that it remained an island throughout the period (Johnson, 1992). There is a change of facies towards more fully marine conditions when the Dinantian is traced round the margin of the Lake District towards the north-west. Here, in West Cumbria, the Dinantian sequence is 274m thick and composed of carbonate with subordinate mudstone and sandstone (Johnson, 1992). The lowest limestone is late Chadian in age followed by thick Holkerian carbonates and the intervening Arundian is absent in the district (Barclay *et al.*, 1994). After variable thin basal conglomerates, the Cockermouth lavas, olivine-basalts, up to 100m thick, underlie the carbonate sequence. The marine limestone members are numbered from the top downwards Second to Seventh; the First Limestone is of Namurian age. The succession shows subdued cyclic deposition and the Brigantian part can be correlated in detail with the Yoredale cyclothems of the Alston Block to the east. The overlying Namurian is 60 to more than 500m thick and is incomplete, owing to a pause in sedimentation near the top. The Coal Measures sequence of west Cumberland is condensed, but is broadly similar to that found in Northumberland and Durham.

(d) **The Northumberland Basin** is separated from the Alston Block by the Stublick-Ninety Fathom fault system and the Carboniferous succession augments in thickness greatly across this line (Fig. 5). The base of the Carboniferous is not seen in the south of the trough, but in the north it succeeds the Upper Old Red Sandstone without break. In fact the precise base of the Carboniferous in the Border region is uncertain. In some regions Upper Old Sandstone fluviatile red beds and cornstones are intercalated in undoubted Lower Carboniferous sediments (Leeder, 1973). In the west, Old Red Sandstone red beds are separated from marine Carboniferous by the Birrenswark lavas and the base of the Carboniferous is taken by tradition at the base of the lavas. According to Hickling & Robertson (1949) a sequence of strata at Carter Bar is mapped by the Geological Survey as Old Red Sandstone on the north of the Border and Carboniferous on the south. The passage from Old Red Sandstone to Carboniferous marine facies is clearly a variable horizon. The lowermost Carboniferous in the east of the region is believed to be in Old Red Sandstone facies, on miospore evidence (Wilson, 1974).

The lowest formation in the Carboniferous of the Northumberland basin is the Cementstone Group which follows the Upper Old Red Sandstone and overlaps on to pre-existing hills at Cheviot where a coarse basal conglomerate is present at Roddam Dene (NU 025205). Situated on the eastern flanks of the Cheviot hills some 10km south of Wooler, the conglomerate is best exposed in the steep-sided valley incised by Roddam Burn. The sequence is approximately 150m thick, and comprises diamict conglomerate, sandstone, siltstone and mudstone in a broadly fining-upwards sequence. The formation is notable for stacked, fining-upwards packages of boulder to pebble conglomerate bearing many sedimentary structures, including channel scours, cross-bedding, small sandy channels and bar-top sand and silt lenses. The lower units are clast-supported, but progressing up the sequence, the average clast size decreases and proportion of pebbly sand matrix increases, so that matrix-support supersedes. This sequence is typical of deposition by bedload streams on an alluvial fan. Despite its proximity to the granitic core of the Cheviot volcanic massif, the clast composition is dominantly andesite, with subordinate proportions of granophyre and granodiorite. Recent work indicates palaeocurrent flows from the north to north-west, where the eroded sediment source would have been andesitic lava flows, in accordance with the observed compositional trend.

The overlying finer grained facies have a sharply erosional base, and well defined channel sandbodies are entrenched into coarse cobble conglomerate. The basal sands are litharenites with clast composition similar to that of the preceding conglomerate, but palaeocurrent flow to the east or south-east is now consistently observed. The channel sands rapidly grade up into horizontally-bedded red silty sand bearing asymmetrical ripples and interference ripples as evidence of a protracted period of shallow water, low energy deposition, perhaps in a lacustrine environment. These beds grade up into massive red silts and muds with horizontal reduction layers and occasional cemented gravelly sand beds. The conglomerate is taken to be basal Carboniferous, though the base is concealed, and no lateral exposure can be traced; the previously noted similarity between the finer grained facies and deposits of the Cementstone Group is entirely superficial. The Roddam Dene conglomerate is interpreted as an alluvial fan deposit, its development probably controlled by movement on local faults. The overlying sandy deposits appear to result from the evolution of a different fluvial system after cessation of fault activity.

The Cementstones consist of a sequence of shale and impure limestone bands that are lagoonal or estuarine in the north, but become more marine when traced westward towards Bewcastle (NY 565747). Marine facies become progressively reduced when traced to the north and east. This change affects all Dinantian and Namurian strata in the Northumberland basin and results in an eastward and northward reduction in the stratigraphically-useful fauna. Consequently there are difficulties in making a detailed correlation of the succession across the region, particularly towards the bottom of the sequence. Algal limestones are well developed towards the top of the Cementstones and are exposed at Rothbury (NU 056017). A widespread shallow-water marine or lagoonal environment developed in the Northumberland basin at this time, as the algal limestones can be correlated with a fair degree of certainty with those of Carter Fell (NT 671033) and Bewcastle (Day *et al.*, 1970).

The Fell Sandstone Group overlies the Cementstones with a diachronous base; the group appears to rise up the succession westwards (Fig. 3). The Cambeck Beds of Bewcastle are apparently cut out by the Fell Sandstones in Redesdale and Rothbury (Day *et al.*, 1970). The Fell Sandstones are typically massive medium-grained sandstones of white, buff or reddened colour interbedded with very infrequent red, purple or greenish-grey silty mudstones. The succession is largely unfossiliferous, but ostracods and the large bivalve *Archanodon jukesi* (Bailey) have been recorded together with some recognizable plant fossils. Cross-bedding is developed in the Fell Sandstones and indicates a derivation of clastic sediment from the north and east. The sandstones were formed in a wide basin in which fluvial conditions were dominant but in which aeolian beach dune and littoral beach sands have also been identified (Robson, 1956; Hodgson & Scott, 1970). In more detail, the Fell Sandstone is believed to have been deposited by a large braided-river complex which drained westwards into a shallow, low energy tideless sea (Turner *et al.*, 1993). Lateral facies changes cannot be assigned simply to a relationship of distance from source and it is suggested that these changes were caused by fluviatile drainage through active tilted fault blocks in the floor of the basin. The Fell Sandstone appears to have been deposited by several axial braided rivers in discrete intrabasinal grabens. Tectonism, rather than eustatic effects controlled sandbody extent and the sandbody is not a basinwide sheet sandstone.

The upper junction to the Fell Sandstone Group is similar to the lower in that it is diachronous and grades into the Scremerston Coal Group. Deposition during the Scremerston was in a delta-flat environment with cycles of sedimentation laid down consisting of, in ascending order, argillaceous limestone, shale, quartzitic sandstone, seatearth and coal. The group is more marine in facies in the west and becomes more deltaic in the east and north. Workable coals are up to 2m thick in the North Tyne-Rede area and in north Northumberland have been mined extensively. The limestone bands contain a restricted coral-brachiopod fauna which is sufficient to show that the base of the Asbian lies near the Barney's Cut Limestone (Fig. 3). The group is believed to be at its maximum thickness in this region with possibly some 1500m of sediments (Day *et al.*, 1970), but this may be an overestimate. To the north the group thins considerably towards the Cheviot axis.

The top of the Scremerston Coal Group is taken at the Redesdale Limestone in the North Tyne and Rede valleys, but this horizon dies out northwards so that in north Northumberland the boundary is taken at the Dun Limestone which is about 100m higher in the succession; this boundary is again diachronous.

A lithological change towards the top of the Asbian, marking the base of the Lower Limestone Group, is the entrance of Yoredale facies with well-developed sedimentary cycles of the type: marine limestone, shale, sandstone, seatearth and coal. The limestones are thicker, more persistent laterally and were laid down under more open marine conditions than those of the underlying Scremerston Coal Group. Shoreward thinning and dying out of limestone bands continues into the Lower and Middle Limestone groups and in north Northumberland only the thicker and most persistent horizons are present (Table 2). Of these the Oxford (= Jew) Limestone is a particularly important marker horizon (Gunn, 1898; Johnson, 1959).

In the area of the Ottercops (NY 950900) and between the rivers Rede and North Tyne, several of the sedimentary cycles contain formations of massive, non-micaceous sandstones, each at least 20m thick, which form such crags as Great Wanney (NY 932835) and the Ottercops themselves. Topographically they resemble the features formed by the Fell Sandstones and, indeed, in the early days they were thought to belong to that group. The top of the Lower Limestone Group is taken at the Oxford Limestone in north Northumberland,

and in the North Tyne and Rede valleys, but at the Bankhouses Limestone, some 70m lower in the succession in south-west Northumberland; the boundary, as defined at the present time, is diachronous.

The Middle Limestone Group at the top of the Dinantian is composed of at least ten well-developed and laterally persistent Yoredale cyclothems (Table 2). They can be correlated with fair precision throughout the Northumberland basin and southwards on to the Alston block (Fig. 3). The Great Limestone at the top is an excellent stratigraphical marker over the Northumberland basin and can be correlated throughout northern England. It represents a lengthy quiescent interval during which marine deposition continued uninterrupted across northern England. It forms the base of the Upper Limestone Group and is known to be of basal Namurian age on fossil evidence.

The Upper Limestone Group continues the Yoredale facies of deposition in the Northumberland basin, but with an increase in the proportion of clastic sediment. Limestone bands contain marine coral-brachiopod faunas up to the Newton, and shelly marine bands continue above this to the base of the Coal Measures (Fig. 4). Upper Limestone Group sedimentation has been interpreted as indicating deposition in river-dominated, interdistributary bay complexes (Elliott, 1976).

In the area of the Shaftoe Crags (NZ 053825) there is an impressive development of non-micaceous sandstone above the Little Limestone. This formation is coarse, and in part conglomeratic with very well-developed cross-bedding. It can be traced northwards to Rothley (NZ 046907) and south-westwards to the village of Ingoe (NZ 038748). Thereafter it is represented in the sedimentary sequence by medium-grained, occasionally massive but frequently micaceous, thin-bedded sandstones, which are more characteristic of the normal sequence. At the top of the Limestone Group. sandstone and grit deposition of the Longhoughton Grits dominates the succession in a similar fashion to that of the Alston Block in the south, though the individual sandstone and grit bands cannot be traced through the region. Following this arenaceous facies, the productive Coal Measures were laid down without break in succession.

(e) **The Tweed Basin**, to the north of the Cheviot axis, contains Lower Carboniferous sediments up to the Great Limestone, but little Namurian, Upper Limestone Group, strata (Figs 3, 5). Traced north from the Northumberland trough the Dinantian succession thins in the vicinity of Cheviot and then thickens into the Tweed Basin (Johnson, 1984). All the major stratal groups of the south are present. The Cementstones continue sedimentation from the Old Red Sandstone without break and are believed to be some 430m thick (Smith, T. E., 1967) rather than 900m suggested by earlier workers. The Fell Sandstones are composed of thick quartzitic sandstone bands with shale partings, in total some 250m thick, and the Scremerston Coal Group, which thins to the south over the Cheviot ridge, augments in thickness again in the Tweed basin to some 275m near Berwick. The sequence is arenaceous with notable phases of delta-swamp deposition which allowed about ten exploitable coal seams to form. Similarly, in the Lower and Middle Limestone groups coal seams are better developed towards the top of the cyclothems and are locally workable. The marine limestones, on the other hand, are thinner than in the south and tend to be split by shale bands. The nearer proximity of the northern shore line is indicated by the increased importance of the coal swamp phase and decrease of the marine limestones throughout the succession in the Tweed Basin.

(f) **Offshore in the North Sea Basin** the Dinantian starts with a continental red bed succession that continues Old Red Sandstone deposition without break. Dominantly clastic facies follow with interbedded limestones in the Courceyan to Arundian interval and thick sandstones, comparable with the Fell Sandstone Group of Northumberland, but persistent over a much wider time span. A thick Asbian and Brigantian sequence has been proved near to the southern margin of the Mid North Sea High with interbedded limestone and clastic sediments of a Yoredale-like sequence (Fig. 2). As in the onshore region of north-east England the Brigantian seems to be constant in facies and widely persistent over much of the southern North Sea. At the south of the Mid North Sea High, Namurian deposits are of similar facies to the underlying Brigantian as is found in onshore Northumberland. Pendleian and possibly Arnsbergian deposits have been proved of shallow water delta facies.

Namurian cover over the Mid North Sea High was probably thin and little information is available. It forms a broad belt flanking the Dinantian on the southern margin of the High and occurs in the cores of at least five major south-east plunging anticlines. Significant penetrations of the Namurian below the Westphalian have been made in the Southern North Sea basin in quadrants 43, 44 and 48 (Fig. 2). Major Namurian depocentres are present in quadrants 41, 43 and 48 where the maximum thickness exceeds 2000m. During the Namurian, the Southern North Sea basin was progressively filled with sediments starting with deep water anoxic black shales and continuing to delta front turbidites, delta front deposits and finally delta top fluvio-deltaic channel sands. The fluvio-deltaic deposits are comparable with the celebrated Namurian grits, Kinderscout, Ashover, Chatsworth, Rough Rock etc. of the Pennine Basin. They are the product of south-west progradation of successive fluvio-deltaic channel sandbodies frequently interrupted by rapid marine incursions.

Correlation of the Dinantian sequence

The Dinantian rocks have proved difficult to correlate from the marine facies of the Ravenstonedale-Stainmore basin in the south and west to the more near-shore deltaic facies of north and east Northumberland. Correlation by coral-brachiopod zones Garwood (1913), Smith (1910) and Trotter & Hollingworth (1932) is unsatisfactory owing to the lack of index fossils north and east of the Alston Block. Microfossil evidence is beginning to give valuable assistance in dividing and dating the successions, but at the present time correlation is best achieved by using all the fossil and lithological evidence. Dinantian correlation currently uses an agreed framework of regional stages throughout the British Isles (George *et al.*, 1976). Evidence for the division and correlation of the Dinantian succession by regional stages is given in the succeeding paragraphs (Fig. 3).

(a) **The Courceyan stage**, the lowest stage of the Dinantian, was referred to as the Tournaisian by previous workers. At Ravenstonedale, in the Stainmore Basin, the Courceyan is exposed lying unconformably above the Silurian Bannisdale Slates (Fig. 3). The sequence consists of the Pinskey Gill Beds, interbedded shales, dolomitic limestones and impure fine-grained sandstones overlain by the Feldspathic Conglomerate division of red and green sandstones and shales with bands of pebble conglomerate. Garwood's Shap Conglomerate is exposed in Pinskey Gill and contains pink feldspar crystals composed of perthitic orthoclase similar to the phenocrysts of the Shap granite. Pseudomorphs after halite occur in sandy and shaly beds towards the base of the Pinskey Gill Beds and indicate early deposition under conditions of an evaporite basin. Courceyan age for the basal part of the Carboniferous succession in Ravenstonedale comes from miospores from the Pinskey Gill Beds (Johnson & Marshall, 1971). Chadian foraminifera have been recorded from the lowest limestones above the Feldspathic Conglomerate division (Ramsbottom, 1977); new miospore and conodont evidence supports these records (Varker & Higgins, 1979; Holliday *et al.*, 1979). Tournaisian miospores have been found in the Cementstones of

Berwickshire (Marshall in Johnson, 1967). The lowest two miospore zones are absent in Scotland and it is probable that at least part of the basal Dinantian is of Upper Old Red Sandstone facies (Wilson, 1974).

(b) **The Chadian** in Ravenstonedale lies above the Feldspathic Conglomerate division and is mainly composed of massive carbonates. It is equivalent, in coral-brachiopod zones, to the upper part of the C_1 Zone and the lower part of C_2S_1,bottom Viséan (George *et al.*, 1976). Chadian age is confirmed by foraminifera in Ravenstonedale but little other evidence is available (Ramsbottom, 1977). The top of the Chadian in Ravenstonedale has been placed slightly below the horizon of the Brownber Pebble Beds by George *et al.* (1976), but this interpretation needs revision according to Riley (1993). The Chadian base cannot be traced further north and east than Ravenstonedale at the present time. Chadian forminifera and conodonts have been recorded in the basal Lynebank Beds of Bewcastle (Ramsbottom, 1977) and more recent conodont and miospore records support this (Armstrong & Purnell, 1987; Purnell, 1992; Mahdi & Butterworth, 1994).

(c) **The Arundian** is equivalent, on the coral-brachiopod zones, to the upper part of C_2 plus S_1 (George *et al.*, 1976). In Ravenstonedale, this stage is indicated by the corals *Michellinia megastoma* (Phillips) and *Palaeosmilia murchisoni* (Edwards & Haime) together with the chonetid brachiopod *Delepinea carinata* (Garwood). The upper part of the stage becomes arenaceous with the deposition of the Ashfell Sandstone, a sandstone and shale sequence approximately equivalent in age to the Fell Sandstones of Northumberland (Fig. 3). The upper boundary of the stage cannot be correlated into the Northumberland basin but miospore evidence indicates the top of the Lower Border Group of Bewcastle is of Arundian to Holkerian age (Madhi & Butterworth, 1994).

(d) **The Holkerian** is mainly equivalent to S_2, of the coral-brachiopod zones, and is characterized in Ravenstonedale by the brachiopod *Davidsonina carbonaria* (McCoy) and by a diagnostic fauna of foraminifera. The stage cannot be correlated to the north and east of Ravenstonedale where the marine carbonates are restricted to thin bands in the succession.

(e) **The Asbian** base is an important boundary for correlation in north-east England (Fig. 3). The stage is mainly equivalent to D_1 on the coral-brachiopod zonal scheme. In Ravenstonedale the base of the Asbian is indicated by the entrance of *Dibunophyllum* with diagnostic foraminifera at the horizon of the Beehive Band (Fig. 3). Characteristic D_1 Zone faunas of corals and brachiopods, including *Lithostrotion junceum* (Fleming) *L. pauciradiale* (McCoy), *Gigantoproductus maximus* (McCoy), *Davidsonina septosa* (Phillips) and *Daviesiella llangollensis* (Davidson) occur in the Stainmore Basin and extend onto the Alston Block. In the Northumberland Basin the base of the Asbian is taken at the Kingbridge Limestone of Brampton which is the lateral equivalent of the Clattering Band of Bewcastle (Day *et al.*, 1970). Although many of the diagnostic corals and brachiopods do not occur in the sequence of the Northumberland Basin, a *Lithostrotion-Semiplanus* fauna enters at the base of the Asbian in the Clattering Band. This deduction of the base of the stage is supported to some extent by evidence from foraminifera (George *et al.*, 1976). Coral faunas decline eastwards and in the North Tyne the base of the Asbian is taken at the entrance of *Semiplanus* faunas in the Barney's Cut Limestone (Fowler, 1966). *Lithostrotion martini* enters at the Old Bridge Limestone and *Dibunophyllum* at the Plashetts Dun Limestone. There is no direct faunal evidence for the base of the Asbian in north Northumberland, but it is thought to lie in the vicinity of the base of the Scremerston Coal Group on miospore evidence from the south of Scotland (Wilson, 1974).

(f) **The Brigantian** is mainly equivalent to the D_2 and D_3 coral-brachiopod zones and is recognized throughout north-east England. The base of the stage is marked by the *Girvanella* Band in the Peghorn Limestone in Stainmore and the Alston block and this horizon can be traced to the Low Tipalt (= Upper Wishaw and Watchlaw) limestone of the Northumberland and Tweed basins (Fig. 3). A characteristic fauna enters at the base of the Brigantian including *Orionastraea* sp., *Lonsdaleia floriformis* (Martin), *Gigantoproductus giganteus* (Martin) and *Tornquistia polita* (McCoy). The top of the stage is taken at the base of the Great Limestone though the top of the Dinantian is probably slightly below this horizon.

Correlation of the Namurian sequence

During the last forty years important advances have been made in both the division and correlation of the Namurian succession in the north of England. The base of the Namurian was fixed near the base of the Great Limestone on goniatite evidence (Johnson *et al.*, 1962) and since then all the goniatite stages have been identified in the region (Hull, 1968; Johnson & Hickling, 1970). Correlation of the goniatite stages across northern England is difficult, but an interpretation was produced by Taylor *et al.*, (1971) and the correlation produced here (Fig. 4) is in general agreement with this. The recognition and correlation of the Namurian stages is briefly summarized in the following paragraphs.

(a) **The Pendleian Stage** (E_1) base approximates to that of the Great Limestone, with late P_2 age *Girtyoceras? costatum* Rupricht in the shales above the Four Fathom Limestone and *Cravenoceras leion* Bisat, low E_1, in the shales above the Great Limestone (Johnson *et al.*, 1962). This is backed by the discovery of *Eumorphoceras medusa* Yates, E_1 age, just above the Great Limestone in the Throckley bore (Richardson, 1966). This genus has also been recorded from the sandstones above the Great Limestone at Chollerford near Hexham (NY 937638) (Johnson, 1986). The precise base of the Pendleian is probably below the base of the Great Limestone, in arenaceous facies in which zonal fossils do not occur.

The Great Limestone at the base of the stage is one of the most characteristic and persistent horizons in the Carboniferous of northern England. Three persistent biostromes occur in the Great Limestone (Johnson, 1958). The *Chaetetes* Band, near the base of the limestone, is present throughout the region as is the central algal *Calcifolium* Band. Near the top of the limestone, but limited to the Alston block, the Frosterley Band is a coral biostrome mainly composed of *Dibunophyllum bipartitum* (McCoy). Above the Great Limestone several thin limestones and marine bands can be correlated with fair precision through the region (Fig. 4).

(b) **The Arnsbergian Stage** (E_2) base is dependent for its recognition on miospore data from the Woodland boring where an E_2 miospore assemblage was found above the Grindstone Limestone (Mills & Hull, 1968). Further evidence of E_2 age comes from records of *Tylonautilus nodiferus* (Armstrong) from the High Wood Marine Beds of Stainmore (Owens & Burgess, 1965) and the Styford Shales and Newton Limestone of south Northumberland (Hedley & Waite, 1929).

(c) **The Chokierian and Alportian Stages** (H_1 and H_2) seem to be thin in the north of England and are only known from miospore evidence from the Throckley boring and from Stainmore (Richardson, 1966; Owens & Burgess, 1965).

(d) **The Kinderscoutian Stage** (R_1) is well authenticated by goniatite records. The base is marked, above the Grindstone Sill of the Woodland boring, by the record of *Homoceras cf. henkei* H. Schmidt, and it occurs again in the Mousegill Marine Beds of Stainmore. *Reticuloceras stubblefieldi* Bisat and Hudson, R_{1b}, has been found above the Whitehouse Limestone of Stainmore and other species of *Reticuloceras* indicative of R_1 have been found in the Roddymoor boring (Hull, 1968).

(e) **The Marsdenian Stage** (R_2) is believed to be thin and it is only known from miospore evidence (Hull, 1968; Ramsbottom *et al.*, 1978).

(f) **The Yeadonian Stage** (G_1) with *Gastrioceras cf. cumbriense* Bisat, G_{1b} age, has been found in the Swinstone Middle Marine Band of Stainmore (Owens & Burgess, 1965), but apart from this record the only evidence of the stage comes from miospore work. The upper boundary of the stage is taken at the Quarterburn Marine Band which is inferred to be the equivalent of the *Gastrioeras subcrenatum* Marine Band at the base of the Coal Measures; this correlation is backed by miospore evidence (Neves *et al.*, 1965; Mills & Hull, 1968; Ramsbottom *et al.*, 1978).

CHAPTER 5

CARBONIFEROUS WESTPHALIAN COAL MEASURES

Introduction

This account of the Coal Measures describes the geology not only of the land region but also of that part of the offshore area of north-east England lying between high water mark and a line approximately 10km east of the present coastline, which extends from the vicinity of Druridge Bay southwards to Hartlepool (Fig. 7). Some notes are also given on the offshore Coal Measures lying further to the east in the North Sea Basin. Starting in 1958 British Coal explored the offshore region up to 10km from the coastline by geophysical surveys, boreholes from a moveable sea tower and from ships, while workings from the coastal collieries have proved new ground up to approximately 8km east of high water mark. The areas north of Druridge Bay and south of Hartlepool are not described as little new information has become available during recent years and the interpretation of the offshore geology must be based on seaward projection from the adjacent land areas.

The proportion of the land region of north-east England directly underlain by Westphalian strata is relatively small; less than one quarter. In Northumberland, it occupies a triangular area from Amble (NU 250045) in the north, where the landward coalfield is terminated by the west-to-east Hauxley fault, to Riding Mill (NZ 018614) in the west, with a string of small outliers continuing further west along the north downthrow side of the Stublick fault. In County Durham, east of a line through Ferryhill (NZ 288327) and Boldon (NZ 341611), and extending to the offshore area, the Westphalian strata are overlain by Permian, forming the concealed coalfield; but in the west they extend into the foothills of the Pennines to Tow Law and almost to Middleton-in-Teesdale (NY 950254). In the south of County Durham the Carboniferous strata are involved in a broad anticlinal structure and a marked northerly dip terminates the Westphalian against the overlying Permian unconformity.

The highest beds in the Westphalian succession occur in the area just west of Sunderland (NZ 364577) where a maximum thickness of around 900m of strata is present. The true base of the Westphalian, the *Gastrioceras subcrenatum* or Quarterburn Marine Band is poorly represented in the region, being known mainly from borehole evidence in County Durham. Much of the Upper Coal Measures, including the whole of the Stephanian, is absent. It is not known whether it was ever deposited or has been subsequently removed by the severe erosion which took place in pre- and early Permian times.

The area is on the whole not well exposed due to the thickness of overlying glacial drift. Only in the coastal exposures, particularly between Tynemouth (NZ 372690) and Seaton Sluice (NZ 340765), can good continuous sections of Westphalian strata be seen (Jones, 1967). Inland exposures are restricted to quarries, mainly in sandstone and ganister, with a few brick pits and incomplete river sections. Most of the geological knowledge of the succession has been derived from onshore and offshore borings, opencast and deep-mine coal exploration.

Conditions of deposition

The Westphalian of Northumberland and Durham comprises a series of deltaic sediments some 900m in thickness. Sandstones, siltstones and shales predominate, with many seams of coal and underlying seatearths. The palaeogeography of the region changed little from the underlying Namurian, the source of sediment being the Caledonian landmass to the north while the open sea retreated further south.

Between the landmass and the open sea stretched a vast delta in which were set 'islands' of non-deposition such as the English Midlands, north and central Wales and the Southern Uplands.

Although now separated by erosion, the coalfields of northern England are considered to have formed part of a continuous sheet of sediment rather than to have been deposited in individual sedimentary basins. There is no sign of facies change towards the margins of the coalfields, as would be expected in separate sedimentary basins, and the small outliers along the Tyne valley to Canonbie provide a link between east and west. It seems very probable that the whole of the northern Pennine area was overlain by Westphalian and the thickness of strata present in the Lower Coal Measures in the Midgeholme coalfield (NY 639588), which is situated on the very margin of the Alston Block, gives no suggestion of thinning towards this area.

Most of the Westphalian arenaceous sediments show a direction of deposition from the north, swinging from north-west, which is supported by evidence from palaeogeography. Some reverse current directions do occur and it is suggested that these can be related to local contemporaneous faulting within the region.

Although the Westphalian sediments form part of a continuous delta rather than a number of separate basins, the individual formations within the sequence are not of marked lateral continuity. The sandstones in particular are of very variable thickness, being in the form of lenses or channel fillings. The coals, too, are incapable of being traced over large distances and individual seams cannot usually be traced for more than 20km without changing in character by splitting or impoverishment. Only the few marine horizons in the succession, which indicate incursions by the sea, can be considered to be laterally continuous, and as such are used for correlation between coalfields (Calver, 1968).

Recent studies on deposition of the Westphalian Coal Measures of the Durham Coalfield show that the sedimentary sequence was laid down on a broad flat deltaic plain. This is part of a much larger Pennine Westphalian province that covers much of northern England and is known to extend offshore both to the east and the west. In early Westphalian A times, a lower deltaic plain setting developed that was within the tidal zone and affected by basinal downwarping. By mid-Westphalian A southwards progradation of the delta had caused a change in the environment to an upper delta plain, above the tidal zone and unaffected by basinal processes (Fielding, 1984). Upper delta plain conditions of deposition, once established, persisted to the top of the exposed Westphalian Coal Measures with only a few marine incursions which might be of lower deltaic plain setting. The lower delta plain environment of deposition is marked by widely separated distributary channels and extensive interdistributary lakes and bays. A low density of channel sandstones is found and thin, but laterally extensive, coal seams. The upper deltaic plain environment develops many distributary channels and produces numerous channel sandstone bodies and thick, but laterally discontinuous, coal seams (Fielding, 1982). Primary red beds, formed under alluvial plain conditions that overlie upper deltaic plain deposits in the Midlands and Southern North Sea basin, are absent over the Northumberland and Durham coalfield owing to late Carboniferous and early Permian uplift and erosion.

Within the Westphalian sequence of the Durham coalfield, thirteen sedimentary lithofacies were recognized by Fielding (1982, 1984). The bulk of these are deposits of distributary channels and interdistributary bays consisting of sandstones, siltstones and claystones. Swamps developed over areas at or near to water-level with the accumulation of peat which was preserved to form coal seams. Near the base of the Westphalian and at the top of the Namurian there are marine, brackish and shoreline deposits with marine bands and quartz arenitic sandstone bodies of wave-reworked deltaic sand (sedimentary ganisters) (Percival, 1981, 1992). Control of Westphalian deposition in the Durham Coalfield is believed to be produced on

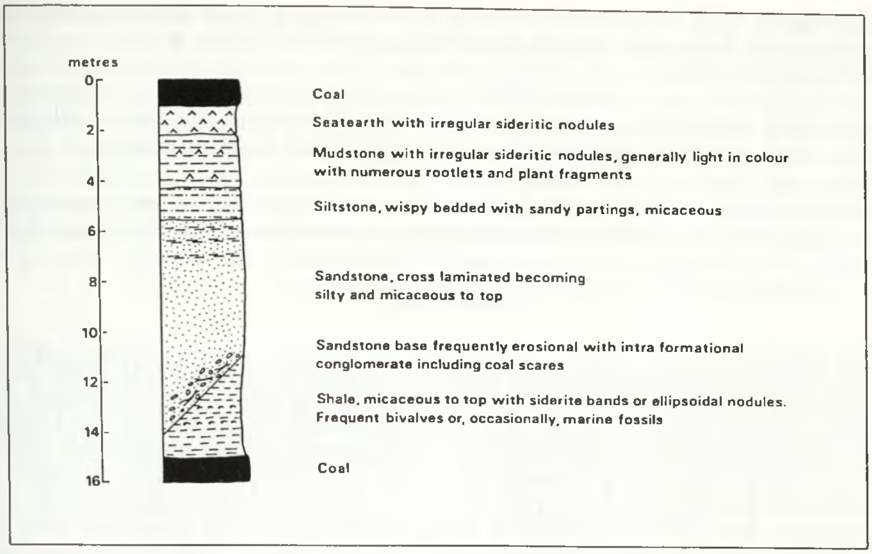


Fig. 6 Model of a typical Westphalian cyclothem.

the large scale by major delta progradation and delta switching, on the medium scale by subsidence produced structurally and by compaction of sediments, and on the small scale by local subsidence and sedimentary processes (Fielding, 1984). The thickest Westphalian coals are found in the Lower and Middle or Productive Coal Measures. They formed in the upper deltaic plain environment controlled mainly by compaction subsidence when not underlain by thick channel sandstone bodies (Fielding, 1984).

The Westphalian sediments are a cyclothemic series of deposits, very similar to those of the Namurian save that the marine influence has become diminished. The limestones and marine shell beds of the Namurian are replaced by horizons of non-marine bivalves or, in some cases, by marine bands containing *Lingula* and foraminifera. A typical Westphalian cyclothem (Fig. 6) has a thickness of the order of 15m, but with an appreciable variation which is largely dictated by the degree of development of the sandstone unit. A summary of the characters of the different lithologies making up the Westphalian cyclothem follows (Fig. 6):

(a) **The coal seams** are of bituminous rank and vary in thickness from a maximum of 3m, in places of seam junction, to thin coal traces; an average thickness is around 0.5m. The coals are bright with vitrinite dominant, especially towards the base of most seams. Cleat is usually strong, becoming very close in the higher rank coals of west Durham, which results in the seams becoming soft. Pyrite and ankerite are the most commonly associated mineral matter forming films on the cleat surfaces.

The thickness to which a coal seam is developed and its liability to splitting is dependent upon the rate of subsidence of the growing peat surface. Too slow a rate of subsidence, due to the presence of thick underlying sandstone which, unlike shale, is not subject to compaction, can result in impoverishment of the coal (Hopkins, 1933). Too rapid subsidence, arising from an excessive shale proportion in the underlying strata or from penecontemporaneous faulting, can lead to splitting of coal seams.

(b) **The shales with ironstone bands and marine marker horizons** directly overlie the coal. The shale is dark but tends to become lighter and more micaceous as the interval above the seam increases. The ironstone bands ('whin girdles' in older literature) are about 40mm thick, sideritic and laterally continuous over individual exposures. In some cases bands of ironstone are absent but, in their place, flat ellipsoidal nodules lie along consistent bedding planes.

Marine and non-marine shell beds are located in this part of the succession. In the case of marine horizons the diagnostic fossils are *Lingula* (generally very small), foraminifera and occasional *Orbiculoidea*. The Ryhope Marine Band has yielded *Anthracoceras* at a number of localities.

(c) **The sandstone unit** of the cyclothem may follow conformably, with gradual coarsening of the sediment from the underlying argillaceous lithologies. More often, however, there is some sign of disconformity at the base of the sandstone and frequently there is marked erosion. Washouts are not uncommon, the base of the sandstone cutting through the shale and ironstone bands and coming to rest on the roof of the underlying coal. The peaty substance of the embryo coal appears to have been resistant to water-scouring and the sandstone may form the roof of the coal over considerable distances. Once, however, erosion of the embryo coal starts, the whole bed of peat may be lifted and broken into mats of leathery material which are incorporated into the base of the sandstone as coal scares (Raistrick & Marshall, 1939). In many cases where coal seams have been worked, the line of washout channels has been traced in considerable detail. The coal scares form part of an intraformational conglomerate, with ironstone pellets and distorted shale fragments, which is incorporated into the base of the sandstone. At some horizons the conglomerate can be very impressive with shale fragments up to 1m in diameter and total thicknesses of conglomerate in excess of 10m.

The matrix of the intraformational conglomerate is fine to medium grain size although some sandstones, such as the Busty Grit and the Upper Crag Point Sandstone (Maudlin-Main), are of much coarser grain size and are regarded as main channel infillings. The absence of non-indigenous, coarse material within the conglomerate indicates an increase of water currents within the area of the delta, resulting from penecontemporaneous faulting or differential subsidence.

The sandstones show good cross-lamination and ripple features, usually indicating a depositing current of northerly origin. The cement is ankeritic with some included pyrite and there is a tendency for the formation of nodular concretions of siderite and ankerite within the body of the sandstone. These concretions, termed 'red horses' by the quarrymen, frequently show complete corrosion and replacement of the original quartz grains.

(d) **The upper argillaceous sediments** overlie the sandstones in the cyclothem. Towards the top of each bed of sandstone, the sediment steadily becomes more micaceous, with gradual intercalation of siltstones. There is a gradual passage, generally through flaggy beds, into siltstones and finally poorly-bedded mudstones with ironstone concretions. The concretions are rounded, but irregular in form; this is in marked contrast to the bands of ellipsoidal concretions in the shale which overlies the coal. This part of the succession is sometimes rich in plant remains, often fragmentary, the most common being *Calamites, Lepidodendron* and *Sigillaria* among equisetales and lycopodiales, with *Neuropteris, Alethopteris, Mariopteris, Pectopteris, Sphenopteris* and *Cyclopteris* among the pteridosperms.

(e) **Seatearth** is the consequence of a gradual transition upwards, as the bedding of the mudstone becomes increasingly disturbed by rootlets. The thickness of the seatearth is variable and does not appear to be directly related to the thickness of the overlying coal seam, but is probably more indicative of the height of the water table and the permeability of the sediment at the time of coal formation. In the Lower Coal Measures (Westphalian A), particularly in west Durham, the seatearths are of a sandy nature and are exploited commercially as ganister. Some of these have been shown to be A_2 (eluvial) horizons of podzolic palaeosols (Percival, 1982, 1983).

Correlation

A stratigraphical column through the Westphalian succession in Northumberland and Durham has been drawn up (Fig. 8). In the past, the nomenclature has given rise to confusion owing to difficulties of correlation and the antiquity of exploitation together with the geographical isolation of the early mining communities. British Coal has now standardized seam nomenclature and has given a series of index letters to the principal worked seams in the sequence. These, together with some of the older district names, have been included for reference purposes.

Difficulties of correlation occur mainly where seams cross major fault lines within the coalfield. Great emphasis was placed in the past upon the correlation between Northumberland and Durham when, in reality, the confusion arose where seams cross the Stublick-Ninety Fathom faults. Some seams change in character, split or die out as they cross major faults. This, particularly in Northumberland, has divided the coalfield into areas within each of which correlation is easy, but between which it is more difficult. These areas, three in number, lie respectively to the north of the Stakeford fault, between the Stakeford and the Ninety Fathom faults and to the south of the Ninety Fathom fault (Figs 1, 7, 18). The Harvey seam shows remarkable persistence over the whole coalfield; other seams are noted for their extreme variability. This is probably a reflection of the structural stability of the area at certain times during the formation of coals.

Although, as in other coalfields, the seams are scattered throughout the sequence, the main workable coals occur below the Ryhope Marine Band, in the lower part of the *similis-pulchra* Zone and in the *modiolaris* and *communis* zones. The sequence in these zones is condensed in the coalfields of north-east England; most of the workable seams are concentrated in the interval between the High Main to Victoria and are confined to 250m of strata. The Victoria Seam is approximately on the same horizon at the Arley Seam of Lancashire and lies just above the upper boundary of the *lenisulcata* Zone. Between the Victoria Seam and the Harvey Marine Band, the sequence is particularly condensed compared with the east Pennine coalfields and is characterised by thick quartzose-feldspathic rocks with the feldspars, frequently altered to kaolinite.

The series of offshore bores put down between 1958 and 1965 in north-east England supplemented previous knowledge. It also provided a complete composite stratigraphical section and faunal sequence extending from approximately 15m into the *phillipsi* Zone above the Top Marine Band down to the Gubeon Marine Band in the upper part of the *lenisulcata* Zone of the Lower Coal Measures (Fig. 8). Correlation of the coal seams is achieved by the use of the non-marine bivalves in the shales overlying the seams and by palynology (the identification of plant spores within the coals and the associated sediments). The marine horizons, of which a considerable number have been identified in the Northumberland and Durham coalfield area, serve as time-markers; they are more persistent than the coals and can be traced throughout the area. Indeed, most of the main faunal marker bands of the east Pennine coalfields have been proved, including some marine bands which have only been recognised offshore (Fig. 8). Other marker horizons containing

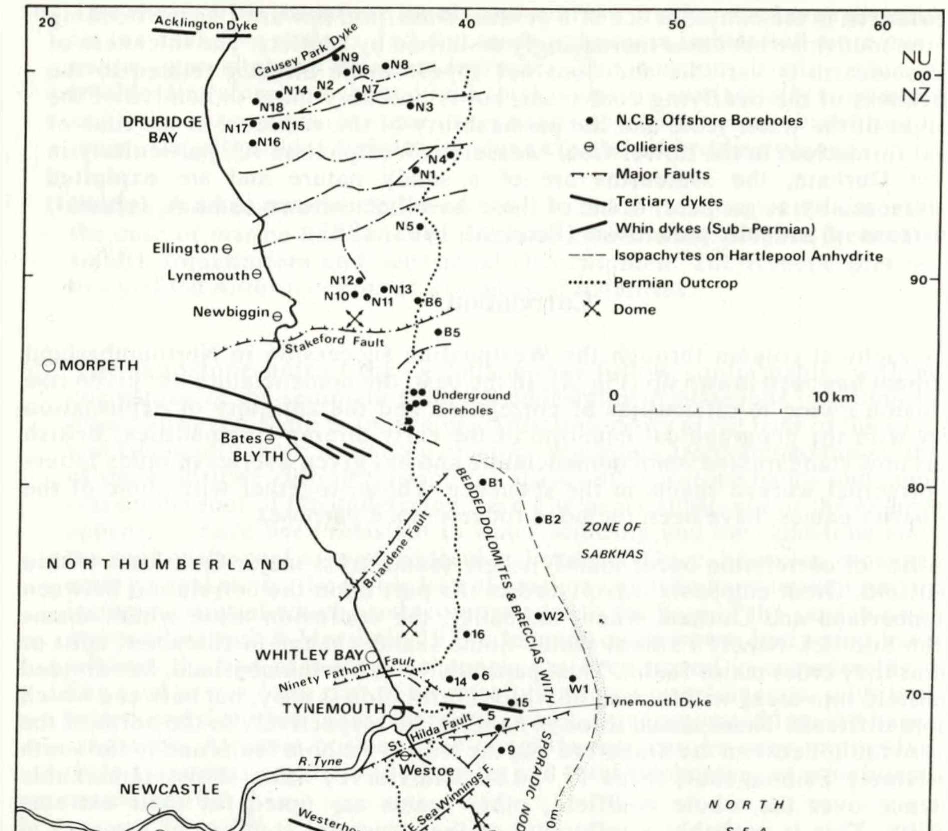


Fig. 7 Generalized map of offshore geology of part of north-east England.

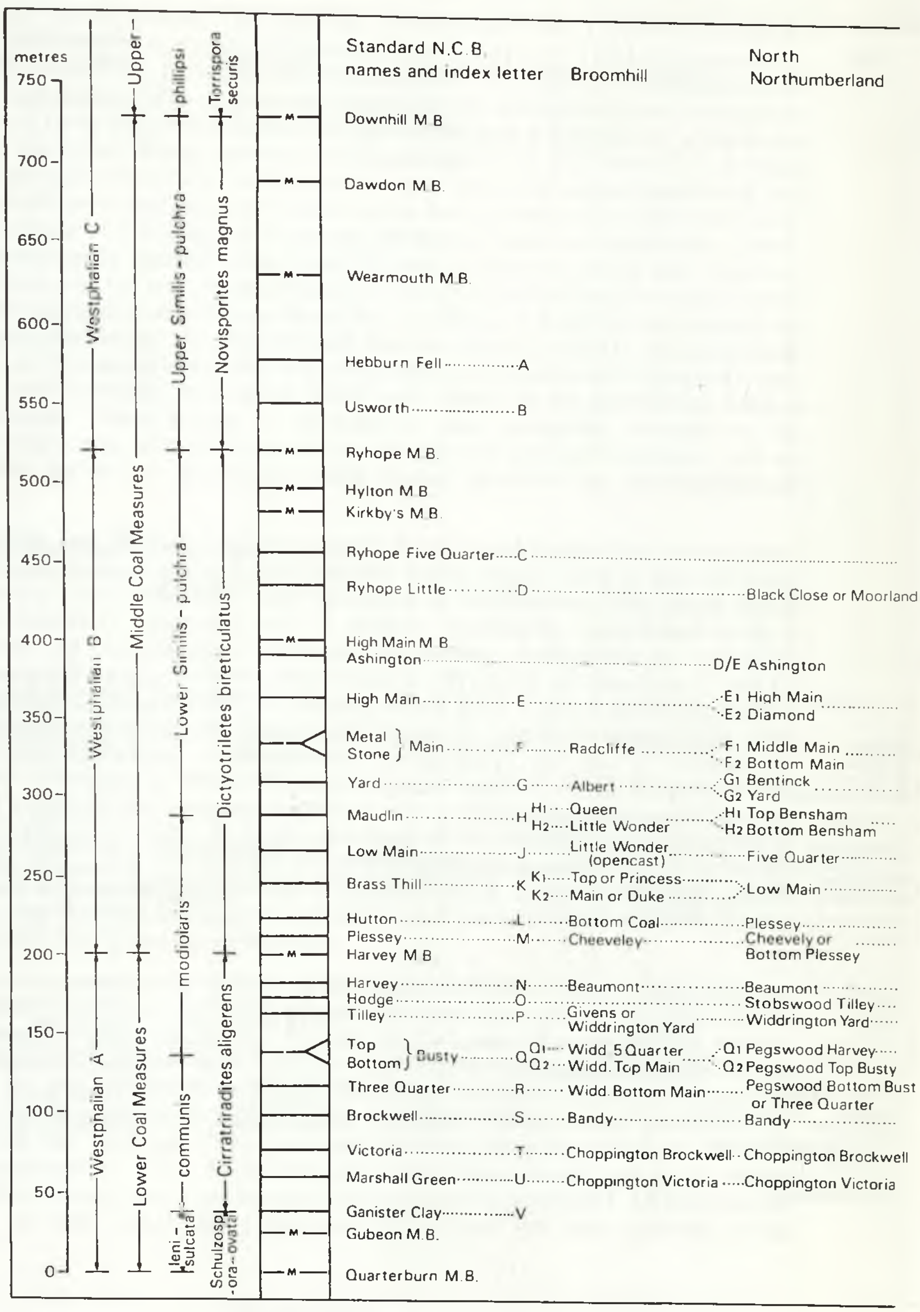


Fig. 8 Comparative sequences of Westphalian coal seams in north-east England.

South Northumberland	North West Durham	Mid Durham	East Durham	Antique Names – mainly in Tyne area
			Three Quarter Seam	Three Quarter (Wallsend)
		Charlaw	Bottom Three Quarter	Seventy Fathom
High Main	Shield Row	Shield Row	Three or Five Quarter E1 / E2	E1 Seven Quarter, Main; Kenton Hall, Benton Seam; E2 Ground Coal, Crow Coal
F1 Metal; F2 Stone	Five Quarter	Five Quarter	F1 Stone Coal	Five Quarter, Main or Grey; Newbiggin Stone Coal; Holywell Reins
			F2 Five Quarter	Hartley Stone Coal (Holywell)
G1 Top Yard; G2 Bottom Yard — Yard	Brass Thill	Main	Main (Yard)	Little
Bensham	Maudlin, Main or Hutton	Maudlin	Maudlin (Bensham)	Grove, Yard or Hartley Stone Coal
Six Quarter; Five Quarter	Low Main or Crow	JK Hutton — Low Main or Maudlin	Low Main (Six Quarter)	Hartley Main or Sluice Coal
K1 5 Quarter; K2 Low Main — Low Main — KL	Brass Thill (Candle),	JK Hutton — Brass Thill or Low Main	Brass Thill (Five Quarter, Low Main)	Low Main, Benwell Main; Grove or Five Quarter
Plessey or Grove — KL	Hutton (Five Quarter)	Hutton	Hutton	Benwell-Main or Low Main (Elswick)
Ruler				
Beaumont	Towneley	Harvey (Beaumont or Tilley)	Harvey	Engine
Hodge	Hodge			
Denton Low Main	Tilley	Tilley, Yard or 3 Quarter	Tilley: Top Busty; Bottom Busty	Cannel or Top Busty; Splint or Tilley
Top Busty	Top Busty or Stone Coal (Ryton)	Ballarat	Brockwell: Top Busty	Low Low Main, Stone
Bottom Busty	Bottom Busty or Five Quarter (Ryton)	Jet, Busty or 5 Quarter	Brockwell: Bottom Busty	Six Quarter, Three Quarter; Five Quarter, Main Coal
Three Quarter	Three Quarter	Three Quarter or Seggar	Three Quarter (Victoria)	Black, Yard
Bandy; Brockwell	Brockwell	Brockwell or Main	Brockwell or Marshall Green	Low Low Main; Horsley Wood, Splint; 5 Quarter or Lower Busty
Choppington Brockwell; Victoria	Victoria	Victoria		
Choppington Victoria; Marshall Green	Marshall Green	Marshall Green		

Estheria or non-marine mussels have likewise been identified and placed in proper relationship to named coals.

Three of the marine bands, namely the Dawdon, Wearmouth and Little were found, for the first time, in offshore borings in the north-east coalfield. The stratigraphical relationship of the Downhill, Dawdon and Wearmouth horizons is of considerable importance. The first-named was discovered originally by a student from Newcastle University during a field excursion when he hammered out a *Lingula* at a point on the south bank of the River Wear just east of Claxheugh rock (NZ 364577). At that time the stratigraphical importance of the discovery was not appreciated and the horizon was not confirmed until marine fossils were discovered in the Downhill bore drilled for the Institute of Geological Sciences between June and September 1964, after which the horizon is named. The bore did not, however, prove the Dawdon Marine Band horizon and the true relationships of these important markers have been proved only by the sequence in offshore bore No. 12 (Fig. 7). Like its occurrence in most other northern coalfields, the Wearmouth Marine Band is mainly characterized by the occurrence of foraminifera along with *Planolites ophthalmoides* (Jessen), and in a subsequent land borehole this same band was found to be associated with a well-defined tonstein. These bands of distinctive clay minerals, thought to be derived from volcanic ash, are much used for correlation on the Continent, but in this coalfield they have not generally been found suitable for stratigraphical purposes.

The Ryhope, Hylton and Kirkby's marine bands have been known for many years over much of the coalfield, but the Little Marine Band, found only in the offshore bores, is both thinly developed and very sporadic in occurrence. The High Main Marine Band is similarly sporadic but is almost invariably associated with a well-defined suite of non-marine mussels including *Anthraconaia cymbula* (Wright), *A. librata* (Wright), *Anthracosia acutella* (Wright), *A. aquilina* (J. de C. Sowerby), *A. concinna* (Wright) and in certain areas with a thick development of *Estheria*. In the offshore area, the Harvey horizon is similarly associated with non-marine mussels including *Anthraconaia modiolaris* (J. de C. Sowerby), *Anthracosia ovum* Trueman & Weir, *Naiadites quadratus* (J. de C. Sowerby) and other forms, and although the marine fossils are not found everywhere, the horizon is very easily recognised in cores. It marks the base of the Middle Coal Measures in British coalfields; this is the junction between Westphalian A and B and is probably the most important stratigraphical horizon (Stubblefield & Trotter, 1957). It occurs in the middle of the worked succession of coals and permits accurate correlation within the coalfields and throughout Britain.

Of the other marine horizons the *Gastrioceras subcrenatum* or Quarterburn Marine Band, which marks the base of the Westphalian, was not proved in any of the offshore bores and is only poorly developed elsewhere. The remaining marine horizons, such as the Gubeon, are concentrated either towards the base of the succession or in the upper, barren measures which are present only in the centre of the syncline in Northumberland and in east Durham, where they generally lie concealed beneath the Permian. The Gubeon Marine Band is mainly a *Lingula* horizon in a sequence of Coal Measures in which coal seams are only thinly developed; they have rarely been penetrated by exploratory boreholes. Lower marine bands occurring in other coalfields (Magraw, 1957) have not been proved in the offshore area.

The outliers

To the west of the main coalfield area three outliers of Coal Measures strata have been preserved on the north, downthrow, side of the Stublick fault (Fig. 1). These are, from west to east, the Midgeholme (NY 639588), Plainmeller (or Plenmeller, NY 735615) and Stublick (NY 861609) coalfields; a small outlier is also present just south of Hexham. As noted in the introduction, although the three outliers lie immediately alongside the margin of the Alston block, there is no thinning of the succession relative to the main coalfield and no discernable change in facies. In recent years extensive exploration of the three outliers has been carried out by the British Coal Opencast Executive which has considerably increased our knowledge of the succession and structure present. One of the outliers, Plenmeller, is at present being worked and details of the geology have been made public. It seems likely that the Stublick and possibly Midgeholme outliers will eventually be subjected to opencast mining. Brief notes on these individual outliers are given in the following paragraphs:

(a) **Midgeholme coalfield**, the largest of the three outliers, contains more than 200m of Coal Measures strata dipping to the south into the fault plane of the Stublick fault (Trotter & Hollingworth, 1932). The Harvey Marine Band has been located near the top of the succession and the stratigraphy down to the base of the Coal Measures is fairly well known (Hopkins & Bennison, 1957). There are nine principal seams, of which the Upper and Lower Craignook (1.1 and 1.6m), the Wellsike (1.5m) and the Midgeholme or Slag seam (1.5m) are the best developed.

(b) **Plainmeller (Plenmeller) coalfield** consists of around 100m of strata of Lower Coal Measures age including nine coal seams. The area is at present dominated by a large opencast coal site which will eventually remove almost the whole of the Coal Measures from the outlier. A total of just over 2 million tonnes of coal is being extracted from six of the nine seams present in the succession in a site extending over 190ha. The seams worked include the Slag, Wellsyke, Quarter, Three-Quarter, Little and two leaves of the Craig Nook. These are stratigraphically equivalent to the Victoria-Top Busty sequence of the main Durham coalfield.

Structurally, the Coal Measures strata are present in two elongated synclinal basins along the north flank of the Stublick Fault, steeply dipping, with gradients ranging from 1 in 3 to 1 in 6 on the limbs. The coals are of low rank, sub-bituminous range.

(c) **The Stublick outlier** is very similar to that at Plainmeller, with just over 100m of strata of Lower Coal Measures age, including eight coals of significant thickness, the best developed being the Main Coal (1.1m). This horizon is considered to be the lateral equivalent of the Busty seam of the main coalfield, the Coom Roof of Plainmeller and the Wellsike of Midgeholme.

The offshore region

The easterly dip of the Westphalian sequence of the Northumberland and Durham coalfield flattens out offshore and changes to a westerly dip that successively brings the beds against the overlying Permian cover. The Coal Measures rocks have been proved in workings from the coastal collieries and by drilling for some 10km east of the present coastline (Fig. 7). The principal coal seams worked vary in thickness from 0.9m-2.1m and range stratigraphically from the Busty seam, in some of the Durham collieries, to the High Main seam at Ellington. This latter is outstanding in that offshore the Main and High Main horizons come together producing a seam which locally reaches a thickness of up to 3.6m, thus accounting for the longevity of the colliery. Further east it is assumed that the Mid North Sea High was covered by a relatively thin onlapping sequence of Westphalian strata, but that subsequently this was removed by pre-Permian erosion.

In the Southern North Sea Basin a full sequence of Westphalian A/B and Westphalian C/D are present underlying Permian cover. The Westphalian A/B depocentre, with over 1000m of sediments, is located in the southern part of quadrant

43 and thins towards the Anglo-Brabant High in quadrant 53 (Fig. 2). They are composed of fluvio-deltaic sediments with thin marine bands that compare in terms of their facies with those described from onshore areas (Fielding, 1984, 1986; Haszeldine, 1983). The fluvial distributary channel sands, equivalent to those described by Haszeldine on the Northumberland coast, show marked east to north-east increase in grain size and sandbody thickness throughout Westphalian A and B. The main difference between the offshore and onshore successions is that the stacked braided channel sandbodies offshore in quadrant 44 are on a larger scale than any onshore equivalents; successive river channels were much larger in the offshore region.

Westphalian C/D sediments are up to 400m thick in the centre of basins, but thin with unconformity and onlap on the underlying Westphalian B around the basin margins. They are dominantly alluvial in character with red mudrocks, well drained palaeosols and numerous mature sandstones and conglomerates of variable thickness. This facies is believed to record the diachronous spread of a well drained alluvial plain system in the late Westphalian. The succession probably includes beds of Stephanian age, but it is not yet possible to identify this division in the offshore region and the full sequence is called Westphalian C/D at the present time.

Economic Exploitation

At the time of nationalization in 1947, the newly formed National Coal Board took control of seventy collieries in Northumberland and 135 in County Durham. Exhaustion of the reserves, economics and politics have over the years led to the progressive closure of all these collieries (Table 3). At the time of preparation of the first edition of this publication in 1980 it was stated that nine collieries were still operating in Northumberland and about twice that number in County Durham; the vast bulk of the coal at that time, and since, being won from the large coastal collieries working offshore reserves. 1993-94 has seen the closure of these last remaining collieries, except for one, Ellington in Northumberland, which passed into private ownership before final abandonment.

Although large scale deep mining has almost finished in the coalfields, several small, private drift mines are still in operation in west Durham and at Blenkinsop, Haltwhistle. The opencast working of coal by British Coal and private operators is still very active. The NCB operates large sites in excess of 200ha, mostly concentrated in the northern part of the Northumberland coalfield between Morpeth and Amble. Extensive dewatering has been carried out and the sites reach depths approaching 200m working through the full succession of the Lower Coal Measures, extracting with overburden to coal ratios around 20:1.

The private operators generally work smaller sites, with fixed, short term contracts often very close to built up areas, cleaning out small pockets of coal containing old workings. Sites are not restricted to the Westphalian and are to be found in more rural areas working coals of Namurian age in Northumberland and, just south of Berwick, in the Scremerston Coal Group.

Coal Character

Although there is much local variation in the development of individual seams, Hickling (1949) showed that the overall thickness of coal in the succession is remarkably constant and that the impoverishment of some seams is compensated by thickening of others.

Although generally thin, the lower coals of Durham have been heavily exploited, particularly in the west of the county, by virtue of their high-grade coking properties, and they are now almost completely worked out, apart from areas currently being exploited by opencast methods. These coals all show impoverishment east of the line

Table 3 Closure of collieries in the Northumberland and Durham coalfield in order of ceasing production

NORTHUMBERLAND

Colliery	Month	Year
West Clifton	May	1947
Callerton Pit	Sep	1948
Gloria	June	1951
Acomb	Aug	1952
Throckley Maria	Mar	1953
Throckley Isabella	Jan	1954
Williams	July	1954
Naworth	July	1954
Throckley Coronation	Aug	1954
New Delaval	Apr	1955
Throckley Blucher	Jan	1956
Nelson	Jan	1958
Rake Lane	May	1958
Lambley	Aug	1958
Stagshaw Bank	Oct	1958
Ventners Hall	Feb	1959
Hartley	Feb	1959
Blackhill	Feb	1959
Montagu	Nov	1959
Dinnington	Feb	1960
Callerton Drift	May	1960
Seaton Delaval	May	1960
Norwood	July	1960
Maude	Dec	1960
North Seaton	Jan	1961
Broomhill	Feb	1961
Hartford	Feb	1961
West Wylam	May	1961
Horton Grange	Jan	1962
Bedlington 'E'	Mar	1962
Seghill	Sep	1962
Barmoor	Oct	1962
Loughbridge	Feb	1963
Seaton Burn	Aug	1963
Hazlerigg	Apr	1964
Stobswood	May	1965
Bedlington 'F'	Oct	1965
Isabella	Feb	1966
Algernon	Feb	1966
Choppington 'B'	Feb	1966
Choppington 'A'	July	1966
Weetslade	Sep	1966
East Walbottle	Oct	1966
Hauxley	Nov	1966
Newbiggin	Nov	1967
North Walbottle	Feb	1968
Bedlington 'D'	Mar	1968
Cambois	Apr	1968
Linton	Sep	1968
Pegswood	Feb	1969
Longhirst	Mar	1969
Rising Sun, Wallsend	Apr	1969
Crofton Mill, Blyth	July	1969
Bedlington 'A'	Sep	1971
Fenwick	Aug	1973
Bardon Mill	Nov	1973
Netherton	Jan	1974
Burradon	Nov	1975
Havannah	Nov	1976
Dudley	Apr	1977
Eccles	July	1980
Woodhorn	Feb	1981
Shilbottle merged with Whittle	Mar	1982
Lynemouth merged with Ellington	Oct	1983
Brenkley	Oct	1985
Bates	Feb	1986
Whittle	Jan	1987
Ashington	Mar	1988
Ellington (care & maintenance)	Jan	1994

DURHAM

Colliery	Month	Year
Dunston & Elswick	Dec	1947
Shield Row Drift	Apr	1948
Grange	April	1948
Tanfield Moor	Oct	1948
Burnhope (Annie & Betty)	July	1949
Hetton	July	1950
Little Burn	Dec	1950
Arnghyll & Cowley	May	1951
Blaydon Burn Mary	Mar	1953
New Brancepeth	July	1953
Axwell Park	Aug	1954
Causey Mill Drift	Jan	1955
Rose Cottage Drift	Aug	1955
Quarry	Sep	1955
Bildershaw	Oct	1956
Blaydon Burn Bessie	Nov	1956
Lilley Drift	Jan	1957
Greencroft Tower	July	1957
Harbour House	Apr	1958
South Shildon	Aug	1958
West Brandon Drift	Aug	1958
Princes Street	Nov	1958
Alma	Nov	1958
Ouston 'E'	Jan	1959
East Hedley Hope	Jan	1959
Ramshaw	Oct	1959
South Garesfield	Feb	1960
Ushaw Moor	Aug	1960
Garesfield	July	1960
Malton	July	1961
Barlow Towneley	Oct	1961
Westerton Drift	Oct	1961
Ravensworth Shop	Feb	1962
Esperley Lane Drift	Feb	1962
Randolph	Feb	1962
Victoria Garesfield	July	1962
Tanfield Lea	Aug	1962
Eldon Drift	Oct	1962
Wingate Grange	Oct	1962
Beamish Second	Nov	1962
Addison	Feb	1963
Fenhall Drift	May	1963
Heworth	June	1963
High Marley Hill	June	1963
Stargate	June	1963
Roddymoor	Aug	1963
Lanchester Towneley	Aug	1963
Crookhall	Nov	1963
South Pelaw	Jan	1964
Haggs Lane	Jan	1964
Watergate	Aug	1964
Phoenix Drift	Aug	1964
Derwent	Nov	1964
Hole-in-the-Wall	Nov	1964
East Tanfield	Jan	1965
Pelton	Feb	1965
Lambton 'D'	Feb	1965
Stanley Burn	Feb	1965
Tudhoe Mill	Feb	1965
Harraton	May	1965
Sherburn Hill	Aug	1965
New Shildon	Aug	1965
Bradley Drift	Sep	1965
West Thornley	Nov	1965
Witton	Jan	1966
Lumley Sixth	Jan	1966
Dean & Chapter	Jan	1966
North Tees	Jan	1966
Clara Vale	Feb	1966
Beamish Mary	Mar	1966
Barcus Close	Apr	1966
Greenside	July	1966
Waterhouses	Aug	1966
Middridge	Aug	1966
Chopwell	Nov	1966
Ryhope	Nov	1966
Deaf Hill	Feb	1967
Thrislington	Mar	1967
Bowburn	July	1967
Brancepeth	July	1967
Staindrop Field House	July	1967
West Auckland	July	1967
Chester South Moor	Oct	1967
Kimblesworth	Nov	1967
Byermoor	Feb	1968
Hamsterley	Feb	1968
Ravensworth Park	Feb	1968
Trimdon Grange	Feb	1968
Handen Hold	Mar	1968
Brandon Pit House	Mar	1968
Emma	Apr	1968
Wheatley Hill	May	1968
Stanley Cottage	May	1968
Brusselton	May	1968
Esh	June	1968
Whitburn	June	1968
Washington 'F'	June	1968
Burnopfield	Aug	1968
Mainsforth	Dec	1968
Craghead	Apr	1969
Tudhoe Park	May	1969
Harton	July	1969
Thornley	Jan	1970
Silksworth	Nov	1971
Washington Glebe	Aug	1972
Shotton	Sep	1972
Medomsley	Oct	1972
Morrison Busty	Oct	1973
Fishburn	Nov	1973
Elemore	Feb	1974
Whitworth Park	July	1974
Usworth	Aug	1974
Kibblesworth	Oct	1974
Langley Park	Oct	1975
Metal Bridge	July	1978
Adventure (Rainton)	July	1978
Hylton	July	1979
Eden	July	1980
Blackhall	Apr	1981
Houghton	Sep	1981
Boldon	June	1982
Marley Hill	Mar	1983
East Hetton	July	1983
South Hetton merged with Murton	Mar	1983
Seaham merged with Vane Tempest	Jun	1983
Bearpark	Apr	1984
Herrinton	Nov	1985
Sacriston	Nov	1985
Horden	Feb	1986
Eppleton (combined with Murton)	Mar	1986
Westoe	Nov	1993
Wearmouth	Nov	1993
Easington	Nov	1993
Dawdon	Nov	1993
Murton	Nov	1993
Vane Tempest	Nov	1993

which approximates to that of the A1 motorway. In the early days of mining, this deterioration in the coking coals led to the belief that there were no worthwhile coal deposits underlying the Permian and, in more recent times, that exploiting the offshore area was a very doubtful proposition. Time, however, has shown that Hickling's postulations were correct, in that eastwards the upper seams in the succession compensate for the impoverishment of the lower seams, certainly in regard to thickness, if not to quality.

Although it is not intended to give a detailed description of the character of individual worked seams in the succession, some note must be taken of the Northumberland High Main seam. This coal, just under 2m thick, underlies the city of Newcastle and was responsible for establishing the reputation of the area for coal production. Worked from shallow mines along the banks of the River Tyne around Benwell, Elswick and Fenham, the outcrop was followed under the Town Moor and further east, as the seam dipped deeper below the surface; its exploitation has left a legacy of old workings throughout Newcastle and Gateshead. As the High Main was followed deeper into the syncline of the Tyne Coal Basin the problems of mining increased, with the need to overcome first water penetration and then gas. The history of the mining of this seam from Newcastle to the centre of the basin at Wallsend, where it is at a depth of over 300m, is a record of the history of the coal mining industry.

Coal rank

The rank of a coal is its degree of maturity or metamorphism. Temperature and time both serve to expel water and the more volatile constituents from the coal, increasing its carbon content and calorific value. The use to which a coal is put is largely dictated by its rank level, low rank coals being used for domestic or power station burning, medium rank for gas and domestic coke production, high rank coals for metallurgical cokes and anthracites for smokeless fuels.

Rank generally increases with depth (Hilt's Law), due to the increase in strata temperatures. The rate of temperature increase, and therefore the rank incurred, is dictated in the main by the proximity and nature of the basement rocks and their thermal conductivity.

In the northern part of the Northumberland coalfield, rank levels are low and the coals worked, mainly by the Opencast Executive, are for power stations and domestic use. Further to the south the rank levels increase (National Coal Board, 1965) due to higher geothermal gradients on the Alston block (Fig. 9). Higher thermal conductivity of the shallow basement strata, including the Weardale granite intrusion, on the block, relative to the thick Carboniferous and possibly Old Red Sandstone sediments in the Northumberland trough, is important in determining coal rank. In County Durham the rank increases to the west, with particularly high levels over the cupola areas of the Weardale granite where the thermal conductivities were especially high.

In the offshore area the rank of the coal generally decreases and only the lowest seams attain the higher rank. Scientific blending of some of the seams with coals imported from Kent and, or, South Wales, enabled a satisfactory metallurgical foundry coke to be produced from Wearmouth, Easington, Horden and Blackhall collieries and so to provide coal suitable for blast furnace coke for the British Steel Corporation plant at Redcar. Seams worked north of the River Wear were mainly directed to the industrial and power station markets, with the Lynemouth-Ellington complex a major contributor to the Alcan aluminium smelting power station. In excess of 8 million tonnes of coal were produced annually from the undersea workings of the major coastal collieries prior to closure in 1993.

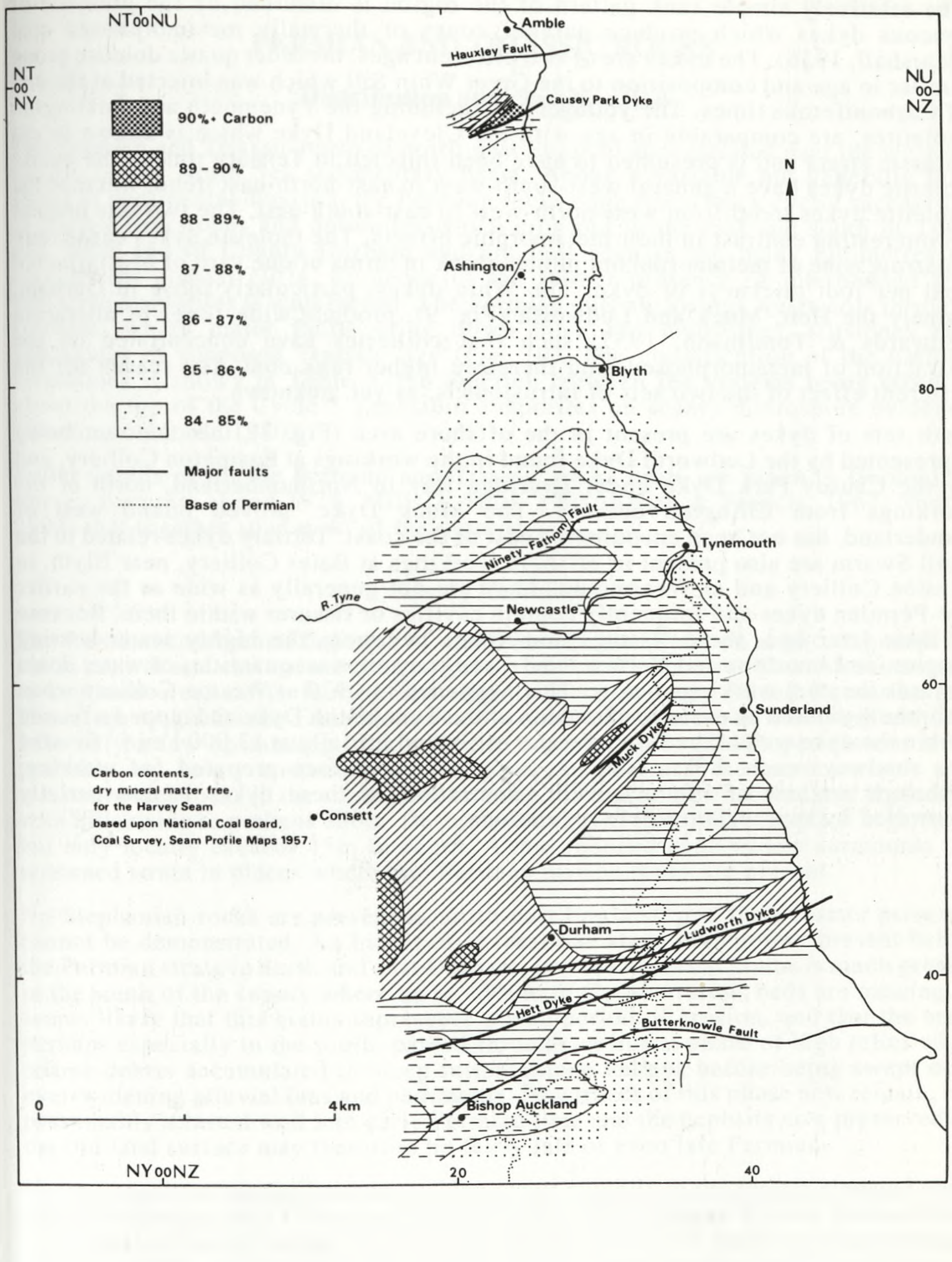


Fig. 9 Map showing coal rank in the Northumberland and Durham coalfield.

The dyke intrusions

The relatively simple rank pattern of the region is disturbed by the presence of igneous dykes which produce parallel zones of thermally metamorphosed coal (Marshall, 1936). The dykes are of two different ages, the older quartz dolerite group similar in age and composition to the Great Whin Sill which was injected at the end of Carboniferous times. The younger set, including the Tynemouth and Acklington tholeiites, are comparable in age with the Cleveland Dyke which is known to cut Jurassic strata and is presumed to have been injected in Tertiary times. The quartz dolerite dykes have a general west-south-west to east-north-east trend, whereas the tholeiite dykes trend from west-north-west to east-south-east. The two sets present an interesting contrast in their metamorphic effects. The tholeiite dykes cause only a narrow zone of metamorphism; miners think in terms of one yard of heat-affected coal per foot thickness of dyke. The Whin dykes, particularly those in Durham, namely the Hett, Muck and Ludworth (Fig. 9), produce wide zones of alteration (Edwards & Tomlinson, 1957) such that collieries have concentrated on the extraction of metamorphosed, and therefore higher rank coal. The reason for the different effect of the two sets of intrusions is, as yet, unknown.

Both sets of dykes are present in the offshore area (Fig. 7), the older set being represented by the Ludworth Dyke found in the workings at Easington Colliery, and by the Causey Park Dyke under Druridge Bay in Northumberland, north of the workings from Ellington colliery. The Muck Dyke, proved inland west of Sunderland, has not been encountered east of the coast. Tertiary dykes related to the Mull Swarm are also present in offshore workings at Bates Colliery, near Blyth, in Westoe Colliery and at Wearmouth. They are not generally as wide as the earlier pre-Permian dykes and frequently contain cavities or fissures within them. Because of their later age, these fissures sometimes penetrate the highly water-bearing Magnesian Limestone and Yellow Sands, and transmit vast quantities of water down towards the coal workings below. This happened in 1970 at Westoe Colliery when a borehole entered an easterly extension of the Tynemouth Dyke and tapped a fissure within the dyke walls. The flow of water estimated initially at 13,000 l min^{-1} flooded two roadways each 0.8km long, as well as a coal face prepared for working. Although no loss of life occurred, penetration of these dykes is now strictly controlled by appropriate safety regulations.

CHAPTER 6

PERMIAN AND TRIASSIC ROCKS

Distribution and classification

The Permian and Triassic rocks of north-east England accumulated near the western margin of the North Sea sedimentary basin. Above a variable but generally thin series of continental deposits, the Permian rocks comprise a thick cyclic succession of marine limestones and dolomites which crop out in the east and south of Tyne and Wear and of County Durham and are best seen in the many kilometres of magnificent coastal cliffs. Evidence of the former presence of interbedded and replacive evaporites is widespread. The Permian outcrop swings westwards in south Durham, where major faults bring down thick red mudstones, siltstones and sandstones of supposed Triassic age (Fig. 10). The classification of the various formations is shown in Table 4, the junction between the systems being taken at about the top of the Cycle 5 Zechstein evaporites on scanty microspore evidence (Warrington *et al.*, 1980).

Fuller details of all the Permian and Triassic rocks units are given in Geological Survey memoirs (Land 1974; Mills & Hull, 1968; Smith & Francis, 1967; Smith, 1994) that together span most of the outcrop.

Early Permian

The Permian continental deposits of north-east England rest on a mature peneplain cut in central and eastern areas on to gently folded Westphalian Coal Measures and in southern areas on to faulted and slightly more strongly folded Namurian and Dinantian rocks. On the Coal Measures the old land surface was low-lying and flat, with only a few upstanding hills and with a gentle eastwards slope; eastern areas probably lay below contemporary sea level. In contrast, the more variable and resistant older rocks in the south gave rise to a rolling, somewhat elevated landscape with hills rising to perhaps 200m. Desert reddening of the old land surface is general, but only locally exceeds 15m in depth. A thin reduced zone widely surmounts the reddened strata in places where late Permian marine rocks are present.

No Stephanian rocks are present in north-east England, and their former presence cannot be demonstrated. An hiatus of at least one stage is therefore present below the Permian strata in north and east Durham, and the apparent hiatus is much greater in the south of the county where up to 1300m of Carboniferous beds are missing. It seems likely that this hiatus represents a long period of erosion, and that the area, perhaps especially in the south, passed through an initial phase of high relief when coarse debris accumulated in steep intermontane valleys before being swept onto ever-widening alluvial fans and pediments. Few traces of this phase now remain, but presumably it lasted well into early Permian time and the deposits now preserved on the old land surface may therefore be fairly late or even late Permian.

These deposits comprise breccias, which occur patchily in the former elevated areas in south Durham and Cleveland, and the generally younger Yellow Sands which accumulated mainly on the lower ground to the north. The breccias are commonly 0.6-1.8m thick and, though grey at depth, are generally yellow-buff in rare surface exposures. They consist of angular and subangular rock fragments up to 0.1m across in a tough grey matrix of calcite- or dolomite-cemented fine-grained sandstone; component clasts are mainly of grey Carboniferous Limestone but red and green rocks occur locally. The breccias are thought to have been residual desert lag or piedmont gravels, but lenses of sandstone near the northern margin of the breccia field may be the remains of small migrating dunes.

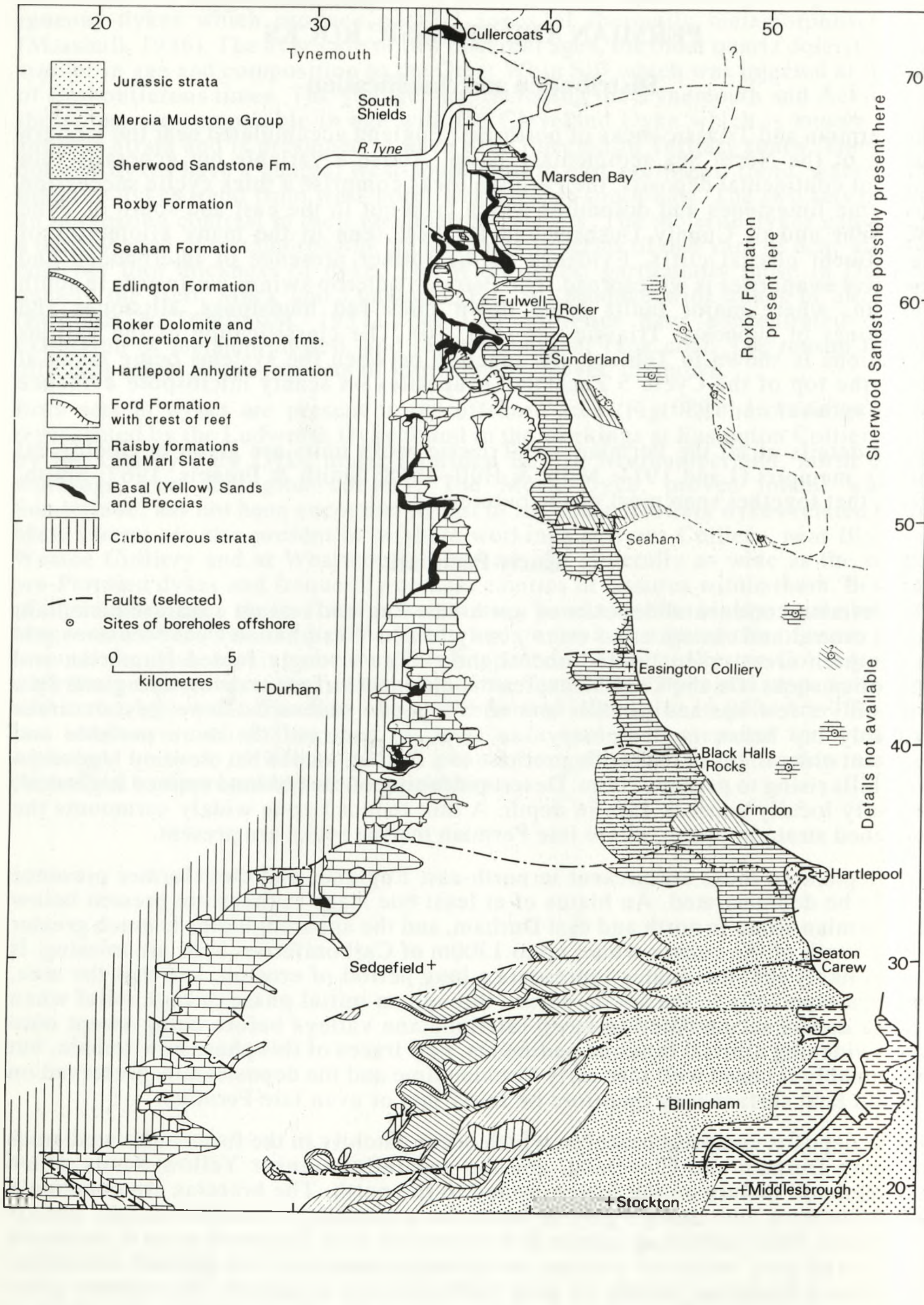


Fig. 10 Map showing the distribution of Permian and Triassic strata in north-east England (based mainly on Geological Survey maps).

Table 4 Classification of Permian and Triassic rocks in north-east England, showing nomenclature from Smith *et al.* 1986 (previous names in brackets).

	Group	Rock Units	Cycle	Typical thickness (metres)
TRIASSIC	Mercia Mudstone Group	Mercia Mudstones (Keuper Marl) with Seaton		205
		Carew Formation at base		3
		Unconformity		
	Sherwood Sandstone Group	Sherwood Sandstone Fm. (Bunter Sandstone)		210
—?—	Eskdale Group	Roxby Formation		120
		Sleights Siltstone Formation	EZ5	3
LATE PERMIAN	Staintondale Group	Sherburn Anhydrite Formation (Upper Anhydrite)	EZ 4	3
		Upgang Formation	EZ 4	0.5
		Rotten Marl Formation	EZ 4	7
	Teesside Group	Boulby Halite Formation (Middle Halite)	EZ 3	35
		Billingham Anhydrite Fm. (Billingham Main Anhydrite)	EZ 3	6
		Seaham Formation	EZ 3	30
	Aislaby Group	Seaham Residue & Fordon Evaporite Formation	EZ 2	60
		Roker Dolomite Fm. (Hartlepool & Roker Dolomite)	EZ 2	60
		Concretionary Limestone Formation	EZ 2	80
		? Hesleden Dene Stromatolite Biostrome	EZ 2	
	Don Group	Hartlepool Anhydrite Formation	EZ 1	80
		Ford Formation (Middle Magnesian Limestone)	EZ 1	100
		Raisby Formation (Lower Magnesian Limestone)	EZ 1	50
		Marl Slate Formation	EZ 1	1
—?— ? EARLY PERMIAN		Yellow Sands and Breccias		15

The Yellow Sands of County Durham and adjoining areas comprise a distinctive unfossiliferous formation of weakly cemented sand disposed in about eleven west-south-west to east-north-east parallel ridges each one to two kilometres wide and up to 60m high, separated by belts where sand is thin or absent. Except in planar-bedded zones up to 4m thick at the top and bottom, the sand is characterized by large-scale trough cross-lamination in roughly parallel truncated sets commonly 2-3m thick. The orientation of foresets and of trough axes indicates sediment transport from the east and north-east (Pryor, 1971; Smith, 1972a; Steele, 1981). The characteristic yellow colour at outcrop stems from limonite coatings on many of the grains, and gives way to blue-grey at depth where pyrite is locally abundant.

Exceptionally, parts of the formation are red in some offshore areas (Smith, 1984) and traces of red coloration are present locally near the bottom of the formation; it seems likely that, in common with most other early Permian sand formations in Britain, much of the deposit was once red.

Petrological analyses by Hodge (1932), Pryor (1971) and Steele (1981) show that the Yellow Sands in Durham and in Tyne and Wear are unimodal to polymodal, medium- to fine-grained sub-arkoses composed mainly of quartz but with 5-8% of potassic feldspars and up to 5% of small rock fragments. A limited suite of heavy minerals is also present. Cements are sparse except at the top and bottom of the formation where patchy calcite and dolomite occur. Pryor demonstrated that frosting of some of the coarse, nearly spherical, grains present resulted from diagenetic effects including chemical etching and the formation of overgrowths of quartz, carbonate and clay minerals. Krinsley & Smith (1981), however, showed that much of the frosting was caused by aeolian abrasion and inferred a contemporary wind velocity of up to 29m sec^{-1} (about 104km h^{-1}) from several of some seventy grains examined.

The depositional environment of the Yellow Sands is somewhat controversial, the generally accepted view that they are an aeolian desert sand formation having been challenged by Pryor (1971) who suggested that they accumulated as sand waves beneath the encroaching Zechstein Sea. This interpretation has found little favour and more recent work by Steele (1981, 1983) and Yardley (1984) has shown that the traditional view of an aeolian origin is more likely to be correct. In the view of these authors the ridges of Yellow Sands are the remnants of elongate sand complexes ('draa') built up by the downwind migration and superimposition of a succession of normal-sized transverse dunes. The deposit may originally have been considerably thicker than now.

Late Permian and Triassic

The late Permian in Britain is conventionally regarded as beginning with the formation of the Zechstein and Bakevellia seas, but World Permian stage and series limits are still in dispute and the convention is arbitrary. Most writers place the Zechstein succession in the Tatarian (youngest Permian) and it has been shown that the formation and filling of the Zechstein Sea may have taken only five to seven million years. The two seas are thought to have been created by the rapid flooding of a chain of sub-sea level inland drainage basins and, by their presence, to have modified the climate around their shores so as to increase rainfall and enable plants to become re-established in former desert areas. Large-scale cyclicity in the deposits of the Zechstein Sea, thought by Smith (1980) to be related to glacio-eustatic sea level oscillations, is reflected in the subdivision into four main groups (Table 4), each of which approximately corresponds to an evaporite cycle. The mutual relationships of the various formations and the areas where these relationships are uncertain are shown in Fig. 11.

In Durham and in Tyne and Wear the Zechstein shoreline lay west of the present outcrop, and most late Permian deposits here were formed some distance offshore under moderate depths of water; only during the closing evaporitic phases of each cycle did the coastline migrate eastwards, and only in the second cycle did continental sediments spread over the area from the seemingly almost permanent land where the Pennines now lie. The palaeogeography of present land areas during the formation of the various lithological units has been summarized by the writer (Smith, 1989) and a broader view of their place in the context of the North Sea Basin is given in Smith & Taylor (1992). Parts of several of the carbonate formations contain a rich and varied fauna, details of which are omitted here for lack of space; a full faunal list is given by Pattison in Johnson & Hickling (1970).

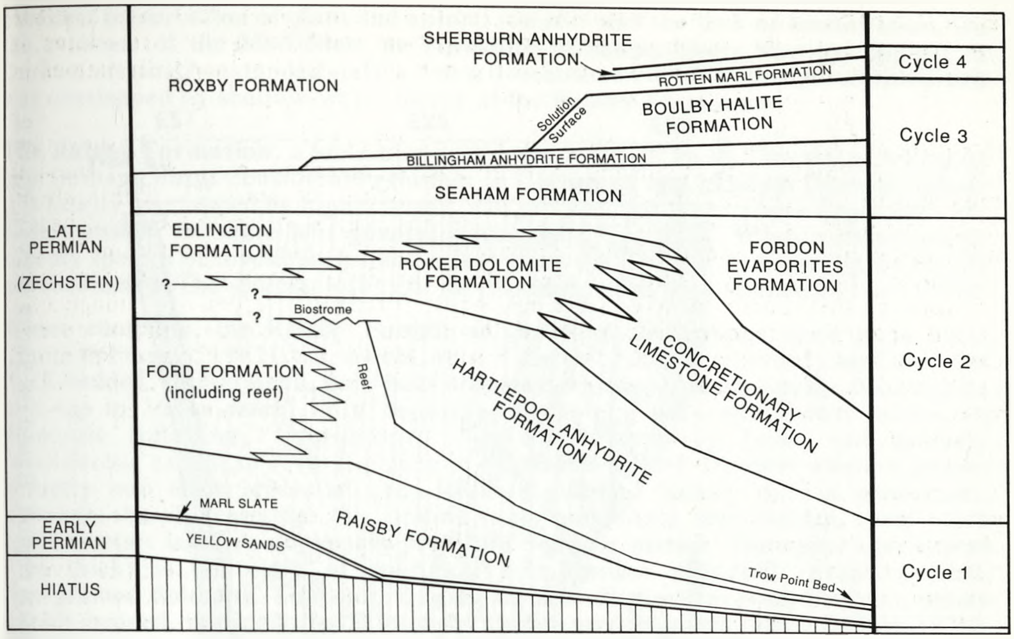


Fig. 11 Schematic section showing the relationship of the main Upper Permian rock units in north-east England.

The Marl Slate, the basal formation of the English Zechstein succession (Figs 11, 12; Table 4), is a distinctive grey to black, finely laminated, calcitic or dolomitic siltstone or silty dolomite and is commonly bituminous. It is generally less than 1m thick, and thins or wedges-out against eminences on the unconformity (especially in south Durham and Cleveland). It is thickest in central Durham, where it locally exceeds 5m, and in the undersea area north of the Tyne; in both these areas it includes beds of limestone (Smith & Francis, 1967; Land, 1974; Magraw, 1975; Turner *et al.*, 1978). Elsewhere, sharp local variations in thickness result from numerous minor submarine slumps.

The Marl Slate is well known for its fauna of palaeoniscid and other fish, and it also contains a few reptilian remains; a limited invertebrate fauna comprises *Lingula* (fairly common), *Discina, Bakevellia* and *Liebea*, and the nautiloid *Peripetoceras* has been recorded. Remains of twelve species of land plants are widespread, but most of the bitumen present is in delicate black lenses and films and may be of planktonic origin. The bitumen is rich in tiny crystals of early diagenetic iron pyrite, and pyrite and other metallic sulphides are common both on joints and in small displacive lenses. Disseminated metallic trace elements, which are most concentrated where the deposit is thin, are less abundant than in the equivalent Kupferschiefer; they have a distinctive vertical distribution over wide areas, which probably indicates that the deposit is not diachronous (Hirst & Dunham, 1963).

The Marl Slate has been regarded as the deposit of a euxinic (stagnant) sea perhaps 60-250m deep. The origin of the metallic trace elements remains uncertain, however, and emanations from submarine springs, deposition from concentrated brines and concentration by planktonic plants all have their proponents. The depth of water probably ruled out a benthic flora and the lack of oxygen probably accounts for the

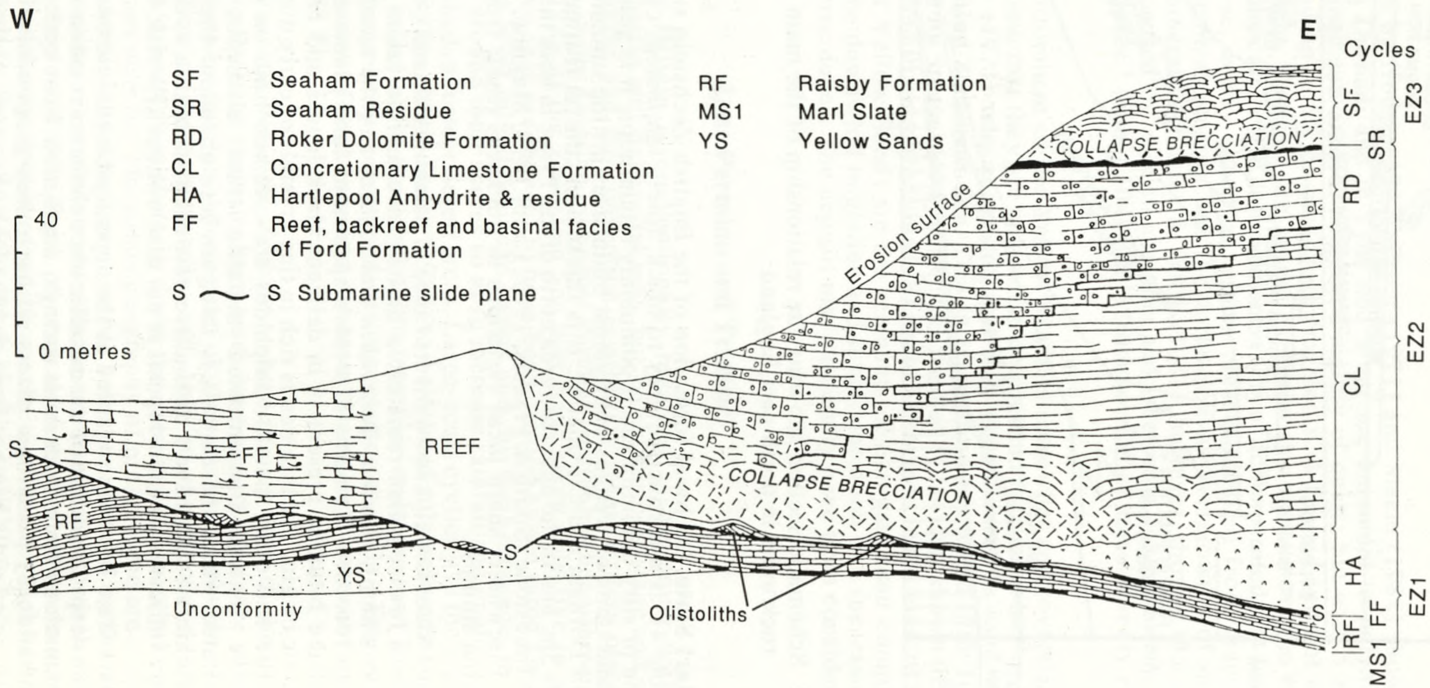


Fig. 12 Generalized transverse section of Permian strata in the Durham coastal region. Based on Smith (1995), fig. 3.2.

excellent preservation of plant and animal remains and the lack of bioturbation. On the evidence of the Marl Slate in Yorkshire, it seems likely that the deposit in Durham originally extended only a few kilometres west of its present outcrop and was overlapped by shallow-water facies of the Raisby Formation.

The Raisby Formation, a lenticular carbonate body, is up to 73m thick in central east Durham, but is considerably thinner in Cleveland and in south Durham, where it is locally overlapped by higher strata, and in Tyne and Wear where upper beds are widely absent. Offshore it is generally less than 35m thick. It has yielded nearly seventy species of invertebrates and a few plant species, but in many places fossils are uncommon. The sedimentology of this formation has been studied by Lee (1990).

Where complete, the Raisby Formation commonly comprises three main units (Smith & Francis, 1967), the lowest, up to 3.6m thick, being of evenly medium- and thick-bedded, fine-grained, pale-buff dolomite which is locally shelly. The middle unit (up to 36.5m thick) is of distinctively mottled grey and brown calcitic or dolomitic limestone, finer-grained than the underlying beds, and sparsely fossiliferous except in several places in central and south Durham where it passes abruptly into thick lenses of grey shelly limestone locally rich in productids; although sharply variable, this unit is most commonly thin-bedded, with black carbonaceous laminae on weakly stylolitic bedding planes. The upper unit (up to 33m thick) is generally of sparingly fossiliferous pale-buff, evenly-bedded, fine-grained dolomite. The subdivisions are less distinct in south Durham, where evenly-bedded, sparingly fossiliferous dolomite predominates (Mills & Hull, 1976). Offshore the formation is generally thin, barren, fetid and pyritic, and contains much secondary anhydrite.

Throughout Durham, Tyne and Wear and also offshore, the Raisby Formation features evidence of widespread submarine slumping (Smith, 1970b) that was on a massive scale at the top of the formation (Fig. 12). Extensive but patchy minor mineralization - pyrite, galena, barite and blende in lower beds, barite and fluorite in the upper - has been investigated by Fowler (1943, 1956), Jones & Hirst (1972), Harwood & Smith (1986) and Lee (1990). Concentrations of iron oxides occur in the slumped strata. From the evidence of instability, lithology, sedimentary structures and fauna, it seems probable that the Raisby Formation in north and central Durham and in Tyne and Wear was formed on the basin-margin slope under normal sea-water perhaps 60-120m deep; in east Durham and offshore, the fetid almost unfossiliferous beds were probably formed on or near the basin floor whilst in south Durham an approach to the Zechstein shoreline is suggested and a number of islands were present.

The Ford Formation is the most extensive formation, at outcrop, in the Permian of north-east England (Fig. 10) and comprises extensive backreef and basin deposits, separated by a strongly asymmetric shelf-edge reef that is known to exceed 100m in thickness in places. The backreef deposits lie west of the reef (Figs 11, 12) and comprise a belt, 3-10km wide, of sparingly shelly oolitic dolomite which passes westwards into a finer-grained calcitic dolomite with a distinctive felted fabric. The oolitic dolomite is commonly cross-laminated and, near the reef, contains abundant multiple grains, pisoliths up to 8mm across and stromatolitic flakes; its fauna is mainly of small gastropods and bivalves, but foraminifera are locally abundant. The calcitic dolomite, farther west, generally lacks strong cross-lamination and shelly fossils but in places contains many burrows; the felted fabric results from the replacement by calcite of small platy calcium sulphate crystals formed diagenetically in the backreef deposits.

The reef crops out for more than 30km and is generally less than 500m wide. It rests on a bank of brachiopods, bivalves and bryozoans and comprises a rigid frame of autochthonous rock bound by bryozoans and encrusting algae and with innumerable pockets of rubbly organic detritus and of inorganic cavity-fill. Higher parts of the reef contain an increasing proportion of algal stromatolites and laminar encrustations, and the uppermost parts are mainly stromatolitic (Smith, 1958, 1981b). Eastern parts of the reef consist largely of talus mixed with the remains of indigenous organisms. A comprehensive review of the fauna of the reef by Hollingworth (1987) was summarized by Hollingworth & Pettigrew (1988).

The reef talus thins sharply into the basin, and beds occupying the same stratigraphical position as the reef appear to be less than 1m thick at distances of more than 5km from the reef front. Their uppermost unit, the Trow Point Bed (Smith, 1986) is a distinctive impure dolomite bed up to 60cm thick of algal nodules (oncoids) and columnar algal-stromatolites, which extends across the basin into Germany and Poland.

The Hartlepool Anhydrite succeeds the Ford Formation in east Durham and offshore (Fig. 12). Most of the anhydrite has been dissolved from land areas, leaving a thin residue (Smith, 1972b). By comparison with the Hartlepool area and elsewhere, however, it seems that originally it formed a belt up to perhaps 155m thick bounded to the west by the steep face of the reef and also thinning sharply eastwards (Fig. 11); if this is correct, its bulk probably lay mainly west of the present coast from Seaham northwards (Smith & Taylor, 1989). The anhydrite is a blue-grey translucent finely crystalline rock with a sparse network (mosaic) of disrupted, distended and distorted stringers of brown dolomite, and dislocated beds of laminated dolomite up to 3m thick.

From the evidence of boreholes in east Yorkshire and the North Sea (Taylor & Fong, 1969; Taylor & Colter, 1975) it appears that upper parts of the Hartlepool Anhydrite may pass eastwards into laminated dolomite and that such dolomite may be present offshore and also in lower parts of the collapsed strata in the South Shields area (NZ 372678). The laminated beds of the overlying Concretionary Limestone, where they have been disrupted by the growth of gypsum crystals after burial, are almost indistinguishable from laminated dolomite beds in the Hartlepool Anhydrite; where such strata are juxtaposed, the placing of the boundary between the two formations may be extremely difficult even where cores are available.

The almost ubiquitous mosaic fabric and the presence of laminated dolomite below and within the Hartlepool Anhydrite were originally interpreted (Smith, 1970a) as evidence that it was formed diagenetically on an extensive coastal sabkha, but the absence of well-defined sabkha cycles is puzzling, and it may be that the sabkha model is not appropriate. I now suspect (Smith, 1989) that the formation may have been built up by layers of bottom-grown selenite (gypsum) and that its present fabric is mainly of diagenetic origin. Acceptance of either hypothesis requires a sea level fall and recovery of at least the height of the reef face (?100m) and the temporary subaerial exposure of the reef itself; the presence of coarse subspherical quartz grains in tension gashes near the top of the reef at Tunstall Hills (NZ 376545), Sunderland, may perhaps be seen as evidence of such exposure.

The Hesleden Dene Stromatolite Biostrome is a distinctive unit that lies between an erosion surface cut on the shelf-edge reef of the Ford Formation and the overlying Roker Dolomite Formation (biostrome is shown on Fig. 11); it has not been reported to the north of Seaham. The biostrome comprises a basal conglomerate up to 18m thick composed mainly of blocks torn from the reef during a phase of lowered sea level, overlain by an extensive and more uniform sheet-like unit commonly 15-25m thick composed of laminated algal-stromatolitic dolomite that features several layers of algal domes each generally 2-5m across and up to 1.5m high. It is not clear whether the biostrome is part of Cycle EZ1 or EZ2, but the presence of many biostrome fragments in collapse-breccias in coastal cliffs near Easington Colliery implies that it is younger than at least some of the Hartlepool Anhydrite and may be wholly younger.

The Edlington Formation is found only behind the line of the reef of the Ford Formation, and there is a strong suggestion that it is a clastic semi-continental deposit overlying the backreef facies and equivalent in age to the Hartlepool Anhydrite and the whole of the Aislaby Group (Table 4). It comprises mainly red terrigenous barren sediments ranging from coarse breccias, where overlapping onto the old land surface, to mudstones elsewhere, and contains a number of beds of nodular and laminated gypsum or anhydrite; some beds of oolitic and algal-laminated dolomite are also present, especially in the east, and may extend landwards from a barrier complex of Roker Dolomite oolite. The formation is up to 45m thick at depth in the south of the region, but appears to thin eastwards; at outcrop it is commonly only 5-15m thick because of dissolution of the evaporites.

The Concretionary Limestone and Roker Dolomite formations are best regarded as complementary parts of a single major clinoform and as the joint representatives of the Cycle 2 carbonates (Figs 11, 12). Though the detail of their mutual contact is uncertain, the two formations together span a continuum of depositional environments ranging from shelf-crest oolite banks (Roker Dolomite facies) to unstable high-, mid- and low-slope deposits (Concretionary Limestone facies). The distribution of fossils and carbonate rock-types in the two formations shows clearly that the Zechstein Sea was strongly stratified at this time, the deeper parts (where most of the Concretionary Limestone was formed) being generally anoxic (stagnant).

The Concretionary Limestone, a sharply lenticular formation best known for its bizarre calcite concretions, is about 100m thick in the Sunderland area but thins southwards and dies out to the south of Seaham. Concretions are present at all levels in the formation but are abundant around Sunderland only at two levels, respectively about 27m and 55m above the base; in most places the Concretionary Limestone is a grey or brown, finely laminated dolomitic limestone or dolomite in which abundant turbiditic (graded) and slumped beds commonly are of cream fine-grained dolomite or altered oolite. A thick lens of oolitic dolomite in cliffs at Marsden (NZ 420640) lies near the middle of the formation and is probably also at least partly allochthonous. Laminated beds of the Concretionary Limestone are generally barren, but have yielded fish remains at Fulwell and Hendon, especially from the so-called 'Flexible Limestone' about 52m above the base of the formation. Ostracods and a limited suite of bivalves and gastropods are found in many of the cream dolomite beds and some of the limestones, especially those between Whitburn and Marsden, are believed to have been formed in the oxygenated waters high on the basin-margin slope. Elsewhere, dense accumulations ('lags') of bivalves and gastropods at the bottom of some graded beds are probably the remains of benthic communities that lived high on the slope but which were swept downslope and entombed in the anoxic zone during episodes of synsedimentary slumping.

Most of the laminated beds appear to have formed *in situ*, and comprise extremely thin alternations of carbonaceous and non-carbonaceous fine-grained carbonate. The carbonaceous laminae, which are generally thinner than the others, may have been formed by seasonal or annual falls of plankton.

The Roker Dolomite Formation crops out mainly at the type locality, at Hartlepool and north of Seaham, but is more completely known from boreholes offshore. It is composed mainly of well-bedded cream and buff granular dolomite, much of it finely oolitic, with small scale cross-lamination and other sedimentary structures and a few slumps and beds with large load casts. A limited bivalve-gastropod-ostracod fauna, locally rich in individuals, is found in some beds. From its lithology, sedimentary structures and faunas, the Roker Dolomite is inferred to be a shallow-water marine shelf deposit, probably formed under moderate- to high-energy oxic conditions in a barrier-bar complex near and landward of the shelf-edge; it is likely to be the source of the slumped shelly and oolitic beds in the Concretionary Limestone.

Dissolution of the Hartlepool Anhydrite, probably by meteoric groundwater during and after early Tertiary uplift, led to foundering by up to 150m of all younger strata seaward of the crest of the Ford Formation reef. The effect of this foundering was to cause dislocation of these strata ranging from barely noticeable open folding and minor faulting to almost complete brecciation, according to the vicissitudes of the dissolution process and the character of the rocks affected. The most severely brecciated rocks were dedolomitized by the reaction of the pre-existing dolomite with fluids rich in dissolved calcium sulphate (Woolacott, 1912); this almost random reaction created a crude mosaic of resistant and less resistant rocks which is the main control on the configuration of the present coastline. Much of the primary lithology of the foundered strata has been obscured by secondary changes related to the foundering, but enough remains to show that Roker Dolomite forms all of the foundered strata near the reef, and that Concretionary Limestone forms most to all of the foundered strata 2-3km farther east (with a varied mixture between) (Fig. 11).

The Seaham Residue is interpreted as the insoluble remains of the Fordon Evaporites (Fig. 12). At the type locality just north of Seaham Harbour it is a heterogeneous mass, up to 9m thick, of angular fragments and blocks of limestone and dolomite in a clayey dolomite matrix rich in quartz; a disrupted bed of white finely-cellular limestone separates a yellow-buff upper layer about 2m thick from a thicker mainly grey layer. The residue is also exposed south of Blackhalls Rocks, where it is ?5m thick and contains relatively fewer rock fragments than at Seaham.

The Fordon Evaporites have been dissolved from all land areas of Northumbria but are preserved at depth a few kilometres offshore where they are composed mainly of gypsum and anhydrite (Smith & Taylor, 1989; Smith, 1994). In the only cored sequence in a borehole some 12km east-north-east of Sunderland, about 20m of halite near the bottom of a 90m evaporite unit was found to overlie interbedded finely laminated dolomite and anhydrite which in turn succeeded Concretionary Limestone interpreted to be of mid- to high-slope facies. The thickness of the Fordon Evaporites here, plus the inferred depositional environment of the underlying stratum, indicates that the cored borehole lies east of the Concretionary Limestone slope. This is in marked contrast to equivalent evaporites proved in boreholes in northern Cleveland, which are 15-30m thick but overlie the Roker Dolomite shelf.

The Seaham Formation is mainly exposed in coastal cliffs at Seaham and Crimdon but is widespread at depth in the south of the region and offshore in the east (Fig. 10). At its type locality the formation comprises about 31.5m of predominantly thin-bedded fine-grained partly pelletoidal brown limestone in which secondary calcite spherulites up to 20cm across are abundant in the middle of the sequence. Here, in places, they merge into thick crystalline beds similar to those of the Concretionary Limestone but without the lamination of the latter. Cross-lamination, ripple-bedding and graded beds occur throughout the formation, but are most common in higher parts, and stromatolitic (microbial) lamination is widespread in the uppermost 1 or 2m. A distinctive biota of *Calcinema permiana* and the bivalves *Liebea squamosa* and *Shizodus schlotheimi* is generally present, but commonly has been obliterated where concretions are most abundant. In the cliffs at Crimdon and in the south of the region much of the formation is composed of soft cream dolomite. Brecciation and dislocation is widespread in lower beds in areas where the underlying Fordon Evaporites have been dissolved, but dedolomitization was not widespread.

From the evidence of its biota, sedimentary structures and uniformity, it seems that the Seaham Formation accumulated on an extraordinarily extensive shelf around the margins of the Zechstein Sea under water generally only a few metres deep and perhaps high sub-tidal. The microbial lamination at the top of formation may owe its preservation to the eclipse of a burrowing infauna by a rise in salinity.

The Billingham Anhydrite Formation of Teesside is generally 4-8m thick, and contains in its lower (bedded) part, laminae and thin beds of dark grey argillaceous dolomite and dolomitic mudstone; this part of the formation is clearly a shallow-water deposit. Higher parts of the formation in places are coarsely nodular, and algal-stromatolitic (microbial) lamination is locally present; anhydrite pseudomorphs up to 6cm tall of bottom-grown selenite are not uncommon in these higher parts. By comparison with the modern evaporites of the Persian Gulf, there can be little doubt that some upper parts of the Billingham Anhydrite formed on a vast arid coastal plain or sabkha complex by displacive growth within algal mats, but other parts formed under shallow marine or lagoonal water.

The Boulby Halite Formation is up to 63m thick around the Tees estuary but ends abruptly inland at a dissolution surface (Fig. 11). Lower parts of the halite contain laminae and beds of halitic anhydrite and dolomite, and a distinctive 1-1.5m sequence (the 'honeycomb-rock') near the base is of complexly interbedded and intergrown anhydrite, dolomite and halite. Most of the Boulby Halite is coarsely crystalline and has a distended mesh chiefly of anhydrite in lower beds and of red mudstone in higher. Flow-lamination is widespread in places where the halite is least impure, and flow accounts for most of the thickness variation. Indications of the former presence of potash minerals occur locally on Teesside. Like the underlying anhydrite, the Boulby Halite on Teesside appears to have formed at or near sea level, parts probably as a primary precipitate under shallow brine but some as a secondary deposit within existing sediments and evaporites.

The Rotten Marl, commonly 5-9m thick, is present only in the south and offshore. It is generally a dull dark red-brown blocky silty mudstone which contains scattered to abundant halite crystals (some euhedral) and a varied network of thin veins of fibrous halite and gypsum. It may be partly aeolian. Lower parts in places contain thin lacy beds of anhydrite and have an anhydrite or halite cement. Sedimentary structures are uncommon on Teesside except in scattered thin sandstone lenses in the uppermost metre or so, but are more abundant farther west where the Rotten Marl passes laterally into red sandstone and siltstone.

The Sherburn Anhydrite Formation, which is commonly 2-4m thick, is less extensive than the Billingham Anhydrite. At or near to the base of the formation is up to 1m of mauve cross-laminated dolomitic anhydrite or anhydritic dolomite, and an equally distinctive mauve bed near the middle of the formation has a fine cellular network of dolomite stringers enclosing single gypsum crystals up to 4mm across. Most of the rest of the formation is of faintly thinly-layered pale grey finely crystalline anhydrite with red haematitic films at uneven intervals and large numbers of 7-12mm tall courses of small anhydrite pseudomorphs after bottom-grown selenite. The basal cross-laminated unit may be the equivalent of the Upgang Formation of the Whitby district. The Sneaton Halite Formation of north-east Yorkshire, which there succeeds the Sherburn Anhydrite, is not present on Teesside, nor has an equivalent residue been recognized.

The Roxby Formation is more varied than the Rotten Marl and comprises a thick cyclic sequence of thinly interbedded red mudstones, siltstones and fine-grained sandstones in which thick beds of blocky mudstone are most common towards the base. Thin beds and veins of anhydrite, anhydrite nodules and an anhydrite cement are widespread in the lower beds, but are rare or absent above. Upwards-fining minor fluvial cycles characterize higher parts of the formation, each cycle, where complete, lying on an erosion surface, beginning with a mudstone-flake breccia in sandstone and ending in a desiccation-cracked dark brown-red mudstone. The sandstones are generally brick-red or pink, and feature ripple laminae, fluidized sediment injection structures and, locally, adhesion ripples. Some beds appear to have been completely retextured, possibly by thixotropic effects or the repeated formation and dissolution of soluble salts (haloturbation). The formation thins sharply westwards, where it becomes increasingly sandy.

The Sherwood Sandstone Group (formerly Bunter Sandstone) succeeds the Roxby Formation by upwards and sideways increase in the relative thickness of the sandstone part of each rhythm and by a complementary thinning of the overlying mudstone part; it is known from boreholes to be up to 210m thick but is exposed only at Hartlepool and in the Tees near Darlington. The Sherwood Sandstone is a fine- to medium-grained brick-red micaceous arkose, generally only weakly cemented by calcite and iron oxides, and commonly cross-laminated in sets up to 0.25m thick. Ripple-lamination is widespread in the sandstone, and mudstone flake-breccias occur at all levels but most commonly in lower parts; mudstone beds, as in the underlying Roxby Formation, generally feature abundant sand-filled desiccation cracks. A small suite of heavy minerals is present (Smithson, 1931).

The lithology and sedimentary structures of the Roxby Formation and the Sherwood Sandstone Group are consistent with deposition from running or standing shallow water on a virtually flat sedimentary (alluvial) plain which, judging from the uniformity and great lateral extent of the deposits and their equivalents in the west, must have covered most of the north of England. It seems that on a broad scale the two formations are probably lateral equivalents, the diachronous base of the latter being progressively older towards the basin margin where the whole sequence may have been of sandstone. Both the Roxby Formation and the Sherwood Sandstone were probably initially grey or brown, but reddened with age.

The top of the Sherwood Sandstone is marked by a slightly uneven erosion surface that extends across much of North Yorkshire and is probably equivalent to the mid-Scythian Hardegsen Disconformity of Germany (Trusheim, 1963; Geiger & Hopping, 1968; Warrington, 1974). This surface is thought to have been caused by gentle regional tilting accompanied or followed by erosion and a depositional hiatus.

The Mercia Mudstone Group (formerly Keuper Marl) crops out widely in Cleveland (Fig. 10) and offshore and is about 240m thick. It was formerly exposed at a number of places in the lower Tees valley and at Lackenby, but is known mainly from boreholes. These show that the group comprises a thin Seaton Carew Formation at the base, a thick unnamed mainly argillaceous sequence in the middle and three formations of Rhaetian age at the top.

The Seaton Carew Formation (0-4m) has been proved in a number of widely-spaced boreholes on Teesside and consists of a mixture of patchily grey-green and red-brown mainly coarse-grained sandstone and patchily green and dark red mudstone. In parts of the formation the mudstone forms concordant beds intruded by sand dykes of polygonal plan, but in other parts the sandstone and mudstone are intricately intermingled and mutually intrusive in amoeboid pouch-like bodies a few centimetres across, but with sharp margins (Smith 1980, Fig. 11); this unusual structure presumably results from fluid movement of the sediment soon after deposition. The sandstone contains abundant coarse subspherical frosted grains and a few very small pebbles, and dolomite and gypsum are present in the matrix; gypsum also forms scattered small patches in the sandstone. This basal formation has many of the features of a slowly accumulated lag deposit. In places it grades into the overlying deposits, but elsewhere it has a sharp eroded top.

The main part of the Mercia Mudstone Group is extremely varied; lower beds, overlying a 4-5m bed of dull, brick red, blocky mudstone or siltstone, comprise a thinly interbedded multicoloured sequence of sandstones, siltstones and subordinate mudstones in which occur several beds of laminated and nodular anhydrite and also a number of mushy layers interpreted as evaporite dissolution residues, perhaps after halite. Beds immediately overlying these supposed residues are brecciated to varying degrees, presumably by collapse, and the breccias and also many of the intervening beds contain thin veins of gypsum. Similar residues and breccias were reported at this level in the Boulby Mine pilot borehole, Staithes (Woods, 1973), and equate with marine halite and anhydrite up to 50m thick in the Whitby area (the Esk Evaporite Formation of Warrington *et al.*, 1980).

Bedded evaporites are thin and uncommon more than 25m above the base of the Mercia Mudstones, although nodules and thin veins of gypsum are abundant at many levels and halite pseudomorphs occur in some of the many green mudstones present. Most of these higher beds are thin or very thin, and much of the formation is composed of alternating mudstones and siltstones with subordinate thin sandstones and dolomites; colours range from purplish-red through mauve, lilac, grey and green, but a few thick beds of severely churned (haloturbated) blocky silty mudstone are characteristically brick red. Sedimentary structures in the sandstones include ripple lenses, minor cut-and-fill structures and mudstone-flake breccias, and small scale flame-structures and load casts are found locally. The mudstones commonly feature sand-filled desiccation polygons, and listric surfaces both along the bedding and at all angles to it, abound. Information on strata in the middle of the Mercia Mudstones is limited, but from the driller's records of old water bores at Middlesbrough it seems that red-brown mudstone with gypsum veins and nodules forms most of this part of the sequence, and this is in accord with equivalent beds at Boulby (Woods, 1973) and in the Whitby area (Raymond, 1953). Highest beds include strata rich in gypsum (the horizon of the Newark Gypsum), known from boreholes and an old pit at Eston, and the sequence ends with the semi-marine Blue Anchor Formation (formerly the Tea Green Marls). Neither this nor the other Rhaetian formations crop out in the area covered by this volume, and will not be considered.

The conditions under which the Mercia Mudstones of Cleveland were deposited are uncertain. These differ from the Roxby Formation in that considerable parts of the sequences are multicoloured and dolomitic. Both formations have so far failed to yield evidence of any shelly fauna or of trace fossils, however, and their lithology, sedimentary structures and also the texture and relationships of associated evaporites are closely comparable. From the absence of shelly fossils, burrows and roots it seems that the Mercia Mudstone environment was hostile to most types of life, and the presence of desiccation cracks and halite pseudomorphs shows that the area was periodically subaerially exposed and periodically inundated by saline water. On balance, the evidence appears to favour deposition on an enormously extensive coastal or lacustrine plain, only slightly above sea level, and subject to shallow flooding from time to time. It seems doubtful if the sea or inland lake was of normal salinity until flooding by the Rhaetian Sea brought to an end the prolonged phase of continental margin deposition.

Table 5 Stratigraphic succession of the Quaternary deposits.

			stage	isotopic stage	begins (yrs BP)	deposits
UPPER QUATERNARY			Flandrian (T)	1	10,000	estuarine and other marine deposits, coastal dunes, alluvium, lake deposits, peats, tufa
UPPER QUATERNARY	Devensian (C)	late	Loch Lomond Stadial	2	11,000	screes, heads, landslip deposits, moraines, alluvium, blockfields
UPPER QUATERNARY	Devensian (C)	late	Windermere Interstadial	2	13,000	alluvium, peat, lake deposits
UPPER QUATERNARY	Devensian (C)	late	Dimlington Stadial	2	26,000	surface and sub-surface ice-contact and pro-glacial glaciofluvial and glaciolacustrine deposits; tills;?? giant erratics
UPPER QUATERNARY	Devensian (C)		middle	3		
UPPER QUATERNARY	Devensian (C)		early	4-5d	122,000	?? loess of Warren House Gill
UPPER QUATERNARY			Ipswichian (T)	5e	130,000	Hutton Henry peat rafts; ?? Newbiggin beach gravel
MIDDLE QUATERNARY			? "Weltonian" (C)	6		? Warren House Till
MIDDLE QUATERNARY			"Ilfordian" (T)	7	*ca* 200,000	Easington Raised Beach
MIDDLE QUATERNARY			? "Weltonian" (C)	8		? Warren House Till
MIDDLE QUATERNARY			later Hoxnian (T)	9		
MIDDLE QUATERNARY			cold stage (C)	10		
MIDDLE QUATERNARY			earlier Hoxnian (T)	11		
MIDDLE QUATERNARY			Anglian (C)	12		
MIDDLE QUATERNARY			Cromerian (T)	13		fissure fillings in Magnesian Limestone coastal cliffs
L/Q			earlier stages (C&T)			

T temperate stage C cold stage

CHAPTER 7

QUATERNARY

Virtually all known Quaternary deposits in north-east England resulted from the most recent, late Devensian, ice sheet glaciation, or were emplaced during subsequent periglacial episodes or in the present interglacial. Information from the region on earlier Quaternary events is minimal. Furthermore, though most of the region is mantled by drift of glacial or periglacial origin, and landforms have been shaped in detail by glacial and periglacial processes, the overall degree of Quaternary modification of the late Tertiary landscape is quite unknown.

In this account references to early papers are omitted in cases where these are listed in cited review articles. Important early papers are, however, listed in the bibliography.

Pre-late Devensian

An ice sheet began to develop in the Antarctic during the early Tertiary, and expanded during the Miocene. By the Pliocene, global climate was oscillating between colder and warmer episodes, and a major step in the amplitude of climatic variation, reflecting more intense cold phases, occurred at about 2.4 Ma BP (before present). The Tertiary/Quaternary boundary is somewhat arbitrarily (in terms of global environmental change) placed at about 1.64Ma BP (Harland *et al.*, 1990). At about 0.9Ma BP the intensity and length of the cold periods increased further, with the rhythmic growth and decay of large ice sheets in the middle latitudes of North America and Europe. These were separated by relatively short interglacials at intervals of about 100,000 years (Boulton, 1992; Bowen, 1991). Global Quaternary stratigraphy is based upon oxygen-isotope variations in oceanic faunas, primarily reflecting global ice volume. The resulting climato-stratigraphic stages are numbered on a count-from-the-top basis, with temperate stages being given odd numbers and cold stages even numbers (Table 5).

The Quaternary is likewise divided in Britain into climatically-based alternating cold and temperate stages, but using mainly biological and lithological evidence. The most recent stages are the cold Devensian (which contains the latest widespread glaciation of the region) and the present Flandrian temperate stage. A stratigraphic framework was provided by Mitchell *et al.* (1973), based mainly on East Anglian and English Midland sequences, but since then its elements have been much debated. A variation on that stratigraphy, which is adopted in Table 5, is offered by Boulton (1992), but is prey to much uncertainty as to the number of stages and sub-stages recognizable in Britain, the existence or not of hiatuses in sedimentary sequences, and correlation into the marine isotopic record.

It remains unclear how many of the cold stages and sub-stages, both before and after 0.9Ma BP, produced major ice sheet glaciations in Britain; many may have given rise only to local mountain glaciation and/or to periglacial conditions. However, during the Anglian cold stage, an extensive ice sheet developed which reached southern England and must therefore have covered the north-east. Similarly, in the late Devensian a major ice sheet covered all or most of the region and extended into the English Midlands. Whether or not an extensive ice sheet developed in Britain earlier in the Devensian is uncertain. During temperate stages Britain experienced climates similar to that of the present, with forest vegetations which, however, contained more and more exotic or extinct species the earlier they occurred in the Quaternary.

In north-east England, because of erosion of earlier Quaternary sediments by the late

Devensian ice sheet, pre-late Devensian deposits (and hence information on earlier Quaternary events) are extremely fragmentary, and are virtually confined to east Durham. Their correlation into the British and global stratigraphies is in most cases speculative.

Smith & Francis (1967) and Francis (in Johnson & Hickling, 1970) have described and reviewed the east Durham deposits. The only ones possibly referable to the Lower and the Middle Quaternary are breccias and clays, now obscured, rammed by a later ice sheet into fissures of the Magnesian Limestone near Blackhall Colliery. An earlier clay, containing seeds, represents a woodland episode of Tertiary or earliest Quaternary age, while a later clay may be of Middle Quaternary age. It contains freshwater shells, peat, tree trunks, insects, rodent teeth and the vertebra of an elephant resembling *Archidiskodon meridionalis*, which may collectively indicate a temperate stage near to the Cromerian.

Just to the north, in a buried valley at the mouth of Warren House Gill, lies the 'Scandinavian drift', formally named the Warren House Till (Francis in Johnson & Hickling, 1970). It is a grey, sandy clay with rounded, Scandinavian, crystalline erratics and also with pre-Quaternary sediments and arctic shells probably from the area of the North Sea. Boulders of larvikite and other Norwegian rocks lie on the beach nearby, and a Scandinavian boulder was also found at Castle Eden Dene. The till requires a cold stage of sufficient duration and intensity for a Scandinavian ice sheet to have reached the Durham coast. It is correlated with the Basement Till of Holderness, Yorkshire, on the basis of lithology, contained fauna and stratigraphical position. Since the Basement Till has been regarded as 'Wolstonian' (Catt, 1991a), so likewise would be the Warren House Till, but given the difficulties with the status of the Wolstonian (Bowen, 1991; Rose, 1987), the till is best regarded at present as simply post-Anglian and pre-Devensian in age. Overlying this till and, like it, covered by Devensian drift, is a brown silt (not now exposed) interpreted by Trechmann (1919) as a loess: the only such deposit discovered in the region. The loess, of unknown age, denotes a cold environment. There is no local evidence of a temperate stage demonstrably separating the Warren House Till from succeeding Devensian deposits, unless it is represented by the weathering of some of the crystalline boulders under Devensian drift.

Also in east Durham, however, rafts of peat incorporated into a Devensian till, and exposed in a temporary road cutting at Hutton Henry, have been assigned by Beaumont *et al.* (1969) to the Ipswichian interglacial. Correlation was based particularly on the high percentages of *Carpinus* (hornbeam) pollen which are considered to be characteristic of the late-temperate zone of the Ipswichian. The peat had been part of a bog overlying a lake fill in an otherwise forested landscape. Another probable interglacial deposit is the 'Easington Raised Beach' (NZ 443453), a calcreted gravel containing an abundant modern-type temperate marine shell fauna and lying on a rock platform at about 32m above sea level. The deposit is overlain by late Devensian till, and from its pebble content was preceded by at least one major glaciation. Amino acid relative dating indicates an oxygen isotope stage 7 age, about 200,000 yrs BP (Bowen & Sykes, 1988; Bowen *et al.*, 1991). However, the altitude of the raised beach presents a difficulty, in that interglacial global ice volumes, and therefore glacio-eustatic sea levels, should have been much as now; the beach may perhaps have formed before complete isostatic recovery of the land after a previous major glaciation.

Farther north, on the Northumberland coast south of Newbiggin, Bullerwell (1910) described a shell-less shingle bed, apparently rather above present sea level, banked against a cliff and, together with the cliff itself, buried under till. The deposit, now removed, included erratics and, as described, was a beach of minimum pre-late Devensian age.

Other evidence of early sea levels comes from raised, presumably marine, rock platforms, in places backed by cliffs, at 18-31m above sea level. and occurring both on the adjacent Lothian and Berwickshire coasts, possibly extending into Northumberland north of the Tweed (Rhind, 1965; Sissons, 1967), and on the Durham coast. In the latter case a widespread, gently sloping platform is cut into the Magnesian Limestone, with a former cliff-foot at altitudes similar to that of the Easington Raised Beach (Bowen *et al.*, 1991). Most of these platforms appear to have been glaciated and therefore at least pre-date the late Devensian. In order to account for their altitude glacio-isostatic depression of the land again seems to be required, and it is possible that platform formation occurred at least in part under periglacial conditions, either shortly after ice sheet retreat or near to a stationary ice margin; Sissons (1982) explained high glaciated rock platforms on western Scottish coasts in this way. It is also likely that the wide wave-cut rock platforms along the north-east coast at present sea level were eroded during one or more interglacials, rather than entirely during the brief period since the culmination of the Flandrian transgression. Till lying on the inter-tidal rock platform at Hauxley (NU 286025), covered by modern beach sand, supports this view.

No local deposits are definitely referable to the cold stadials and milder interstadials of the early and middle Devensian, although some of the sub-fossil material described below may be of such ages.

There have been numerous finds of sub-fossil Quaternary vertebrates in the region, although many are considered to be of Flandrian age. Apart from the elephant and associated fauna from Blackhall Colliery, mentioned above, the only reasonably certain pre-Devensian specimen is a hippopotamus (*Hippopotamus amphibius)* molar from a gravel pit four miles northwest of Stockton-on-Tees (Sutcliffe, 1959 and pers. comm.), of presumed Ipswichian interglacial age. This is the most northerly hippo yet discovered. Late Quaternary cold climate mammals, which may be of Devensian age and dating from either before the advance or after the retreat of the late Devensian ice sheet, include:

woolly mammoth (*Mammuthus primigenius*)	from Hartlepool Docks (Howse, 1861);
woolly rhinoceros (*Coelodonta antiquitatis*)	from glaciofluvial sand and gravel under a till unit at Brierton, West Hartlepool (Trechmann, 1939a);
giant deer (*Megaceros giganteus*)	from Seaton Carew, on till under submerged peat; from Mainsforth, near Ferryhill, 'in clay' and considered to be the first find in England; and from South Shields 'under clay' (all Howse, 1861);
elk (*Alces alces*)	from Neasham, near Darlington, in late-glacial peat and older than a 10,800 yrs BP radiocarbon date (Trechmann, 1939b; Blackburn, 1952); from the base of blanket peat in the upper valley of the Chirdon Burn, a western tributary of the North Tyne (Howse, 1861; Day *et al.*, 1970).

Late Devensian

The last interglacial, the Ipswichian, ended and the Devensian cold stage began with the onset of cooling about 122,000 yrs BP; further severe cooling occurred at *ca*75,000 yrs BP. The Devensian ended at 10,000 ^{14}C yrs BP. In Britain the main glacial advance of the stage occurred during the Dimlington Stadial of the late Devensian, between 26,000 and 13,000 yrs BP (Rose, 1985); the ice sheet had a lobate margin south of the region, and reached its maximum extent at *ca* 18,000 yrs BP. Deposits of this ice sheet are ubiquitous in the lowlands and extensive in the hills, and include both tills, and glaciofluvial and glaciolacustrine gravels, sands, silts and clays. These drifts presumably contain large volumes of reworked earlier Quaternary sediments. The Dimlington Stadial ice is presumed also to have re-emphasized bedrock erosional forms initiated during earlier glaciations.

Correlation of late Devensian deposits with deposits outside the region is on freshness of constructional forms, lateral continuity, lithology, radiocarbon ages and stratigraphical position.

(a) **Accumulation areas** and flow directions of the late Devensian ice sheet are inferred from erratic trains, striae, till macrofabric and matrix characteristics, drumlin orientation, ice-moulded rock features and the alignment of major glacial drainage channels. Flow lines as they may have been when the ice was last active are shown on Fig. 13. Most of the region was glaciated by ice originating externally to the north and west, but flow was strongly influenced by local topography. It has been generally conjectured that as source areas varied in their dominance with the progress of glaciation, so the confluent ice masses jockeyed in a complex manner, particularly in the lowland areas, and possibly also overrode one another. The southward deflection of Cheviot, and Tweed valley, ice along the coastal belt was for long assumed to have had an ultimate cause in powerful Scandinavian ice off the present coast and confluent with British ice, but evidence of marine conditions in the central North Sea during the glacial maximum (Cameron *et al.*, 1987; Sejrup *et al.*, 1987) seems to preclude this possibility. However, the extent of Devensian/Weichselian ice in the North Sea basin remains uncertain (*cf.* Ehlers & Wingfield, 1991). It is possible that glacio-isostatic downwarping at the ice sheet margin, and/or a forebulge further east, played a role in the lateral deflection of thin marginal ice (Ehlers & Wingfield, 1991). Western ice flowing through the Tyne Gap was also deflected, in this case south-eastwards. Striae and erratics both indicate that at an earlier phase than that depicted in Fig. 13, but not demonstrably during the late Devensian glaciation, inland ice had been free to flow eastwards towards the area of the North Sea.

The external ice sheets, on the evidence of erratics, failed to override the higher parts of the north Pennines (Alston Block) and of the Cheviot Hills; Vale of Eden ice, for example, appears not to have crossed the Pennine fault-scarp much south of Hartside Pass (NY 648417) or much north of Little Fell (NY 784217). It remains uncertain whether the locally-generated glaciers in these uplands were complete ice caps, or alternatively, formed less extensive glacier networks leaving the summits and high divides free of ice at least during the late Devensian glaciation. The latter view, of emergent nunataks, is supported by the apparent absence of till from such areas and by the former intensity of periglacial processes there (Burgess & Wadge, 1974; Carruthers *et al.*, 1932; Raistrick, 1931). Complete burial by an independent ice cap, confluent with external ice, was, however, advocated for the Cheviot Hills by Clapperton (1970). That the ice was local in this case is indicated by exclusive presence of locally-derived tills, outward carry of erratics, orientation of erosional forms and alignment of meltwater channels. That it covered the summits is indicated by the elevation of erratics (although none is present on the higher summits themselves) and channels, with further support from a consideration of the likely altitude of the firn line in this region. Indeed, Clapperton considered that local ice domes may have accumulated not only on the high ground of the igneous massif, but on broad summits as far south-west as Peel Fell (NY 625997). In the north Pennines, the upper dales of the Wear and Tees contained

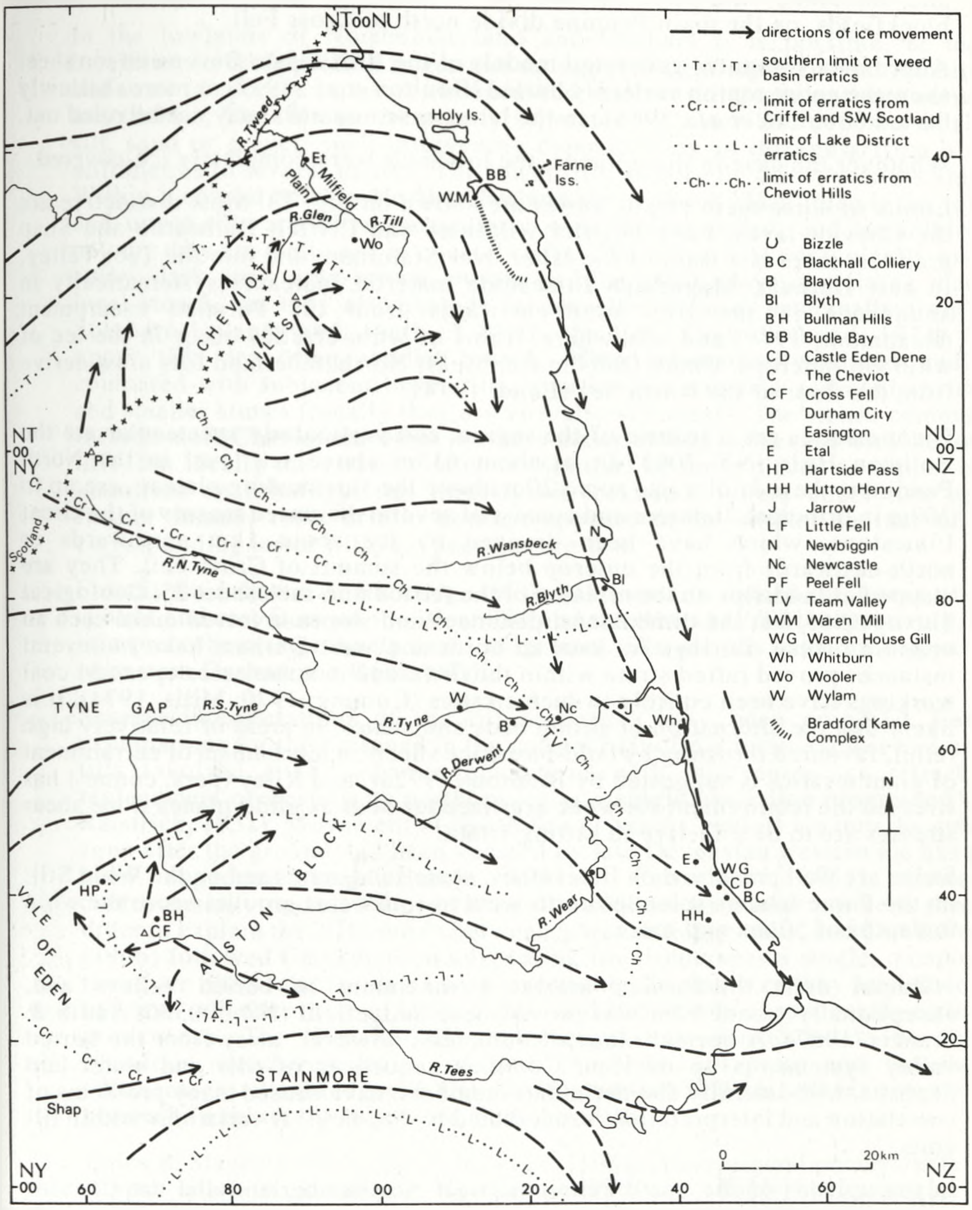


Fig. 13 Map showing the pattern of ice movement in north-east England during the Dimlington Stadial, at a late stage of glaciation.

exclusively local ice (Raistrick, 1931), and as regards the interfluves and summits, arguments similar to those adduced by Clapperton for the Cheviots support complete burial by glacier ice. Further support comes from ice-moulded and smoothed sandstone surfaces at altitudes of up to 740m OD, amidst blockfields, on the main Pennine divide north of Cross Fell.

Alternative computer-generated models of the British late Devensian ice sheet show the entire region as deeply buried (Boulton *et al.*, 1977) or more shallowly buried (Boulton *et al.*, 1985); in the latter case nunataks may not be ruled out.

Whatever the case in the uplands, the lowlands were completely ice-covered.

Limits of some main erratic suites are shown on Fig. 13. Most distinctive are the Cheviot lavas, Lake District volcanics and Criffel, Dalbeattie and Shap granites; there is a train of the latter over Stainmore and into the Tees valley. In east Durham, Magnesian Limestone material increases systematically in abundance in the tills south-eastwards from the Permian escarpment (Beaumont, 1971) and, elsewhere, trains of whin erratics occur in the lee of whin sill outcrops. Chalk flints in south-east Northumberland tills must derive from the floor of the North Sea (Land, 1974).

Giant erratics are a feature of the region, and particularly spectacular are the Bullman Hills (NY 706374), at about 615m above sea level in the North Pennines; these knolls rise some 20m above the surrounding plateau, are up to 200m in principal diameter and consist of several displaced masses of the Great Limestone, which have been dragged by ice about 1km northwards or north-eastwards from the outcrop below the summit of Cross Fell. They are mapped as landslips on the revision of the Alston one-inch sheet 25, Geological Survey 1965, but the dimensions, distances and slopes involved make such an origin unlikely. Borings for coal in north and west Durham have in several instances proved rafted strata within the drift, and in some cases opencast coal workings have been entirely in such erratics (Cuming, 1970; Mills, 1974). It is likely that the alternation of strong beds and shales, in areas of relatively high relief, favoured thrusting by cold-based ice sheets; a mechanism of entrainment of giant erratics is suggested by Boulton (1972a), and Riley (pers. comm.) has stressed the requirement for weak argillaceous beds as glide-planes if ice shear stresses are to be effective in rafting strata.

Striae are well preserved on limestones, some sandstones and on the Whin Sill; on the Farne Islands splendid north-west to south-east grooves score the whin to depths of 50mm and more.

(b) **Glacial drift** thicknesses are at a maximum in buried valleys and, exceptionally, about 92m was proved near Sedgefield (NZ 390300; Smith & Francis, 1967). A normal range of thickness, however, away from the buried valley systems, is up to 15m. Complex sequences of tills and water-laid deposits, with laterally discontinuous members, have caused many problems of correlation and interpretation, exacerbated by lithological variations within till units.

In the uplands of the north Pennines, west Northumberland and the Cheviot Hills, till is discontinuous. On the interfluves and cuestas it tends to be thin, and sandy or stony, or completely absent. On the lower slopes it is, in general, distributed asymmetrically, with deep and extensive sheets only on the lee sides of the valleys with respect to ice sheet flow. This pattern of distribution indicates dominant erosive activity of ice on interfluves, and slopes facing up-glacier, and complementary deposition of lodgement till on lee slopes. At the heads of the Pennine dales, till occurs at least up to 615m above sea level (Johnson & Dunham, 1963) and in the Cheviot Hills to about 455m (Clapperton, 1970). In the lowlands, till is more or less ubiquitous except where sandstone and Whin Sill cuestas and knolls protrude, and on the crest of the Magnesian Limestone cuesta. The Quaternary Map of the United Kingdom: North (Institute of Geological Sciences, 1977), gives a generalized picture of the distribution of till in the region.

In the lowlands of Northumberland and Durham it is possible, at many localities, to distinguish a lower and an upper till (in some coastal localities, and some temporary exposures in open-cast coal workings, more than two units are visible). The tills are frequently separated by water-laid deposits of clay, silt, sand or gravel; such intervening deposits vary in thickness from a few millimetres to several metres. The lower tills usually lie directly on rockhead. Within a coastal belt (in Northumberland up to about 15km inland) the lower and upper tills are often particularly well differentiated, and separable on colour; they are well seen in coastal cliffs. The lower tills are typically tough, stony, dark grey, grey-brown, purple or blue gritty clays containing mainly local stones, but they also include far-travelled erratics principally from the Southern Uplands and, south of Blyth, the Lake District (Land, 1974). The upper tills are often reddish-brown, often prismatically-jointed and, as compared with subjacent lower tills, may be less compact and contain fewer and smaller stones (locally they are virtually stoneless). The stones commonly include more Cheviot and other northern material than is the case with the lower tills, but locally the erratic content is similar. In some places an 'upper till', identified on lithology, lies directly on rockhead. Where upper tills occur further inland, their erratic content appears to be similar to that of the corresponding lower tills, but sections are few.

Francis (in Johnson & Hickling, 1970) has formally named the lower tills in central and east Durham the Wear Till and the Blackhall Till respectively, and interprets them as probably basal lodgement tills. He has named the upper till of eastern Durham the Horden Till.

Several interpretations of the till sequences have been proposed. Earlier explanations for the presence in the coastal belt of distinctive lower and upper tills involved either separate glaciations with intervening ice retreat, or replacement of western by northern ice as a single glaciation progressed (*e.g.* Raistrick, 1931). Movement of North Sea (Tweed-Cheviot) ice into the coastal zone after the ground had been vacated by late Devensian western ice has also been suggested (e.g. Smith, 1981a). Carruthers (1953), however, controversially postulated overriding of a western by a later northern sheet in order to explain the differences between lower and upper tills, and Catt & Penny (1966) followed Carruthers in advocating for Holderness a single, composite, tiered ice sheet, the result of such overriding. In this way they explained the upwards sequence there of Drab, Purple and Hessle tills of supposedly different provenance. The 'Hessle Till', however, is now considered to be only a Flandrian weathered facies of both the Drab (Skipsea) and the Purple (Withernsea) tills (Madgett & Catt, 1978), but Catt (1991a) still favours a tiered glacier to explain the other east Yorkshire tills.

Eyles & Sladen (1981), and Eyles *et al.* (1982), have argued persuasively that 'upper tills' in south-east Northumberland are simply the post-glacially weathered zones of otherwise more or less homogeneous lodgement tills, 'lower tills' having remained unaltered. Deep weathering penetration is claimed to be promoted by the seasonal cracking and prismatic jointing associated with the dry climates of eastern coastal regions. The same authors additionally point out that ribbon-like interbeds of water-laid sand and gravel, and laminated clay, would form in ephemeral subglacial fluvial channels and lakes at the base of temperate ice sheets during lodgement till emplacement. Just such shoestring interbeds occur at many horizons in the local tills, and their use to define lower and upper tills is therefore invalid.

Alternatively, and in quite different glaciological context, Boulton (1972b) described how complex sequences of tills, glaciofluvial and glaciolacustrine deposits, similar to those observed in a number of localities in north-east England, arise at the glacier margin during the decay of a single ice sheet. Upwards sequences of lodgement, melt-out (from stagnant ice under a confining overburden) and flow tills are emplaced, the till units separated or not by gravels, sands, etc. The processes involved resemble in many ways those inferred by Carruthers, based on detailed examination of some of the local drifts.

Finally, Eyles *et al.* (1982), from detailed examination of till sequences in south-east Northumberland opencast coal workings, suggested that multiple till complexes arise from 'unconformable facies superimposition'. As the ice sheet switched between depositional and erosive modes, concurrent minor changes in vector caused variations in lodgement till lithology from one depositional phase to the next; the lensate till units have cross-cutting erosive relationships.

To summarize, the presence of two or more superimposed tills and (where present) interbedded water-laid sediments might be explained by any, or a combination of:

1. Separate glacial advances or readvances (tills emplaced by lodgement, intervening outwash);
2. Composite, stacked ice sheets (tills emplaced by lodgement and by other mechanisms?);
3. Distinct emplacement mechanisms (lodgement, deformation, melt-out, flow, etc.);
4. Post-glacial weathering (of lodgement tills);
5. Unconformable facies superimposition (tills emplaced by lodgement); on a larger scale lithological variations caused by major shifts in ice flow direction and source areas during a glacial cycle.

It is very likely that different explanations apply to different localities within the region, but that over wide areas combinations of (4) and (5) apply.

As noted, laminated clays and silts, and sands and gravels, are widely associated with the tills. Very locally they underlie the lowest till, but they generally occur within or between till units or as surface deposits. Most of these water-laid deposits, like the tills, are believed to be of late Devensian age, with the more extensive sediment bodies being emplaced during final deglaciation.

(c) **Deglaciation** was rapid. The Blackhall Till is correlated with the Skipsea Till of Holderness, which was deposited by ice advancing some time after 18,000 yrs BP (Francis in Johnson & Hickling, 1970), and the ice sheet had melted in much of Scotland by 13,000 yrs BP. Boulton *et al.* (1985) and Boulton (1992) have reconstructed from geomorphological features isochrons of ice retreat northwards and westwards through the region, but (see below) the existence of ice-dammed lakes in near-coastal areas of Northumberland and Durham is evidence of the separation of North Sea and western ice, and of a more complex pattern of retreat than is depicted on the isochron maps. Melting was, as far as the evidence for this region goes, uninterrupted. Copious meltwater, charged with debris released from the ice or derived from drift, eroded channels and laid down glaciofluvial and glaciolacustrine sediments in ice-contact and proglacial environments. Such deposits, where they remain at the surface, have been mapped on the official large-scale drift maps as *inter alia* 'sand and gravel', 'laminated clay' and 'terraces'. However, the most recent comprehensive small-scale remapping of the country's superficial deposits was by the Soil

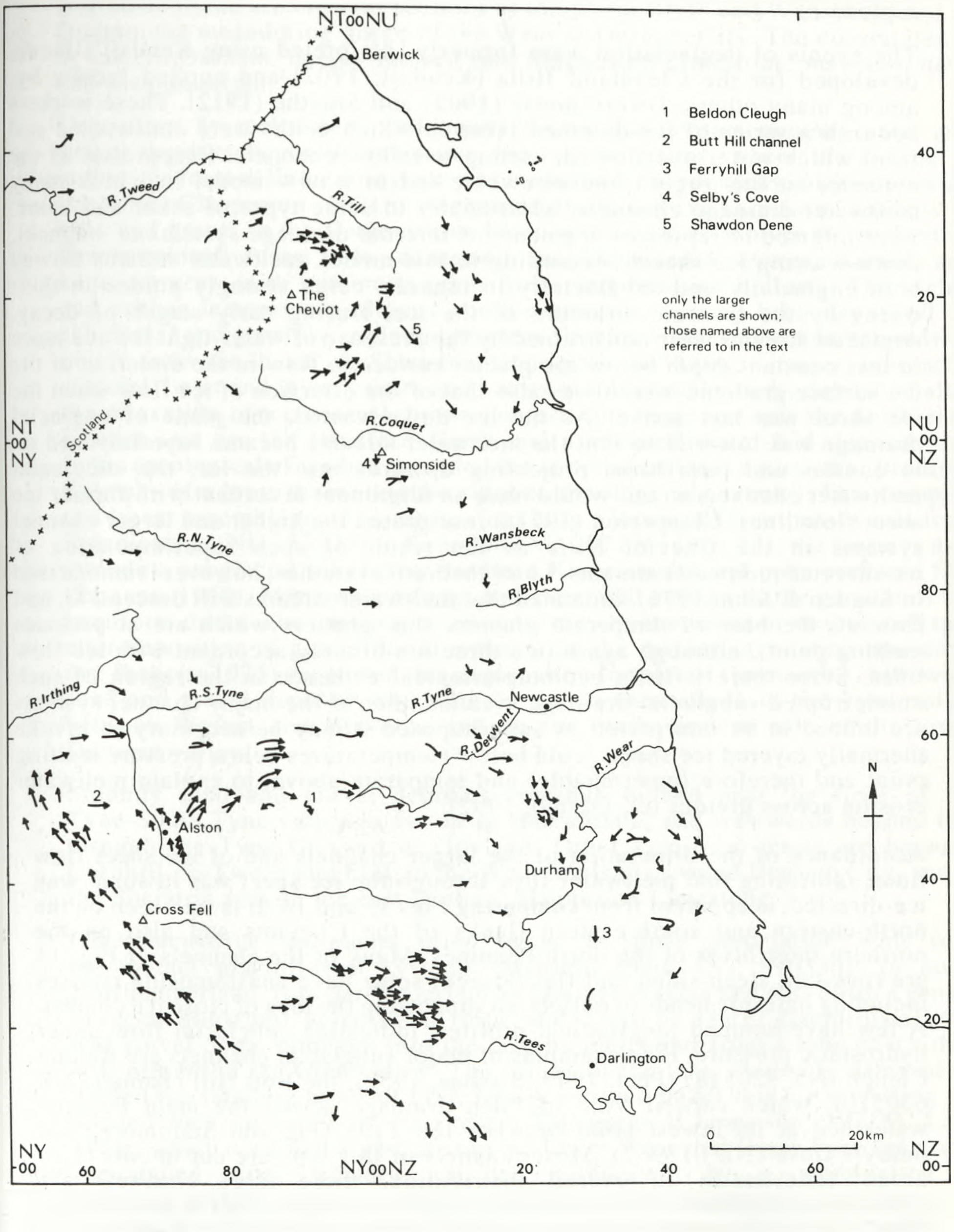


Fig. 14 Map showing the distribution of glacial meltwater channels in north-east England (compiled from various sources).

Survey of England and Wales, and their distribution can be interpreted from the Survey's 1:250,000 soil map of England and Wales (1983). Catt (1991b) figures their distribution in lowland north-east England. No glaciomarine or glacio-aeolian deposits of late Devensian age have been described from the region.

The events of deglaciation were formerly interpreted using Kendall's model developed for the Cleveland Hills (Kendall, 1902) and applied locally by, among many others, Dwerryhouse (1902) and Smythe (1912). These workers adduced a series of ice-dammed lakes in which deltas were constructed and from which water overflowed, cutting overflow channels. Reappraisal of the evidence in this region and elsewhere led to a new model in which many meltwater drainage channels, additionally to some types of esker and kame, were inferred to represent segments of internal drainage systems of stagnant, down-wasting ice sheets. According to this model, meltwater streams flowed both englacially and subglacially in tunnels, being strongly guided in their traces by the tectonic structure of the ice. During early stages of decay, englacial streams were constrained by the presence of water-tight ice at a more or less constant depth below the glacier surface to flow in the direction of the ice surface gradient, which was also that of the direction of ice flow when the ice sheet was last active. As the ice down-wasted, the plane of englacial drainage was lowered so that the meltwater streams became superimposed on to cuestas and interfluves projecting upwards into the ice; the subglacial meltwater channels so cut would have an alignment accordant with former ice sheet flow lines. Clapperton (1971a) interpreted the higher and larger channel systems in the Cheviot Hills as the result of such superimposition of ice-directed meltwater streams. Later theoretical studies, however (summarized in Sugden & John, 1976), indicated that meltwater streams will descend to, and flow at, the base of temperate glaciers (i.e. glaciers which are at pressure melting point), although again in a direction broadly accordant with ice flow lines. Since there is little geomorphological evidence in the region of such uninterrupted subglacial drainage systems, then if the major channel systems are indeed to be interpreted as superimposed it may be necessary to invoke thermally layered ice sheets, cold below (temperatures below pressure melting point and therefore impermeable) and temperate above, to explain meltwater erosion across divides (cf. Olvmo, 1992).

Accordance of the orientation of the larger channels and of ice sheet flow lines, indicating that meltwater flow through the ice sheet was in some way ice-directed, is apparent from comparing Figs 13 and 14. It is well seen on the north-eastern and south-eastern flanks of the Cheviots and also on the northern interfluves of the north Pennines. Many of the channels of Fig. 14 are rock-cut, steep-sided and flat-floored; some have anastomosing courses including multiple heads or outlets, so supporting the idea of close ice control. A few have humped longitudinal profiles, indicating subglacial flow under hydrostatic pressure. Fine examples of major subglacial channels are Beldon Cleugh (NY 920518) (Peel, 1949; Sissons, 1958), the Butt Hill channel (NY 630510), which carried Vale of Eden drainage across the main Pennine watershed at its lowest point between the Tyne Gap and Stainmore, and Selby's Cove (NZ 018952). Most channels of this type are cut in cols or in broad valleyheads. In overall distribution, these large channels are concentrated where meltwater was flowing across the grain of the topography. They may well have discharged meltwater, and been enlarged, in successive glaciations.

As the interfluves emerged, marginal and submarginal channels were eroded along valley sides. Meanwhile, thinning and wasting of the ice sheets extinguished any regional hydraulic pressure gradients which had previously directed meltwater flow; smaller subglacial channels were then cut more or less freely down-slope. Many hundreds of channels in the region were probably eroded in these ways. Internal glacier drainage may also have initiated the many rock gorges where modern rivers trend at variance to their partly or completely buried valleys, or follow entirely new courses; examples of such gorges in east Northumberland are those of sections of the rivers Blyth and Wansbeck, and in Durham the meandering gorge of the Wear at Durham City. The coastal denes of eastern Durham, deeply incised into Magnesian Limestone, may also have had such an origin.

Deposition by meltwaters took many forms. Ice-contact moundy sand and gravel deposits occur in numerous separate localities, where the escape of meltwater from disintegrating ice was impeded by topography, or by opposing ice lobes. Clapperton (1971b) interpreted the extensive kamiform deposits of sand and gravel in the Cementstone basin south-east of Wooler as ice-contact constructional forms. He described inter-connected eskers, kames and kame-terraces, with numerous kettle holes and dead-ice hollows. The higher and earlier features are aligned south-eastwards, having been deposited by subglacial and possibly englacial streams flowing in that direction towards an outlet from the basin at Shawdon Dene (NU 045160), a major subglacial channel. Later and lower eskers and kames in this complex were deposited after the relaxation of ice control, by drainage at this stage towards the north-east. Further east are the Bradford Kame and associated water-laid deposits and forms (geological usage has extended the appellation from a part - the 'Bradford Kaims' - of a long, discontinuous ridge to the ridge as a whole). This complex is a linear assemblage of features, stretching 13km south-southeastwards from Spindlestone (NU 152233) to Fallodon (NU 207236) (Fig. 13); the features may include a subglacial esker (the Bradford Kame itself) and open crevasse fills (Parsons, 1966). Much uncertainty, however, still surrounds the genesis of the kamiform drifts. The topography of some may be the result of chaotic collapse after deposition of glaciofluvial material on the surface of wasting masses of ice. Francis (1975) suggested this explanation for part of the massive, billowing sand and gravel deposits which lie on the southern flank of the Tyne valley between Wylam and Blaydon, and on the north-western side of the lower Derwent valley.

Moundy sand and gravel deposits continue in and near the floor of the Tyne-South Tyne valley as far up as Haltwhistle, and westwards beyond that through the Tyne Gap col at Gilsland. Other kamiform tracts are between Cornhill-on-Tweed and Etal, in the Wear lowlands around Durham City, and in the Sheraton area on the east Durham Magnesian Limestone.

Glaciolacustrine sediments often occur in close association with such ice-contact glaciofluvial systems. Milfield Plain (NT 990330), in north Northumberland, is in part underlain by laminated clays and silts (with a veneer of recent alluvium), at least 22m thick, and in part by a large glaciofluvial sand and gravel delta, built out into the lake by meltwater from a lobe of ice then still present in the Glen valley. The waters of the lake, evidently dammed by Tweed ice standing at about Etal, finally escaped under this ice in cutting the incised rock meanders of the present Till gorge (Clapperton, 1971b). Lake Wear, which occupied a vast area in the lower Wear and lower Tyne area, was impounded, after western ice had withdrawn, by a combination of Tweed-Cheviot ice in the North Sea basin and the Magnesian Limestone escarpment. In it were deposited both laminated clays and silts, and sands, of the Tyne-Wear Complex (Smith, 1981a). Much of the built fabric of Tyneside and Wearside consists of bricks from Lake Wear clays. The lake received meltwater drainage from an enormous catchment to the north-west and west, including northern Cumbria, and the now dry Ferryhill Gap (NZ 300330), which has probably had a complex history as a meltwater channel, may have functioned for a time as a drainage outlet (Raistrick, 1931). The laminated silts and clays of Lake Wear are widely overlain by a thin diamict, the Pelaw Clay, of uncertain origin; it also overlies other deposits. Smith (1981a) suggested that it resulted from periglacial mass flow processes. Glaciolacustrine clays also occur on the dip slope of the Magnesian Limestone cuesta south-west of Peterlee, in the lower Tees area and in the south-east Northumberland coalfield area.

Proglacial valley trains of outwash sand and gravel occupy the floors of the major valleys. These fills are prominently terraced in the Tees, Wear, Tyne and Tweed valleys and, in the case of the Tweed, terraces can be traced upstream into ice-contact deposits formed at stagnant margins of the shrinking ice sheet (Rhind, 1968).

Although detailed modern mapping of the distribution and morphology of these meltwater deposits is lacking in much of the region, the kamiform ice-contact sands and gravels, and the glaciolacustrine sediments associated with them, occur in three main contexts. In each, meltwater drainage impedance was to be expected.

1. In topographic basins, such as those between the Cheviot Hills and Fell Sandstone cuesta in north Northumberland, and between the North Pennine foothills and Magnesian Limestone escarpment in central and northeast Durham;

2. In a broad north-south zone some kilometres inland from the coast, in the assumed suture zone of western and northern ice (*cf.* Catt, 1991b);

3. In main valleys, *e.g.* that of the South Tyne/Tyne and Tweed, where copious meltwater drainage from a large area occurred through stagnant, retreating ice margins.

In the case of Lake Wear, both the first and second cases apply.

(d) During **Late-glacial** times, after the retreat of the late Devensian ice sheet, periods of periglacial climate and environment were interrupted by the mild Windermere Interstadial at *ca* 13,000-11,000 yrs BP. The ensuing Loch Lomond Stadial (*ca* 11,000-10,000 yrs BP. and equivalent to the Younger Dryas of the Continent) was a brief period of particularly severe cold (Table 5).

During the periglacial phases, dominant frost processes were effective in scree formation, and it is likely that block screes below the crags of both the Whin Sill and the thicker sandstones were substantially formed at this time (Tufnell, 1969). The closely-jointed volcanic rocks of the Cheviots are very frost-susceptible, and disintegrated to form the widespread fine to medium-coarse scree aprons of steep lower hill-slopes. Also in the Cheviots, both weathered granite and volcanics, and till derived from these rocks, underwent solifluction during the late-glacial period. Soliflucted sheets of stony-loamy sediment now form smooth, sloping terraces on the lower valley sides, terminating in bluffs above the rivers and streams (Douglas & Harrison, 1987). In the higher uplands generally, much drift is inferred to consist of soliflucted 'head'. Above about 615m in the north Pennines there are blockfields ('carrs'), large-scale patterned ground and cambered sandstone beds, all probably relict although small-scale stone polygons still actively form at these elevations (Burgess & Wadge, 1974; Tufnell, 1969). Major landslips, usually of sandstone overlying shale, and toed by moraine-like rubble, may be of late-glacial age; an example is the feature called Upper Stony Holes (NT 656011), near Peel Fell. The former presence of permafrost is indicated by ice-wedge pseudomorphs and reticulate crop marks on the glaciofluvial delta of Milfield Plain, and wedges or involutions have been observed at several other localities in sand and gravel.

In the Cheviot Hills there are about a dozen good tors, in granite and metamorphosed lava at 395-660m above sea level (Clapperton, 1970; Clark, 1970). They occur near to pockets of deeply-rotted *in situ* bedrock, and a periglacial environment may be necessary both for the granular disintegration of bedrock to an irregular, deep weathering front and for subsequent stripping of regoliths to reveal the tors (Worsley, 1977).

During the Loch Lomond Stadial an extensive ice cap formed in the Scottish Highlands, and cirque and valley glaciers reoccupied parts of the Lake District (Sissons, 1980) and other upland areas in northern England. Such a readvance has not been proved in north-east England, although the fresh hummocky moraines described by Johnson & Dunham (1963) in some of the valleys of the Pennine western fault-scarp and by Clapperton (1970) in the Bizzle cirque (NT 920220) in the Cheviots, may belong to this period (Douglas, 1991).

Also probably dating from this cold stadial is a well-developed, submerged shoreline; a wave-cut rock platform tilts from present sea level in the Forth to 18m below present sea level at Burnmouth, and may be near 20m below present sea level at Berwick (Sissons, 1974).

Flandrian

The present, Flandrian, temperate stage began at 10,000 yrs BP. By about 7,000-6,000 yrs BP global sea level had risen glacio-eustatically to approximately its present position. No late-glacial raised shorelines are known to occur in the region. However, low Flandrian raised shorelines, a metre or so above present high water mark, occur on Holy Island and elsewhere on the Northumberland coast, where relative sea-level changes have been investigated by Plater & Shennan (1992). They used altitudes of dated transgressive and regressive contacts in borings through intercalated sequences of peat and marine-estuarine sediments, and found that in the last 8,000 years relative sea level has changed by only approximately 2.6m. Along the north-east coast as a whole, the main deposits of intertidal sediments are west of Holy Island, in Budle Bay and in the Tees estuary. On low coasts dune cordons have been constructed, and on prograding coasts such as at Ross Links (NU140380) more extensive dune systems occur; the Northumberland coast, unlike the cliffed coasts of much of Durham and of Berwickshire, has long stretches of dune.

Apart from the buried peats just referred to, peats up to 3m thick and 'submerged forests' are periodically exposed at or below high water mark at numerous coastal sites (Trechmann, 1947). They presumably mainly date from periods of lower relative sea level during the Flandrian. However, post-5,000 yrs BP dates from peat and a tree stump at Low Hauxley (Innes & Frank, 1988) suggest that coastal recession involving dune migration landwards over perimarine peats may in some cases be responsible for the occurrence of foreshore peat and associated sub-fossil trees, rather than vertical sea-level movements. Peat deposits inland include both extensive ombrogenous blanket mires in the wet uplands, and basin peats. Some of the latter deposits occupy kettle holes and other depressions in glacial drift, while numerous other examples occur in ice-eroded depressions between the cuestas on either side of the Roman Wall in west Northumberland. The blanket peats are generally less than 2m thick, but some basin peats, many of which occupy former lake sites, exceed 7m in thickness.

Flandrian stream activity has been profoundly affected by forest clearance, land drainage, cultivation, mining and gravel extraction, so that the nature and distribution of much recent alluvium, including that of the lower river terraces, owe much to anthropogenic causes. In particular, the lower terraces of the South Tyne/Tyne system are considered by Macklin & Lewin (1989) to be a direct consequence of excess floodplain and channel bed aggradation during the main lead and zinc mining period in the North Pennines, followed by recent incision.

Landforms and the Quaternary

The region experienced more than one ice-sheet glaciation and presumably many and prolonged periods of periglacial conditions; since ice is a powerful agent of erosion, and periglacial processes can also be geomorphically effective, it is likely that very substantial changes in the landscape have occurred since the end of the Tertiary. There is, however, scant evidence on which to base estimates of magnitude. Furthermore, the basal temperature regime of glaciers critically affects processes of erosion, transport and deposition, and since information on temperature characteristics of Quaternary glaciers is both exiguous and inferential, there is good reason for caution in geomorphic interpretations.

Certainly drift deposition has brought about substantial topographic changes in the lowlands, as has been confirmed by detailed rockhead contouring (Maling, 1954; Anson & Sharp, 1960; Cuming, 1970, 1977); in general, relief amplitude at the surface is less than that at rockhead, owing to drift deposits being thicker in valleys and basins. Extensive coastal areas are above sea level only because of the presence of glacial drift. In many areas where till is at the surface, the terrain consists of featureless or irregularly undulating till plains, but drumlin fields occur on Tweedside, west of the lower North Tyne valley, in the Tyne Gap area, in the middle Tees valley and elsewhere. Thin tills on limestone benches, and on the dip slopes of limestone cuestas, are commonly punctured by lines of 'shake holes' - subsidence dolines a few metres in diameter where till has collapsed into solution fissures (Clayton, 1966).

Buried valleys have long been a subject of speculation and the rockhead mapping has provided much new information. Some underlie or are offset from surface valleys, while others are without surface expression. The large buried valleys are wider than their surface equivalents and descend to at least 30m below present sea level where they cross the present coastline but, beyond the fact that they must be at least of pre-late Devensian origin, their age is unknown; they may reasonably be inferred to relate to low relative sea levels of Quaternary cold stages. Their fills consist predominantly of water-laid sediments.

The uplands of the region have been profoundly modified by glacial erosion, presumably by areal scouring during phases when ice sheets were warm-based (cold ice being generally protective with respect to the landscape). First, the cuestas of the Northumberland trough are accentuated where ice sheet flow lines were parallel to the strike, as was the case in the vicinity of the Roman Wall in west Northumberland, and are degraded where flow was transverse to the strike (Clark, 1970). Additionally, the shales cropping out between the accentuated west-east cuestas of west Northumberland were eroded by the eastward-flowing ice so as to leave, in the floors of the inter-cuesta vales, numerous enclosed basins. These formerly contained lakes, most of which however have been extinguished by peat accumulation (some of the deep basin peats referred to earlier); a few lakes have survived, such as Crag Lough (NY 765680). Second, many upland valleys aligned transverse to ice movement are strongly asymmetrical in cross-section, particularly the northern dales of the north Pennines, but also in the North Tyne area and on the margins of the Cheviot Hills. The valley sides facing into the direction from which the ice was flowing have apparently been selectively steepened by glacial erosion (while till deposition was on the opposite, lee, sides as indicated earlier). Furthermore it is the same, steepened slopes of the Pennine dales which exhibit well-developed structural benching and this is probably also a consequence of active glacial erosion. Asymmetrical glacial steepening, together with roughening of the steepened slopes, is similarly described for some Southern Upland valleys by Sissons (1967). A non-glacial explanation of valley asymmetry has, however, also been proposed (Beaumont, 1970). Third, isolated hills, in the Cheviots and elsewhere, possess a 'stoss-and-lee' form - steepened up-glacier and stream-lined down-glacier - which is the complement of valley asymmetry. Related features are the crag-and-tail forms, developed where outcrops of the Whin Sill lay in the path of southward flowing ice in north-east Northumberland.

Evidence also indicating locally intense linear glacial erosion in the lowlands comes from the very detailed contour maps of rockhead relief in the lower Tyne area by Cuming (1970, 1977), based on borehole data. These maps show that the partly-buried Tyne valley is a broad, deep, steep-sided trough with local over-deepening, as is also the partly-buried Team valley connected to and orientated south-eastwards from the Tyne valley. Sugden (1974) and Sugden & John (1976) have discussed the mechanisms of selective linear streaming and erosion within the body of an ice sheet along valleys suitably aligned in relation to ice flow. It is possible that the Tyne and Team troughs were eroded by glacier ice in this way, one trough being diffluent with respect to the other. (The Tyne estuary would then be a fjord!). Bouledroua *et al.* (1988) have published rockhead profiles, based on electrical resistivity traverses, for the Tyne Gap area between Gilsland and Greenhead. The Tyne Gap col is also a partly buried valley, which has a shape and dimensions consistent with its interpretation too as a glacial trough selectively eroded within ice sheets.

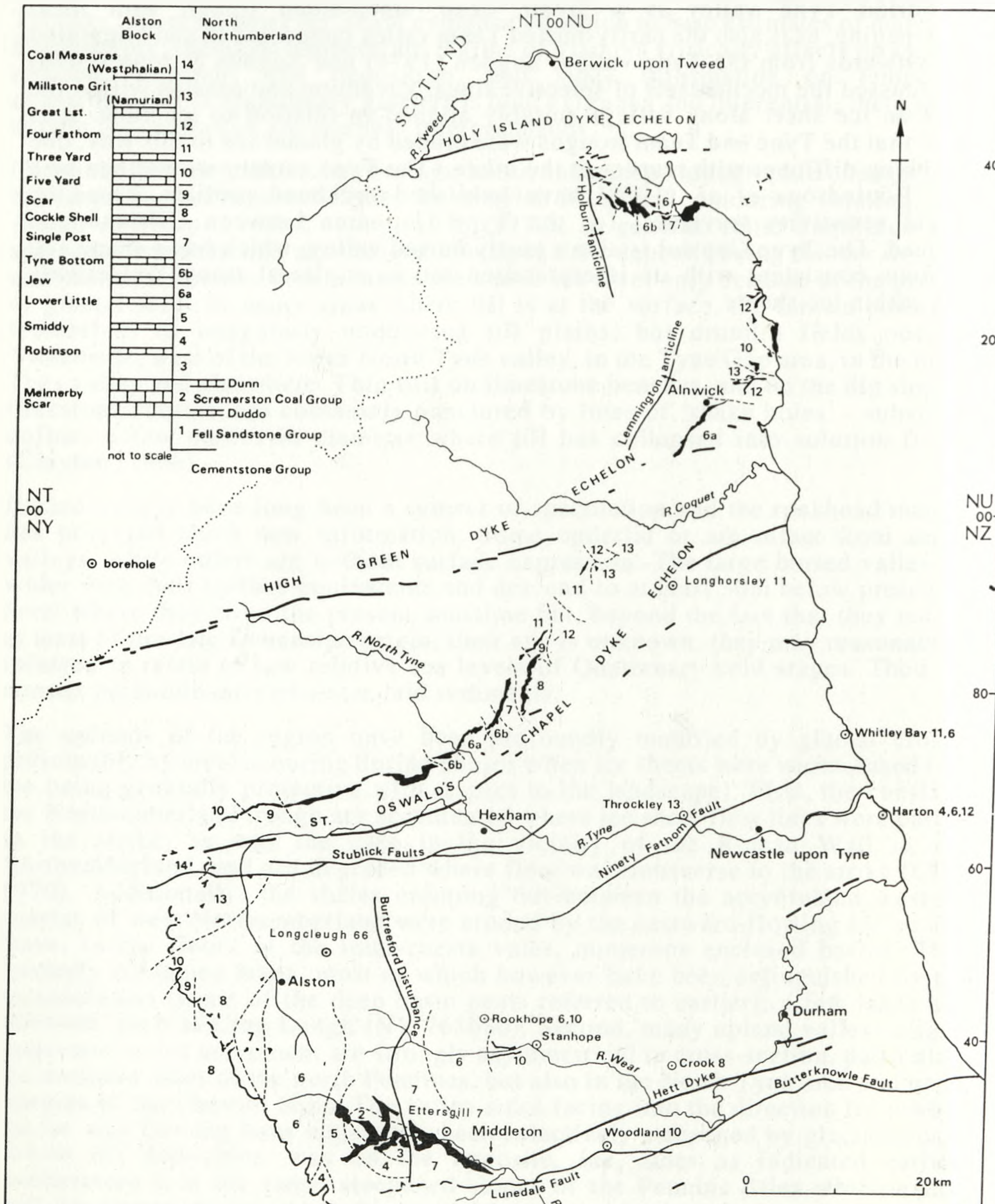


Fig. 15 Map showing the outcrop of the Great Whin Sill, the associated dykes and the location of deep boreholes in north-east England.

CHAPTER 8

IGNEOUS ROCKS

The Weardale Granite

Attention has been drawn by Dunham (1934, 1948, 1952, 1990) to the zonal arrangement of the epigenetic veins and replacement deposits in the Carboniferous rocks of the Alston Block; this zonal pattern, discussed elsewhere in this volume (p348) shows a marked similarity to that in other regions, such as Cornwall, where veins are associated with granitic bodies. Thus it was suggested that the source of the Pennine ores might lie in an intrusion buried below a cover of Carboniferous rocks.

Metamorphosed slate from the Lower Palaeozoic in the deep boring at Crook (Woolacott, 1923; Lee, 1924), together with a similar change in the folded rocks of the Teesdale inlier, provided indirect evidence for the presence of an intrusive body in depth. In addition, Bott & Masson-Smith (1953, 1957) obtained geophysical evidence of a negative gravity anomaly over the northern part of the block, which they interpreted in terms of a concealed granite body. A trial boring was therefore put down at Rookhope, County Durham (NY 938428), to test this hypothesis. Granite was reached in February 1961 at a depth of 390.5m (1281ft). The hole was deepened to 2650ft (807.7m).

The results were surprising, for while the geophysical calculations had been substantiated, it was found that the granite had a weathered cap and was clearly pre-Carboniferous in age and that mineralization continued down into the granite itself.

The detailed account of the petrography of the Weardale granite, which is given in Dunham *et al.* (1965) is only briefly described here. Hand specimens of the normal granite show a sub-horizontal, planar foliation defined by the micas and a parallel alignment of quartz 'eyes'. Even in the uppermost 1.5m (5ft) of the granite, which shows subaerial weathering, the preferred orientation of the 'eyes' is still recognizable. The rock is non-porphyritic. Both muscovite and biotite are abundant, with the latter (chloritized in the upper part of the core) causing a mottled appearance. The euhedral crystals of plagioclase (*ca* 3mm long) have a yellowish tinge, due to slight seriticization, and potash feldspars (+ 3mm long) are common. The 'eyes' of quartz become less abundant below 685m (2245ft). The plagioclase feldspars have the composition of Ab_{2-6}, while the potash feldspars vary in character from orthoclase to microcline; a myrmekitic texture is seen at the junctions between the albite and potash feldspars. Muscovites, biotites and pennine chlorites form intergrowths and the biotites contain inclusions of zircon and monazite. Accessory minerals in the form of apatite and magnetite-ilmenite are usually associated with albite.

Fine-grained aplites (fourteen in number) and coarse-grained pegmatites (twenty-nine) exceeding 20mm in thickness, occur at intervals throughout the granite core, lying sub-parallel to the foliation. The aplites are free of biotite and are richer in albite than the normal granite; they also contain microcline, quartz and muscovite. The latter show preferred orientation and impart a fine lamination to the veins. The pegmatites consist of segregations of albite, microcline, quartz and muscovite in random orientation.

The geochemistry of the Weardale granite is discussed by Dunham *et al.* (1965), Holland (1967) and Holland & Lambert (in Johnson & Hickling, 1970). It was found that the granite above 670m is significantly enriched in Fe_20_3, $Mg0$, K_20, $Ti0_2$, Sr, Ba and Zr, and impoverished in Na_20 and Pb compared with the granite below this depth. Holland concluded that, on balance, magnetic differentiation from a common magma, with subsequent emplacement of one granite after another, was the most probable cause of these variations. This type of episodic emplacement has been proposed for plutons elsewhere (Harry & Ritchie, 1963).

Radioactive dating of the granites, collected at depths from 564m (1850ft), and downwards, indicates a geological age of 410 ± 10Ma, while a sample of aplite from 656.5m (2154 ft) provides a date (which may indicate its real age of intrusion) of 390 ± 8Ma. It seems probable that the granite originated from a primary source, such as the upper mantle, without any protracted history prior to emplacement.

The Weardale granite occupies a volume of some $7000m^3$ (Bott & Masson-Smith, 1957), reaching a depth of about 10km. The present evidence which suggests that, in the Rookhope area, the granite was once in magmatic form, poses the problem of how this granite was emplaced. There is no stratigraphic or structural evidence that favours forceful intrusion. Bott (1967), and Bott & Smithson (1967), using geophysical evidence, have argued that mechanisms involving stoping were fundamental to the emplacement of this granite batholith. Alternatively, if the process of formation of such granites extended over tens of millions of years (Curtis *et al.*, 1958) or even several hundred million years (Lambert & Holland, 1972), then the objections raised against forceful emplacement become less cogent. Forceful, yet incremental, intrusion over such a long period, at the rate of, at most, one cm per year (Lambert, 1964) would have its volume displaced by continuous erosion at the surface. It is possible that, in this way, granites 'make room for themselves'.

The geochemical evidence suggests that, even within the limited penetration of the Rookhope borehole, two phases of the Weardale granite existed. It is proposed that, after solidification following the initial phase, slow upward progression of the granite was induced by repetitive emplacement of sill-like granite intrusions until the granite formed an eroded but hardened surficial cap to a still actively evolving granite many kilometres below. The high rank of the Namurian coals of the Alston Block (Trotter, 1954) and the development of the ore veins, both in the upper part of the granite as well as in the Carboniferous cover, are consistent with this proposed mechanism.

Holland and Lambert also noted a geochemical and isotopic similarity between the granites of the Lake District and those of Weardale. This link has been greatly strengthened by the geophysical evidence of Bott (1974). Bott visualizes a composite granite batholith underlying the central and northern parts of the Lake District, connected by a ridge passing beneath the Vale of Eden and linking the granite of Shap with those of Weardale (Fig. 5). It would appear therefore that the Weardale granite is simply an integral part of a much more extensive Caledonian granite that underlies much of northern England. One can only reflect that, had the forces of erosion been somewhat more rigorous, the preoccupation of geologists in this region would have been with granites rather than with coals and their associated deltaic deposits.

The Lower Old Red Sandstone (Cheviot) igneous complex

The geology of the Cheviot Hills has been studied from the time of the early pioneers. Mapping of the region and petrological investigations have been carried out mainly by the officers of the Geological Survey of Great Britain. Two memoirs have been published, the earlier by Clough (1888) and the more recent one by Carruthers *et al.* (1932). In the latter, the chief advances lay in the petrographical descriptions of the igneous rocks, since the maps produced by Clough and Gunn required little modification. Both these memoirs referred only to the English side of the Border; no memoir has been published on the Devonian (Old Red Sandstone) igneous rocks of the Scottish side. A published guide to the district (Robson, 1976) provides a summary of the geology, but no modern study of the genesis of the

Cheviot igneous complex has yet been carried out.

The Cheviot pyroclastic rocks. The Silurian strata break surface only in the north-west of the Cheviot Hills, apart from a minute outcrop against the Fawdon fault (NU 018145) where they can be seen towards the sources of the Coquet, Kale and Jed (NT 780090). They are overlain in the north-west by about 70m of pyroclastic deposits, varying from coarse conglomerates to fine ash. There are two excellent sections of these rocks along the Border area, in Ravenscleugh below the summit of Thirl Moor (NT 806084) and in the Gaisty Burn (NT 784105) at the head of the Kale Water. In addition, thinner pyroclastic deposits occur, interbedded with lava flows, throughout the Cheviot Hills, some as little as 2m in thickness, others 20m or more. Fragments of rhyolitic lava occur within the main succession in the north-west, with angular clasts of Silurian slate. The ash beds are mainly acidic and are often well-graded.

The Cheviot lavas. In the Border area, the pyroclasts are overlain by rhyolite lavas, of which there are two varieties. One of these, composed of perhaps only a few flows, weathers purple or grey and in the hand specimen can be distinguished from the dominant andesites by the presence of small, often minute phenocrysts of biotite. In thin sections of these rocks, occasional phenocrysts of alkali feldspar may also be seen, set in a groundmass of quartz and feldspar. The other variety of rhyolite forms several of the high hills along the Border line including Windy Gyle (NT 855152). The rock readily crumbles to form loose scree slopes and in this respect is very characteristic and distinct. It is identified in the field by its abundant and large phenocrysts of biotite and much altered feldspar. The groundmass contains quartz and feldspar.

The main group of lavas is composed of andesite which varies in colour from very dark to light grey and purple. Generally these lavas are porphyritic, with phenocrysts of andesine-labradorite, which are frequently decomposed. The rock is well-jointed and usually much altered. In thin section, the phenocrysts of rhombic-pyroxene, and less frequent clino-pyroxene, are seen to be invariably altered. These lavas are found throughout the Cheviot region; in the west, near Carter Bar (NT 698068), pyroclastic deposits and rhyolites are absent and the andesites directly over-lie the Silurian. Eastward, the long dip slopes of the andesites are covered by the strata of the Cementstone Group. These volcanics are remarkably and monotonously uniform, and it is very difficult to identify individual flows petrographically, unlike some other regions of Old Red vulcanicity.

A very fresh variety of andesite, originally described by Tate (1868) as a pitchstone-porphyrite, but more recently designated by the term 'glassy andesite' (Carruthers *et al.*, 1932), can readily be distinguished, in the field, from the normal succession of andesites. These pitchstone-andesites are grey to black, weather with exfoliation, and are invariably cut by thin red veins which are often no more than 2mm in width. In the hand specimen, fresh plagioclase laths can be seen, which under the microscope are identified as labradorite. Unaltered phenocrysts of rhombic pyroxene and augite also occur, set in a groundmass of fresh feldspar and glass. These rocks are to be found in widely scattered areas of the Cheviot country, always in association with the normal andesites. Thirlwall (1981) analyzed forty Cheviot andesites during a study of Old Red Sandstone volcanic rocks and concluded that they were more uniform than those of other British areas.

A third group of lavas, the oligoclase-trachytes, were first described by Carruthers *et al.* (1932); they occur in only one restricted area at the head of the River Alwin (NT 921117). In the field, they can be recognized by their platy structure and under the microscope they exhibit a groundmass of feldspar, mainly oligoclase, and altered pyroxene. Phenocrysts of feldspar are not abundant.

Many of the lava flows in the Cheviot Hills present cracked and slaggy surfaces which, in some cases, are filled with a fine green sediment. This sediment occasionally shows graded-bedding. The clearest exposures occur at Carshope on the River Coquet (NT 847115), but the widely-distributed pebbles of this material in stream beds indicate that these so-called sandstone dykes must be present within the lavas in other parts of the region. These dykes or veins seem to be fairly common in the lavas of Lower Old Red Sandstone age elsewhere and were first described by Geikie (1897). They are extremely well-developed in east Scotland in similar lavas along the shore south of Montrose (Robson, 1948).

The Cheviot granite. The granite which was intruded into the andesites of the eastern part of the Cheviot region has been dated at *ca* 380 Ma (close, in age, to that of Weardale granite) whereas the lavas give an average age of *ca* 390 Ma (Mitchell, 1972). The intrusion produced a significant metamorphic aureole in the surrounding lavas. The relationship between granite and lava has recently been investigated with the aid of a proton magnetometer and is the subject of a separate study (Robson & Green, 1980). In the field metamorphosed lavas can at once be distinguished from the normal, altered andesites by reason of their almost black appearance and their fresh, indurated character; they are best exposed in numerous tors which they form round the granite outcrop, and in occasional stream sections. Kynaston (1905) noted how the lavas of the aureole differ in composition from the normal andesite by the presence of biotite, pyroxene and magnetite.

The granite itself occupies a surface area of about $70km^2$, but much of the ground is peat-covered and outcrops are infrequent. Fortunately there are a few well-exposed tors and several stream sections. The petrography of the granite was first investigated by Teall (1885) and later by Jhingran (1942). The latter author described variations in composition which are restricted to fairly clearly-defined areas; he named them as the marginal, the Standrop and the granophyric varieties.

Jhingran described two types of inclusions within the granite, which might be termed macro- and micro-inclusions. The former are often large masses of metamorphosed lava caught up at the time of intrusion; they form the prominent tors. Some of these have subsequently been recognised as roof pendants. The micro-inclusions are more basic in composition, and can be seen as dark spots in the hand specimen. A more recent study by Al-Hafdh (1985) indicates that the granite is composed of a multiple ring structure formed by six successive intrusions of granite, produced in two cycles and related by crystal fractionation. The sequence of intrusions, the oldest first, is: 1) Marginal granodiorite (medium-grained grey); 2) Dunmoor granodiorite (pink, porphyritic granophyric); 3) Standrop granodiorite (coarse grey); 4) Linhope granodiorite (coarse brown); 5) Hedgehope granodiorite (fine, porphyritic) and 6) Woolhope granite (fine, saccharoidal). The granodiorites contain both clino- and rhombic-pyroxene in addition to biotite. The first three agree with Jhingran's groupings. Small areas show potassic and sericitic hydrothermal alteration and tourmalinization has occurred particularly in the Linhope and Hedgehope granodiorites and in the Woolhope granite.

The granite is cut by the NE-SW trending Harthope Fault and is apparently exposed at two levels of erosion; it is deeper and has steeper contacts in the south than in the north, where many contacts are almost horizontal.

The Cheviot dykes. Dykes of Lower Old Red Sandstone age are common in the southern area of the Cheviot Hills, less persistent in the north and almost entirely absent in the west. They have been classified by the officers of the Geological Survey (Carruthers *et al.*, 1932) as mica-porphyrites, quartz-porphyries, felsites and pyroxene-porphyrites. The first-named of these varieties are by far the most abundant. Though it is difficult to recognize the varieties except under the petrological microscope, the dykes as a whole are readily distinguished from the lavas into which they have been intruded. Weathered surfaces possess invariably a red tinge, in contrast to the grey or purple of the lava surfaces, while the fresh dyke has a strong pink colour and is coarser in grain. Several of the dykes can be traced for some kilometres across the lava country.

Under the microscope, the Cheviot dykes all appear to have a similar groundmass of acid feldspar and quartz, but they differ from one another in the composition of their phenocrysts. The mica-porphyrites contain phenocrysts of plagioclase feldspar and biotite; the quartz-porphyries, in addition, show phenocrysts of quartz, while the pyroxene-porphyrites exhibit a porphyritic texture with augites as well as plagioclase feldspar and biotite phenocrysts. The felsites possess only occasional phenocrysts of plagioclase feldspar and biotite; in this variety, the phenocrysts of plagioclase have the composition of andesine-to-labradorite whereas in the others they approach the composition of albite.

The Cheviot laccolith. A wide outcrop of mica-porphyrite occurs along the southern margin of the igneous massif in the neighbourhood of Biddlestone (NT 961084). The material is extensively quarried and forms part of a laccolithic body which continues northwards, under the lavas, almost as far as the southern boundary of the Cheviot granite. The lavas have been arched by this intrusive mass to form the Biddlestone anticline. Moreover, the trend of the dykes on either side of the laccolith is such that they converge northwards in an inverted V-form towards the anticlinal axis. This trend suggests that the effect of the intrusion set up a local stress field, which produced tension gashes in the lavas running parallel with the strike and major joint directions, respectively, of the underlying Silurian rocks.

The Cheviot siliceous veins. A series of highly siliceous veins, some of which also contain calcite, occur in vertical fractures in the lavas of the Cheviot Hills. Several of these veins can be seen in the upper reaches of the Coquet valley and can be traced along outcrop for several kilometres. Unlike the dykes, they form strong features, such as that at Raker Crag (NT 849102) which has a wall-like appearance. The boundary between vein and lava is not always sharp, for the vein material can be seen permeating the lava. Field evidence indicates that the injection of these siliceous veins post-dated the dyke intrusions.

They probably represent the last phase of Lower Old Red igneous activity, perhaps in the form of hot solutions welling up from depth. They are described by the Geological Survey as 'crush lines' or 'shatter belts', but it is doubtful to what extent they may have been associated with fault movements.

In the Cheviot Hills, the Old Red Sandstone igneous cycle began with the extrusive phase, which is dominantly andesitic in composition; this was succeeded by the major acid plutonic intrusion and completed by the phase of minor acid intrusions, mainly dykes. In Argyllshire, Scotland, there is a similarly complete cycle, but in the Ochil and Sidlaw Hills, the Pentland and the Braid Hills, only the extrusive phase is present.

Lower Carboniferous igneous rocks

A period of significant vulcanicity marked the beginning of the Carboniferous. Volcanoes were concentrated at many centres in England, Ireland and Scotland. In Scotland, volcanic activity was extensive in the Midland Valley and in the region near the border with England (Francis, 1965, 1967; Tomkeieff, 1937; MacGregor, 1948). The volcanism in the Midland Valley began in the Tournaisian and terminated in Stephanian; in the Border country the main period of volcanism occurred at the base of the Carboniferous but renewed activity took place in the Viséan.

The few Lower Carboniferous igneous rocks that occur in Northumberland represent the outlying remains of part of the volcanic suite of the Border country. The lavas of the Border country occur in three areas (Fig. 1). A northern group, up to 120m in thickness, known as the Kelso Traps, crop out in the Merse on Tweedside (Eckford

& Ritchie, 1939; Tomkeieff, 1945) and directly overlie Upper Old Red Sandstone. A central group called the Cottonshope lavas occurs in upper Redesdale at the base of the Carboniferous (NT 790048). The southern group, the Birrenswark lavas, extends discontinuously from north of Caddroun Burn, Roxburghshire (NY 580995), to the Solway Firth (Pallister, 1952; Elliot, 1960; Lumsden *et al.*, 1967).

According to Leeder (1974b), the early Carboniferous Birrenswark lavas were erupted from a north-east-trending fissure or a linear series of necks, and show considerable variation in thickness, with a maximum of over 90m. He relates the fissure line to the pivot line of a half-graben which initiated the Northumberland trough. The remains of over fifty volcanic necks, mainly agglomerate-filled but some of composite nature, are exposed between Langholm and Kelso (NT 735340). Many of these necks pierce rocks of Tournaisian age and therefore are not related to the early episode, but to later activity during the Viséan. According to Leeder (1947b) the Viséan volcanic eruptions were related to the northern margin of the Northumberland trough. The Kershopefoot lavas crop out south and south-east of Langholm near the top of the Middle Border Group (Lumsden *et al.*, 1967) and reach 30m in thickness. The Glencartholm Volcanic Beds, which are mainly pyroclastic rocks with only subordinate lavas, are probably of Holkerian age. They occur at the base of the Upper Border Group (= Scremerston Coal Group) and reach 150m in thickness (Lumsden *et al.*, 1967).

The majority of Carboniferous lavas are alkaline olivine-basalts which have been classified by MacGregor (1928) as follows:

(a) Macroporphyritic basalts:

Markle type - with phenocrysts of labradorite and olivine
Dunsapie type - with phenocrysts of labradorite, olivine and augite
Craiglochart type - with phenocrysts of olivine and augite

(b) Microporphyritic basalts:

Jedburgh type - with phenocrysts of labradorite and olivine
Dalmeny type - with phenocrysts of olivine, labradorite and augite
Hillhouse type - with phenocrysts of olivine and augite

The lower part of the Kelso Traps is composed of Jedburgh and Markle type basalts, whilst Dalmeny and Dunsapie types comprise the upper part (Eckford & Ritchie, 1939; Tomkeieff, 1945, 1953b). The Birrenswark lavas of Dumfriesshire are mainly Dalmeny and Jedburgh types with subordinate Dunsapie and Markle types (Pallister, 1952; Elliot, 1960).

A thin representative of the Kelso Traps is exposed in north Northumberland at Carham on Tweed (NT 800384). The Cottonshope group of lavas occur in the Cottonshope Burn (NT 790048), Spithope Burn (NT 765050), at Hungry Law (NT 747062) and between the Bateinghope Burn (NT 700045) and the Chattlehope Burn (NT 730028). The most accessible of these Redesdale lavas are those in the Cottonshope Burn where Tomkeieff (1931) recognized three individual flows; only one flow has been recognized at the other localities. The lower lava, 12m thick, marks the base of the Carboniferous. It has a slaggy top in which there is some sedimentary infilling. The middle lava, 6m thick, lies directly on the lower and is separated by 6m of sediments (including an impure limestone in which fragments of lava have been found) from the upper lava, which is 6m thick. The Cottonshope lavas have been classified as Dalmeny type but are highly amygdaloidal and considerably altered.

Intrusive basalts of Lower Carboniferous age are exposed in north Northumberland on Catcleugh Shin, Carter Fell (NT 671033), and on Lumsden Law (NT 727055). The Catcleugh Shin basalt is intruded into a Carboniferous agglomerate neck, which occurs for the most part in Scotland, and extends into Northumberland as a sill at the junction of the Cementstone and Fell Sandstone Groups. Southwards, the sill transgresses into the Fell Sandstone. The basalt at Lumsden Law has the form of a small boss. Both intrusions are typical Markle basalts, but the Lumsden Law basalt has larger olivine phenocrysts than that at Catcleugh Shin.

The Great Whin Sill and its associated dyke suite

(Permo-Carboniferous)

The Whin Sill, because of its resistance to weathering relative to the Carboniferous sediments into which it was intruded, almost invariably forms an impressive topographic feature. This feature of the sill is perhaps most conspicuous to the west of the North Tyne where it forms a magnificent north-facing scarp, capped by the Roman Wall.

There can be little doubt that the Whin Sill is the type example of the common concordant intrusion universally called a sill. In the early days of lead-mining it was common practice to refer to persistent beds as sills; indeed there are many sedimentary horizons in the local succession still referred to as sills (e.g. the Firestone Sill). At about the same time, rocks of exceptional hardness were frequently termed whin and thus the intrusion became known as the Whin Sill even before its igneous character was appreciated.

After its recognition as an igneous rock, it was at first considered to be a lava flow and thus restricted to one geological horizon (Phillips, 1836). The intrusive nature of the sill was first suggested by Sedgwick (1827) and confirmed by Tate (1867, 1871) and by Topley & Lebour (1877).

The Whin Sill complex is formed by a series of sills of varying thickness presumably linked together at depth, and by a suite of dykes which trend slightly north of east; all are of basaltic composition. The sills frequently maintain the same stratigraphical horizon for several kilometres before dying out or transgressing to a different horizon. Five separate sheets of Whin Sill have been recorded in north Northumberland by the Geological Survey at horizons ranging from low in the Scremerston Coal Group to near the top of the Namurian (Gunn, 1900; Carruthers *et al.*, 1927). Two moderately thick sills are well exposed east of the North Tyne. Although many small sills are known, only one, the Little Whin Sill in Weardale, has been dignified by a special name: this sill has, however, proved to be of great petrological interest (Dunham & Kaye, 1965). An account of the Whin Sill and associated dykes has been produced by Dunham & Stresser-King (1982).

Distribution The complex injection of the Whin sills and dykes produces a semi-continuous outcrop pattern of sills that is governed by the general structure of the region (Figs. 1, 15).

(a) **The Whin Sill** appears in the Kyloe Hills in the north and sweeps in an arc round the Cheviot massif forming the crags at Bamburgh (NU 185350) and the Farne Islands (NU 218358). It reappears on the coast at Snook Point (NU 247262) and forms the coastline between Dunstanburgh (NU 259222) and Cullernose Point (NU 260187), from where a rather discontinuous outcrop trends south-west towards the North Tyne. East of the North Tyne, two sills about 1.5km apart are present in the Bavington (NY 983803)-Kirkwhelpington (NY 996845) district. To the west, the outcrops affected by the gentle South Tyne syncline trend a little south of west and form the impressive north-facing crags of the Roman Wall country.

Near Denton Fell (NY 613627) the outcrop turns southwards and the sill, which is thin in this district, has a sinuous outcrop because of the steep-sided valleys that notch into the flat-lying rocks of the west-facing escarpment of the Alston

Block. The most southerly outcrop on the Pennine edge is at Christie Bank (NY 771207) where the sill is faulted against limestone. The sill is well exposed in upper Teesdale where it is very thick (up to 73m) and is responsible for the well known waterfalls at High Force and Cauldron Snout. Small faulted exposures are present in Lunedale (NY 850240) and along the line of the Great Sulphur Vein (Fig. 19). In Weardale, the Whin Sill has the form of a phacolith, in the neighbourhood of the Burtreeford disturbance (Wager, 1929), while, to the east, the Little Whin Sill outcrops between Eastgate and Stanhope (NY 970385) (Dunham & Kaye, 1965).

The Whin Sill has been encountered in several boreholes and in many mineworkings. In the Roddymoor Borehole (NZ 167370), near Crook, the Whin Sill was encountered at a depth of over 305m, with a thickness of 57m (Woolacott, 1923). The Ettersgill borings (NY 892290) proved the Whin Sill to be respectively 67.5m and 74m thick, and to lie in the Alternating Beds below the Single Post Limestone (Dunham, 1948). The Rookhope Borehole (NY 935429) sectioned the Little Whin Sill, 2m thick within the Three Yard Limestone and the Great Whin Sill, 58.75m thick beneath the Jew limestone (Dunham *et al.*, 1965). The Woodland Borehole (NZ 067263) encountered the Little Whin Sill, 2.18m thick, some 12m below the Four Fathom Limestone; boring terminated after passing through 18m of the main sill below the upper part of the Three Yard Limestone (Mills & Hull, 1968; Harrison, 1968). This borehole is particularly interesting as it lies south of the Hett Dyke which was previously considered to coincide closely with the southern termination of the Whin Sill. In the Longcleugh Mine No. 1 Borehole (NY 768518) near Ninebanks, West Allendale, 81m of Whin Sill occurs 17m below the Tyne Bottom Limestone and the sill is 90m thick at Blackdene Mine, Weardale (Dunham, 1990, p48) (Johnson *et al.*, 1980). The Harton borehole (NZ 396656) proved the Whin Sill in three leaves, namely the upper (below the Great Limestone) - 51.3m thick, the middle (below the Tyne Bottom Limestone) - 4.6m thick, and the lower (below the Upper Smiddy Limestone) - 33.5m thick (Ridd *et al.*, 1970). In the Throckley Borehole (NZ 160676) a single leaf of the Whin Sill, 38.4m thick, was found some 30m above the Great Limestone. The Whin Sill in the Whitley Bay Borehole (NZ 350752) was in two leaves of 65m and 37m thickness found respectively at the horizons of the Three Yard and Jew limestones. Near Longhorsley a borehole (NZ 148946) proved the Whin Sill to be 76m thick at the level of the Four Fathom Limestone.

The stratigraphical horizons at which the various sills have been found are indicated in Fig. 15. The Whin Sill is found at its lowest stratigraphical levels near its northerly and southerly extremities (in the west Kyloe Hills and in upper Teesdale respectively). It is found at its highest level in the Midgeholme district (NY 639588), where it is emplaced in Coal Measures; but it is also at high levels south of the River Coquet and north-east of Alnwick.

(b) **The Whin Dykes** which are associated with the Whin Sill have a general east-north-east trend and occur in four spatially distinct groups. The most northerly group is the Holy Island dyke-echelon which is slightly north of all known exposures of the Whin Sill. It can be traced from the Tweed valley, 0.7km south of Coldstream (NY 842398), to a sunken reef, beyond the coast, known as Steel End (NU 180420). It consists of a right-handed echelon of dykes. The dykes vary in width from 3m up to 61m at the Castle (NU 137417) on Holy Island. The present upper surface of much of the Holy Island dyke is distinctly chilled and thus marks the true upper surface of a dyke that 'topped', never having risen to higher stratigraphical levels (Randall & Farmer, 1970).

The second group of dykes known as the High Green dyke-echelon lies south of the Cheviot mass. It is a left-handed dyke-echelon which converges eastward towards the Holy Island dyke-echelon. This system begins west of the North

Tyne and crosses the coast near Boulmer (NU 267144). Some of these dykes attain widths of over 65m.

The third group of dykes, the St Oswald's Chapel dyke-echelon, is also left-handed but the echelon structure is less well developed than in the High Green dyke-echelon. It commences near Haltwhistle, converges slightly towards the High Green dyke-echelon and crosses the coast in Druridge Bay (NZ 273997). The undersea extension of this dyke-echelon has been proved by work carried out on behalf of the National Coal Board. The Causey Park dyke forms a conspicuous feature in the records of a 'Sparker' survey of the undersea extension of the coalfield as described by Clarke. Also metamorphosed sandstone and 'coked' coal were recovered in 1973 from bore N9, drilled from the Whimpey 'Sealab', some 6.5km offshore, in line with the dyke (D. Magraw, pers. comm.).

The most southerly of the groups of dykes is known as the Hett dyke-system. It does not have a quite so well-developed echelon structure as the other groups and indeed much of the length of the system is taken up by the Hett and Ludworth dykes. The echelon structure begins at Long Fell on the Pennine edge and crosses the coast north of Horden (NZ 449409). Some of the dykes send off small sills to the south but otherwise all outcrops of the Whin Sill occur to the north of these dykes. The dykes vary in width from 1-10m. The small Wackerfield Dyke occurs some 8km south of the Hett dyke-system. Fig. 7 shows the *en echelon* Ludworth dyke offshore.

The near-vertical south wall of the Ludworth dyke was encountered in the North Engine Plane drivage, approximately 1.6km north of the shaft at Horden Colliery. Eastwards the intrusion, which has been traced for several kilometres, shows *en echelon* features. Although a large area of devolatilization of coal is characteristic of this group of dykes in the on-shore area (see below), the width of this zone decreases offshore. However, the recent offshore bore E2 (NZ 555480) proved a highly-altered coal in a position significantly north of the anticipated continuation of the dyke. This might indicate a considerable step to the north on the part of the intrusion, or the possible occurrence of small sills similar to those found in Bowman Colliery (D. Magraw, pers. comm.).

Other discordant intrusions of the Whin Sill suite, which do not fit with the four major groups of dykes, include that at Cullernose Point (NU 260187) and the Muck intrusions near Biddick (Old Castletown Colliery) (Fig. 7). The Muck dyke probably owes its name to the considerable amount of heat-affected strata associated with white trap (rather than fresh dolorite) in the mine workings at Hylton Colliery (D. Magraw, pers. comm.). Armstrong & Price (1954) considered the intrusion, formed of dyke stringers and a sill 0.3m thick, to lie within the 60m-wide Biddick fault zone. However, in recent years, the discovery of dolerite in the Maudlin workings at the now closed Washington Glebe Colliery indicates that the intrusion lies slightly north of the fault at this point and that dyke and fault converge at Hylton. No trace of the dyke has been found east of Hylton (D. Magraw, pers. comm.).

(c) **The magnetic anomalies** created by both the Whin Sill and its associated dykes, especially north of the River Tyne, can be traced on the Aeromagnetic Map of Great Britain, produced by the Geological Survey of Great Britain (1968). The magnetic anomalies over the sill occur as 'lows' whereas those over the dyke suite are 'highs'. Giddings *et al.* (1971) found that the Holy Island Dyke has a direction of magnetization which indicates that the magnetic pole at the time of crystallization was located at latitude 38° N and longitude 177° E and that this position is statistically indistinguishable from that determined for the Whin Sill by Creer *et al.* (1959). The 'highs' over the dykes were explained by the dykes being magnetically unstable, due to the grain size of the ore minerals, which allowed the dykes to take on a strong secondary component of magnetization induced by the earth's present magnetic field which obscures their stable primary magnetization.

(d) **The petrography** of the Whin Sill suite has been covered in considerable detail, but it would appear that despite a reputation for uniformity each new investigation seems to reveal additional features of interest.

(i) The 'normal' rocks. The most common or normal rock of the Whin Sill suite has been described by Teal (1884b), Thomas (in Carruthers *et al.*, 1927), Holmes & Harwood (1928) etc. It is a dark, blue-grey, quartz-dolerite with an average grain size from 0.5 to 1.0mm. Plagioclase laths An_{40-62} form an interlacing network showing a sub-ophitic texture with rather granular aggregates of augite. Elongated prisms of pigeonite and, or, stumpy enstatite crystals are invariably present. The rock is sprinkled with titano-magnetite in skeletal or individualized form whilst alkali-feldspar, micro-pegmatite and quartz occur interstitially. Occasional phenocrysts, 2mm or more in length, of both pyroxene and strongly-zoned plagioclase An_{38-73} are not uncommon. Brown hornblende, biotite and chlorite are common secondary minerals and apatite in needle-like form and pyrite are also common. It has been recorded that rhombic pyroxene is especially rare in the north but much more common in the south. Dunham *et al.* (1972) record four types of pyroxenes, namely an orthopyroxene and three types of clinopyroxene (augite, pigeonite and an intermediate form), from the cores of the Throckley Borehole. They also record submicroscopic exsolution lamellae in the pyroxenes which increase in width towards the centre of the sill.

(ii) Fine-grained rocks of basaltic composition. The actual contacts of the sill are tachylitic in character but grade into the rocks of normal type over distances of about 2m. Small phenocrysts of plagioclase and pyroxene or aggregates of serpentine and iron ore are common. Several workers have considered the latter to be pseudomorphs after olivine although the only fairly recent reference to it is that by Tomkeieff (1929). The first report of olivine in the Whin Sill was made by Allport (1874) after an examination of 'a well crystallised greyish-black basalt' from Ward's Hill (NZ 078965) which contained 'a few serpentinous pseudomorphs of olivine'. Subsequently, fresh olivine Fa_{15} has been reported from the Little Whin Sill in Weardale (Dunham & Kaye, 1965).

Fine-grained veins of basalt of irregular shape and width are intrusive into the main sill at a number of localities (Smythe, 1930b). Petrographically these rocks resemble the chilled facies of the Whin Sill, but they are obviously younger than the crystallization of most of the sill. A vein of this type found in Barrasford quarry (NY 913745) is porphyritic with a mainly glassy ground mass, it has a thin band of rock at its contact with the normal dolerite which is intermediate in grain size between the basalt vein and the dolerite. This suggests that there has been some 'remelting' of the already crystallized host rock. This vein is transgressed by a thin aplite vein.

(iii) The coarse-grained rocks. Rocks coarser than the normal dolerite with all the essential mineral constituents visible to the naked eye are not uncommon in Teesdale (Dunham, 1948), but the most interesting rocks of this group are the dolerite-pegmatites first noticed by Sedgwick (1827) and studied in detail by Tomkeieff (1929). These rocks are reported from the region of the South Tyne and Tees, but can also be found at several places in Northumberland. The pegmatites, found in the upper half of the sill, occur as flat lenticular masses parallel to the upper contact. The layers vary in thickness from 10mm to 2m and may show rapid thinning or bifurcation. The boundary between the pegmatite and the normal dolerite, although sharp in hand specimen, shows a rapid but continuous transition from one variety to the other in thin section.

The most easily accessible locality where the dolerite-pegmatites can be examined is the roadside quarry above High Force (NY 881283). The rock is characterized by long, often curved, blades of lustrous pyroxene (augite and some pigeonite), up to 50mm in length, which frequently occur in clusters radiating inwards from the margins of the layers. Feldspars in the rock are usually smaller than the pyroxenes, but often have a noticeable prismatic development. The rock always contains a patchy development of quartz, micropegmatite (the latter is often red-coloured due to the presence of minute hematite flakes) and large grains or long narrow plates of iron ore. Dolerite-pegmatite layers in Northumberland seen at Hair Crag quarry (NU 154076) and Snab Leazes quarry (NU 226142) sometimes have a central core of red-coloured aplite.

Tomkeieff suggested that the dolerite-pegmatite represents a 'wet' fraction of the magma which would allow the development of coarse crystals and a more complete segregation of acid material in the later stages of crystallization. The latter under favourable conditions would escape and form aplite veins.

Other varieties of coarse-grained rocks from the Whin Sill have been recorded below 'vesicles' filled either with pectolite or containing quartz and calcite (Tomkeieff 1929; Randall, 1959a).

(iv) The acid rocks. The commonest variety of the acid rocks associated with the Whin Sill are the pink-to-red aplitic veins (up to 20mm wide) which intrude both the sill and the dykes. They are common in Northumberland and are best seen between Cullernose Point (NU 260187) and Dunstanburgh (NU 259222). At Barrasford Quarry they have been seen to cut both intrusive tachylite veins, and the pegmatite found below certain vesicles. The felsitic rock of these veins, which shows no distinct chilling, consists almost entirely of turbid acid feldspar and micropegmatite. The red colour is due to the presence of minute flakes of hematite.

Small spheroidal aplitic inclusions within the Whin Sill at Snook Point (NU 247262) have been described by Smythe (1914) and Tomkeieff (1929). The inclusions are up to 22mm in diameter, consist of fine-grained acid rock, and have plates of pyrrhotite on their lower hemisphere. Tomkeieff has described one inclusion from Snook Point which contains an inner zone of aplite and an outer zone intermediate between this and the normal dolerite.

(v) Vesicles. Small, generally spherical vesicles are common in the chilled rocks of the sills and dykes. Usually they contain calcite, quartz and chlorite with traces of pyrite. Larger vesicles up to 0.3m diameter, however, have been described in the upper half of the sill from Copt Hill (NY 853405), Caw Burn and Barrasford quarries. These vesicles have a thin 10mm layer of coarse rock at their base. Pectolite has been found completely filling vesicles at the above localities. It characteristically grows as white radiating crystals and, at Barrasford (Randall, 1959b), is associated with small amounts of calcite and datolite. At Barrasford, much of the pectolite has been replaced by stevensite, the X-ray powder pattern of which contains lines characteristic of heat-treated material, suggesting that the pectolite was replaced before the sill became cool.

At Barrasford also, the pectolite-bearing vesicles are associated with both dolerite-pegmatite and partially-filled vesicles containing calcite and quartz, which also have a layer of coarse rock at their base.

An unusual type of vesicle occurring in the upper contact layers of the Whin Sill at Harkess Rocks (NU 178359) has been described by Smythe (1930a). These structures are sinuous up to 6.1m long, but only some 10mm in thickness and show a ropy-flow structure on their inner base. Smythe deduced that these structures were caused by the 'slow flow of a highly viscous liquid with a free surface' at the base of a gas bubble; because of the curvature of the flow wrinkles, the direction of movement during intrusion must have been from east to west. Similar ropy-flow structures indicating intrusive flow from west to east have been reported from the flat-lying upper surfaces of the Holy Island Dyke (Randall & Farmer, 1970).

(vi) Alteration. Whilst the Whin Sill is generally considered a fresh rock, it has at many localities suffered various types of modification. Almost invariably, open joints are iron-stained and natural outcrops consequently tend to have an ochreous hue even though newly-broken rock is grey-blue. Wager (1929) and also Smythe (1930b) have described the chloritization, pectolization and alteration of the Whin Sill by vein solutions. Ineson (1968) has made a detailed

Table 6 Chemical analyses of the principal igneous rock types in north-east England.

	1	2	3	4	5	6
SiO_2	66·96	61·47	62·32	72·17	50·32	57·57
TiO_2	0·41	0·57	0·48	0·18	2·48	1·24
Al_2O_3	15·62	16·18	15·62	15·45	15·41	13·11
Fe_2O_3	1·46	1·34	0·61	1·59	3·09	3·12
FeO	1·84	3·66	3·84	-	8·92	6·60
MnO	tr	0·09	tr	0·61	0·18	0·12
MgO	1·63	3·56	2·28	0·27	4·89	4·29
BaO	-	-	-	-	0·03	0·06
CaO	2·49	4·52	4·52	0·93	8·86	7·10
Na_2O	3·58	3·17	3·88	4·20	2·03	2·62
K_2O	3·88	3·54	1·35	5·16	1·06	2·21
P_2O_5	0·33	0·37	0·24	-	0·22	0·19
U_2O_3	-	-	-	-	-	0·04
CO_2	-	-	-	-	-	0·28
S	-	-	-	-	0·15	0·13
H_2O+	1·46	1·56	3·59	-	1·30	1·20
H_2O-	0·20	0·25	1·10	-	0·75	0·94
	99·86	100·26	99·83	100·01	100·10	100·82

1 Cheviot granite, granophyric variety (Jhingran, 1942)

2 Cheviot granite, marginal variety (Jhingran, 1942)

3 Cheviot pyroxene andesite, Blindburn variety (Jhingran, 1942)

4 Weardale granite, mean analysis (Holland and Lambert in Johnson and Hickling, 1970)

5 Average whin sill from 2950 samples (Smythe, 1930)

6 Tholeiite of Cleveland type (Holmes and Mockler in Hickling et al. 1931)

study of the development of white whin (a clay-carbonate rock) adjacent to barites veins. White whin also invariably forms when a dyke or sill is intruded adjacent to a coal seam; the most obvious feature of the rock is the successive replacement of pyroxenes, groundmass feldspar and phenocryst feldspar by carbonates.

(e) **The chemistry** of the Whin Sill has been investigated most notably by Smythe (1930b). Not only did he analyse the individual rocks of the sill, but also regional group samples including the 'average whin', a sample composed of 2950 rock chips collected from practically every fresh exposure of the sill (Table 6). These analyses prove that there are no significant regional variations in the composition of the sill and clearly refute earlier suggestions that assimilation of sedimentary rocks took place during intrusion (Clough, 1880). Holmes & Harwood (1928) showed that there are no significant chemical or petrological differences between the Whin Sill and the associated dykes. Dunham & Kaye (1965) emphasize two trends shown by the Whin Sill suite: 1) silica- and alkali-enrichment and 2) iron-enrichment. They also indicate that the whin magma has chemical characteristics intermediate between alkaline and tholeiitic magma-types, but that petrographically it is dominantly tholeiitic. Thorpe & Macdonald (1985) interpret slight variations in the concentrations of Zr and Nb in the chilled margins and interiors of the Whin Sill suite as evidence of heterogeneity in the source of the whin magma. Randall (1989) presented several analyses of Whin Sill variants and numerous microprobe analyses of their minerals, all from Barrasford. Using the mineral analyses in geothermometric calculations he concluded that the sill was intruded at about 1150°C, the main crystallization being completed at about 1025°C and the pegmatites and aplites solidified between 750°C and 570°C.

(f) **Metamorphism** can be seen to have occurred in rocks of suitable composition, lying either above or below the contact, up to distances of 30m from the intrusion itself. Normally the effects of metamorphism are slight, being restricted to recrystallization in pure limestones, occasional spotting of shale and hardening in many other rock types. The metamorphosed rocks, even from rafts within the sill, frequently retain identifiable fossils. However, a long list of minerals (including garnet, idocrase, wollastonite, biotite, andalusite, cordierite, pyroxene and anthophyllite) has been discovered in the metamorphic rocks associated with the sill, largely as a result of the research of Hutchings (1898). Robinson (in Johnson & Hickling, 1970) records some soda-metasomatism and metamorphism in the Cow Green district which took place under hornblende-hornfels and albite-epidote-hornfels-facies conditions.

Coals are markedly affected by the heat of intrusions (Fig. 9, p281), the rank increasing towards the intrusion until the coal is modified by plastic flow before finally turning into a natural coke (Edwards & Tomlinson, 1957). The change of rank in coals adjacent to the Whin Sill dyke suite, especially in the case of the Hett and Muck dykes, is obvious on the seam profile maps of the National Coal Board (1965). Trotter & Hollingworth (1928) record incipient coking 106m below the Whin Sill at Gair's Colliery. Jones and Cooper (in Johnson & Hickling, 1970) have developed a technique for using reflectivity measurements to determine the rank of organic material in sediments and in this way were able to detect the metamorphic effect of the Whin Sill in the Harton Borehole at distances of 425m above and 180m below the sill.

(g) **The age** of the Whin Sill and the structural controls during the time of intrusion have both been subjects for investigation over the years. The Whin Sill complex intersects Coal Measures (Westphalian), but not Permian rocks and since three pebbles of Whin Sill type have been found in the Upper Brockram (Holmes & Harwood, 1928; Dunham, 1932), the complex appears to have been emplaced as indicated by Gunn (in Carruthers *et al.*, 1927), during the time represented by the unconformity between the Upper Carboniferous and the Permian of the north of England. Supporting evidence comes from the fact that the sill has been affected by the mineralization centred on the Alston Block and that detrital fluorite is present in the Permian Yellow Sands (Versey, 1925). K-Ar determinations by Fitch & Miller (1967) suggest an age of 295 Ma.

It would appear that the intrusion of the sill was penecontemporaneous with the late Carboniferous folding, for the Whin Sill at Copt Hill in Weardale, associated with the Burtreeford disturbance (Wager, 1929), has the form of a phacolith; yet in Teesdale the sill changes horizon abruptly across this faulted monocline as if cutting across a pre-existing fold. At the western margin of the Alston block (Trotter & Hollingworth, 1928), and in the Holburn anticline (Carruthers *et al.*, 1927), there is evidence that folding began before intrusion and that the steeper western limbs of the folds inhibited further extension of the sill. Much faulting preceded the intrusion of the sill, which often transgresses along fault planes, but there is evidence of movement by means of wrench faulting after intrusion (Trotter & Hollingworth, 1928). Major horizontal slickensides and sheared dolerite, caused by movement along the Longhoughton fault, are well displayed in Ratcheugh Quarry (NU 235156).

Holmes & Harwood (1928), although admitting there is no visible proof of dykes acting as feeders to the sill, thought that it was probable that they

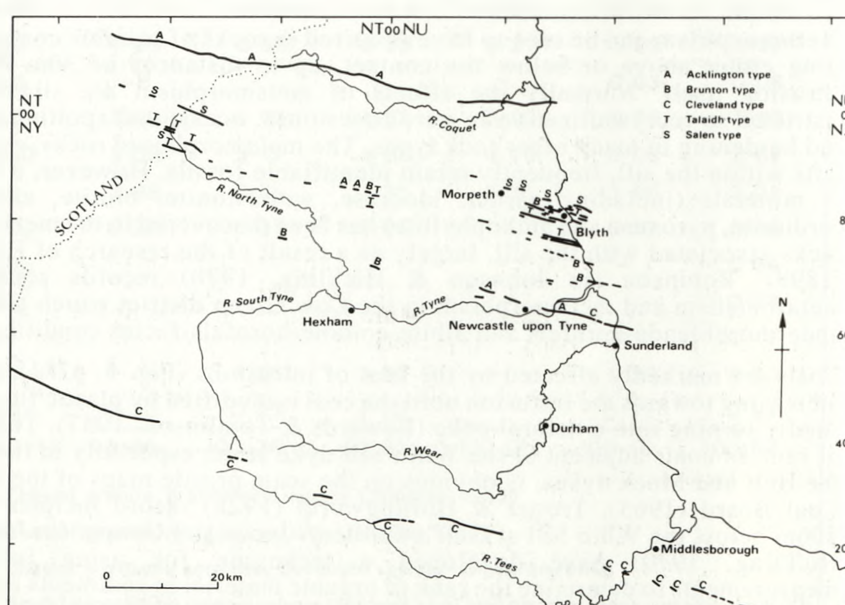


Fig. 16 Map showing the distribution of Tertiary dykes in north-east England.

functioned in such a manner. This concept was later supported by Anderson (1951). If this were so then one might expect the sills to be thickest adjacent to the dykes, but this is not the case. However, Francis (1982) put forward a theory that overcomes this difficulty. He suggests that magma rises in the dykes at the edge of basins developed soon after the formation of the sediments, which would be water saturated, and assisted by gravity, travels down dip to produce sills which would be thickest away from the dykes. An alternative theory of sill emplacement proposed by Smythe (1930b) in which the sills were fed along 'ducts of sill-like configuration' still bears consideration.

Holmes & Harwood (1928) explain the origin of the two northerly dyke-echelons as a result of the east-west compression which produced the Holburn and Lemmington anticlines when the Cheviot massif moved east, relative to the country both north and south. They liken the fissures, occupied by the dykes, to the marginal crevasses of a glacier. Anderson (1951) points out that the analogy is not sound as the dykes of the two echelons do not lie at about 90° to each other and he prefers to consider the dyke echelons as sub-parallel and due to tension. Wilson (1970) notes that the angle between the orientation of the individual dykes, and the trend of the echelon, accords with intrusion along Riedel R-Shears. He states that in a zone of wrench movement both Riedel R-Shears and tension fractures lie in the same quadrant and, therefore, Holmes & Harwood's notion of the eastwards regional translation of the Cheviots with the dykes emplaced during a period of east-west compression remains feasible. Shiells (1961) considers that the sill was intruded into potential voids of horizontal shear fractures during the same compression. It is interesting to note that intrusion of the sill along low angle fractures has been recorded east of the North Tyne (Randall, 1959a).

The two most southerly groups of dykes appear to be related to the edges of the Alston block although only the western part of the St Oswald's Chapel dyke-echelon is adjacent to the block edge; the eastern part approaches and resembles the High Green dyke-echelon.

The subject of the intrusion of the Whin Sill complex in relation to structural movement is also considered in the chapter on structure.

The Tertiary Dykes

Distribution and characteristics. The basic dykes which trend west-north-west to east-south-east in the north of England are part of a dyke-swarm which radiates from the Tertiary igneous centre on the Isle of Mull. The trend of these dykes is reasonably consistent and is sufficiently characteristic to prevent confusion with the west-south-west to east-north-east-trending dykes of the Whin Sill suite. The dykes do not normally form obvious topographic features and are best observed in coastal exposures. Although stream exposures exist, much information about the dykes comes from coal-mining operations. The dykes are discontinuous and thus can be described as linear echelons.

The most northerly dyke passes close to Hawick (NT 505154) near the Scottish Border and Acklington (NU 230020) near the Northumberland coast; the most southerly dyke outcrops in the Cleveland district, while a concentrated belt of dykes occurs in the vicinity of Morpeth and Blyth (Fig. 16). These dykes have been encountered during the investigation and exploitation of the undersea extension of the coalfield, particularly in the workings of the Westoe and Blyth collieries. Small sills associated with the dykes have been found in the Top Brockwell seam and in the split Hutton seam (D. Magraw, pers. comm.). Opencast working along the line of the Acklington dyke at one point encountered a small sill, less than one metre in thickness, but no dyke.

The penetration of dykes in the course of mining operations is undertaken only with great caution since the occasion when a borehole ran into the easterly extension of the Tynemouth Dyke and tapped a fissure, presumably connected to the water-bearing Yellow Sands and Magnesian Limestone. This caused flooding of adjacent roadways and workings, with an initial measured flow of water, estimated at 13600 litres per minute (D. Magraw, pers. comm., p285).

(a) **The petrography** of the dykes has been described in important papers by Teall (1884a, b, 1888, 1889), Heslop & Smythe (1910), Heslop & Burton (1912), Smythe (1913, 1914), Mockler (1927) and Holmes & Harwood (1929). The contributions by Holmes & Harwood and Smythe & Dunham (1947) include significant chemical analyses.

It has been common practice to refer to the Tertiary dykes as tholeiites (Holmes & Harwood, 1929), but the term, as then used, had textural as well as general compositional connotations, indicating rocks of essentially basaltic type with a glassy mesostasis between feldspar laths forming an intersertal texture.

According to Holmes & Mockler (in Hickling *et al.*, 1931), all the dykes contain a framework of basaltic minerals set in a glassy or devitrified mesostasis which is either iron-rich or of a quartz-alkali-feldspar composition. Pyroxenes and olivine are more abundant than feldspar - a feature which distinguishes the Tertiary dykes from rocks of the Whin Sill suite. Anorthite, as individual phenocrysts or in clusters of phenocrysts, is scattered in variable concentration in most of the dykes.

Details of the petrography and chemistry of the dykes are to be found in Holmes & Harwood (1929), who identified five different types, namely those of Salen, Brunton, Talaidh, Acklington and Cleveland. The first of these types has compositions similar to that of the Whin Sill, but the Acklington and Cleveland types are of andesitic nature.

(b) **Amygdales** occur in many of the dykes, in a manner similar to those described in the Tynemouth Dyke by Teall (1889). They are spherical and may contain glass, carbonate and sometimes chlorite. Almost invariably they are surrounded by a rim of tangentially-arranged plagioclase laths as a result of expansion of the original vesicles, on release of pressure, in a magma containing abundant feldspar laths. Tomkeieff (1953a) has suggested that the amygdales are the result of liquid immiscibility and that the entire filling represents the solidification products of this liquid.

(c) **Mineralized cavities**, of which several large examples, each up to 36m in length, 7m in height and 4m in width, have been reported in dykes intersected during coal-mining operations (Randall, 1953; Randall & Jones, 1966). The cavities are thought to originate by the incorporation of coal into the dyke material at the time of intrusion and its subsequent gasification. The mineralization of the cavities is unrelated to their formation and is due to deposition of minerals by percolating ground waters.

(d) **Metamorphism**, but only to a slight degree, with induration and hardening, is generally noticeable in the sedimentary rocks adjacent to the dykes, with the exception of the coals. Coal seams are considerably affected by the heat of the dykes during intrusion. The rank of the coal increases with closeness to the dykes and the coal may be extensively coked adjacent to the dykes (Armstrong & Price, 1954). However, the changes in the rank of coal associated with the Tertiary dykes appear to be much less extensive than similar changes adjacent to Carboniferous dykes. The position of the former are hardly perceptible on the seam profile maps of the Northumberland and Durham coalfields (National Coal Board, 1965). This would suggest that the rank of coal is more easily modified shortly after its formation than at a later time.

(e) **The age** of the Tertiary dykes in north-east England is based on scanty field evidence. In the moat of Tynemouth Priory, a mainly grassed-over exposure reveals the Tynemouth Dyke cutting the Permian Yellow Sands and in Yorkshire the Cleveland Dyke is obviously post-Liassic. Using K-Ar radiometric isotope dating techniques the minimum age of the Cleveland Dyke was found to be 58.4 ± 1.1 Ma (Evans *et al., 1973)*

Palaeomagnetic studies, also on the Cleveland Dyke (Giddings *et al.*, 1974), reveal that the magnetic pole at the time of intrusion was located at latitude 75°N and longitude 120°W. This agrees well with data from other British Tertiary dykes (Dagley, 1969).

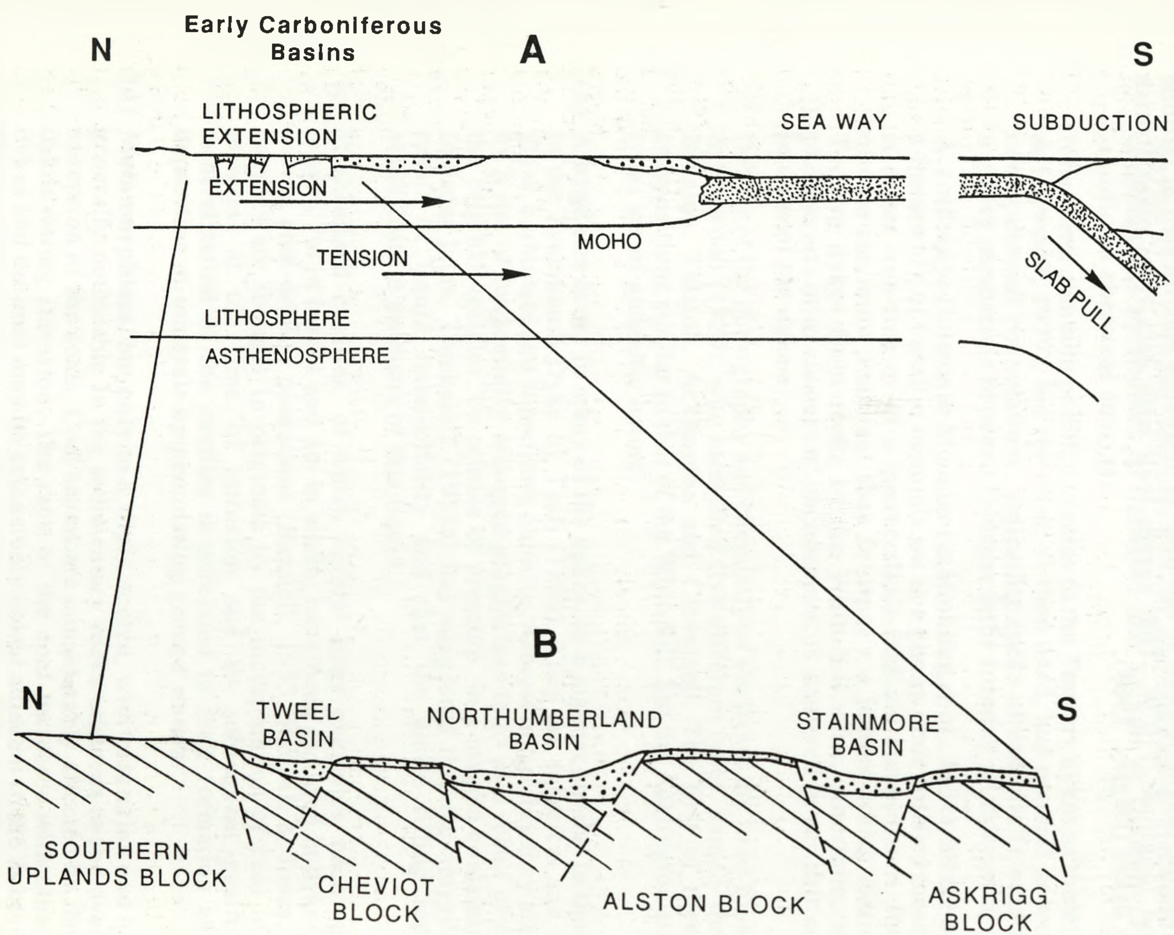


Fig. 17 Lithospheric extension origin of early Carboniferous basins (adapted from Bott, 1987, and Leeder, 1988). **A**. Hypothesis of tension and extension in the crust. **B**. The resulting block and basin structure of north-east England.

CHAPTER 9

STRUCTURE

Basement structure and the Caledonian earth movements

The geology of northern England consists of a sedimentary cover of Carboniferous and Permo-Triassic rocks resting unconformably on a basement of Lower Palaeozoic and early Devonian sedimentary, volcanic and intrusive rocks. In Lower Palaeozoic times the area lay beneath the Caledonian Iapetus Ocean, separating two continental landmasses to the north-west and the south-east. Subduction of the ocean floor beneath the palaeo-North American continent to the north-west was accompanied by deposition of sediment from northerly-derived turbidity currents in front of the subduction zone (McKerrow *et al.*, 1977; Leggett *et al.*, 1979) or in a back-arc basin (Barnes *et al.*, 1986; Stone *et al.*, 1987). During and after sediment deposition, subduction related tectonic activity and continental collision resulted in extensive deformation of the sediments which have been sliced-up into several fault-bounded blocks. Within each block thick greywackes overlie thin oceanic graptolitic shales younging to the north-west closest to the subduction zone, with successive slices younging to the south-east. Slow convergence of the continents and closure of the ocean in Late Silurian or Lower Devonian times was accompanied by calc-alkaline volcanism. The Cheviot and Weardale granites were emplaced within the Lower Old Red Sandstone lavas and Skiddaw slates respectively at this time, creating gravity deficiencies which led to slow isostatic readjustment by uplift of these areas. The line of ocean closure, and continental collision, termed the Iapetus suture zone, trends in a north-easterly direction through the Solway Firth and beneath the Carboniferous cover (Phillips *et al.*, 1976; McKerrow & Cocks, 1976; Freeman *et al.*, 1988). The planar, unbroken geometry of the line of closure suggests a strike slip origin (Glennie, 1990). The Iapetus Ocean served to separate the North American and southern European continents and faunal provinces, with the result that there is great lithological variation across the line of suture. However, the simple two plate tectonic model of Wilson (1966) and Dewey (1969) is incompatible with the results of recent surface studies of the British and Irish Caledonides (Soper & Hutton, 1984; Barber, 1985; Hutton, 1987) which favour a more extensive multiple suture zone extending from the Highland Border fault to south of the Lake District (the Midland Platform). According to these models the Iapetus suture forms part of this suture zone, and marks the boundary between accreted terrains from the northern and southern margins of the Iapetus Ocean. Ocean closure and continental collision resulted in the formation of a large megacontinent (referred to as Laurussia by Glennie, 1990), and uplift of a major mountain range. This was followed by erosion, regional peneplanation and deposition of the continental Devonian Upper Old Red Sandstone in the Tweed, Oldhamstocks and Scottish Border Basins; in the Northumberland Basin the Upper Old Red Sandstone was a period of non-deposition.

Good examples of the structures in the Lower Palaeozoic greywackes can be seen on the coast between Burnmouth and Eyemouth, and in Galloway west of the Solway Firth. The dominant structural trend here is north-east to south-west, a trend which also dominates in the basement rocks where they lie concealed beneath the younger sediment cover in Northumberland and Durham. This same trend is apparent in the south of Scotland, which is dominated by a regional scale anticline modified on its northern margins by the post Caledonian Southern Uplands fault, downthrowing to the north. Between Burnmouth and Eyemouth the greywackes show a steep north-westerly dip, in the direction of stratigraphic younging, and are underthrust from the north-west by north-east trending strike faults consistent with idealized trench-slope subduction models. On the south-east side of these underthrust faults the steeply dipping beds show a series of complex large-scale fold structures, with local isoclinal folding. Within the folded belt the scale and complexity of the folding varies. Minor folding is dominated by tight V-shaped folds and box folds with amplitudes up to 17m (Sheills & Dearman, 1966, fig. 2c), but drag folds, incongruous folds and unusual cross-folds also occur (Dearman *et al.*, 1962). Many of these local folds occur in zones where folds change from gently plunging folds to those with a much steeper attitude. These transitions, together with steeply plunging folds in evenly inclined strata reflect strike slip movement along the bedding. Many phases of deformation have been recorded in the strata along the Berwickshire coast and the south-west of the Southern Uplands, with a final relief of pressure in a south-west to north-east direction resulting in the formation of a pattern of north-west to south-east trending major joints. The regional structural trends in the Lower Palaeozoic basement rocks exerted a considerable influence on later earth movements.

Late Devonian-Early Carboniferous rifting and the formation of the Northumberland Trough

In late Devonian and early Carboniferous times the structure of northern England consisted of a number of basins and blocks (Fig. 5, p257). Differential rates of fault controlled subsidence allowed for the accumulation of thick sequences of sediments in the more rapidly subsiding basins with thinner, incomplete sequences across the more buoyant granite-cored blocks which formed structural highs resistant to subsidence. Sediments were deposited in the Tweed Basin, the Northumberland Trough, the Carlisle Basin and the Stainmore Trough (Fig. 5), with rapid increases in thicknesses of up to 2000m across the Stublick-Ninety Fathom hinge fault and the Lunedale-Butterknowle hinge fault due to contemporaneous fault movements. The largest of these basins was the Northumberland Trough which forms a north-east to south-west orientated structure divided into two sub-basins (Leeder, 1976): the Solway Basin in the west, which is concealed beneath younger Permo-Triassic sediments, and the Northumberland Basin in the east (Figs 5, 17). The Northumberland Basin has an asymmetric profile with an overall shape resembling that of a half graben. The deepest part of the basin, with maximum sediment thickness, lies adjacent to the Stublick-Ninety Fathom fault system, which defines its southern margin; northwards the basin shallows and the succession shows an overall thinning over a distance of about 157km (Freeman *et al.*, 1988). The geometry of the basin suggests that it was initiated in late Devonian or early Carboniferous times by a north-south dominated extensional stress field. Confirmation of the tectonic setting of the basin is provided by the presence on deep seismic profiles of a pronounced lower crustal layering typical of rift provinces and regions of elevated heat flow (Allmendinger *et al.*, 1987). A typical feature of regional scale rifting is the development of a thick syn-rift sediment package against one or both of the basin margins (Badley *et al.*, 1988). The over- thickened Dinantian succession adjacent to the Stublick-Ninety Fathom fault system, and its northward (basinal) thinning, may be an expression of this syn-rift sedimentation. Extension and rifting have been attributed to tension induced by closure of the Rheno-Hercynian seaway through the northerly migration of a subduction zone located to the south of Britain in the Iberia, American and Massif Central region (Bott *et al.*, 1984; Leeder, 1988) (Fig. 17A). The location of the north of England basins was attributed to inherited Caledonide crustal weaknesses (block and basin structure) (Fig. 17B). However, Haszeldine (1984) maintains that basin formation was unrelated to inherited Caledonian crustal weaknesses. He considers basin formation to be a response to the opening of the Atlantic proto-ocean to the north and west of Britain rather than to subduction to the south. Critical examination of these ideas in terms of the revised Carboniferous time scale of Lippolt *et al.* (1984), the palaeontological evidence and modern theories of rift tectonics, show convincingly that there is little evidence to support such claims (Leeder, 1988; Besley, 1988).

The seismic reflection data of Chadwick & Holliday (1991) reveals the presence of a crustal scale, east-north-east trending Caledonian thrust zone dipping northwards beneath the faulted southern margin of the Northumberland Basin. Extensional reactivation of the middle and upper parts of this thrust zone in Carboniferous times along the line of the Stublick-Ninety Fathom normal fault is thought to be the most likely cause of fault controlled subsidence and basin formation. They also showed that the Iapetus suture subcrops some distance north of this shear zone beneath the central part of the Northumberland Basin. The association of the basin with the crustal scale Iapetus suture zone is thought to be responsible for its greater lateral extent compared to other Dinantian basins farther south. A similar mode of origin is favoured for the Tweed Basin, which is interpreted to have formed in response to reactivation of a thrust slice in the Southern Uplands. The Tweed existed as a separate basin until Asbian times when regional subsidence occurred and the Tweed and Northumberland Basins merged into a single basin.

Evidence of significant extension during evolution of the Northumberland Basin is provided by the thick sequence of syn-rift sediments in the basin, the basal Dinantian volcanics, which are attributed to extensionally induced decompressive melting (Leeder, 1988) and the high Carboniferous heat flow (Creaney, 1980). Subsidence curves for the basin reveal a rather complex picture in that the initial fault controlled syn-rift subsidence was not instantaneous but occurred at intervals throughout early to mid Dinantian times with one of the major phases probably occurring during deposition of the Arundian to Holkerian Fell Sandstone (Fig. 3, p252-3). Active extension and rifting probably ceased early in the Namurian and was followed by a regionally extensive post-rift, predominantly unfaulted, thermal subsidence phase which continued into the Westphalian but declined exponentially with time. The basin now formed part of the much larger Central Pennine Basin in which the axis of maximum subsidence lay in the vicinity of Manchester during Westphalian times.

Structural development of the Northumberland basin

Most of the literature on the structure of the Northumberland Basin is concerned with the origin and development of the basin. Comparatively little attention has been paid to the deformation and structural evolution of the sediment fill. The most significant papers on this subject are those of Kent (1966) and Shiells (1964). Kent (1966) describes thinning of the sediments and a reduction in block and basin topography when traced to the south on to the Lincolnshire shelf, where deformation is very restricted. Shiells (1964), however, recognizes considerable deformation in the north-eastern part of the basin, and the existence of three types of structural environment which occurred during Upper Carboniferous times: (1) accommodation of large folds; (2) lateral shear fault structures; and (3) minor regional compressive structures. The large-scale folding was controlled by the Lower Palaeozoic and Old Red Sandstone basement with the thick wedge of basin sediments lying on the inclined undulating basement, showing strong asymmetric folds. The Cheviot igneous mass is thought to have played an important role in deformation. The major compression was directed in an east-west direction, but the sediments to the north and south-east of the Cheviot were able to accommodate this quite easily. However, those directly east of the Cheviot were more confined and hence deformed quickly, the resulting differential movement initiating shear zones to the north and south. In the south the Swindon and Cragend-Chartners Fault complex was a direct result of this movement which fractured the basement and facilitated the intrusion of basic magma.

The Northumberland Basin can be divided into separate areas on structural grounds, each area being identified by its varying depth of Dinantian sediment cover. The location of these areas and the major faults and folds are shown in Fig. 5. The structural evolution of the basin and its infill can be divided into several phases (Monro,1986) (Table 7). The first phase occurred as a result of isostatic readjustment following emplacement of the Cheviot and Weardale granites in Lower Old Red Sandstone times. These movements probably established the lines of the Pressen-Flodden faults and the Alwinton and Ridlees faults north and south of the Cheviot massif, and the trends of the Stublick-Ninety Fathom fault system and Butterknowle Fault on the northern and southern margin of the Alston Block. At the same time sedimentation occurred uniformly across to the Eden Valley and the Lake District, prior to initiation of the Pennine faults (Fig. 5). These faults were activated from Middle Old Red Sandstone times onwards, as evidenced by the appearance of Cheviot granite material in basal Carboniferous circum-Cheviot alluvial fan conglomerates (Robson, 1980), and by the unroofing of the Weardale granite prior to burial by Asbian sediments. The basal Carboniferous Roddam Dene conglomerate on the eastern side of the Cheviot massif shows a fining-upward trend from conglomerate to sandstone, consistent with the gradual erosion of a tectonically uplifted Cheviot source and the sourceward shift of the depositional system through time. Thus, the Cheviots were a positive area at this time actively shedding detritus

Table 7 Main events in the structural evolution of north-east England with emphasis on the Carboniferous Northumberland basin.

TERTIARY				N - S COMPRESSION Faulting and reactivation of existing faults
MESOZOIC				No recorded events
PERMIAN				EXTENSIONAL SUBSIDENCE WHIN SILL EMPLACED
		300		E - W TRANSPRESSION
CARBONIFEROUS	WESTPHALIAN		THERMAL SUBSIDENCE	Folding and reactivation and reversal of some existing faults Localised tectonic activity
		315		
	NAMURIAN			REGIONALLY EXTENSIVE UNFAULTED THERMAL SUBSIDENCE
		326		
	VISEAN		RIFTING	Decreasing fault activity and subsidence INTRABASINAL SYN - DEPOSITIONAL FAULTING Formation of mini - grabens FAULT CONTROLLED SYN - RIFT BASIN SUBSIDENCE BLOCK AND BASIN STRUCTURE ALONG LINES OF EXISTING CRUSTAL WEAKNESS
		360 Ma		N - S EXTENSION AND RIFTING DUE TO BACK ARC STRETCHING
OLD RED SANDSTONE				EMPLACEMENT OF AND SLOW ISOSTATIC UPLIFT OF WEARDALE/CHEVIOT GRANITES CLOSURE OF IAPETUS OCEAN AND CONTINENT COLLISION
SILURIAN				IAPETUS OCEAN SUBDUCTION

into the basin. Similar conglomerates of alluvial fan origin have been recognized on seismic profiles adjacent to the Stublick-Ninety Fathom fault system defining the footwall zone of the basin. The Stublick-Ninety Fathom fault has been interpreted as a listric normal fault which soles out at depth when traced northwards into the basin. However, there is no evidence of this on seismic sections which show only a sub-planar normal fault geometry inconsistent with the development of an extensionally driven roll-over fold against the fault plane (Kimbell *et al.* 1989; Collier, 1989). On the Alston Block, Lower Palaeozoic rocks were eroded away, at least in the area of the Rookhope Borehole, and Carboniferous sediments were laid down on the weathered surface of the Weardale Granite. In Durham sedimentation did not begin until the Holkerian, whereas in the Cheviot area sediments, possibly as old as Tournaisian, were deposited on the Lower Old Red igneous rocks.

The second phase of evolution of the Northumberland basin took the form of syn-sedimentary faulting, resulting in differential subsidence which began in the early Dinantian (Table 7). A graben formed between the Harretts Linn and Antonstown faults at the western extremity of the basin, within which 2km of sediment is thought to have accumulated (Day *et al.*, 1970); significantly more than is preserved on either side of the graben. An increase in thickness of the Upper Border Group sediments north of the Antonstown Fault (southern margin of the graben) in the Bellingham area, gives some indication of the longevity of the faults. Furthermore, the Harretts Linn Fault along the northern side of the graben may join up via the High Green Echelon Dyke with the Cragend-Chartners Fault, south-east of which is another thickened sedimentary sequence (Johnson, 1984). However, it should be stressed that the existence of a deep graben structure, containing locally overthickened Carboniferous sediments in the Bellingham-North Tyne Valley area, is not supported by recent seismic and stratigraphic studies (Werngren, 1987) and the relative significance of this second phase of earth movements is uncertain. According to Dearman (1980) the second phase of earth movements was an Hercynian induced east-west compression equivalent to the third phase of earth movements, documented below. Extensionally driven syndepositional faulting was active throughout the Dinantian (Table 7), most of the faults being parallel to the Stublick-Ninety Fathom fault system. These intrabasinal faults, antithetic and synthetic to the main bounding faults created mini-grabens within the main basin structure, which locally trapped the axial drainage system, encouraging the development of vertically stacked, fault-bounded sandbodies as in parts of the present day Rio Grande Rift (Reitlinger *et al.*, 1979). Changes in polarity along the fault systems within the basin are consistent with the development of transfer zones which are en echelon areas of overlap or offset between normal fault segments. Within such zones the footwall of one fault passes into the hanging wall of the adjacent structure (Rosendahl *et al.*, 1986). Up to three possible transfer zones were recognized by Turner *et al* (1993) allowing the regional drainage system to move between different fault blocks.

A third phase of movement in the Northumberland basin occurred during and after late Westphalian times when the basin was partially inverted due to closure of the seaway to the south of Britain and the development of a single phase of east-west to south-east to north-west transpression (Table 7). This movement led to the reactivation and reversal of some of the early syndepositional normal faults, especially those oblique to the axial trend of the basin along its northern and western margins (Collier, 1989). Stacking of sandbodies in the fault hanging wall and the thickening and splitting of coal seams across the fault trace are consistent with fault reactivation in Westphalian A and B times. Additional evidence of this tectonic activity is provided by the presence of feldspathic sandstones, such as the Seaton Sluice sandstone, at the top of the Westphalian A and the middle of the Westphalian B, which differ in their source area, texture, mineral composition and fluid flow characteristics from other sandstones in the Coal Measures succession. The sandstones are attributed to rapid fault controlled uplift and erosion of granitic provenance rocks, such as the Farne granite (Fig. 2, p239), located in the present day southern North Sea, some 80km off the Northumberland coast (Turner & O'Mara, 1993).

Late Carboniferous transpression was also responsible for the development of asymmetric anticlines such as the Holburn and Lemmington anticlines by compression against the resistant Cheviot massif (Fig. 1). These north-south trending fold structures have a steeper western limb and are often reverse faulted; the faults trend concentrically with the margins of the Cheviot Block. Additional evidence of these compressive forces is provided by the easterly-directed Pennine thrust, the east-facing monoclinal Burtreeford Disturbance and the Dent Fault, which is also associated with an east-facing monocline. Evidence from the Berwick area suggests that vertical uplift may have played a role in the growth of these structures. These same compressive forces are also held responsible for the Bewcastle Anticline in the south-west, although this is now regarded as a sediment drape over a fault-bounded basement horst which represents a continuation of the Pennine ridge (Bott *et al.*, 1984). Confirmation of east-west compression comes from the study of small scale structures in Dinantian and Namurian limestones inland and along the coast at Scremerston and Beadnell (Shiells, 1964). Along the South Tyne Valley, minor structures show evidence of north-south stress, possibly in response to adjustment movements against the Stublick fault. The nature and timing of this phase of deformation is uncertain, but it has been related to renewed strike slip tectonics in northern Britain which produced a north-east movement of the Cheviot Block relative to the Northumberland Basin. As a result of this transpression, and the eustatic low stand of sea level caused by the Permo-Carboniferous Gondwana glaciation, erosion of the Coal Measures occurred during the time interval between the Westphalian and the middle Lower Permian. In the southern part of County Durham the Coal Measures are folded and show a northerly dip terminating against the Permian unconformity. Beneath this unconformity the Coal Measures are reddened to a depth of about 20m, due to the effect of Permian desert weathering.

The fourth phase of deformation of the Northumberland basin involved mainly transcurrent faulting (Jones *et al.*, 1980) and is thought to have been responsible for the failure of the Cheviot massif along the dextral Thieves-Gyle-Harthope fault zone, the dextral shift of the Ridlees-Alwinton and Featherwood faults and the development of a series of east-north-east to west-south-west trending minor faults. The Thieves-Gyle-Harthope fault zone is attributed to rejuvenation of an older Caledonian suture and its eastward continuation has displaced the axis of the Holburn Anticline (Fig. 1). The line of this fault zone, which trends slightly east of south-west to north-east, forms a prominent topographic feature across the Cheviot Hills (Robson, 1976). Many other parallel fractures in the south-west of the Cheviot area have been recorded, while a conjugate group, of which the Breamish Fault is the most notable, is also present.

Along the southern edge of the Cheviot massif, the Ridlees, Alwinton and Featherwood faults follow a similar trend, and it is likely that some of the movement along them was also dextral. Towards the northern edge of the massif the Yetholm and College faults probably developed a dextral movement as a result of anticlockwise rotation within the massif itself, against the less resistant beds of the Tweed Basin. Wrench faulting across the Yetholm Fault displaced what must have been a single fracture, forming the now separated Pressen and Flodden faults (Robson, 1977). The Whin Sill was also intruded at about this time (295+6 Ma, Fitch & Miller, 1967), late in the Upper Carboniferous, associated with the prior development of a tensional stress field with an inferred east-west axis of maximum stress (Table 7). This resulted in transcurrent faulting of the Whin Sill. The effects of compression on the Whin Sill can be seen in the development of horizontal slickensiding, especially in the old quarry at Ratcheugh near Alnwick. Some of these movements have affected Permian rocks on the eastern edge of the Alston Block.

Subsequent extensional subsidence occurred from Permian times onwards (Table 7) in response to a regional transtensional stress field with a right lateral shear component that reactivated pre-existing normal fault lines, including the Maryport Fault. Although this extension has been linked to the development of the North Sea Basin from early Permian times onwards, just how long it continued for in the Northumberland Basin is uncertain. In the Solway Basin there is evidence to suggest that it continued sporadically through the Jurassic and into the Cretaceous when extension ceased.

The Alston Block

On the Alston Block the earliest Upper Carboniferous tectonic event was the cessation of block subsidence, which probably correlates with the intra-Westphalian unconformities in the Cumberland and Canonbie Coalfields (Fitch & Miller, 1967). Tectonism affected the region in Late Carboniferous times but, generally speaking, the block sediments were more protected from deformation than those in the neighbouring basinal areas by the relatively near-surface rigid basement rocks. A similar pattern is discernable in the Cheviot igneous region where folding is almost absent. However, some folding did occur across the Alston Block forming, for example, the Teesdale dome (Dunham, 1948) and the steep thrust-faulted monocline associated with the Burtreeford Disturbance. However, faults predominate, many of them providing conduits and host structures for the late Carboniferous Pb-Zn-F-Ba mineralization of the northern Pennine orefield.

Folds are represented by the east-facing monoclinal structure of the Burtreeford Disturbance, which trends north-north-west to south-south-east, and is the dominant structure of its kind on the Alston Block. It has a vertical displacement of up to 150m and later faults, some reversed, follow the fold which is itself deflected around protrusions of the basement granite, indicating continuity at depth (Fig. 5). The much gentler Teesdale dome structure is an east-west plunging periclinal fold. Doming persisted into late Hercynian times and may have been a side effect of the continued regional uplift. Calculations for a north-south section of the dome suggest a stratal extension of the order of some 25m must have occurred at the level of the Great Limestone. Faulting accompanied doming, and the formation of tension cavities on some of the fault planes accommodated this extension.

Three main groups of faults on the Alston Block occur where they are mineralized to form economic mineral veins (Fig. 19). Those trending east-north-east usually have small throws of less than 12m. In these tension cavities the mineralization of, for example, the Boltsburn and Blackdene veins occur. The second main group of faults, known locally as 'cross veins', trend north-north-west and have throws of up to several tens of metres. Occasionally they are reverse faults, as at Swinhopehead, but they are seldom mineralized or cavernous. A third set of faults trends broadly west-north-west. These are often mineralized and form the 'quarter point' vein class. Several of these structures, such as the Red and Slitt veins, can be traced over more than 9km. True vertical displacements are unusual, but underground mapping has proved sinistral wrench displacements of up to 30m. Wrench movement, together with the observation that the downward narrowing of the tension cavities is not nearly so marked on the east-north-east veins, suggests that this fault set may form part of a shear couple around the east-north-east aligned axis of compression. The conjugate set would be made up of the rather unusual north-north-east faults such as Henry's-Breckonsyke, Scaithead and East Greenlaws veins, although there are no observations of dextral shear displacement on these structures. If these west-north-west and east-north-east faults are a conjugate pair then, with the north-north-west fractures, the pattern may be considered as a response to a west-south-west to east-north-east stress field, analogous to that described by Sheills (1964) in his study of the minor structures in north Northumberland.

Joints are ubiquitous throughout the area and are thought to predate the intrusion of the Whin Sill (Dunham, 1933; Moseley & Ahmed, 1967). The joints probably formed in response to early uplift and folding, and according to Moseley & Ahmed (1967) they follow Caledonian basement trends.The two principal joint sets (east-north-east and north-north-west) lie parallel to the two main sets of faults (Fig. 19) and are perpendicular to the bedding, irrespective of lithology. Dunham (1933) regarded these sets as a conjugate shear pair, but the high angle between them suggests that this interpretation may not be correct, and that the north-north-west set represents an earlier pair, since the second least principal stress appears to have been east-north-east throughout much of the remainder of the deformation (viz. the east-north-east trend occupied by the Whin dykes and the productive fissure veins). Supporting evidence is the east-north-east folding that predates tension fissuring, and by the fact that later north-north-west fracturing shows signs of compression, sometimes to the extent of reverse faulting.

The Whin intrusions, of early Stephanian age (Fitch & Miller, 1967), are an important datum in orefield history since they clearly postdate certain structures and predate mineralization. They postdate the end of regional block subsidence and coincide with the onset of Upper Carboniferous compressional uplift. Moreover, large sills such as the Whin are generally emplaced within one or two kilometres of the contemporary land surface as horizontal sheets. Since the Great Whin Sill is markedly transgressive in a radial sense about upper Teesdale and Burtreeford, it may be assumed that the sediments had already been folded. Indeed, as in its relationship with the beds across the Holburn Anticline, the sill has been shown to transgress to successively higher horizons away from the general area of the Burtreeford Disturbance, and appears to have been intruded along a horizontal plane cutting the disturbance (Dunham, 1948). Regional doming continued after intrusion and is broadly co-axial with the pre-whin folding, although there was no longer any influence from the Burtreeford Disturbance.

As in north Northumberland, there is evidence for echelon-dyke intrusion in south Durham; for example, the whin intrusion known as the Hett Dyke continues eastwards as the Ludworth Dyke (Figs 9, 15). These dykes occur along fractures parallel with the east-north-east group of faults and joints. In post-whin times mineral emplacement continued along these same east-north-east trends. The persistence of mineralization is seen in some mines where early infillings have been fractured and veined by later minerals.

Northumberland and Durham Coalfield

Apart from the coastal sections, subsurface structural information on the Coal Measures is sparse. The coalfield is bounded on the north and south by the east-north-east trending Hauxley and Butterknowle faults respectively (Fig. 1). Both faults downthrow to the south; the Hauxley fault by about 100m, and the Butterknowle fault by about 250m. The coalfield faults follow three principal trends: west-south-west to east-north-east, west-north-west to east-south-east and north-north-west to south-south-east (Fig. 7, Table 8).

Many of the major faults cross the area in a broadly west-east direction with occasional north-north-west to south-south-east fracture zones, the latter showing a similar trend to the Castle Eden Disturbance, the Burtreeford Disturbance (Dunham, 1948) and many other major faults, especially those on the western side of the country. Minor faults with small throws and variable trend are also common. The Hauxley, Stakeford, Ninety-Fathom and Butterknowle faults show several features in common. The strata on the downthrow side of the faults shows steep dips in the opposite direction to that of the throw. This was referred to by miners in the phrase 'the strata rise to a dipper and dip to a riser'. The faults also show subsiduary, steep folding along the plane of movement, with the axes orientated at high angles to the

Table 8 Principal faults in the Coal Measures of north-east England.

FAULTS	DOWNTHROW		TREND
	Direction	Amount	
STAKEFORD	NORTH	approximately 107 metres	generally WSW-ENE
NINETY FATHOM	NORTH	up to 167 metres	between WSW-ENE and WNW-ESE
ST. HILDA	SOUTH	maximum 133 metres	WSW-ENE
EAST SEA WINNINGS	SOUTH	259 metres	WSW-ENE on echelon with St. Hilda fault
SEAHAM HARBOUR	NORTH	estimated maximum 305 metres	WSW-ENE
EASINGTON	NORTH	91 metres	WSW-ENE
OFFSHORE ZONE	TROUGH COMPLEX	Displacement about 1122 metres	NNW-SSE

fault plane, indicative of substantial lateral movement along that plane, consistent with a dextral shift. The fault pattern in the coalfield is similar to that documented for north Northumberland and the Alston Block. A marked structural depression, the Cambois-Seghill Syncline, occurs south of the Stakeford fault and continues southwards across the Ninety-Fathom Fault (Land, 1974). Within this basin the direction of faulting is more dominantly east-north-east although the Ninety-Fathom fault has a somewhat variable trend. The syncline can be traced as far south as the Tyne, where its axis passes beneath Wallsend (NZ 343658). Here the structure is known as the 'Tyne Coal Basin' and it has had a major influence on the historical development of the coalfield (Raistrick, 1952). South of the Tyne the syncline flattens out and the strata assume a gentle east-north-east dip, overlain over much of east Durham by Permian rocks.

From Druridge Bay southwards to Seaham Harbour (Fig. 7) the offshore area shows a series of structural highs or 'domes' aligned more or less parallel to the coast, separated by structural 'lows' commonly associated with major faults. The domes, which are 3-5km across, with maximum dips on the flanks of up to 10°, carry the coal to shallower depths, close to the sea bed or the base of the overlying Permian rocks. This adversely affects the safety of undersea mining. The Vane-Tempest structure, north of the Seaham Harbour fault (Fig. 7), is approximately 6.5km long and aligned north-north-west to south-south-east. Dips on the west facing flank of the structure are up to 40° and almost vertical close to major faults. The structure owes its origin to the west-south-west to east-north-east compression responsible for the Burtreeford Disturbance farther west, and similar compressional structures in north and west Northumberland. South of Seaham Harbour the offshore structure is simple, with gentle undulations superimposed on a gentle easterly dip.

The presence of Permian strata in the south-west of the region provides a means of confirming the pre-Permian date of the Whin intrusions and of determining the age of some of the later movements, for which evidence is not available in north

Northumberland or the Alston Block. For example, in the coalfield renewed movement at a later date, along older lines of weakness, displaced the Permian Magnesian Limestone. Many of the resulting faults show that movement in the Coal Measures was at least twice as great as that in the Permian, with the scale of folding being less during the later phase of tectonic activity. This was not confined to an easterly tilt of the beds, as suggested by some workers, but also involved renewed upfolding of the domes in post-Permian times.

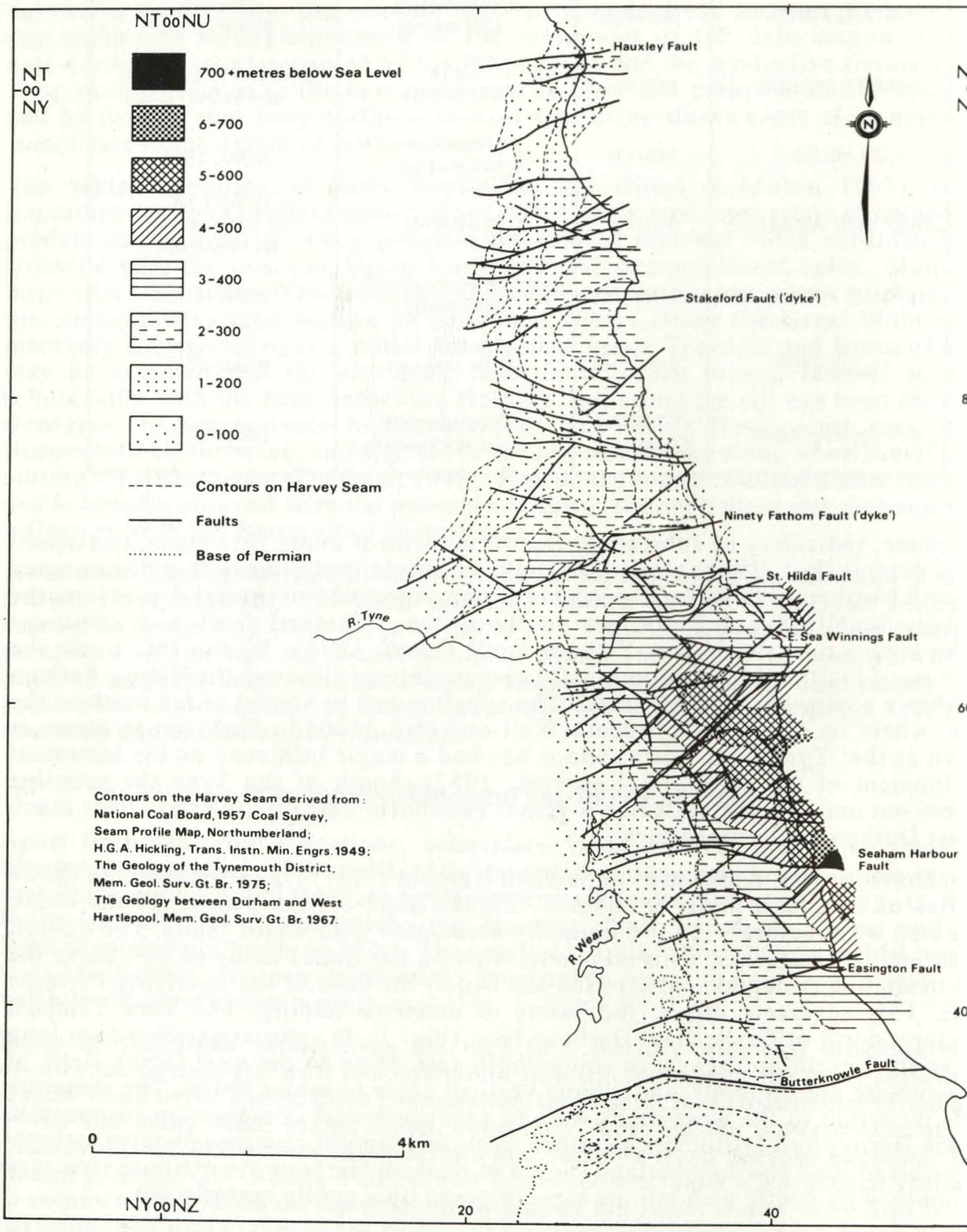


Fig. 18 Structural map of the Northumberland and Durham coalfield.

Tertiary movements

Tertiary movements developed in response to a north-south compressive force (Table 7), and are thought to be responsible for much of the faulting seen today, including reactivation of many of the major faults such as the Pennine Fault bordering the western side of the Alston Block. Movement along this fault resulted in uplift of Lower Carboniferous limestones above the younger, low-lying Permo-Triassic sediments of the Vale of Eden, along the Pennine escarpment. The easterly tilt of the north Pennines, due to movement along the Pennine and Dent faults, may also have occurred at this time, together with the reactivation of pre-Carboniferous basement structures which again controlled levels of renewed subsidence between basins and blocks. Tertiary basin inversion followed and the area was subjected to erosion.

Tertiary earth movements were accompanied by igneous activity, and emplacement of a suite of east-south-east tholeiitic dykes (Fig. 16), which genetically are associated with the Tertiary volcanic province of western Scotland. The most northerly dyke is the Acklington dyke and the most southerly the Armathwaite-Cleveland dyke. Evidence of the north-south compressive stresses operating at this time is seen in the lateral displacement of the Acklington dyke in late- or post-Miocene times in the vicinity of the Cheviot Hills (Robson, 1964, 1977). The direction of movement suggests a sinistral response along north-east to south-west wrench faults.

In the northern Pennine orefield, post-ore faulting occurs in mineral veins as prominent features known locally as cheeks, backs, leaders or slickens, which carry sub-horizontal slickensides. Three main types of fault can be recognized. The first type of fault occurs at the margins of veins but seldom penetrates deep into the vein itself. Displacement along these faults is usually very small, except locally where faults may cut and displace veins laterally by up to 1m. Two trends are discernible, parallel to the master joint-fault trends. At Redburn mine (Fig. 19) the proportion of each trend varies along and across individual orebodies, and as such resembles reactivated second-order faulting. The second type of fault occurs within and aligned parallel with the main veins. Slickensides are again horizontal with movements of up to a few metres, sometimes during mineralization. Evidence of this is seen in the brecciation of early minerals followed by the healing and cementation by later phases of fluorite and other minerals. The third type of faults are thrusts, which are less common than other post-ore faults. At the Redburn Mine a thrust fault strikes 082° and displaces the Far North Branch vein some 8m to the south; the dip of the thrust plane varies from 20° to horizontal. Slickensides are sub-horizontal, indicating strike-slip movements. Similar structures have been recorded from Groverake and Stotsfieldburn mines.

Measurement of K-Ar ratios from clay gouges associated with these structures indicates several phases of movement in Mesozoic times and possibly later (Dunham *et al.*, 1968). Within the zone of oxidation slickensiding results in polishing and limonitization of limestone surfaces. These movements can probably be explained in terms of stress field adjustments as the Alston Block was uplifted to its present state of isostatic near-equilibrium, rather than Tertiary movement. Nevertheless, evidence for vertical movement in the Tertiary is seen in the fault scarps within and bounding the Cheviot Hills, and along the fault lines, such as the Pennine Fault, bordering the Alston Block. Furthermore, the concentration of earth tremors, such as those at Kirby Stephen in 1970, suggests recent readjustment on this boundary fault system (Browning & Jacob, 1970).

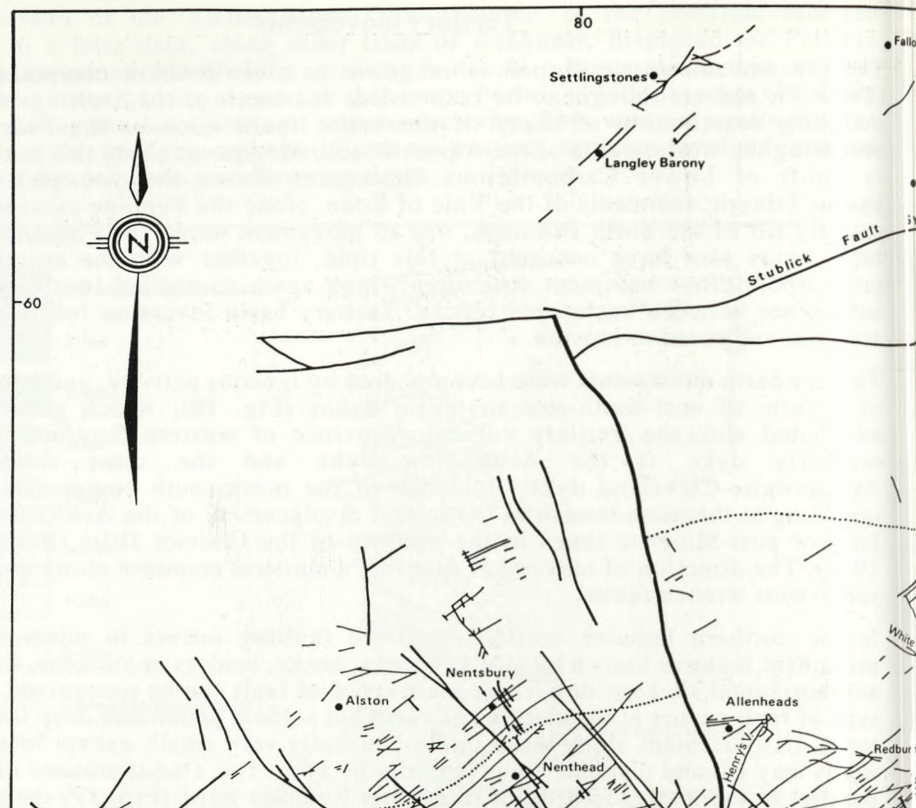
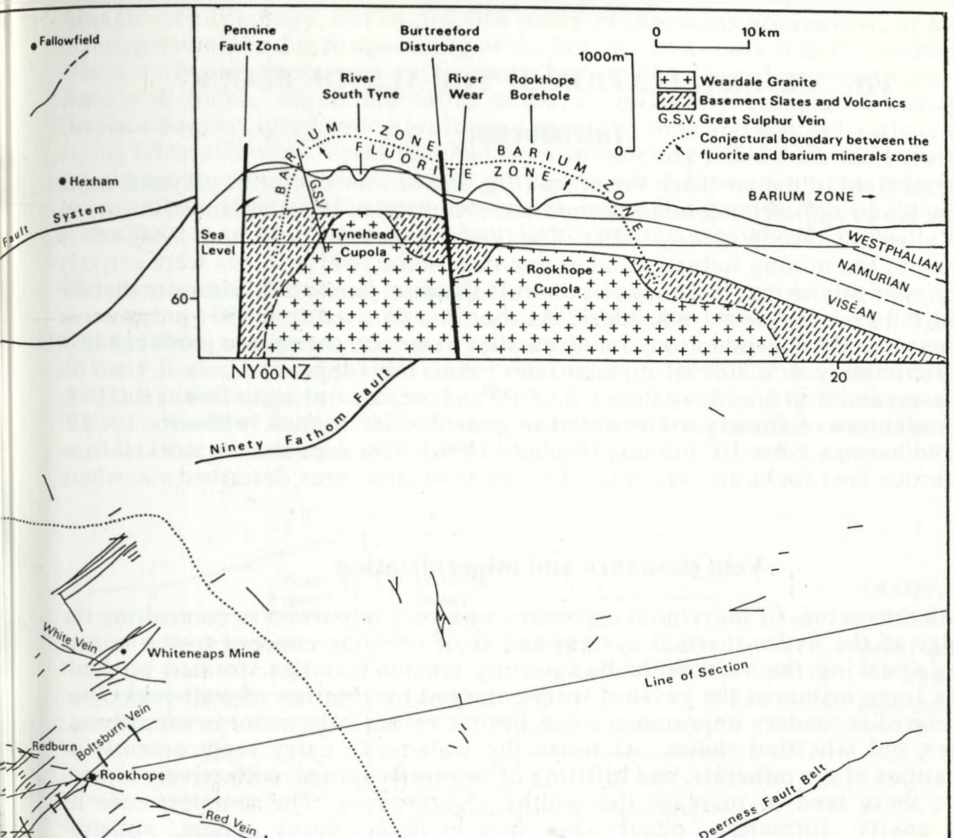


Fig. 19 Map showing the fault and mineral-vein pattern in the Pennine orefield.


Fallowfield
Pennine Fault Zone
Burtreeford Disturbance
0
10 km
1000m
0
River South Tyne
River Wear
Rookhope Borehole
Weardale Granite
Basement Slates and Volcanics
G.S.V. Great Sulphur Vein
Conjectural boundary between the fluorite and barium minerals zones
BARIUM ZONE
FLUORITE ZONE
BARIUM ZONE
BARIUM ZONE
GSV
Hexham
Fault System
Sea Level
Tynehead Cupola
Rookhope Cupola
WESTPHALIAN
NAMURIAN
VISÉAN
60
NY00NZ
20
Ninety Fathom Fault
White Vein
Whiteneaps Mine
Line of Section
Redburn
Boltsburn Vein
Rookhope
Red Vein
Deerness Fault Belt
Stanhope
40
Wolsingham
Slitt Vein
Crook
NNW
Joint Directions
ENE
Flushimere
Sharnberry Vein
Coldberry
Middleton in Teesdale
Lunedale Fault
Outer margin of Fluorite Zone
Burtreeford Disturbance
Faults
Known Mineral Veins
0
10 km
20
NY00NZ
20

CHAPTER 10

THE MINERALIZATION OF THE ALSTON BLOCK

Introduction

The mineral field of the northern Pennines (Fig. 19) has for centuries played a major role in the history of settlement and economic evolution of these uplands (Raistrick, 1934; Wallace, 1890; Wooler, 1926). The years between 1950 and 1990 saw a resurgence of the mining industry and at one time some twelve mines were actively developing, or producing, the gangue minerals fluorite, barite and witherite that the old metal miners considered worthless. At the time of writing (1993) only two of those mines remain in production. Traditionally, however, the region produced lead ore (approximately 4×10^6t of concentrates) zinc ore (approximately 0.3×10^6t concentrates) and iron ore (more than 1.85×10^6t of ore) according to Dunham (1959, 1990). Production of fluorspar amounted to over 2×10^6 tonnes, witherite 1×10^6 tonnes, and barytes 1.5×10^6 tonnes (Dunham 1990). The deposits are worked from Carboniferous host rocks and are related to the vein structures described elsewhere (p341).

Vein structure and mineralization

The detailed structure of individual orebodies was very important in controlling the 'plumbing' of the hydro-thermal system and is of obvious concern to the miner. Generally speaking the vein orebodies occupy tension cavities, formed on fault planes. In some instances the cavities were enlarged by solution of wall-rocks, but this must be of secondary importance since similar vein widths occur in sandstones, limestones and silicified shales. At times the wall-rocks carry replacements, or disseminations of ore minerals, and infilling of solution cavities, collectively known as 'flats'; these tend to increase the widths of ore-zones. The simplest case of orebody cavity formation occurs on quarter-point veins where sinistral displacements of tens of metres are known.

Since the original faults were sinuous, movement tended to open tension cavities where the vein azimuth was west-to-east rather than west-north-west (Fig. 20). Cavity width is, therefore, related to the magnitude of horizontal displacement and

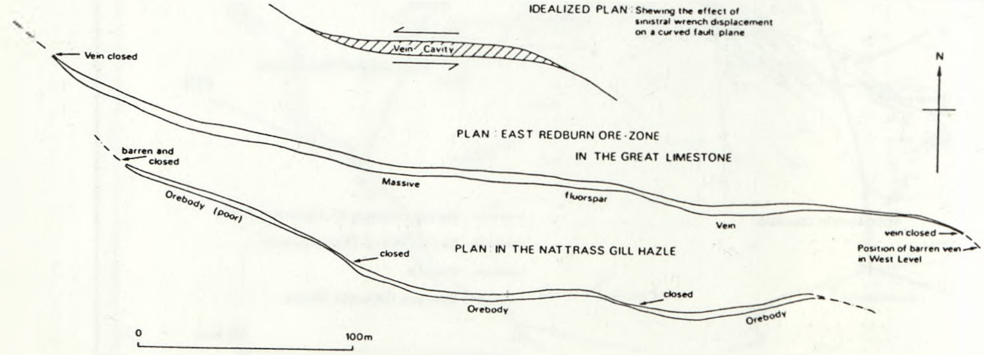


Fig. 20 Plan of the Red Vein, east Redburn ore-zone.

degree of change of azimuth. Theoretically the cavities should extend unchanged through each lithology, but in practice many of the veins are narrow, or closed, in shales, presumably due to squeezing of the hot, wet beds back into the opening space. Where early solutions were sufficiently strong, they could penetrate and silicify shale wall-rocks, which thereafter acted as relatively competent cavity walls. Displacement occurred over a prolonged period of time and was certainly continuing during mineralization. Veins that had been completely filled with early material did not always reopen down the centre during renewed movement, but vein infillings are usually symmetrical across the centre line. The final width of quarter-point orebodies can be up to 10m, as at Stotsfieldburn and Whiteheaps mines.

The more common style of orebody formation predominates on the east-north-east veins occupying normal faults. The mechanism, described in detail by Dunham (1948, 1990), operates where the fault is refracted to a shallow dip as it enters soft or shaly beds. Vertical displacement then tends to produce tension cavities where the fault is more nearly vertical, i.e. in the hard rocks (Fig. 21). Dunham also noted that, as a result of the regional doming, such faults must become overall more nearly vertical in depth and cavities must decrease in width. East-north-east vein orebodies

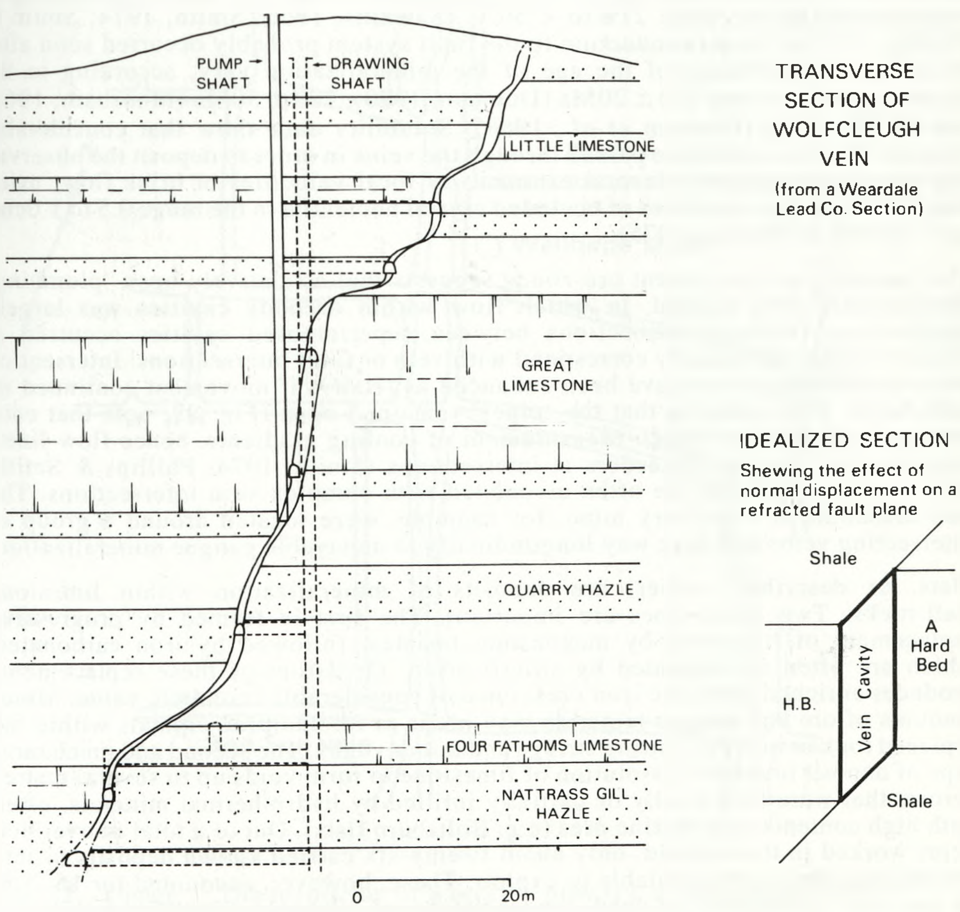


Fig. 21 Section of Wolfcleugh Mine, Rookhope.

are usually of the 'ribbon' type, so-called since length (up to 1km) greatly exceeds height and width. They are sealed above and below by shale. Abnormal stratigraphical conditions, such as thickening of sandstones in washout sequences, benefit both the quarter-point and the east-north-east veins, and may enable 'bonanza' orebodies of unusual height to form. These have provided some of the most prolific vein orebodies in the orefield, e.g. Sikehead, Crawley, Eggleshope-Sharnberry, Lodgesike and Coldberry. A similar result was produced by the baking of shales above and below the Whin Sill, so that they could behave as good, competent wall-rocks - at Settlingstones and Blackdene mines for example.

The vertical displacement on most of the east-north-east productive veins is less than 12m. Once the throw begins to exceed the thickness of individual hard and soft beds in the host rock succession, then the chances of finding good, hard rocks on opposing walls of the fault are obviously much reduced, and the veins tend to be choked with shaly gouge. In addition to normal movement, there could be some wrench displacement along east-north-east veins. The only good evidence for this, however, is found at Burtree Pasture Mine, where folded wall-rocks appear to have been shifted sinistrally.

Fluid inclusion studies have shown that the mineralizing solutions were aqueous brines with characteristics of 21 to 23 equivalent weight % NaCl, circulating at temperatures in the range 219 to < 50°C (Sawkins, 1966; Smith, 1974; Smith & Phillips, 1975). Their introduction to the fault system probably occurred soon after its inception. Estimates of the age of the mineralization vary, according to the method used, between 292 ± 20Ma (Dunham, 1990), 280 ± 30Ma (Moorbath, 1962) and 255 ± 12Ma (Dunham *et al.*, 1968). Solubility data show that considerable volumes of brine must have passed through the veins in order to deposit the observed thicknesses of minerals. Several estimates of local velocities of brine flow, using calculated settling velocities of occluded crystal nuclei, lie in the range 0.5 to 1.0cms sec^{-1} (Smith & Phillips, 1975).

The geometry of the present ore-zones suggests that a relatively open 'plumbing' system must have existed, in which flow within orebody cavities was largely longitudinal. Vertical connections between superimposed cavities occurred at 'feeder' points that usually correspond with vein or fault intersections. Intersection breccia-zones appear to have been enhanced as feeders if movement continued on both faults, thus ensuring that the 'pipes' remained open (Fig. 22; note that each vein set can shift the other). Measurement of cooling gradients, hence flow lines, confirms the location of feeders at intersections (Smith, 1974; Phillips & Smith, 1974). Lead ore shoots are often associated with complex vein intersections. The rich oreshoots at Nentsbury mine, for example, were located around a group of intersecting veins and gave way longitudinally to unpayable gangue mineralization.

Flats, as described earlier, are deposits of mineralization within limestone wall-rocks. Two main types are important. The first is formed by progressive replacement of limestone by magnesium bonates, followed by iron carbonates, which are often accompanied by silicification. Oxidation of these replacements produces enriched limonitic iron ores; once of considerable economic value. Minor amounts of ore and gangue minerals may occur as idiomorphic crystals within the replaced rock or in cross-cutting strings and minor vughs. The second and much rarer type of deposit involved dissolution of limestone to form voids up to several metres across, that were then totally or partially infilled by hydrothermal minerals, often with high contents of lead-zinc ores (e.g. Boltsburn flats). Out of a total of over 600 veins worked in the orefield, only about twenty-six carried known deposits of this second type that were profitable to exploit. These, however, accounted for 15-20% of the total production of lead concentrates and probably 80-90% of the zinc concentrates. Both types of flats are most common in coarsely sparitic horizons with the Great Limestone, and are most often formed when the thickness of shale in the overlying Coal Sills group exceeds around 40% of the total thickness of the group

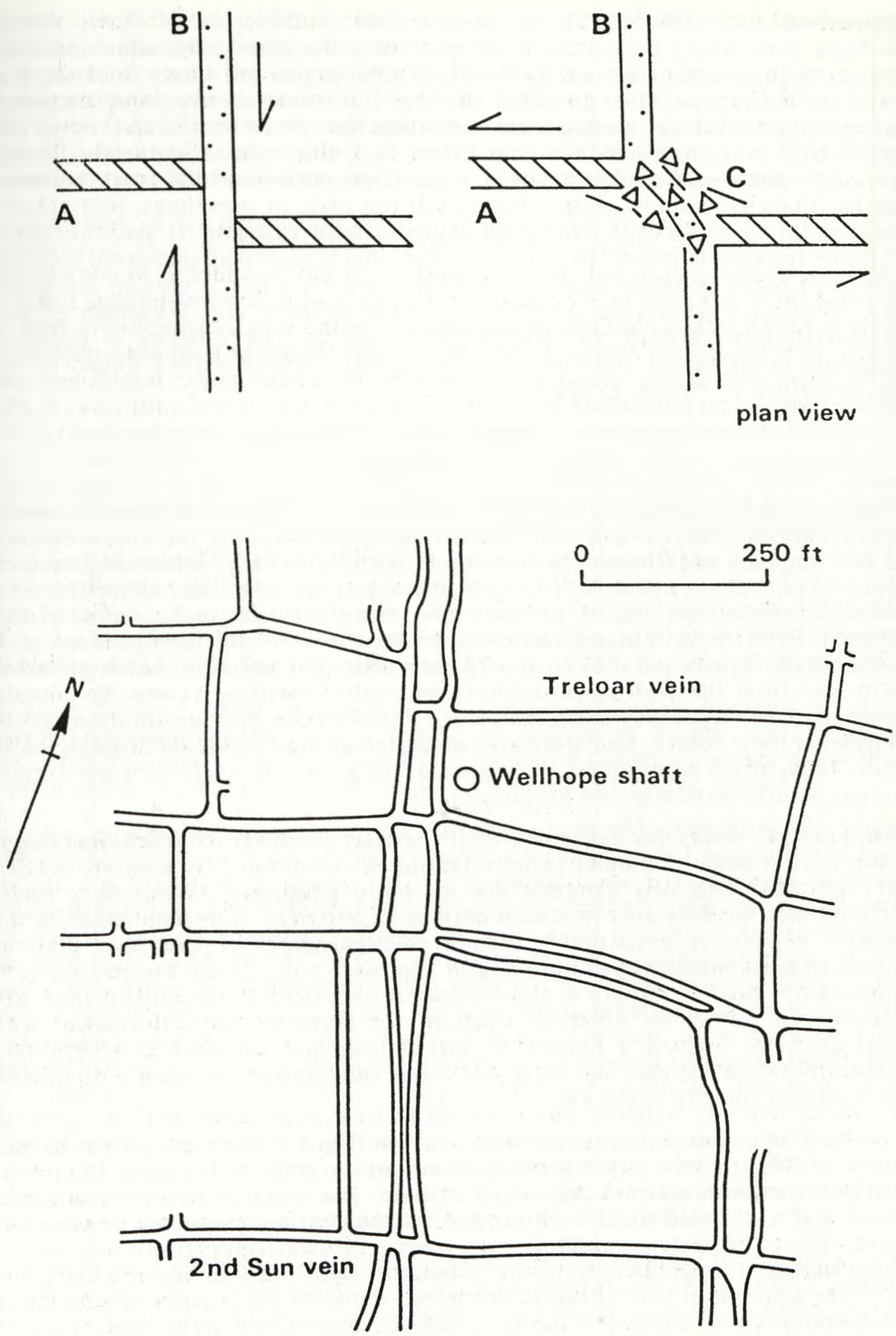


Fig. 22 Upper: The formation of a breccia pipe (c), at the intersection of two active faults A and B.

Lower: Plan of part of Nentsbury Mine, Nenthead showing a complex of intersecting veins.

(Greenwood & Smith, 1977), suggesting that constriction of flow, above the limestone, has forced the solution laterally into the more permeable and reactive parts of the limestone. Conversely, flats are seldom present where thick sandstones overlie the limestone. Flats do occur in other limestones in the sequence, and may be especially well-developed in limestones that have been heated and recrystallized by proximity to the Whin Sill (e.g. at Etters Gill, Rotherhope and in the Rookhope Borehole) - but these constitute only a small proportion of the total, known, flat deposits. Flats are usually more common at the ends of ore-zones, particularly on quarter-point veins, where ironstone deposits tend to occur if the vein trend is unsuitable for vein deposits. In part, however, this is due to an increased brecciation of the wall-rocks in these zones, exposing a greater surface area to metasomatic attack. Wall-rock alteration in both the Whin dolerite and Weardale granite is characteristically sericitic to intermediate argillic. The dolerite is particularly susceptible to alteration and conversion to a clay-carbonate rock known as white whin, described by Wager (1929).

Mineralogy

The primary and secondary mineralogy of the orefield is given in Table 9, compiled mainly from Dunham (1948, 1990), and is fairly typical of low-medium temperature lead-zinc deposits in carbonate host rocks. Dedicated work by mineralogists such as Bridges, Ixer, Vaughan and B. Young over the last ten years has identified several additional, minor, species of primary and secondary minerals, summarized in Dunham (1990). Vein mineralization is in the form of alternating, more or less monomineralic crusts parallel to the fissure wall. Crystal orientation shows that growth was from the wall towards the vein centre. Infilling is usually complete, although narrow vughs may mark the centre line. The ore-bearing solutions evolved with time, at their source, and were also modified as they travelled through the vein system. Thus, broad mineralogical changes occur across veins, from walls to centre, and along veins, vertically and longitudinally.

Dunham (1934, 1948) has described major spatial zonation of vein mineralogy in which a central zone of fluorite mineralization is surrounded by a baryte-witherite zone (Fig. 19). The two gangues are mutually exclusive except in a narrow, ill-defined intermediate area in which neither is abundant. Sulphide minerals show a broader concentric zonation in which predominantly copper ores give way outwards to predominantly lead ores, then lead with zinc, in the fluorite zone. The base metal ores decline rapidly in significance within the barium mineral zone. Zone boundaries are offset on opposite sides of the Burtreeford Disturbance, which appears to have formed a barrier to circulation and allowed a mineralogical imbalance between the east and west sides, e.g. the relative abundance of zinc ores to the west and fluorite to the east.

The earliest solutions entering the veins in the fluorite zone deposited marginal selvages of fine-grained, often grey, chalcedonic or jasperoid quartz. Copper and iron sulphide assemblages are associated with this phase and show a general vertical zonation and a detailed local longitudinal zonation around orebody feeders. The deepest, most central assemblage is pyrrhotite-chalcopyrite giving way to chalcopyrite-pyrite-marcasite to pyrite-marcasite and finally to barren chalcedonic quartz. The volume of this phase is not great, the only major exposure being the Great Sulphur Vein. There is evidence, though, that as some fluorspar veins are followed to depth they bottom out into predominantly early phase material, e.g. Stotsfieldburn and Cambokeels mines. The uppermost limit of early phase deposition dips gradually deeper towards the barium zone and probably never enters that zone. Examination of individual orebodies, such as those on Red Vein, may show very marked accumulations of quartz-chalcopyrite at vein intersections, changing when followed along the orebody into narrower marginal selvages of quartz-marcasite, then eventually into a cheek of barren quartz before dying out.

Wall-rock silicification and Mg-Fe metasomatism were probably contemporary with early phase deposition. Solution of the ramifying lead-zinc 'flat' voids must also have occurred at about the same time, though they are sometimes found separated from the parent veins by belts of silicified limestone, e.g. Boltsburn. Fluid inclusions in the early quartz are rarely adequate for temperature studies, but in several instances yield higher temperatures than fluorspar in the same vein. Na-K weight ratios in inclusion leachates vary from 2.8 to 9.4 (mean 5.9, three samples).

The main phase of ore deposition generally follows fairly abruptly, although a few centimetres of interbanded material can often be present, sometimes including pseudomorphs of quartz and fluorite. Fluorite, clear and milky cockscomb quartz, galena and sphalerite were deposited in alternating bands until the veins were full. They were also deposited in the flats, but frequently left the cavities unfilled. Galena and sphalerite zonation is apparent in so far as zinc values tend to increase towards the top and lateral extremities of quarter-point ore-zones, and sphalerite commonly occurs as cementing breccias of main phase minerals, indicating its late introduction. Fluorite fluid inclusion temperatures, corrected for pressure, lie in the range 124° to 219° (more than 300 specimens) and Na-K weight ratios of fluid inclusion leachates vary from 5.25 to 17.3 (mean 11.7, thirty-two samples). Fluid inclusion temperatures remain steady across all the veins that have been studied, including one which was 9.3m wide, showing that main phase deposition must have been of short duration, probably measurable in thousands of years. If the duration had been much greater, then the effect of continued heat exchange between rocks and brines would have tended to raise the rock temperature virtually to that of the brine, in which case the details of internal cooling gradients would have differed from those observed by fluid inclusion measurements (Smith, 1974; Smith & Phillips, 1975).

The main fluorite phase was usually followed by small amounts of barren, coarsely-crystalline quartz and dolomite or calcite in vughs, and by narrow, cross-cutting veinlets of chalcedony. Fluid inclusion temperatures are lower than in the main phase. Na-K ratios are 9.25 to 14.75 (mean 13.1, five samples).

The same sequence of phases is not present in the zone of barium minerals. Fluorite, in the few places where it occurs with baryte, always preceded deposition of barium minerals, e.g. Pikestone, Coldberry Hill, Flushiemere and Hilton mines. Alternating crustiform banding of baryte, witherite, quartz, galena and sphalerite is comparable with fluorite vein morphology, though the veins tend to contain very pure gangue with very little sulphide. At Settlingstones mine, for example, the vein averaged nearly 78% witherite, 4.5% baryte and only 0.1% galena, occasionally attaining widths of 9m (Dunham, 1948). In this instance, the contaminating baryte has formed by secondary sulphatization of witherite that may, in turn, have replaced original baryte veinstone at a late stage in the mineralizing process (Hancox, 1934). Baryte and witherite veins extend well into the Durham coalfield, the best deposits following the Deerness fault belt (Fig. 19). The isolated Haydon Bridge (NY 843645) mining field, which includes the Settlingstones, Stonecroft-Greyside and Fallowfield mines, forms the northernmost limit of the orefield, although sporadic galena-baryte-calcite veins are known from the Northumberland limestones, decreasing in frequency northwards away from the Alston Block.

Fluid inclusions in baryte are generally gasless (i.e. indicating formation at $<50^{\circ}$C) though one specimen from Nentsbury yielded temperatures of 126-129°C (Sawkins, 1966). Na-K ratios of leachates range 10.9 to 46.0 (mean 25.4, six samples, including Sawkins' results).

Genesis

The concentric nature of the mineral zonation and the correlation between the outline of the fluorite zone and the shape of the upper, cupolated surface of the basement granite must feature strongly in any consideration of genesis. The lateral secretion theory of Wallace (1861) and whin-derivation theory of Sweet (1930) were discussed and refuted by Dunham (1934) who proposed a deep granite source for the solutions, the mineral zonation finding parallels with parts of the Cornubian orefield. The Rookhope Borehole proved, however, that the pre-Carboniferous Weardale Granite could not have been the direct source of the mineralizing brines, although it may have acted as a structural guide (Dunham *et al.*, 1965). Dr Holland, discussing the origin of the pluton (see above, pp313-4), has suggested that younger granite might exist at greater depth. Sawkins (1966) and Dunham (1993) proposed that evidence from fluid inclusions supported a two-phase hydrothermal system in which hot, fluoride-heavy metal-sulphate-rich brines, derived from below the crust, rose into the Teesdale dome and mixed with cool, barium chloride-rich connate brines migrating updip from the Coal Measures basin. Fluorite was supposed to have been deposited by cooling, until the hot brines reached the present zone boundary where mixing with the connate brines caused dilution. Baryte was then precipitated by chemical reaction. The modern occurrence of barium chloride brines, albeit in restricted environments, in the coalfield (Edmunds, 1975), lent support to the theory. The discovery of zirconium aureoles around fluorspar veins (Ineson, 1969) and of high rare earth contents in the fluorite, sometimes totalling up to 0.1% (Smith, 1974), provided further evidence of a magmatic contribution to the fluoride-bearing brines and favoured perhaps a differentiated alkaline igneous source. While not altogether precluding magmatic contributions, the sulphur isotope data published by Solomon *et al.* (1971) are so atypical of magmatic sulphides that the authors were led to suggest that the fluorite zone minerals were deposited from a cooling connate brine of Lower Carboniferous derivation that had leached ore components from reservoir and passage rocks during deep circulation. The heat source they proposed was the cooling whin magma chamber, but it now seems that an earlier heat flow event, dated prior to 293 Ma, must have been involved (Creaney, 1980; Dunham, 1990). On the basis of barium aureoles around fluorite veins in the Weardale granite (Solomon, 1966), barium was also believed to have been carried in the hot, ascending chloride brines and baryte was precipitated by reaction with sulphate-rich connate brines, again of Lower Carboniferous derivation.

Until 1947, weekly production of hundreds of tonnes of 'blanc fixe' grade precipitated baryte was obtained from pump water in Durham and Northumberland collieries, aptly demonstrating the potential of formation waters for forming mineral deposits.

Lesser mineralization of the Alston block

In addition to the Pennine Pb-Zn-F-Ba type, there were several other episodes of broadly hydrothermal epigenetic mineralization. These are, in approximate order of decreasing age:

(a) **The barren quartz veins** which have been emplaced in the Lower Palaeozoic basement rocks.

(b) **The pegmatitic and other veining** which is developed in the Weardale Granite. Normal Pennine-type Pb-Zn fluorite veining occurs in the granite in addition to molybdenite-bearing pegmatites, quartz-tourmaline veins and hydrothermal veins of quartz, dark purple fluorite, haematite, manganese oxides, garnet and epidote (Dunham *et al.*, 1965). Quartz and fluorite from the latter occurrences yield fluid inclusion temperatures of 244° and 261° (ΔT 22° and 24° respectively). Fluid inclusions in the fluorite (from 695m (2085ft) in the Rookhope Borehole) yield a mean freezing temperature of -25.9°C with no eutectic effects, probably indicating a higher calcium content than the normal Pennine-type fluids. Secondary inclusions in this fluorite and in quartz from 549m (1649ft) yield corrected mean formation temperatures of 198° and 192°, and an equivalent salinity of 21.2% NaCl, all of which are more comparable

Table 9 Mineralogy of the northern Pennine ore deposits.

PRIMARY MINERALS

FLUORITE ZONE

Fluorite	**Quartz**	**Galena**	**Sphalerite**
Chalcopyrite	Pyrrhotite	**Pyrite**	**Marcasite**
Calcite	Aragonite	**Dolomite**	**Ankerite**
Siderite	Strontianite	Jamesonite	Haematite-in Jasper
Kaolinite-? primary	Millerite	Glaucodot	Gersdorffite
Ullmannite	Arsenopyrite	Tetrahedrite	Bournonite
Cosalite?	Cassiterite	Bismuthinite	Scutterudite
Cobaltite	Synchysite	Monazite	Xenotime

BARIUM MINERALS ZONE

Baryte	**Witherite**	**Barytocalcite**	**Alstonite**
Quartz	**Galena**	**Sphalerite**	**Pyrite**
Chalcopyrite	**Calcite**	Aragonite	**Dolomite**
Ankerite	**Siderite**	Strontianite	Ullmannite
Millerite	Harmotome	Hydrocarbons	Marcasite
Arsenopyrite	Tetrahedrite group mineral		Niccolite
Magnetite			

SECONDARY MINERALS

Cerussite	Anglesite	Pyromorphite	**Smithsonite**
Hemimorphite	**Hydrozincite**	Goslarite	**Malachite**
Azurite	Chalcanthite	Covellite	Native Copper
Marcasite	**Limonite**	**Haematite**	**Goethite**
Baryte	**Jarosite**	**Melanterite**	**Epsomite**
Gypsum	Copiapite	Erythrite	Berthierine
Greenockite	Rosasite	Aurichalcite	Psilomelane
Cinnabar	Goslarite	Ferricopiapite	Linarite
Brochantite	Crysocolla	Wroewolfeite	Serpierite
Devilline	Annabergite		

The bold type indicates the more common minerals, the normal type indicates scarce minerals.

Sources: Dunham, 1948, 1990: Dearman & Jones, 1967; Smith, 1973; Smith & Hardy, 1981; Ixer *et al.*, 1979; Vaughan & Ixer, 1980; Ixer, 1986; Young, 1985, a, b, c; Young *et al.*, 1984, 1985, 1987, 1989; Young & Francis, 1989.

with nearby Pennine-type veinlets. This evidence suggests that a higher temperature hydrothermal mineralization of the granite preceded the Pennine veins and it is tempting to correlate this with final-stage magmatic activity (Smith, 1974).

(c) **The rich bands of pyrite nodules** which are found in several places in the sediments underlying and overlying the intrusions of the Whin Sill (e.g. Great Whin Sill at Wynch Bridge; Little Whin Sill at Greenfoot Quarry; Whin dyke at Closehouse). Some nodules also contain chalcopyrite, with minor pyrrhotite, galena and blende.

(d) **The disseminated baryte mineralization** with occasional galena, blende, fluorite, hydrocarbons and copper ores which are contained in the Permian Lower Magnesian Limestone of east Durham (Fowler, 1943, 1956). Structural controls are sometimes evident, for example in the Ferryhill area (Hirst & Smith, 1974) and at Raisby Hill, suggesting upward migration of Coal Measure brines into sulphate-enriched environments.

(e) **Minor mineralization** occurs within the Coal Measures, apart from those massive barytes-witherite veins which are included within the mineralization of the east Durham coalfield and which constitute the fringe of the north Pennine orefield. There is, for example, fairly pervasive ankerite mineralization, even on coal cleat, which Smythe & Dunham (1947) were unable to ascribe, in the main, to the Pennine orefield. Galena and blende are occasionally found in the course of mining and opencasting of coal, sometimes as discrete masses of discontinuous veins several centimetres in width, but more usually as films on joint faces. Randall & Jones (1966) record several instances of baryte, calcite, ankerite, pyrite, marcasite and possibly galena in cavities associated with Tertiary tholeiite dykes. Some of these minerals are thought to be derived from formation brines within the Coal Measures.

CHAPTER 11

HYDROGEOLOGY

Introduction

Hydrogeology is that branch of geology (or hydrology) which deals with the occurrence and properties of subsurface water, or groundwater. While the surface water hydrology of north-east England has been recently described in some detail (Archer, 1992), no published account of the hydrogeology of the region has previously appeared, though there are several unpublished summaries (Anderson, 1941, 1945a; Northumbrian River Authority, 1973; National Rivers Authority, 1993). In part, this omission reflects the fact that groundwater amounts to only 10% of the public water supply in north-east England, though the overall importance of groundwater to water resources and ecology in the north-east is in no way represented by this figure. To redress this balance, the following summary will consider the hydrostratigraphy of the north-east and the overall importance of groundwater. The rock sequence and its disposition in north-east England is given on Fig. 1.

Hydrostratigraphy of north-east England

'Hydrostratigraphy' is the classification of rock sequences according to their ability to store and transmit water (Seaber, 1988). In essence, the process of hydrostratigraphic classification involves the definition of aquifers (units which store and transmit significant quantities of water) and aquitards (lowly permeable units which retard the regional flow of groundwater). Discussion of hydrostratigraphic units implies some consideration of the hydraulic conductivity (i.e. permeability with respect to water) and water quality associated with particular stratigraphic units or parts thereof. Thus in the discussion which follows, reference will be made to the transmissivity (T) of hydrostratigraphic units, defined as the product of the saturated thickness and mean hydraulic conductivity of a given aquifer. Transmissivity is best understood as the effective ability of an aquifer to transmit water, as it recognizes that a very thin aquifer is of little value irrespective of its hydraulic conductivity. It is the combination of high hydraulic conductivity with a large saturated thickness which really counts, and this is the very combination described by a high transmissivity. Notes on the total dissolved solids (TDS) content and the concentrations of major dissolved ions in groundwater will also be given where appropriate.

Pre-Carboniferous

Little information exists on the hydrogeology of the pre-Carboniferous succession of north-east England. It is nevertheless clear that very little groundwater circulation can be occurring in the Silurian greywackes and shales of Teesdale and Upper Tynedale (Younger, 1991, p16). The existence of major fault-controlled valleys in the Cheviot granite massif (such as Harthope, NT 950220) suggests the existence of localized groundwater flow along fracture planes, though in general the Devonian of the Cheviot igneous complex does not host significant groundwater circulation. Indeed the Cheviot volcanics are noticeably lacking in the rubbly horizons, vesicular zones and thermal contraction joints which normally conduct significant groundwater flow in lavas and tuffs (Younger, 1991, pp16-17). The Weardale Granite probably hosted some hydrothermal fracture-flow during the mineralization of the Alston Block, though there is no evidence for modern circulation in the granite.

Lower Carboniferous

The lowermost **Cementstones Group** in both Redesdale and the Tweed Valley is sufficiently arenaceous that it may be considered a reasonable prospect for groundwater development, although to date only three licensed boreholes exploit these sandstones (one in Coquetdale, the others on the banks of the Till at Tiptoe, NT 909420). In the central outcrop area (near Glanton, NU 063146), however, the sandstones are fine-grained and of low permeability.

The Fell Sandstone Group is the most important aquifer in Northumberland, and it has been exploited for public supply for over a century. Previous accounts of the hydrogeology of the Fell Sandstone (Hodgson, 1970; Hodgson & Gardiner, 1971; Cradock-Hartopp & Holliday, 1984) imply that the Group acts as a single aquifer, with shale interbeds being insufficiently thick and laterally persistent to isolate effectively adjacent aquifer sandbodies from each other. However, recent borehole investigations have established that the Fell Sandstone generally comprises up to seven separate sandstone aquifers, effectively confined by thick, laterally persistent mudstones (Younger, 1992b; Turner, Younger & Fordham, 1993). These sandstone aquifers all retain considerable interstitial porosity and permeability (Bell, 1978), and joints enhance the permeability near outcrop. However, only the thicker units are sufficiently transmissive to supply enough water for public supply abstractions. Thus the four licensed boreholes which together supply around 11,000 m^3d^{-1} to the Berwick area draw their water from the two thickest sandstones, the Murton Crags Formation and the Peel Knowe Formation. Both of these sandstones reach 70m in maximum thickness and have transmissivities of around $100m^2d^{-1}$. Lateral equivalents of the Murton Crags Sandstone are also used for public supply in the Wooler area (Fowberry Borehole NU 027293) and at Rothbury (springs at Cartington, NU 042044, and Tosson, NU 030002). Fell Sandstone water is generally soft (total hardness 100mg l^{-1}) and lowly mineralized (TDS 300mg l^{-1}), and is of Ca-HCO_3 facies. pH is frequently low (6), sometimes requiring adjustment prior to use in public supply.

The overlying **Scremerston Coal Group** is predominantly an aquitard, except in west Northumberland, where equivalent Upper Border Group strata include some sandstone aquifers; one such sandstone is pumped for public supply at Stonehaugh (NY 799765).

Within the **Lower and Middle Limestone Groups** a number of thick and permeable sandstones function as aquifers, albeit of limited lateral extent (Younger, 1991, 1992a). The hydrogeology of these sandstones is similar to that of the Fell Sandstones. In the Northumberland Basin the limestone units are generally of little hydrogeological importance, though on Holy Island (NU 134428) a public water supply borehole exploits a limestone aquifer. On the Alston Block, the limestones support localized karst flow systems (Kennard & Knill, 1969), some of which feed high-yielding springs.

Upper Carboniferous

The Namurian Upper Limestone Group and **Longhoughton Grits** ('Millstone Grit') include a number of permeable sandstone units which are exploited for private water supplies. Large springs associated with the basal Millstone Grit are used for public supply in the Allendale and Alston areas.

Coal Measures hydrogeology is complicated due to the extensive disruption of the natural groundwater hydraulics by coal mining. Before mining, the Coal Measures comprised confined sandstone aquifers separated by shale and coal aquitards. There was very little meteoric groundwater circulation in this sequence, and much of the

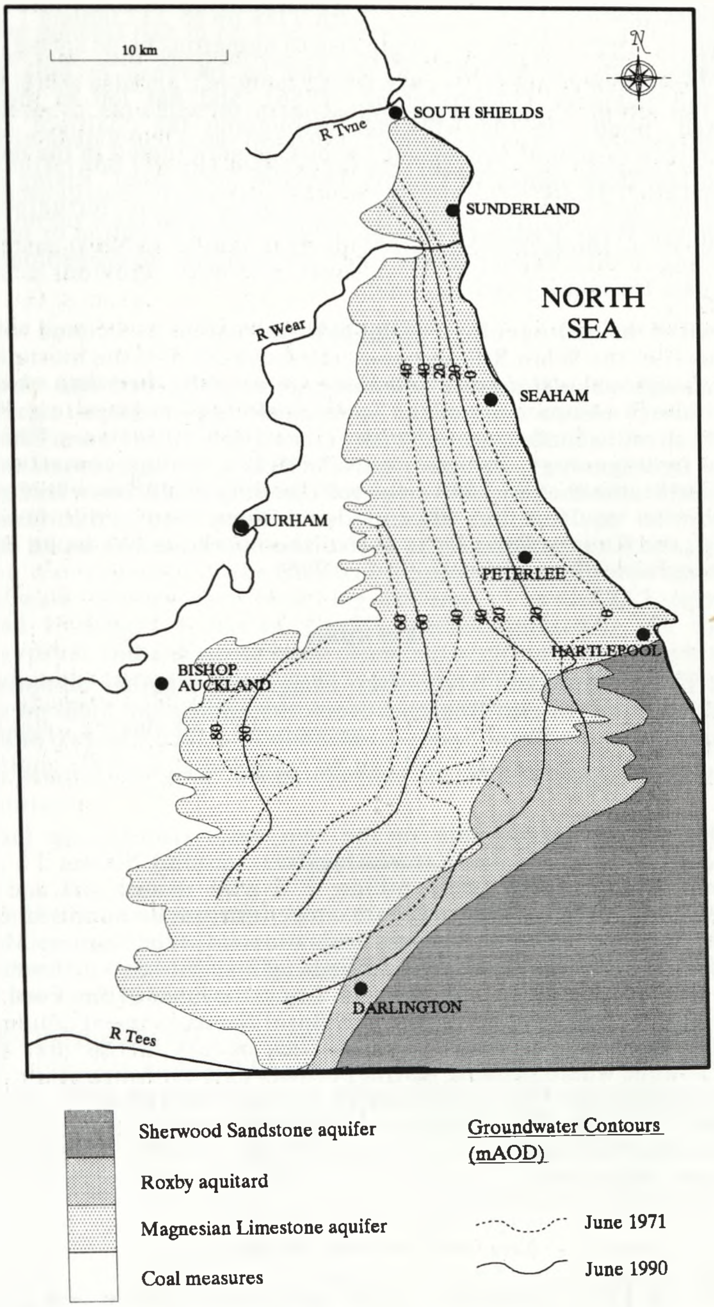


Fig. 23 Hydrogeological map of the Magnesian Limestone Aquifer of County Durham, showing selected groundwater contours for June 1971 and June 1990. Note the general rise in water levels over the 20-year period, due mainly to reductions in abstraction where coastal boreholes were affected by subsurface seawater intrusion. Some of the rise in the south-western part of the aquifer is due to cessation of dewatering in underlying coal workings (cf. Younger, 1993). Drawn from data in Northumbrian River Authority (1973) and from archive data of the National Rivers Authority.

natural groundwater was highly saline (with TDS up to 237,000mg l^{-1}) (Anderson, 1945b; Edmunds, 1975), formerly giving rise to numerous brine springs in the lower Tyne and Wear valleys. Mining has caused an increase in bulk permeability throughout the sequence (Minett *et al.*, 1986), and has led to the creation of interconnected 'ponds' in old workings throughout the coalfield. Cessation of dewatering in this system of subsurface 'ponds' is anticipated in the next few years now that the last deep mines in County Durham are closed. Rising groundwater levels will result, and eventually surface discharges of acidic, ferruginous water are anticipated in the Wear Valley (Younger, 1993). The prevention or remediation of pollution arising in this manner seems likely to dominate hydrogeological research in the north-east for many years to come.

Little is known of the hydrogeology of the basic intrusions associated with the Upper Carboniferous (i.e. the Whin Sill and associated dykes). For the most part the Whin Sill lies above regional water table and there are no published data on its hydraulic behaviour, although common alteration features along joint faces (e.g. Hornung and Hatton, 1974) attest to former groundwater circulation in fractures. The dykes have an ambiguous hydrogeology. In some cases the dykes, or their contacts with country rock, are so permeable that they have caused flooding problems where groundwater from the Permian aquifers has flowed down them into active coal workings. Paradoxically, the Causey Park Dyke in Northumberland acts as an impermeable barrier to groundwater flow (Minett *et al.*, 1986).

Permian

The Permian Basal Sands and Magnesian Limestone together comprise the most important aquifer in north-east England. Notwithstanding the local presence of the Marl Slate aquitard at the Basal Sands-Limestone interface, the two units generally exhibit good hydraulic continuity, and can be regarded as a single aquifer for most purposes.

Water quality is indistinguishable in the two units (illustrating the hydraulic continuity), and is generally hard (total hardness around 500mg l^{-1} as $CaCO_3$), moderately mineralized (TDS about 600mg l^{-1}), with neutral pH and displaying Ca-Mg-HCO_3 facies. Locally high sulphate concentrations (around 150mg/l) reflect dissolution of anhydrite in the Edlington Formation (Middle Permian Marls) which locally functions as a 'leaky' aquitard maintaining a slight head difference between the Seaham Formation (Upper Magnesian Limestone) and the Ford Formation (Middle Magnesian Limestone). Flow in the Basal Sands is intergranular, whilst in the Magnesian Limestone formations, most flow occurs in fractures (with some intergranular storage where suitable matrix porosity exists). Amongst the Magnesian Limestone formations, the Ford Formation is generally considered the best prospect for groundwater development due to the presence of complex reef-related structures which are frequently permeable (Northumbrian River Authority, 1973), although the Raisby (Lower Magnesian Limestone) and Seaham Formations both yield substantial quantities of water where fracture frequency is high.

Examination of available data suggests that transmissivities in the Magnesian Limestone aquifer vary from $15m^2d^{-1}$ to $4600m^2 d^{-1}$, though a more restricted range of 60-800$m^2 d^{-1}$ is more commonly encountered in practice (cf. Armstrong *et al.*, 1959; Cairney, 1972). In the southern area of the outcrop, good hydraulic connection exists between the Magnesian Limestone and the River Skerne (Cairney & Hamill, 1977; Hamill, 1980; Younger, 1993) and the river serves to drain groundwater from the aquifer. Apart from the possibility of limited discharge to the Wear and Tees, most of the remaining outflow from the Magnesian Limestone is probably via submarine discharges into the North Sea.

The Permian is exploited extensively for public water supply, meeting about 30% of the demand in the Sunderland area, and providing the entire public supply to

Hartlepool. Total licensed abstractions from the aquifer currently exceed 140,000 $m^3 d^{-1}$, and the general rise in regional water levels over the last twenty years (Fig. 23) indicates that this abstraction is easily sustainable. This regional rise in groundwater levels reflects a gradual adjustment in pumping patterns in response to former problems of seawater intrusion in coastal boreholes. In the future, as rising groundwater in abandoned Coal Measures impinges upon the Magnesian Limestone (which will buffer the low pH waters) further increases in the total resource in the aquifer are anticipated. However, wells exploiting the Basal Permian Sands may suffer pollution for want of buffering capacity in the aeolian quartz sands (Younger, 1993), and there is concern that high sulphate concentrations in the rising waters might persist in the Magnesian Limestone.

Triassic

The mudstone aquitards of the uppermost-Permian Roxby Formation (Upper Permian Marls) separate the Magnesian Limestone aquifer from the Triassic Sherwood Sandstone Group. Nationally, the Sherwood Sandstone is second only to the Chalk in importance as a public supply aquifer. Nevertheless in north-east England the Sherwood Sandstone aquifer is of little importance. This is partly due to low permeabilities (transmissivities generally below 80 $m^2 d^{-1}$), reflecting the fine- grained distal facies of the sandstones at this northern extreme of their main outcrop. The water quality in the Sherwood Sandstone aquifer is also poor in this region. The water is very hard (reaching 1000mg l^{-1} as $CaCO_3$), relatively saline (TDS around 1500mg l^{-1}) and of Ca-SO_4 facies, reflecting the dissolution of associated gypsum and anhydrite beds. Thus at the present time there are no public supply abstractions from the Sherwood Sandstone in the north-east, though licensed abstractions (largely of non-potable water) for various industrial purposes amount to approximately 12,500 $m^3 d^{-1}$ at present.

The Mercia Mudstone Group which overlies the Sherwood Sandstone Group is an efficient aquitard.

Quaternary

Little groundwater is abstracted from the Quaternary of Northumbria; however, Quaternary deposits have considerable hydrogeological importance, since they mediate recharge to the underlying aquifers and also control certain aspects of river flow behaviour (see below).

Where dense lodgement till is present, as in much of the coastal plain, recharge may be minimal. However, in much of County Durham, the Quaternary glacial sequence includes many sand and gravel units which both function as perched aquifers and allow recharge to the underlying aquifers. Perched sand and gravel aquifers often cause problems for drillers attempting to reach the Magnesian Limestone aquifer, particularly where 'running sand' enters the borehole. To date no detailed hydrogeological analysis of the Durham glacial sequence has been undertaken, despite its clear importance for understanding recharge to both the Magnesian Limestone and to the mined Coal Measures.

In the Northumbrian uplands and the Tweed valley, the tills are dissimilar from the low-permeability lodgement tills of the coastal plain. In these areas, deformation tills (brecciated and comminuted masses of local bedrock) are present. Thus the Fell Sandstone aquifers tend to be overlain by drift which has hydraulic properties similar to those of the aquifer itself (Younger, 1992c).

Valley train sand and gravel deposits in the region generally display high permeabilities. For instance hydraulic conductivities around 140 m d^{-1} are recorded for the floodplain gravels of the Breamish (Younger, 1991), while those of the Lower Tees lie in the range 200 to 2000 m d^{-1} (Mason, 1992, pp100-101).

Thick peat deposits blanket much of the Northumbrian uplands, and they are an important element of the hydrological system, since they control both flood runoff and baseflow in upland streams. Field investigations are currently underway to assess the hydrogeology of upland peat in the region.

Groundwater and the environment

Groundwater Pollution. Despite the well-known industrial history of north-east England, very few cases of groundwater pollution have been recorded in the region. Indeed, pollution due to industrial activity has only affected two licensed boreholes in the entire region. A borehole at Millhill (NZ 412425) formerly used for public supply was taken out of use after a fire at an adjacent organic chemical plant on 16 March 1986 led to localized pollution of the Magnesian Limestone aquifer. Most recently (in October 1991), a private borehole in the Fell Sandstone near Berwick-upon-Tweed was polluted by the solvent perchloroethylene which entered the aquifer via a soakaway on adjacent factory premises (Environmental Data Services, 1992; Kershaw & Clews, 1993).

The low level of industrial groundwater pollution probably reflects two circumstances:

(i) The fact that the most important aquifers (the Magnesian Limestone and Fell Sandstone aquifers) have largely rural outcrop areas, away from sites of heavy industrialization.

(ii) The role of glacial tills in restricting ingress of pollutants into the aquifers.

Although aquifers which outcrop in rural areas elsewhere in the UK are subject to diffuse pollution by nitrates and pesticides, these pollutants are generally not a problem in aquifers in the north-east. This presumably reflects the scarcity of intensive arable agriculture in the region, as well as the protection afforded by the tills.

Groundwater pollution by landfill leachate has also had limited impact to date. Much publicity surrounded the 1990 discovery of cyanide pollution in Magnesian Limestone groundwater near a tip contaminated with presumed cokeworks waste at Bishop Middleham, County Durham. However, the pollution was not traceable more than 200m from the tip, and the nearest public supply borehole lies some 7km away. In another well-known case, hexavalent chromium entered the Sherwood Sandstone aquifer from a landfill in a disused aggregate quarry in the Cleveland Dyke at Coatham Stob (NZ 406163); again, effects were localized and posed no threat to borehole abstractions.

Groundwater and River Flows. North-east rivers are renowned for their 'flashy' runoff behaviour, with very high flood discharges superimposed on a relatively low long-term baseflow (Archer, 1992). This low baseflow reflects the generally low permeability and storage of the Lower Carboniferous rocks which underlie much of the catchments of the Tyne, Wear and Tees. Nevertheless, when the fifteen-day minimum mean flow data for gauging stations throughout the region (presented by Northumbrian River Authority, 1973) are examined, headwater streams draining peat-covered areas are found to have much higher baseflows (mean of $190m^3\ d^{-1}\ km^{-2}$ of catchment area) than the river basins as a whole (mean of $86m^3\ d^{-1}\ km^{-2}$). This suggests that upland peat plays an important role in sustaining baseflows during dry periods. Paradoxically, because the water table is at or near the surface in most upland peat systems, surface runoff is generated rapidly during rain storms, accentuating the flashiness of the river hydrographs.

The permeable Tees gravels were mentioned above. Analysis of flood hydrographs for the Tees has shown that, under certain conditions, there is an anomalous net loss of total flow volume as the flood wave passes downstream. This has been attributed to ingress and temporary storage of flood water in the permeable floodplain gravels (Mason, 1992, pp100-101).

Groundwater and Ecology. Groundwater discharge supports a number of important ecological niches in the region. Most notable of these is the SSSI known as Hell's Kettles (NZ 281109). Here saw-sedge dominated swamp vegetation is supported by hard water rising from the confined Magnesian Limestone aquifer (presumably through a breccia funnel), forming ponds in natural subsidence hollows developed on the Roxby (Upper Permian Marl) aquitard. A second example is the small travertine-depositing spring near Shotton (NZ 410399), which is fed by water in a perched glacial gravel aquifer.

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Entries in **bold** type refer to Tables and Figures

The Geologists' Association, founded in 1858, exists to foster the progress and diffusion of the science of Geology. It holds lecture meetings in London and, via Local Groups, throughout England and Wales. It conducts field meetings and publishes Proceedings, Field Guides and Circulars regularly. For further information apply to the Honorary General Secretary, The Geologists' Association, Burlington House, Piccadilly, London W1V 0JU.

Trans. nat. Hist. Soc. Northumb. **56**, 393-420 (1995)

ANNUAL REPORT
OF THE
COUNCIL
FOR THE
YEAR ENDED 31 JULY 1995

THE NATURAL HISTORY SOCIETY OF NORTHUMBRIA

PRESIDENT

His Grace the Duke of Northumberland

VICE PRESIDENTS

The Viscount Ridley
A H Dickinson
R W T Thorp
Sir James Steel
M J Hudson
J Alder
Dr G A L Johnson
D F McGuire
D R Shannon
D P Walton
I D Moorhouse
Mrs M A Patterson
Dr A G Lunn
A M Tynan

COUNCIL

(1) **Elected by members**:
1992 - Mrs S Chambers, Mrs J Holmes, Dr T G Walker
1993 - H Baird, Dr J M Jones
1994 - K Patterson

(2) **Nominated by sections:**
Dr A G Lunn (botany), L Jessop (entomology), Dr G A L Johnson (geology), E Slack (Gosforth Park), Dr D Gardner-Medwin (library), Dr C Redfern (ornithology), Professor R B Clark (publications)

(3) **University representatives:**
Dr A J Richards, Dr B J Selman, P S Davis

TRUSTEES

A H Dickinson, R M Gledson, I D Moorhouse, Mrs M A Patterson, The Viscount Ridley, D R Shannon, E Slack, D C Souter, R F Walker

HONORARY TREASURER
E Slack

SECRETARY
D C Noble-Rollin

GENERAL PURPOSES COMMITTEE
P S Davis, Dr A G Lunn, Dr D Gardner-Medwin, D R Shannon, E Slack, J North-Lewis

SOCIETY REPRESENTATIVES

Coquet Island Advisory Management Committee: I D Moorhouse, D C Noble-Rollin

Fontburn Reservoir Wildlife Advisory Group: I S Davidson

Lindisfarne National Nature Reserve:
Advisory Committee: D G Bell
Wildfowl Panel: D C Noble-Rollin

Museum Management Committee: Dr D Gardner-Medwin, D C Noble-Rollin, E Slack, Dr R Stobbart

STAFF:
Mrs P Hammock, Mrs M A Patterson, Mrs R Wolland

GOSFORTH PARK NATURE RESERVE
Warden: P Drummond

THE HANCOCK MUSEUM
Principal Keeper: A Coles

ANNUAL REPORT OF THE COUNCIL FOR THE YEAR ENDED 31 JULY 1995

This report is one of success, progress and consolidation after the concerns and doubts of only three years ago.

More members are participating in the activities of the Society, the Hancock Museum exhibitions and events continue to attract extraordinary large numbers of visitors, Gosforth Park reserve has better future prospects than for some time, a full and varied programme of lectures and field meetings has been maintained and the preparation of further *Transactions* continues. The library expands as one of the best natural history libraries outside London and improvements continue in the storage and curation of our collections.

Membership has improved slightly and the Society's financial position remains enviably healthy. The only downside element of this most satisfactory situation arises from the necessity to increase the membership rates of subscription from 1 August 1995 to enable the Society to maintain its activities and objectives.

MEMBERSHIP

The total membership (with 1994 figures in brackets) on 31 July 1995 was 921 (900). This was made up of 6 (7) honorary members, 43 (42) life members, 582 (580) members who receive *Transactions*, 259 (239) members who do not receive publications, 22 (20) associate members, 1 (3) school and 8 (9) complimentary members. Several people make payments under long-standing bankers' orders ranging from £1 to £9, when these sums were the current subscription rates, and they are regarded as donors and not members.

The Council reports with much regret the death of six members, J Rendall Bartlett, Mr C Gray (1971), Mr E Harvey (1985), Mr H G Potter(1984), Mr J C Riddell (1949) and Sir James Steel (1967). The dates in brackets are the year in which they joined the Society.

HONORARY MEMBERSHIP

At last year's annual meeting, it was suggested that the Society should in some way honour Professor Swan for his contribution to the Society's scientific standing with the production of the *Flora of Northumberland*. The Chairman said that this was in hand and during the year various possibilities were discussed at Council. The highest honour that the Society can bestow on its members is honorary membership. The rules of the Society state, 'Honorary members shall be persons who have rendered special services to the Society or who are eminently distinguished in the realms of natural history. The number of honorary members shall be limited to twenty'. It was agreed at the January Council meeting that Professor Swan should be awarded honorary membership and Council recommends that he should be elected at the November annual meeting.

COUNCIL

At the annual meeting in November 1994 Mr Ken C Patterson was elected to Council and Dr Peter Garson, Mrs Patrica Hammock and Mrs Anna Newson retired by rotation.

Mr Ken Patterson has been the secretary of the geological section for a number of years. He lectures in geology at the Centre for Continuing Education at the University of Newcastle upon Tyne and is a retired teacher.

PUBLICATIONS

Since the publication of volume 56 part 2 in April 1994, the Society has been engaged in the rewriting and editing of the second edition of *The Geology of North East England*. As many members know, the death of Dr Douglas Robson, the editor and principal author of the first edition, was a great loss to the Society, and as a tribute to him and his work for the Society, Council decided that the second edition should be renamed 'Robson's Geology of North East England'. The scope and scale of this production has had echoes of the *Flora of Northumberland* in its complexity. By the time members receive this report they will be in possession of copies of this excellent update. Council would like to thank all the authors for their contributions and the editor, Dr G A L Johnson, for his hard work during the year on bringing together the text from so many authors and overseeing the numerous proofs and corrections, and also Margaret Patterson and Prof R B Clark for their proof reading of the drafts.

Other publications produced were 'Birds on the Farne Islands in 1994' and the 1994 annual report, both now part of the *Transactions.* Unlike the previous year, the Farne Island report has been produced as a small issue of the *Transactions.* This facilitates a quick turn-around which is necessary as this paper is sold by the National Trust at their Seahouses shop and therefore has a clear Easter deadline each year.

STAFF AND MANAGEMENT

During the autumn two members of the staff left. Mrs Joan Shannon, who looked after exchanges and binding, decided to retire in August. However, with a small amount of persuasion she continued her work until Christmas, for which we were very grateful. Her decision to retire was based partly on the fact that her husband, Derek Shannon, was retiring from the University at the turn of the year. Joan has worked in the office for thirteen years and her contribution to the running of the Society has been very important. At the time of Grace Hickling's death she took on the complicated and difficult task of maintaining the Society's correspondence with innumerable exchanges, journal subscriptions and the bindery, a task which she tackled with efficiency and good humour.

Mrs Sue Carter also decided to leave in August in order to pursue her interest in painting and drawing at the University of Newcastle upon Tyne. She has worked for the Society for fifteen years and has quietly come in every week and simply dealt with covenants, bankers orders and, more recently, the computer membership, with an efficiency that only came to light after she left. The Society would like to wish her every success in her new venture.

It became apparent that at least one new member of staff would have to be appointed. The post was given to Mrs Patricia Hammock who is known to many members for her work on the Gosforth Park reports and who has been of great assistance in a voluntary capacity in the lay-out and production of the *Flora of Northumberland.* Patricia comes in twice a week and is now responsible for the covenants, bankers orders and exchanges, while continuing some of her voluntary work for the Society when time permits.

Mrs Rita Wolland continues with her work looking after the day-to-day accounting, field meeting bookings and the continued ringing returns from the Farne Islands, but she is now taking a larger part in looking after the membership records.

Mrs Margaret Patterson continues her secretarial work and is assistant editor of the *Transactions.* A great deal of her time this year has been spent in the preparation of material for 'Robson's Geology of North East England' and the Society is particularly indebted to her for her work on the indexing and final proof reading of the copy, on which she spent many hours.

Mrs Joan Holding has worked extremely hard this year preparing and updating the diagrams for 'Robson's Geology of North East England', which has been very precise and meticulous work. Apart from this she has continued to illustrate the bulletin and to undertake other graphic tasks that have come up. The Society would like to thank her for her dedication throughout the year.

During the summer Dr Jeremy Holding offered to help in the office and immediately became involved in updating the journal database and in preparing a paper for English Nature concerning wigeon and brent numbers on the Lindisfarne National Nature Reserve. Both these tasks were of great assistance to the Secretary.

Throughout the year Mrs Janet Angel has assisted in analyzing the logbooks from Gosforth Park. She comes into the Society's office periodically to collect the information and a month or two later returns with detailed lists of species seen etc. Also helping with Gosforth Park, Ms Vicky Orrell attempted to prepare vegetation maps from historical documents available in the Society's library. Unfortunately she had to leave the area before completing this, but has prepared base maps which hopefully another volunteer will be able to complete in the near future.

Mrs Anna Newson has finished cataloguing the Bewick vignettes and tailpieces as far as she was able and, after discussion, Mr Iain Bain agreed to edit her text and to add information on a number of drawings that have yet to be identified. Since then she has worked diligently on upgrading the catalogue of papers in the *Transactions* which should eventually become both a subject and author database and a catalogue which will be printed in the *Transactions* for the use of members.

Mrs June Holmes has continued her work on the Bewick birds but increasingly has been required to use her knowledge of the Bewick collection to help and assist other workers in their studies. This has included the production of a display for the City Council for which she wrote the text and prepared the photographs ready for the graphic artists. More recently she has been offered a grant to undertake the cataloguing of all the manuscripts within the museum (which coincided with the birth of her second child Rebecca). The Society would like to thank her for all her work and Council hopes that she will be able to continue both her family responsibilities and her valuable contribution to the museum.

Without the support and help of this dedicated team of volunteers and staff the Society would not be able to undertake so many commitments, and Council would like to thank them all for their contribution throughout the year.

HANCOCK MUSEUM

Museum Performance Following the extraordinary success of Dinosaurs Alive! in 1993-1994, this year was always going to be difficult. The projected visitor figures were set at 140,000 for the financial year 1994-1995. The figure actually achieved was 138,375.

Permanent Galleries

'The Living Planet' Work has begun on the 'Living Planet' gallery and it is hoped that it will open before the end of December. This will form the first phase of the new 'Earth Galleries' to be built in the rear of the museum (the current location of 'Yesterday's World').

'Earthworks' A grant of £104,000 has been offered towards phase 2 of the project - 'Earthworks', which will be the new interactive geology gallery.

Temporary Exhibitions This report covers a period of almost frenetic exhibition activity within the museum.

'Claws' (July 26 - February 6) 'Claws' was the exhibition about cats (wild and domestic) that opened right at the end of July 1994. It proved extremely popular with visitors, although it could not compete with the previous exhibition 'Dinosaurs Alive!'in terms of visitor numbers. It did however attract record numbers of visitors for the summer period. 'Claws' differed from all the other recent blockbuster exhibitions in that it was 'home grown'. The advantage of this is that it is now touring other museums around Britain. The cost of staging the exhibition was calculated in such a way that the revenue generated from the tour would offset the costs. The interest in the exhibition has been so great however that by autumn 1996 it should be generating a profit.

At Kirkleatham Old Hall museum in Cleveland, although 'Claws' was the first exhibition with an admission charge, it created a 96% increase in visitors over the equivalent period the previous year. After a relatively quiet spell in Middlesbrough, it is now generating record visitor numbers at Sunderland museum. Future venues include Oldham, Dundee and Glasgow museums.

'Saints and a Sinner' (29 October - 30 April) This was the intriguing title of an exhibition prepared by Les Jessop initially for Sunderland museum on the Backhouse family. The Backhouses were Quakers, bankers and naturalists living in the north-east. Their bank was based in Darlington but several of the family were resident in Sunderland, and a large collection of natural history and archaeological specimens are held by Sunderland. The saints of the title were the good Quaker philanthropists of the family, whilst the sinner was Edmund Backhouse, a notorious character who is remembered for swindling and for his obscene diaries. Visitors to the exhibition were asked questions about themselves to find out how saintly, or otherwise they were.

'Monster Creepy Crawlies' (16 Feb - 3 June) The museum was honoured to be chosen as the launch-pad for this brand new exhibition built by ex-Natural History museum designer Henry Lowe. The exhibition attracted nearly 18,000 visitors in the first couple of weeks.

'Wildife Photographer of the Year' (5 March - 9 April) This ever popular exhibition featured images from the 1993 competition. It provided added entertainment for visitors queuing to see the Monster Creepy Crawlies!

'Megabugs' (24 June - 31 October) This is the second part of the Hancock's Year of the Bug and features giant animated insects built in Japan, and circulated by the Natural History museum. It was officially launched on 27 June by Professor David Bellamy. The occasion was also marked by the presentation to Professor Bellamy of a copy of Baker and Tate's 'A New Flora of Northumberland and Durham' (1868) in recognition of the great assistance that he has provided to the Hancock over many years.

Education Work - Schools There is little doubt that the Hancock has established itself firmly at the centre of teaching in the history curriculum. It now has the highest number of school visits of any Tyne and Wear museum.

Claws! Despite efforts to make Claws! particularly relevant to the needs of the National Curriculum, the response to this exhibition from schools was poor.

Time Travellers The popular Time Traveller's 'drama in education' activities associated with the Land of the Pharaohs Gallery were repeated this year and were a great success with 4,005 children taking part.

Victorian Activities Two full weeks of Victorian hands-on activities were booked well in advance, and again many schools had to be turned away. This experience suggests that the museum should develop this particular side of its coverage in order to capture a greater and a more diverse schools audience.

Year of the Bug The eventual demand for 'Monster Creepy Crawlies' and 'Megabugs' was so great that early openings and a compressed booking system were introduced to answer the demand. On weekdays the museum now opens at 9.40 (only for school parties).

Family Fun 1994 summer holiday activities concentrated on the 'Claws!' exhibition with talks on cat care by the RSPCA, mask making and face painting, as well as a one day animation workshop. The exhibition was also supported with a children's quiz sheet, (a joint promotion with 'Cats' at the Laing Art Gallery) and two activity sessions in Newcastle libraries with storytelling and mask making.

The highlights of the year's programme included Bedbugs Nights sleep-overs with a moth-catching activity, and the ever popular Spider Days, with the greatest variety of spiders and insects ever shown at the Hancock. The Whit half-term activities concentrated on building a giant ladybird with sculptress Christine Hill. Many children were involved over the week and the resulting model is now on display in the Children's Gallery at the Laing Art Gallery, providing a useful advertisement!

The Family Fun programme for the summer was launched with a fascinating talk and demonstration on 'Insect Eating'. Dick Vane Wright from the Natural History museum offered dry-roasted mealworms and fried locusts to hungry visitors. A 'Behind Scenes

Tour' to look at the butterfly collections was well attended and children particularly enjoyed the storytelling event and two day cartoon workshop.

Student Placements The Hancock is one of the most sought-after venues for student placements, and it is unfortunate that we have neither the space nor the staff time to agree to all the requests. We were however delighted to welcome Sarah Kenyon from the University's Museums Studies course. Sarah had previously been a volunteer working on the museum's spirit collections. During a project placement and an eight-week work experience placement, Sarah contributed effectively in a number of areas, not least documentation. Most notably, however, she produced an invaluable report on the functions and effectiveness of our environmental recording activities. We shall certainly be using this to consider our activities in the future.

Equal Access A complete Access Audit of the building has been carried out and this has been incorporated into the Hancock's Access Strategy. It is inevitable that there are certain issues that it will be difficult to address due to the age of the building and its conservation status. Nevertheless, it should be our goal to make the Hancock as physically and intellectually accessible as possible.

Building Maintenance and Development August saw the opening of the refurbished Hancock toilets. Credit is due to the Society's Chairman who was also the clerk of works to the project. Most visitors agree that the new toilets are a great improvement on their predecessors. In addition, an adapted toilet for disabled visitors and a parent and baby room have been provided.

Work has just begun on formulating a bid to the National Heritage Lottery Fund. It is the intention to seek Lottery funding for a five year development plan. This will include provision for the new gallery in the Society's library, complete refurbishment of the museum's roof, renewal of a large proportion of the existing galleries and, most significantly, the development of an extension into the museum's rear car park area. These are obviously early days, but as they say 'If you don't ask, you don't get!'. Even if the Heritage Lottery Fund looks favourably on the application, there is still the need to raise matching funds and this is not likely to be easy.

Collections Management This has been another busy year in terms of collections re-storage and documentation.

Without doubt one of the greatest achievements was the completion of the re-storage of the bird-wing butterflies by Roger Stobbart. The collection proved more bulky than expected and a third cabinet has had to be purchased this year. Documentation of the collection is also under way. Significant progress has been made in the long-term re-storage of the geology collections. All the cabinets in the 'so-called' fossil corridor have been renewed with the effect that the collections are much more safely and efficiently stored. In addition, the storage within cabinets has been improved.

Work by all our dedicated volunteers has continued: Paddy Cottam continues to develop and curate the osteology collections, whilst Ron Cook has again been active with the Cyperaceae and the Graminae components of the herbarium. Liz Watson and a group of students from the University have done a splendid job in re-organising the ethnography stores.

The environmental monitoring system installed last year has proved invaluable in providing up to date and easily accessible information on the temperature and humidity of selected areas. Further sensors have been purchased this year to expand the scope of the system. It has already provided disturbing results for some collection areas, notably the bird gallery and the Abel's Ark display. Portable de-humidifiers have been purchased to alleviate problems identified by the new monitoring system.

Acquisitions The following specimens have been acquired during the year covered by this report:

Large block of limestone containing *Syringopora* corals from Pike Law Mine donated by Mrs S Bridges.

Pyrrhotite and Pyrite from Cambokeels Mine, Weardale donated by Mr B Young.

Millerite from Coldberry Gutter in Teesdale collected by S McLean.

Gastropod limestone from Ries meteorite crater sediments near Nordlingen, Germany, collected by S McLean.

Green Turtle donated by Mrs M Craker

Skin of a lynx donated by Ms Roberta Morgan

A cuckoo donated by Mr C Sherris

Collection of Lepidoptera from Peninsular Malaysia donated by Mr T H Carr

Carapace of a Green Turtle donated by HM Customs and Excise

A collection of marine algae from Dr G Hardy

Sundry collections associated with Dr Helena Heslop-Harrison from the University of Newcastle upon Tyne.

Marketing and Publicity Once again, the museum has had to market itself aggressively in the face of falling visitor numbers to attractions all around the country. Whilst the visitor figures for this year are understandably less than for the previous 'dinosaur' year, they are still showing an upward trend. The link up with Eldon Square shopping centre for 'Year of the Bug' has been extremely productive. Their financial contribution was also matched by a contribution from the North East's Sponsors Club which we gratefully acknowledge. In addition, Tyne Tees Television have been extremely generous in donating the services of a production team to make our TV commercials. There is no doubt that television advertising would have been out of the question had TTTV not saved us all the production costs. As always, credit is due to Tyne and Wear Museum's Marketing Section, and in particular Ms Margaret Watson who organised the Year of the Bug campaign.

The most notable press success has been the amazing publicity that surrounded the launch of the 'Year of the Bug'. A significant element in publicising this was the visit of Scorpio from the TV programme 'Gladiators'. 'Monster Creepy Crawlies' was featured on three national TV channels (including a spot on the BBC's Blue Peter programme) and in four national daily newspapers. The other major 'coup' was the coverage of the opening of the new toilet facilities by Tyne Tees TV. As ever, coverage in the media has been extremely good, and great credit is due to Ms Helen Gray, Press and Information Officer for Tyne and Wear Museums.

Commercial Performance Despite our all but achieving the projected visitor figures, the income from admissions for the financial year 1994-5 was substantially lower than we predicted. This reflects the large number of free and concessionary admissions. This was balanced, in part, by improved performance in the shop. Our thanks are due to Mrs Vera Faulkner who is responsible for all commercial buying.

The year began with the departure of the franchise holders in the cafe. We are extremely grateful to Mr Derek Robinson and his company Callerton Catering for stepping in and taking on the cafe at very short notice.

Grants and awards The year began with the Hancock receiving a special commendation for the 'Claws!' exhibition in the BT North East Museum of the Year Awards.

The Hancock was one of only four museums in the country shortlisted for a Gulbenkian Award (category of Best Provision for Visitors with Disabilities). No decision on the winner has yet been made.

The most impressive achievement during the year was winning the new Tyneside Innovation Award for Retail and Tourism. The museum won this in the face of stiff competition from over fifty other retail and tourism operators. This success was almost certainly instrumental in securing a provisional European Regional Development Fund (ERDF) grant of £104,000 for Earthworks, the main capital grant achieved this year.

The major cash sponsorship received was for 'Year of the Bug' from Eldon Square, and this received an award from the North East's Sponsors Club.

As ever, the North of England Museums Service has provided generously. This has included grants in aid of projects relating to the conservation of collections, the production of education materials, the Living Planet Gallery, and the marketing of particular events. In addition, they have contributed towards the Lottery bid feasibility study.

MUSEUM MANAGEMENT COMMITTEE

Staff The current staff is as follows:

Alec Coles (Principal Keeper)
Steve McLean (Keeper of Geology)
Les Jessop (Keeper of Biology)*
Helen Fothergill (Assistant Keeper, Geology)*
Eric Morton (Assistant Keeper, Biology)
Kirsty Ramshaw (Biology Assistant)
Gillian Mason (Assistant Education Officer)
Fiona Fenwick (Secretary)
Kevin Hughes (Environmental Recording Assistant)
John Pratt (Chief Attendant)
Anne Aspery (Senior Attendant)
Kath Catherall (Attendant)
John Connell (Attendant)
Susan Davison (Attendant)
Angus Thompson (Attendant)
Christine Hughes (Cleaner)
Lillian Livingston (Cleaner)

*Based at Sunderland Museum

Volunteers The Hancock continues to depend on its regular volunteers who, between them, contribute the equivalent of at least two extra members of staff. The following list is of those who have contributed regularly over the last year.

Ron Cook Botany/Oology Curation
Paddy Cottam Osteology Curation
Melissa Murphy Education Materials
Louise Hollingworth Hancock Library
Roger Stobbart Entomology Curation
Matthew Wasserman Biological Recording
Liz Watson Egyptology/Ethnography Curation
Darren Hudson Geology
Elaine French Geology

The Committee met on two occasions during the year and discussed the matters that are covered in the museum report. Finance was agreed for the coming year and a sub-commitee formed to liaise between the Society and Tyne and Wear Museums on the bid for lottery money. This project is progressing with money from the North of England Museums Service for the feasibility study. At the October meeting a constitution which had been circulated was discussed outlining the terms of reference of the new enlarged committee set up when the museum management was taken over by Tyne and Wear Museums.

FINANCE

The deficit for the year after appropriating £3,000 to the Gosforth Park Nature Reserve Restoration Fund is £4,783 (1994 surplus £6,768).

This reversal of the Society's fortunes was predicted in October 1994, when Council approved the budget for the year to 31 July 1995 and was subsequently explained to members at the annual meeting in November of that year.

Most of the income and expenditure shows only minor changes from the previous year and these require no further explanation. However, the principal changes giving rise to this deficit are set out as follows:

		£
Decrease in sales of the *Flora of Northumberland*		11,464
Increase in cost of production of 'Robson's Geology of North East England' included under *Transactions*		1,790
Increase in appropriations (£3,000-£1,750)		1,250
Increases less decreases in all other headings of income and expenditure		728
		15,232
Less:		
Increase in investment income	2,017	
Decrease in lease of office machinery	1,664	3,681
Movement from surplus to deficit (£6,768 + £4,783)		£11,551

It was obvious that the sales of the *Flora of Northumberland* would fall sharply after its launch in the spring of 1994 but the proceeds received in the year under review did not meet expectations. 'Robson's Geology of North East England' is a much improved version of the original production and should sell to students and geologists over the next few years; however, the expense of this improvement is reflected in the cost of production. The lease of the Society's excellent photocopier was completed in February 1994 when it was purchased for a nominal amount: it continues to perform well but of course the cost of leasing has ceased.

Further changes in our investment portfolio by switching cash deposits with the Charities Deposit Fund into narrow and wider range securities improved the income from investments by just over £2,000.

The appropriation to Gosforth Park Nature Reserve is required in order to complete restoration schemes which will return the lake and the reedbed to its former state. The cost is significant but with grants from English Nature and the earmarking of a legacy from the late Sir James Steel this work can be completed in the next two years. We are now working much more closely with the new management of High Gosforth Park and the management of the nature reserve will run much more smoothly than in past years.

From reading the above members will readily appreciate why subscriptions needed to be raised on 1 August 1995 after remaining unchanged for two years.

Apart from the changes in investments referred to above there have been no material changes to the Balance Sheet. The affairs of the Society continue to show a sound financial position represented by its reserves and long term investments which continue to improve over their original cost at very acceptable levels. It is essential to maintain this financial stability and members' attention is drawn to the fact that over 50% of the Society's total income is derived from investments.

The financial statements to 31 July 1995, independently reviewed by Price Waterhouse, were approved by Council on 6 October.

After fifteen years as Honorary Treasurer, having been elected at the 1980 annual meeting, Edwin Slack retires from this position at the annual meeting but will continue as a trustee and investment adviser and will as serve on the Gosforth Park Management and the Museum Management committees. Mr Slack has said: 'Having enjoyed my years as your honorary treasurer and already being retired from professional practice for more than six years it is time to hand over the reins to my son Richard who is also a chartered accountant and a graduate of St Andrews University. I thank you all for your support over the years and feel certain you will continue this to my successor who has a safe pair of hands and will give you sound advice and many years of service.'

It is imperative to arrange a smooth handover of the accounts when a change of treasurer occurs and when Edwin Slack announced his wish to retire, Council's dismay at losing his expertise was considerably relieved when he advised that his son Richard was prepared to accept the position. In July, Council agreed to Richard working in tandem with his father from 1 August and he will be nominated by Council for the position of honorary treasurer at the annual meeting for members' approval.

Council records its profound gratitude to Edwin Slack for his professionalism in guiding the Society through financial minefields for fifteen years. In his first year the Society had net assets (excluding the Hancock Museum, the collections and the library) of £38,356. These net assets are now valued at £278,797 and, even allowing for inflation, reflect not only a great improvement in the Society's prosperity but a considerably greater workload and responsibility for the honorary treasurer.

AUDIT

The Charities Act 1993 Part IV exempts the Society from requiring a full audit of its financial statements for the year to 31 July 1995. We are, however, required to have our annual accounts independently reviewed by a suitably qualified accountant. This will reduce our costs for accountancy charges by more than 50%.

Council agreed to an independent review at its meeting of 14 July 1995 which will necessitate changes to the rules of the Society.

These changes have been approved by the Charity Commissioners and will be included in resolutions to amend our rules at the annual meeting which members are recommended by Council to accept.

This is a cost saving exercise available to all charities with an annual income of less than £100,000. The Society will continue to prepare its accounts on the same basis and format as in previous years and Price Waterhouse will undertake and report upon the review.

Provision has been made for a full audit to be carried out if at any time in the future this is deemed to be necessary.

LIBRARY

For years the Society's elaborate arrangements for exchanging copies of the *Transactions* for the equivalent publications of about fifty other learned societies and museums from all over the world have been in the careful hands of Mrs Joan Shannon. Every issue received, or more trickily **not** received, was recorded, together with those of the twenty or so periodicals we buy for the library. Each was acknowledged, boxed and shelved and eventually sent for binding. We are very grateful for the meticulous and devoted work she gave to this task; she will be missed. Only the combination of two people (Mrs Tricia Hammock, who will deal with exchanges and journals and Mrs Helen Dalrymple, who is working in a voluntary capacity on preparing journals for binding) and one computer was deemed capable of replacing her. Mrs Helen Roscoe helps each Wednesday to catalogue the separates. Council would like to thank them all and also Mr and Mrs Trevor Hardy for their yearly effort in helping with the library cleaning, an unglamorous but essential job. However the development of the library as an effective asset for our members is largely due to the many hours of devoted work by Hugh and Stella Chambers. They open the library every Wednesday morning throughout the year and deal with the loan requests and queries that come in every week, and they have introduced and maintained the computer catologue and entered details of about 5,500 books and offprints over the last few years. It would have been very difficult to run the library without them.

Mrs Paddy Cottam has replaced Mr Allan Watson as mammal section representative on the library committee. Allan had contributed the expertise of a university safety officer as well as a mammalogist to the committee and we are grateful for his advice.

The library evening on 16 December celebrated the 150th anniversary of The Ray Society with a display of our complete collection of its historic publications, including some rare hand coloured copies. Mr Peter Davis and Dr David Gardner-Medwin provided commentaries on the Ray Society and on John Ray. Another occasion with special interest for lovers of books was Mr Iain Bain's informal and erudite display and discussion of some books and letters from his own incomparable Bewick collection. He commented extempore on some of our Bewick watercolours and engravings set up for the occasion.

This year eighty-two books and sixty-eight offprints were added to the library. Most of the offprints were from a collection started by Professor G A Lebour and continued by his successor in the University Chair of Geology, Professor George Hickling, which was transferred from the museum; they date from 1845-1950. The remaining twenty-five were donated by their authors, and form a valuable addition to our collection of works by local naturalists. Of the books, forty-three were purchased new, eleven second hand and twenty-one were donated, the rest being exchanges or *objets trouvés*. Dr G Anderson of Colchester gave us a fine association copy of John Hancock's *Catalogue of the birds of Northumberland* inscribed by the author to the eminent entomologist Edward Newman and containing a signed handwritten letter from Hancock to a Mr Bridwell, dated 27 Aug 1884, expressing relief that the opening ceremony for the Museum was over. Mr J Milligan gave a copy of Professor Kingsley Dunham's *Geology of the Northern Pennine Orefield (Tyne to Stainmore)* 1949 (unaccountably not till then in our collection). Dr D B Smith presented a copy of his *Geology of the country round Sunderland.* Miss Dorothy Hutchinson gave copies of seven letters and cards sent to her in 1931-43 by George Temperley. Other gifts were from Ms M Bartlett, Mrs Paddy Cottam, Mr Peter Davis, Dr Denis Gibbs, Mr M Myers, Mrs Helen Roscoe, Mr Derek R Shannon, Dr Denys B Smith, Professor George A Swan, Mr Tony Tynan, Mr S C Votier, Mr E J Watson, The Library of Congress, the RSPB and anonymous donors. We are grateful to them all. Other important acquisitions this year include a number of geological maps completing our set for local and neighbouring areas, and *General view of the Agriculture of the County of Northumberland* (1797) (with *Cumberland and Westmorland*), by J Bailey and G Culley.

ACTIVITIES

Ornithology section The winter programme of the ornithological section began with Mr Iain Bain giving members a delightful insight into many of the Society's Bewick drawings and also some of his own collection which he brought with him. The display was prepared on the Friday afternoon and erected in time for the meeting at 7.00pm. This created a great deal of work for Mrs June Holmes, Mrs Anna Newson, and Hugh and Stella Chambers who also supplied refreshments after the lecture. Everyone agreed it was an enjoyably informal evening and quite different from our normal lectures.

The ornithologists continued their programme with the Pybus Memorial Lecture given by Dr Algirdus Knystautas who spoke on 'A Naturalist's journey across Russia'. This was so popular that once again the Society had to hire the Curtis Auditorium. It was estimated that at least 250 attended the lecture, an increase on his last visit in 1991.

The autumn was rounded off with an audio visual presentation by Allan Potts on 'Wildlife of the Falkland Islands'. As usual it was a flawless performance of beautiful slides, music, wildlife recording and commentary based on two recent visits to the islands by Allan and his wife.

January brought the welcome return of John Walton, the head warden of the Farne Islands, to talk on 'Birds of the Farne Islands'. He outlined many of the monitoring tasks that are part of modern management and talked about the interesting developments with the breeding of Elsie, the lesser-crested tern with Sandwich terns and the probability that the offspring have returned and are now attempting to breed.

On 27 January Dr Colin Bradshaw gave an entertaining talk on 'Sweet and Sour migration' recounting two recent visits to China that included in the parties members of the Society. His adventures included the good and bad points of trying to birdwatch in a country that is only beginning to cater for tourism. The audience was disappointingly small as Newcastle had most of its entire winter's snowfall between 3.00pm and 8.00pm that day. The winter programme ended with the Secretary, David Noble-Rollin, giving a talk on 'Bird photography the easy way' in which he concentrated on his many adventures in search of a good bird picture. He showed examples of pictures taken by methods which varied from stalking birds and big game on foot to using canoes down the Suwannee river.

The outdoor programme began with the pelagic cruise on 10 September, a joint venture between the North Northumberland Bird Club and the Society. The weather was beautiful and the sea was calm but unfortunately the birds were absent. Members cruised up and down throwing delicious rotting fish overboard to attract sooty shearwaters and other birds, with little success. The verdict on the day was that the weather was too good for pelagic species. Holy Island on 15 October proved more successful with excellent views of red-necked grebes in partial breeding plumage, black-throated and red-throated divers and a peregrine. The group finished an exciting day with a glaucous gull at Seahouses on the way back to Newcastle.

The next meeting on 21 January was to Aberlady Bay and Musselburgh which was slightly marred by the weather deteriorating during the day. However, many of the species that are traditionally part of this annual event were seen, with the added bonus of excellent views of little auks. The final winter meeting on 18 February was to Loch Ken and Murray's Monument where once again members saw many of the birds that they hoped for including white-fronted geese and peregrine. The weather, once again, became progressively wetter as the day proceeded, making useful observation at the monument very difficult.

The summer field meetings got off to an encouraging start with the Northumberland coast trip on 29 April. There were superb views of a wryneck and brambling on the Crooked Lonnen on Holy Island, and some members also saw a great grey shrike before the bus set off down the coast. The outing ended on another high with two whimbrel in front of a hide at Druridge Bay. The Northumberland Wildlife Trust held a dawn chorus walk in Gosforth Park Nature Reserve on 7 May which proved successful and was well attended. On 13 May the summer programme ended with a visit to the Harthope Valley to look for Cheviot birds. After a very good start in the car park where a garden warbler put on a show of singing at the top of a bush until everyone who had arrived early had seen him, members saw ring ouzel, pied flycatcher and green woodpecker.

Botany section The winter lecture programme got under way in October, with Stewart Hedley of English Nature describing 'The National Vegetation Classification', and in particular how the plant communities of northern England fitted into it. Then in November Drs Carol and Ian Bainbridge described the alpine flora of 'The Pyrenees' (if that is not a contradiction in terms). After Christmas, in February, Dr Oliver Gilbert spoke on 'The natural history of urban wasteland', a subject about which he has written a standard text-book, and explained why we should love, and not hate, Japanese knotweed. Finally, in March, Dr Gordon Beakes in 'An Australian spring' described his visit to Canberra and illustrated his talk with magnificent slides.

The summer field trips are increasingly well-supported, not least the one in June led by Professor Swan to Simonside, where one of the objectives - duly achieved - was to find the rare dwarf cornel. In early July Mr John Taylor showed members around Shibdon Pond, a famous plant locality adjacent to the new Newcastle western Bypass in Blaydon. Later in the day they visited Lockhaugh Meadows and the adjacent woodland, part of the Derwent Walk Country Park; the 'meadows' are ancient lowland grassland with a good flora, and are astonishingly bucolic for a site so close to the Tyneside conurbation. Finally, at the end of July, members had their regular longer-distance excursion, meeting at the top of Honister Pass in the Lake District in order to examine Honister Crags. Dr Lunn led them relatively safely among the calcareous crags and gullies to examine such mountain plants as green spleenwort, mountain everlasting, mountain sorrel and roseroot.

Mammal section The winter programme began with Dr Peter Evans talking on 'Whales and dolphins around the British coast'. He explained the work of the Cetacean Group of the Mammal Society and gave members a great deal of helpful advice on identifying the whales and dolphins that are seen along our coasts.

On 3 February the Society was once again treated to an excellent talk by Dr Pat Morris who spoke on 'What's special about British mammals'. He outlined the effect of our isolation and the ice ages on the fauna in his usual easy manner, giving a brief account of a very complex subject. The result was both informative and entertaining.

The indoor programme ended with an excellent talk by Bob Wilkin entitled 'There are aliens in our midst'. This took a closer look at the increasing number of records of exotic animals at large in Britain both today and in the past. He took some care to explore the many sightings of 'large' cats and to show the incredible range of introduced mammals that now live in a feral state in Britain.

The mammal section field meetings began on 20 May when Bob Wilkin took a group to look for otter signs. Members enjoyed better weather than on the previous otter outing. Visits were made to two sites on the River Wansbeck and one on the Hartburn, a lake and drainage system, the confluence of a small burn running into the River Coquet.

Otter spraint was found at all these sites, and mink skats or droppings were found on the River Wansbeck. Mink padding or footprints were found on both the Wansbeck and the Coquet. The group also looked at an otter holt on the Wansbeck which showed signs of active use. Two sections of road were viewed where in recent years otters have become casualties. The group saw a specially constructed 'otter proof' fence built by the Northumberland Wildlife Trust, which it is hoped will prevent further deaths. As in previous years lunch was taken at Richard Cansdale's home, during which a lively discussion took place on otters, badgers and water pumps, ending what had proved to be an interesting day.

On Monday evening 12 June members gathered at Wallington for a bat watch lead by the National trust warden Richard Dickinson. The weather prior to the meeting had been very cold for the time of year and this rather affected the roosting behaviour of the bats. However they saw Whiskered/Brandt's bats (best distinguished in the hand) and also Daubenton's flying over the river. Richard, who often has to look after injured bats introduced the party to three tame individuals that he was caring for, two noctule and one Natterer's.

Geology section There were six lectures during the winter beginning in October with Dr Brian Young of the British Geological Survey who gave an excellent lecture on 'Metalliferous mineralisation in the English Lake District'. His lecture was a well-structured discourse on the history of mining and the distribution of the mineral veins, concluding with an attempt to explain how the deposits were generated and emplaced within the rocks. His lecture was liberally illustrated with colour slides with some excellent ones showing quite small and perfectly formed crystals and his lively manner encouraged quite a number of questions at the end. An audience of forty-four was reluctant to let him finish.

During November, Dr Matthew Collins from Fossil Fuels and Environmental Geochemistry at Newcastle University spoke on 'Molecular Palaeontology; applying medical techniques to the study of ancient molecules'. He gave an excellent lecture on the art of studying small samples of fossil organic matter. Though the audience of fifty-five did not see any live dinosaurs, their curiosity was partly satisfied with a demonstration of how plastic building bricks could be used to illustrate the complexity of DNA. It was a difficult topic for the layman to understand but Dr Matthews managed to bring this nearer in focus with his audience. The pertinent questions at the end proved that he had been successful.

Dr Mark Noel from Durham University delivered the December lecture on 'Archaeological Geophysical Surveying' and was able to show the result of some of the recent researches in Northern England. He showed data and reconstructed field maps from the Roman fort at High Rochester, Greta Bridge and Lanchester. He also had data from Whitby Abbey and Ancroft, near Berwick, to give an insight into the medieval landscape. Some quite dramatic findings were shown of the barrack buildings at High Rochester and indications of the proximity of Dare Street. Members who had been viewing Tony Robinson's recent programme 'Timewatch' on Channel Four found his demonstration of some of the equipment and the results most interesting and many of the techniques were similar. Over fifty members were present.

During January Dr Colin Scrutton of Durham University came to talk about Palaeozoic Corals and sixty-two members attended to hear that, contrary to popular belief, corals were much more adapted to muddy conditions and were well able to cope with soft substrates. He concentrated mainly on the Colonial Tabulate corals, and showed by simple modelling how their varied growth forms reflected the changing conditions of the Palaeozoic sea floor.

The February lecture had a capacity audience to hear David Archer talk on 'The River Tyne and its great floods'. David is Principal Hydrologist at the National Rivers Authority in Gosforth and is responsible for forecasting floods and involved with regulation of the Kielder Dam outflow. The February floods in the middle Tyne valley had encouraged so many members to attend. His lecture was historical in part, referring to past floods, and also technical, because of the present methods used to predict future flooding. He was well questioned at the end of his lecture regarding the recent problems.

The final lecture of the winter was by Dr Alick Walker who discussed 'The Enigma of Archaeopteryx'. He had an audience of over sixty and introduced the reptiles as a fossil group spending some time explaining how the classification of Archaeopteryx had evolved over the years. He showed slides of the quarries in the Solenhofen district and of the specimens that had been found there. He also delighted the audience by bringing out model specimens of this primitive bird which were some of the accurate plaster casts he had in his possession. Careful drawing on a large scale of the head of this creature had helped him to relate the bird to what he hoped was its proper ancestry. Members followed his argument carefully and some useful questions were put to him at the end of the lecture.

The September field meeting was attended by ten members who travelled by car with Dr J M Jones, the section Chairman, to the Liddesdale area on the Borders, to see some classic areas of the Carboniferous in the Archer Beck and Penton Linns sections. Mick Jones was in good form and the weather stayed mostly kind so the small group was able to learn much about the Border groups in the Carboniferous. However, the first locality had been somewhat obscured by extensive forestation but in the afternoon the Archer Beck was most interesting with the core of an anticline exposed and beds standing nearly vertically. This allowed four or five cyclothems to be followed, using some rich fossil horizons which assisted in the identification of the sequence in this classic site.

For the visit planned for October with Mrs Joan Kirk, six members made the long journey down to Malham. The weather was quite unpleasant in the morning and as the group walked down the dry valley to the cove examining the geomorphology of the limestone area they found the walk not as dry. However after some ferrying by car, the afternoon in Gordale was much better with the rain easing to allow the collapsed cave, now a deep gorge, to be appreciated fully. The reef facies in the limestone was clearly seen which made the day one to remember.

The first field day of 1995 on 27 May was led by Dr Denys Smith, one of the contributors to the field geology publication by the Yorkshire Geological Society. Indeed, most of the field visits in 1995 were planned with this publication and the Society's own new edition to replace Dr Robson's *Geology of North East England* in mind. As we have come to expect from this leader the visit was well prepared as Denys had produced an excellent hand-out for the day of the 'Geology of the Magnesian Limestone from South Shields to Seaham'. He had also been successful in organising the weather which was excellent for walking. Some fine cliff scenery was seen and a lunch stop at the foot of Marsden Rock allowed members to soak up the sun. After a stiff climb up the steps the party moved on to Roker, the Hendon cliffs (where a fine sequence of the concretionary limestone allowed members to collect some good specimens at the base of the cliffs), the Tunstall Hills and finally Seaham. Some excellent geology was seen and explained lucidly by Dr Smith who was enthusiastic and patient with the fourteen members attending.

At the end of June Dr J M Jones again acted as leader for a group of nineteen members who followed his itinerary along the Roman Wall country. He allowed some digression into archaeology along the way. The party walked west of Cawfields to Aesica, after having a long look at the transgression of the Whin Sill in Cawfields quarry. The afternoon was spent following the Haltwhistle Burn southwards and examining the Yoredale sequence from the Three Yard Limestone almost to the horizon of the Oakwood Limestone. Again there were other digressions into the industrial archaeology of the exploitation and processing of the coals, shales and limestones.

The last geological event of the Society's year was on 8 July and was a visit to the Northern Pennine Orefield with Dr Brian Young, an acknowledged authority on the area. Members again followed his itinerary fairly closely, starting in Rookhope where the group of eighteen was shown the Rookhope Core and told of the importance of the discovery of granite beneath the Pennines. They then moved to West Rigg quarry to see one of the world classic sites of ore flats developed from the Slitt Vein. The Groverake mine and associated mines of Frazer's hush were looked at from the road on the way to Killhope Mining Centre and afterwards Dr Young took the party upstream to Old Moss Vein which crosses the bed of the Killhope Burn. Many minerals occur here and the Frosterley marble and a *Gigantoproductus* band occur just downstream from the vein. The party finished in Nenthead where Dr Young explained something of the history of this old 'Klondike' town. He then took the party up the Nent Beck to see the Great Limestone faulted at Carr's vein and afterwards the old smelt mill with the restored assay office. The weather was especially kind and excellent for walking, which made the whole visit a memorable one.

Entomology section The entomology section's lectures have generally been attracting disappointingly low attendances over recent years and this year, in order to attract a range of members not necessarily interested in entomology, the content of the talks contained a mixture of very general topics and a more specialised talk that covered plants as well as insects which, it was hoped, would attract botanists and biologists as well as entomologists. In the end, the attendances did not seem to be appreciably larger than last year.

The first meeting, on 30 September, was addressed by Alex Weir, a mature student who is researching for a PhD at Newcastle University. Given the somewhat dramatic title 'The Battle of the Chitins', the talk described the very wide range of interactions between insects and fungi, from fungivorous insects to entomogenous fungi, before focusing on the biology of the Laboulbeniales, a group of minute fungi that is parasitic on insects. The lecture included the results of Alex's own researches into the fascinating, and little known, ecology of this group. What may have struck the audience initially as a somewhat esoteric subject was presented in a clear and straightforward manner, and a great deal of discussion followed the talk.

Michael Mann is the leading expert in the north-east on the maintenance of living arthropods, and devotes much of his time towards the care and welfare of his spiders, insects and other arthropods. On 20 January he gave a talk, 'Exotic Spiders and Insects', about the range of species he holds, describing their biology and aspects of their conservation as well as the problems of keeping them alive. The talk was illustrated not only by the usual slides but also by a small collection of his 'pets', which proved to be an interesting focus for the discussion afterwards.

The last session of the season, on 24 March, coincided with the showing of 'Monster Creepy Crawlies', the largest-ever exhibition at the Hancock Museum to be devoted entirely to arthropods, featuring giant moving insect models as well as a range of 'hands-on' educational interactive exhibits. The section leader, Les Jessop, who is also Keeper of Biology at the museum, gave a brief introduction to the exhibition, explaining the administrative mechanics behind bringing a blockbuster exhibition to Newcastle and marketing it to the public. Members then proceeded to the gallery for a guided tour of the exhibits and a discussion about what the designers were trying to achieve and how they went about it.

There has been very little interest in the outdoor meetings in recent years. An average of four people attend each meeting and some meetings have attracted no members at all, which is very embarrassing when a guest speaker is involved. It was therefore decided to suspend the programme of entomological field meetings for 1995: if there is a clear sign of demand in future years they will be resurrected.

GOSFORTH PARK NATURE RESERVE

As mentioned in the last annual report the ownership of the Gosforth Park estate changed hands during August 1994. Mr Allen Creedy and the Secretary had a very productive meeting in late September with Mr Glossop, the Chief executive of the new owners, St Modwen's Properties plc. Mr Glossop outlined the company's policy and assured us that in future there would be cooperation and the Society would be able to manage the reserve effectively. In outline, he approved the work of desilting the remainder of the old lake bed and the installation of sluice gates to control water levels. There was also discussion on the overall management of the estate for wildlife and the advisory role that the Society could undertake. Throughout the year this atmosphere of cooperation has continued and the Society is able to look forward to a more secure future and prepare long term plans for the management of the reserve.

In March the High Gosforth Company was approached for written permission to begin the desilting of the lake in August/September 1995. At this point it became clear that the racecourse was undergoing a major revitalization programme which included drainage and watering of the course during the summer. Because of this it was felt prudent to postpone the desilting until there was a better understanding of the drainage and water potential of the area. During the summer there have been meetings between the Society and the racecourse's surveyors and engineers to prepare a programme of work that will make it possible to maximize the water potential for both the racecourse and the wildlife in the reserve. The Society welcomes the straightforward attitude and professional approach of the new company.

During the year there have not been many reports of unusual birds in the reserve but it is worth noting that a marsh harrier was seen again in the spring which means that this species has visited the area at the beginning of the breeding season for the last four years. Confirmation by the ringing group of the breeding of lesser whitethroat increases the number of important species now using the SSSI. They were recorded in 1992, 1994 and the present year but before this the last logbook entry was in 1980. Also water rail were heard in April and May and the numbers of reed warblers ringed were about the same as last year (see ringing report). A visit from a long-eared owl was reported by the warden, Paul Drummond; according to the logbook the last sighting was in 1988.

No major work projects were undertaken during the present year and the only work carried out was maintenance. This involved Society work parties run by the warden and also a substantial contribution by the Urban Fringe Area Management Scheme (UFAMS) under the direction of Mr Allen Creedy, Countryside Officer for the planning division of the development department at the Civic Centre. The Council would like to thank everyone involved for all their hard work throughout the year.

Trespass and poaching have been under control this year mainly due to the constant pressure of the wardening organised by Mr Paul Drummond and supported by his wife, Mary. This work has been assisted by a few dedicated members who turn out night and day to help him chase any would-be poachers. Council would like to thank them for their valuable contribution, and also Mr Dave Fuller of the Scout Camp for his active cooperation in wardening the racecourse end of the area.

The Gosforth Park Management Committee has held six meetings during the year and has had one resignation and one appointment. Council would like to thank Mr David Holgate for his work in the reserve both as its warden for many years and latterly as a member of the committee. He regretfully gave in his resignation as his new job with the RSPCA means that he is based in Wakefield. The appointment of Mr Allen Creedy to the committee has greatly helped in the interchange of ideas between UFAMS and the Society and will certainly help with future negotiations with the new management on the future of the whole estate.

RINGING GROUP

In 1995, the 'constant effort' ringing at Gosforth Park entered its eighth year. This ringing study contributes important data to the British Trust for Ornithology's Integrated Population Monitoring programme, designed to allow variation from year to year in breeding performance and the numbers of breeding birds to be assessed. Although this represents the mainstay of the group's ringing activities, ringing at a small number of coastal sites in the late summer and autumn has been continued this year. In addition, the group has initiated a study of seabirds breeding on Coquet Island which we hope will be maintained in the long term and will provide data allowing the foraging success of adult birds to be monitored through measurements on the growth characteristics of their chicks.

The constant effort netting programme is carried out using six standard nets erected in the same sites at regular intervals throughout the spring and summer. Additional nets are often used at nearby sites, so that the number of nets in use at any one session may vary. More nets were operated during each visit this year and this is reflected in the overall total for birds ringed in Gosforth Park which, at 737 (Table 1), is the highest yet. The number of willow warblers caught has increased substantially since last year, from 66 to 111 (Table 1). However, the total of eighty-two sedge warblers is down slightly from the ninety-nine in the previous period. The number of reed warblers ringed has remained about the same at fifteen. Although the number of tits ringed has also increased substantially compared to the previous period (Table 1), this is due to ringing at the feeding station during December 1994 to January 1995 as part of a short term study of post-juvenile moult in relation to body condition and social dominance in blue and great tits. Notable species caught during the year included a kingfisher, four great spotted woodpeckers, a grasshopper warbler, nuthatch and three lesser whitethroats. In addition, two new species appearing on the ringing list for Gosforth Park are common and jack snipe (Table 1). These were caught in early spring by setting nets over a patch of bare mud resulting from clearance of some dead reed stems during the previous autumn. Since fifty or so snipe seem to roost in the reserve during the day, it will be worthwhile increasing the group's efforts on these species in the future to get more accurate estimates of numbers and the origins of these birds.

Ringing at the group's main coastal site, Newton Pool, continued from mid-September in 1994. The number of birds ringed increased from eighty-one in 1993 to 231 in the 1994 autumn. The most abundant species at this site were wrens, dunnocks and robins. There was a small influx of goldcrests (twenty-one ringed) which brought with them a firecrest. Other notable species were singles of reed warbler and yellow-browed warbler. In addition to the ringing at Newton Pool, ninety-nine birds were ringed at the Arnold Reserve, Craster and seventy-seven at Holywell Pond.

With respect to recoveries and controls, details on two sedge warblers have been reported since the last report. A first-year sedge warbler ringed in the reserve on 18 July 1993 was controlled by ringers at Finistere, France, on 4 August the same year: a movement of 813km in less than seventeen days. The fact that this bird had moved a considerable distance south by early August is an indication of how rapidly young birds move away from their natal areas. The second reported movement concerns a sedge warbler controlled by the group in Gosforth Park Nature Reserve on 8 May 1995. This was originally ringed on 12 September 1994 at Icklesham, Sussex, by the Rye Bay Ringing Group, and brings the number of controls involving Gosforth and Icklesham to three. We are still awaiting details on another sedge warbler controlled in the reserve in the 1995 breeding season.

Table 1

Birds ringed during the period 1.8.94 to 31.7.95 at Gosforth Park Nature Reserve (GOS), and Newton Pool, the Arnold Nature Reserve (Craster) and Holywell Pond (NAH). Figures in brackets for the GOS totals are ringing totals for the same period the previous year.

	GOS	NAH		GOS	NAH
Kestrel	0	1	Firecrest	0	1
Meadow Pipit	0	1	Long-tailed Tit	42 (17)	5
Jack Snipe	2	0	Willow Tit	5 (8)	1
Snipe	4	0	Marsh Tit	0	1
Kingfisher	1	0	Coal Tit	18 (5)	9
Great Spotted Woodpecker	4 (3)	0	Blue Tit	134 (88)	98
House Martin	1	4	Great Tit	78 (26)	10
Wren	26 (27)	40	Nuthatch	1	0
Dunnock	27 (14)	40	Treecreeper	6 (4)	0
Robin	34 (35)	31	Magpie	0	1
Blackbird	28 (33)	24	Jay	4 (4)	0
Song Thrush	8 (5)	3	Starling	0	2
Grasshopper Warbler	1	0	Chaffinch	8 (2)	5
Sedge Warbler	82 (99)	21	Goldfinch	2	0
Reed Warbler	15 (14)	1	Redpoll	0	1
Lesser Whitethroat	3 (1)	1	Linnet	0	4
Whitethroat	1	1	Greenfinch	0	3
Garden Warbler	7 (3)	0	Bullfinch	8 (11)	10
Blackcap	27 (28)	4	Yellowhammer	0	2
Yellow-browed Warbler	0	1	Reed Bunting	40 (27)	46
Chiffchaff	7 (15)	3			
Willow Warbler	111 (66)	11			
Goldcrest	2 (4)	21			
			TOTAL	737	407

This year, the ringing group started work on a new project based on Coquet Island. The aims of this study are two-fold: (1) to mark a sample of black-headed gulls, fulmars, Sandwich, common and arctic terns each year so as to collect data on the movements and mortality patterns of Coquet seabirds; (2) to carry out a detailed study of tern growth to develop simple indices, based on aspects of relative chick growth, that can be used to monitor the foraging success of adult birds. Poor weather and inadequate manpower at a critical period prevented the group from ringing Sandwich terns and meant that fewer numbers of other species were ringed than anticipated. The final ringing totals for Coquet Island were 150 black-headed gulls, 198 arctic terns and twelve common terns. The arctic and common terns were ringed during four visits to the island at intervals during the breeding season. Measurements of growth in weight and dimensions were obtained from arctic terns of known age, and this has been extremely valuable in providing baseline data for further studies (Figure 1a & b). The Society is extremely grateful to Rob Lidstone-Scott, the warden of Coquet Island, and to Vicky Heaney and her assistant, researchers from Glasgow University, for recording chick hatching dates for us, and to the boatman, Mr Dave Gray, who took the ringing group out to Coquet Island throughout the season.

From its activities during the past year, the ringing group is going from strength to strength and we hope that this trend will continue in the future. The Society's Council would like to thank the RSPB and the Coquet Island management committee for their permission to carry out ringing studies on Coquet Island, Mike Freeman, warden of Newton Pool, and the Northumberland Wildlife Trust for permission and encouragement to ring on the land in their care, and Major John Carr-Ellison for the use of his beach chalet at Newton as a base.

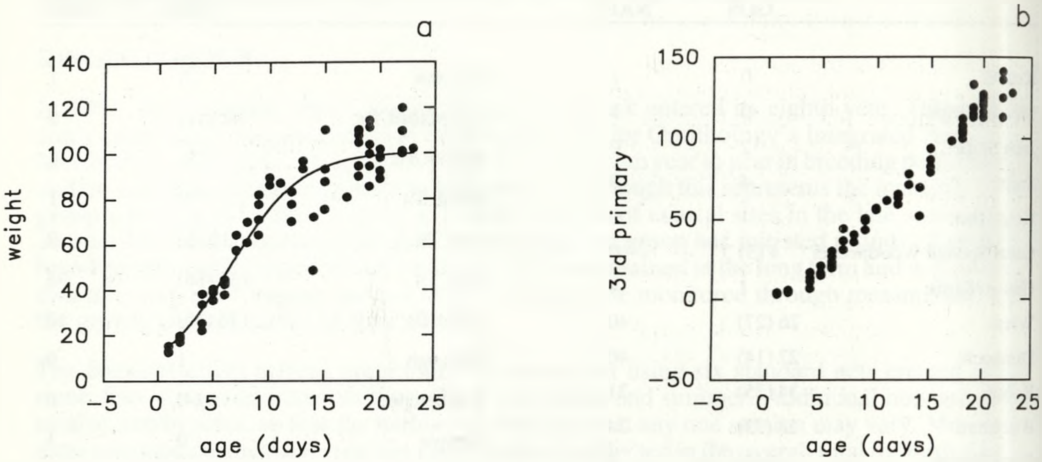


Fig. 1 Measurements of weight in grams (a) and 3rd primary feather length in mm (b) for arctic tern chicks of known age on Coquet Island in 1995. The curve in (a) is a logistic growth curve fitted by least squares.

THE FONTBURN RESERVOIR WILDLIFE ADVISORY GROUP

There were no meetings of this group during the year.

COQUET ISLAND MANAGEMENT ADVISORY COMMITTEE

The committee met only once during the current Society year, on 9 November 1994, having decided not to hold a spring meeting in 1995 and to postpone the site visit until August. The main discussions at the meeting concerned whether the committee was advisory or management. Copies of the original documents forming the reserve from the Society's archives were used to reiterate the purpose and management function of the committee.

The 1994 report was tabled and showed that again numbers of most species had increased and production was average. The roseate terns showed a further increase to thirty-five pairs.

At the meeting the Secretary asked if the Society could have permission to start a long-term monitoring programme to study the effects of the changes of food availability by measuring the growth rates of tern chicks. It was agreed that as there was no spring meeting Dr Chris Redfern and the Secretary would prepare an explanatory paper and a programme of research that would be circulated around the committee. The outcome was that the RSPB agreed to a three year trial study. The results of the first year appear elsewhere in this report.

LINDISFARNE NATIONAL NATURE RESERVE

Lindisfarne Wildfowl Panel The panel met on four occasions during the year which included a special meeting in July 1995 to discuss the formation of a refuge area within the National Nature Reserve. The main issue addressed by the panel was the continuing decline in wigeon numbers wintering on the reserve. They discussed the findings of the study undertaken by Sunderland University into the effect of punt gunning on the slake which showed that the link between punt gunning activity and reduced number of wigeon was not proven. This coincided with a request from the punt gunners to return to the previous higher level of activity as the study was now complete. As with other members of the committee, the Society was asked to comment on the letter and give its opinion as to whether punt gunning should increase. With the help of Dr Jeremy Holding and figures supplied by English Nature the Secretary prepared a paper on the changing numbers of wigeon and brent geese and drew the conclusion that the wigeon were becoming passage migrants on the reserve instead of autumn residents. In other areas this type of trend has been reversed by the creation of non-shooting refuges within the reserve and this was recommended in the paper.

Other members of the panel had obviously come to similar conclusions. The outcome of the debate was that punt gunning could be increased from three days a week to five and the panel should produce a plan for half the area of the reserve to become a non-shooting refuge. The programme on how this will work is now being formulated. The most likely result is a detailed assessment of the use of the slake this winter without any change and then with this base information a five year ban on shooting over half the National Nature Reserve.

Lindisfarne Advisory Committee The Advisory Panel met twice during the year and apart from discussion of the matters covered under the Wildfowl Panel they were informed that English Nature had been successful in the public inquiry into bait digging and that in future none would take place in Budle Bay. Also a voluntary ban on the use of lead shot would come into force in September 1995 and be monitored by the Wildfowl wardens. One of the continuing areas of concern is the spread of *Spartina* which has been pushed back by hand-digging carried out by wildfowlers but it is hoped that a grant from the Wildfowl Habitats Trust towards machinery will help with the control, and also the British Trust for Conservation Volunteers were employed to undertake more digging. Other areas of work included a dam installed at the Lough because of the dry summer and more screening of the hide with trees.

THE SECRETARY

This report has made a few quiet references to the Society secretary, Mr David Noble-Rollin, but he has been responsible for so much of the Society's recent success. Nearly every activity covered by this report has involved his initiation, supervision and completion and not least the organising of the winter and summer programmes with guest speakers and field meetings.

The publication of the *Flora of Northumberland* and 'Robson's Geology of North East England' was prepared in the Society office and went out to commercial firms only for the bulk printing and the binding. The setting up of the printed text, maps, drawings and photographs was carried out by David with his staff and voluntary workers.

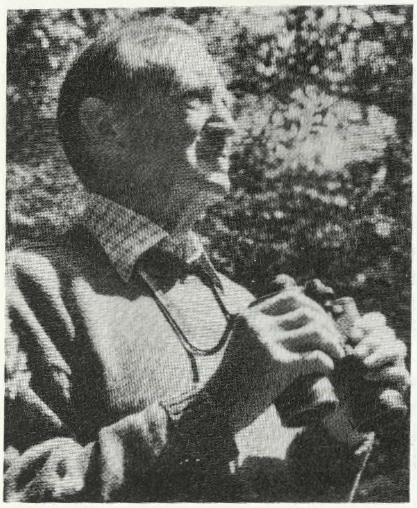
He represents the Society on several local committees, lectures and leads ornithological field meetings including overseas tours, and as an accomplished natural history photographer has added another special quality to our publications. The continuing and expanding excellent cooperation with the Tyne and Wear Museums Service relies upon David's successful day-to-day relationship with the museum staff.

Council records its appreciation of all his work and the considerable contribution he has made to the successful year recorded in this report.

DEREK R SHANNON

Chairman of Council

SIR JAMES STEEL



Sir James Steel photographed by James Alder

Sir James Steel, Chairman of Council from 1972 to 1986, died on 17 November 1994 after a long illness. He was 85.

Sir James joined the Society in April 1967 and later that year was elected to Council. In November 1970 he became a Vice President of the Society and in January 1972 Chairman of Council in succession to Mr C H Brackenbury, who had held the post for eleven years.

His distinguished business career commenced in the family business of Steel and Company, once the world's largest crane manufacturer, and he rose to become Chairman and Managing Director until he retired in 1966, when the company went public as the Steel Group. However, this was not a normal retirement and he accepted many and various further challenges. He was the founding Chairman of the Washington Development Corporation (1964-77) and from this position brought into being the Wildlife and Wetlands Centre in Washington. Ornithology was his main leisure pursuit and he remained a Vice President of the Wildfowl Trust. Other chairmanships held during his 'retirement' included that of the British Productivity Council, the Textile Council, the merchant bankers Rea Brothers, the shipping company Furness Withey and the North of England Building Society. Youth clubs, the Girl Guides, YMCA and the Territorial Army all benefited from Sir James' support.

For his services to industry, he was awarded the CBE in 1964 and was knighted in 1967. Then in 1974 Sir James was appointed Lord Lieutenant of the new metropolitan county of Tyne and Wear, serving for ten years as the Queen's representative, and during the whole of that busy decade he was also Chairman of Council of the Society. Somehow he managed to cope with this enormous workload but remained the most unflappable and softly spoken gentleman.

In 1987 his wife, Margaret, died at their home at Fawnlees Hall, Wolsingham, and he turned to completing a book about his birdwatching travels immediately after the war years, when he travelled the world seeking business orders, and later following his retirement. *Bird Quest* was published in 1989, adorned by beautiful soft pencil drawings by James Alder, and describes his experiences in pursuit of birds in many lands.

During his long term of office as Chairman of Council, Sir James played an important part in Society affairs. In his first year of office he initiated a review of the Society's role when

> '... certain organisations were expanding at a rate much higher than that registered by the Natural History Society and this led to a discussion on whether or not the Society should abandon its present policy and, instead, strive to become a "popular" institution. It was generally agreed that such a drastic change would be most undesirable...'.

In 1974 Sir James led the negotiations leading to the agreement with the University of Newcastle upon Tyne regarding the leasing of the museum, the site and the collections to the University to manage. This ensured the well-being of both the Society's Hancock Museum and the collections, and the furtherance of the Society as a learned body. In recognition of his work for the Society, Sir James was elected an Honorary Member in 1985.

He was charming, friendly and down-to-earth and my lasting memory will be of Sir James and Lady Steel in sparkling form on 30 May 1981 when they had invited twenty birdwatchers from the Society for a day on their estate. After a warm welcome and coffee on the lawn we split into two groups and met again for afternoon tea at Fawnlees Hall. Their hospitality was marvellous. We were given the freedom of the house to wash and rest and then they both ensured that we thoroughly enjoyed all the various items of food and homemade cakes and scones. It had been an extremely hot day and I was dehydrated but Sir James was always carrying a full teapot and kept my cup full.

DRS

FINANCIAL STATEMENTS

31 JULY 1995

INCOME AND EXPENDITURE ACCOUNT

1994			
£		£	£
24,703	SALARIES, PENSION CONTRIBUTIONS AND NATIONAL INSURANCE		25,119
3,663	PRINTING AND STATIONERY		3,966
2,308	POSTAGE AND TELEPHONE		2,327
1,894	INSURANCE		1,869
958	REPAIRS AND RENEWALS		1,109
1,175	GENERAL EXPENSES		1,338
5	LICENCE FEE		5
775	AUDIT AND ACCOUNTANCY FEES		400
800	SUBSCRIPTIONS TO SOCIETIES		903
1,832	LECTURE AND FIELD MEETING EXPENSES		1,838
	TRANSACTIONS		
5,303	Expenditure	7,093	
1,048	Less: Proceeds of sale	821	
4,255			6,272
1,331	LIBRARY – Books	1,337	
1,349	– Rebinding and renovating	856	2,193
1,997	GOSFORTH PARK NATURE RESERVE		2,232
1,664	LEASE OF OFFICE MACHINERY		—
2,436	DEPRECIATION		2,410
	APPROPRIATIONS		
—	Gosforth Park Nature Reserve Restoration Fund		3,000
1,750	Provision for deferred repairs		—
6,768	EXCESS OF INCOME OVER EXPENDITURE FOR THE YEAR		—
£59,663			£54,981

SOCIETY OF NORTHUMBRIA

FOR THE YEAR ENDED 31 JULY 1995

1994			
£		£	£
	SUBSCRIPTIONS		
13,325	Annual subscriptions	13,414	
221	Add: Transfer from Life Members' Fund	240	
13,546			13,654
1,398	DONATIONS...		972
7,200	UNIVERSITY OF NEWCASTLE UPON TYNE		7,500
24,565	INVESTMENT INCOME (GROSS)		26,582
12,954	SALES OF FLORA OF NORTHUMBERLAND		1,490
—	DEFICIT OF EXPENDITURE OVER INCOME FOR THE YEAR..		4,783
£59,663			£54,981

BALANCE SHEET

1994 £		£	£
	GENERAL FUND		
	Balance at 1 August 1994...	106,678	
	Less: Excess of expenditure over income		
106,678	for the year (Note 4)...	4,783	101,895
2,704	LIFE MEMBERS' FUND (Note 5)................................		2,839
	T B SHORT MEMORIAL FUND (Note 6)		
	Balance at 1 August 1994...	93,572	
93,572	Add: Surplus on sale of investments..............................	1,959	95,531
	GRACE HICKLING MEMORIAL FUND (Note 6)		
	Balance at 1 August 1994	78,393	
78,393	Add: Surplus on sale of investments	139	78,532
	PROVISION FOR DEFERRED REPAIRS		
3,000	Balance at 1 August 1994 and 1995		3,000
	GOSFORTH PARK NATURE RESERVE RESTORATION FUND		
	Balance at 1 August 1994	5,000	
5,000	Add: Transfer from income and expenditure account	3,000	8,000
8,539	CREDITORS, ACCRUED CHARGES AND SUBSCRIPTIONS RECEIVED IN ADVANCE		18,203
£297,886			£308,000

Approved by Council on 6 October 1995

D R SHANNON – Chairman

E SLACK – Honorary Treasurer

SOCIETY OF NORTHUMBRIA

31 JULY 1995

1994			
£		£	£
	FREEHOLD PROPERTY (Note 2)		
	Hancock Museum		Not valued
	Lake Lodge		
3,899	Cost	3,899	
5,300	Electrical installation	5,300	
9,199		9,199	
6,626	Less: Depreciation	6,704	
2,573			2,495
	HIDES, EQUIPMENT, OFFICE FURNITURE AND COMPUTERS (Note 3)		
17,111	Cost 1 August 1994	17,406	
295	Additions	2,199	
17,406		19,605	
12,824	Less: Depreciation	15,157	
4,582			4,448
	INVESTMENTS IN TRUSTEE SECURITIES, AT COST		
	Quoted		
138,350	Narrow range	158,122	
51,866	Wide range	64,429	
40,559	Special range	39,730	
	(Market value £385,678 – 1994 £332,405)		
	Unquoted		
	Charities Official Investment Fund		
10,000	9,750 shares of no par value	10,000	
	(Redemption value £67,103 – 1994 £60,115)		
240,775			272,281
6,645	INCOME TAX RECOVERABLE, ACCRUED INCOME AND PAYMENTS IN ADVANCE		5,744
	CASH AT BANK		
39,712	Charities deposit fund	16,979	
1,337	Deposit account	4,015	
2,262	Current account	2,038	
43,311			23,032
£297,886			£308,000

STATEMENT OF TRUSTEES' RESPONSIBILITIES

The Trust deed, the Charities Act 1993 and the Charities (Accounts and Reports) Regulations 1995 require the trustees to prepare accounts for each financial year. In preparing these accounts, the trustees are encouraged to follow the recommendations outlined in Statement of Recommended Practice No. 2 - Accounting by Charities (issued by the Accounting Standards Board in 1995).

The trustees consider that in preparing these accounts, they have used appropriate accounting policies, consistently applied and supported by reasonable and prudent judgements and estimates.

The trustees are responsible for keeping proper accounting records to enable them to ensure that the accounts comply with the Charities Act 1993. They are also responsible for safeguarding the assets of the charity and hence for taking reasonable steps for the prevention and detection of fraud and other irregularities.

ACCOUNTING POLICIES AND NOTES

1 Basis of accounting

The acounts have been prepared under the historical cost convention.

2. Freehold property including Library and Collections

(a) No value was attributed to the Hancock Museum at the date of its completion in 1884. The building is leased to the University of Newcastle upon Tyne which is normally responsible for all repairs and improvements.

(b) (i) The cost of Lake Lodge, less donations and grants received, of £3,899 is depreciated at 2% per annum.

(ii) The cost of installing mains electricity, less donations received, of £5,300 has been fully depreciated.

3. Hides, equipment, office furniture and computers.

The cost of the hides, equipment and office furniture is depreciated at 10% per annum and computers at 20% per annum.

4. Income and expenditure account

The excess of income over expenditure for the year is arrived at after appropriations to special funds for the purpose of setting aside temporary surpluses of income to meet future expenditure.

5. Life members' fund

Amounts received in payment of life subscriptions are taken to the life members' fund and are released to income and expenditure account over a period of 20 years in equal annual instalments.

6. T B Short and Grace Hickling Memorial Funds

The funds from these legacies are invested in accordance with the Trustee Investment Acts and are subject only to expenditure for special projects.

7. Capital commitments

	1995	1994
	£	£
Contracted	–	–
Authorised by Council	4,500	2,500

8. The Society is a registered charity, official number 526770.

ACCOUNTANT'S REPORT TO THE MEMBERS OF THE NATURAL HISTORY SOCIETY OF NORTHUMBRIA

We have carried out an independent examination of the accounts for the year ended 31 July 1995 set out on pages 416 to 420.

Respective responsibilities on trustees and reporting accountants

As described above the trustees are responsible for the preparation of the accounts. It is our responsibility to form an opinion, based on our independent examination, on those statements and to report our opinion to you.

Basis of opinion

Our work was conducted in accordance with the draft general directions of the Charity Commissioners, and so our procedures consisted of comparing the accounts with the accounting records kept by the society, and making such limited enquiries of the officers of the society as we considered necessary for the purposes of this report. These procedures provide only the assurance expressed in our opinion.

Opinion

In our opinion:

a)the accounts are in agreement with the accounting records kept by the society;

b)having regard only to, and on the basis of, the information contained in those accounting records;

i) the accounts have been drawn up in a manner consistent with the accounting requirements of the draft regulations of the Charities Act 1993.

ii) the Society satisfied the conditions for exemption from an audit of the accounts for the year specified in the draft regulations of the Charities Act 1993.

PRICE WATERHOUSE

Reporting Accountants
89 Sandyford Road
Newcastle upon Tyne
NE99 1PL

6 October 1995

Trans. nat. Hist. Soc. Northumb. **56**, 393-414 (1996)

BIRDS ON THE FARNE ISLANDS in 1995:

compiled by

JOHN WALTON

National Trust Property Manager

edited by

MARGARET PATTERSON

INTRODUCTION

The wardening team sailed out to the islands on 24 March where they were met by two black guillemots, a Northumbrian rarity, and a house sparrow, a Farnes rarity. The team's departure from the islands having been delayed by storms it was 8 December when they came ashore, the delay providing records of three arctic redpoll - a rarity by any standard. Between these two dates 180 species were recorded on the islands - a new record eclipsing the 179 of 1991 and 1994. More importantly, the breeding bird population continued to show an increase with an estimated population of 69,860 pairs, an all time high. Fulmar, guillemot and razorbill reached record levels, the latter an increase of 53% on the 1994 figure. Shags began a welcome recovery from the 1994 'crash'. Roseate terns provided the bad news with only two pairs nesting on the islands, the lowest number ever recorded. Swallows nested in St Cuthbert's Chapel for the sixth successive year whilst for the third year a pair of starlings used the 14th century window as a nest site. Twenty-three species bred on the islands.

Passage birds, excluding the 'exotica', were represented by 157 species. Two of these were new to the island list: dowitcher sp. and lanceolated warbler. Arctic redpoll was recorded for the second-fourth time with hawfinch making a third appearance. Black-necked grebe, Cory's shearwater and rustic bunting were recorded for the fourth time with Mediterranean gull (2), Pallas's warbler and corn bunting making fifth appearances. Logged for the sixth occasion were Leach's petrel and osprey, with yellow-breasted bunting making its seventh appearance, nightjar its eighth and house sparrow its tenth. Other species of note included Mediterranean shearwater, storm petrel (2), grey phalarope (2+), little auk (1,000s), wryneck (2), bluethroat (10), icterine warbler (5), barred warbler (2), red-backed shrike (2), scarlet rosefinch (3), Lapland bunting (2), ortolan bunting (3) and little bunting. 8 September will long be remembered as the day when classic 'fall' conditions brought a deluge of birds onto the islands - almost 1,000 individuals of twenty passerine species. Details can be found in the body of the report but 150+ redstart, 260+ willow warbler and 75+ pied flycatcher gives a flavour.

Thanks go to the 1995 wardening team of Andy Baxter, Alex Chown, Chris Drake, Tim Drew, Martin Hodges, Nick Litlewood, Stef McElwee, Scott Paterson and Mike Pilsworth, as well as to various boatmen, for supplying the records which make up this report.

Regular readers will notice one major change: no bird ringing report. The ring recoveries and sightings have been incorporated into the main body of the text under the species headings. Thanks are due to Mrs Rita Wolland for her contiuing work which makes such a contribution to this report.

Details of all the birds are given in the following list: this follows the order and scientific nomenclature of Professor Dr K H Voous' list of recent holarctic species (1977), except for the shearwaters and gannet which adopt the new changes recommended by *Ibis* **133**, p 438. Where appropriate, the figures for 1994 breeding birds are included, for comparison, in brackets.

Red-throated Diver *Gavia stellata*

1-15 recorded almost daily from 25 March until 29 April. Four records in May of 1-4 birds, a single north through Staple Sound on 10 June, and 1-4 on four dates in August. Becoming regular from 4 September until the end of the season with a maximum count of twenty-one on 2 November.

Black-throated Diver *G. arctica*

Winter-plumaged birds recorded on four dates from 28 March-29 April (all singles with two on 12 April). A summer-plumaged bird flew north through Inner Sound on 30 May. Singles recorded on five dates in November.

Great Northern Diver *G. immer*

The first record of the year came on 30 September when one flew directly over the Zodiac inflatable in which the wardens were travelling. Birds were then recorded on twenty-six dates between 5 October and 7 December. A bird in Staple Sound on 21 October still retained its summer plumage.

Great Crested Grebe *Podiceps cristatus*

Singles flew north through Inner Sound on 15 April and 27 August.

Red-necked Grebe *P. grisegena*

Spring records of 1-5 on five dates from 27 March-26 April. One flew north through Staple Sound on 28 August with two north on 30 August. 1-10 were then seen daily from 21 October until the end of the season, with eight together just off Brownsman on 7 December.

Black-necked Grebe *P. nigricollis*

One flew north through Inner Sound on 4 October. Fourth record for the islands and last recorded in 1990.

Fulmar *Fulmarus glacialis*

Birds were occupying potential nest sites on 24 March. Desertion for the 'honeymoon' period was evident between 25 April and 16 May. The first egg was laid on Knoxes Reef on 17 May with first young on West Wideopen and South Wamses on 3 July. 262 (253) pairs nested as follows: Inner Farne 37 (41), Knoxes Reef 17 (31), West Wideopen 20 (20), East Wideopen 16 (12), Skeney Scar 2 (1), Staple Island 44 (34), Brownsman 57 (55), North Wamses 27 (24), South Wamses 33 (32), Big Harcar 1 (1), Northern Hares 4 (2), Longstone End 4 (0). The first young fledged from Inner Farne on 21 August and the last on 12 September from Knoxes Reef. Blue phase birds were recorded on 23 and 24 April, 12 June, 4, 16, 17 and 29 August. Birds were absent from mid-September until 29 October with *ca* 220 present from early November onwards.

One found 'trapped' in the Brownsman vegetable garden on 24 April and released by the wardens had been ringed on North Ronaldsay, Orkney, in 1990.

Cory's Shearwater *Calonectris diomedea*

On 28 August seawatching had been promising and good numbers of shearwaters were seen from 1800 onwards. Whilst watching sooty and Manx shearwaters a single Cory's flew north through Staple Sound at 1855. Fourth record for the islands and last recorded in 1990.

Sooty Shearwater *Puffinus griseus*

A single bird flew north through Staple Sound on 28 June, with one north and one south on 9 July, the earliest ever records from the islands. Then recorded on thirty dates from 6 August-21 October. Numbers generally 1-40 with the largest day count occurring on 28 August when 127+ moved north past the islands.

Manx Shearwater *P. puffinus*

Records of 1-3 on seven dates in April, 1-21 on four dates in May (plus one freshly-dead below Longstone light), then almost daily from 1 June to the end of September. A record passage for the islands occurred on 9 July when 476 moved north. There were two records for October of one and four birds, with two flying north on 3 November being the final record.

Mediterranean Shearwater *P. yelkouan*

One flew north through Inner Sound at 1325 on 7 September.

Storm Petrel *Hydrobates pelagicus*

One was watched feeding off Gun Rock on 2 October before flying off north in strong south-westerly winds. Another was seen off Crumstone on 17 October.

Leach's Petrel *Oceanodroma leuchora*

On 8 June, during a period of strong north-westerly winds, one flew north off Brownsman, heading out towards Longstone. Sixth record for the islands and last recorded in 1991.

Gannet *Morus bassanus*

Seen almost daily with numbers markedly reduced from late September onwards. Peak spring passage of 1,000+ per hour, flying north, recorded on 8 and 24 April with an autumn peak (and an island record) of 5,647 north in three hours on 4 September. Lone birds were on the islands on 8 May, 3 and 7 June and 13 July.

Cormorant *Phalacrocorax carbo*

Birds were present on the islands on 24 March with nest building noted from 31 March. First egg, in a herring gull's bill, was recorded on 22 April. 223 (205) pairs nested as follows: East Wideopen 115 (105), North Wamses 108 (100). The first chicks fledged on North Wamses on 3 July with the last fledging on East Wideopen on 3 September. Birds were scarce from late September onwards.

Two Farne-ringed birds were noted breeding in the East Wideopen colony - both were thirteen years old.

Shag *P. aristotelis*

Many birds were on nests on 24 March although it was not until 12 April that eggs were recorded on both Inner Farne and Staple Island. 1,016 (771) pairs nested as follows: Megstone 6 (7), Inner Farne 171 (156), West Wideopen 85 (84), East Wideopen 60 (38), Skeney Scar 70 (54), Staple Island 255 (174), Brownsman 157 (87), North Wamses 22 (12), South Wamses 61 (58), Roddam and Green 14 (14), Big Harcar 72 (55), Longstone End 43 (32). The first young was recorded on 14 May with first fledging on 28 June; last fledging was on Inner Farne on 25 October. It is probable that a pair on Staple Island reared two broods, the first time that this has been recorded from the islands. Whilst this record is not 100% certain we do know that a number of pairs on the Isle of May were double-brooded this season (first confirmed record in the British Isles). A very unusual record from Brownsman on 19 November was of a first winter bird eating a song thrush.

Whilst the majority of ring sightings were of birds marked on the islands there were seven birds ringed on the Isle of May, Fife Region, and two from Craigleith, Lothian Region. Two Isle of May birds were found dead and Farne ringed birds were recovered at Holy Island, Pennan, Grampian Region, Arbroath, Tayside, Sandsend, Yorkshire, Castle Rising and Caister on Sea in Norfolk. The oldest bird was twenty-one years.

Grey Heron *Ardea cinerea*

1-3 were recorded regularly throughout the season, although there were no records between 15 May and 9 July. Recorded far more often from the inner group of islands.

Mute Swan *Cygnus olor*

Two flew west over Inner Farne on 4 April, three south on 16 August, three south on 1 October (landing in Inner Sound) and two south on 19 October.

Whooper Swan *C. cygnus*

Fifteen flew north through Inner Sound on 30 March, with two south and two north over Inner Farne on 29 October.

Pink-footed Goose *Anser brachyrhynchus*

There was only one spring record of thirty-nine north through Inner Sound on 25 March. Autumn records were of two north and a flock of fifty-three north on two dates in late September, fifty-nine south and sixteen north on 29 and 30 October and finally sixty south through Inner Sound on 2 November.

Greylag Goose *A. anser*

Five moved north-east on 14 April, thirteen north on 17 June, one north-east on 22 August and eight south-west over Brownsman on 16 October.

Canada Goose *Branta canadensis*

Four flew north through the Kettle before landing on the north shore of Inner Farne on 6 June, and four passed south through Staple Sound on 30 September.

Barnacle Goose *B. leucopsis*

One flew over Inner Farne in the company of six snow geese on 25 August, the wardens expressing reasonable doubts as to their origin! Passage was recorded on the last three days of September with day totals of seventy-seven, twenty-two and 146. Then 1-5 were logged on four dates in October.

A colour-ringed barnacle goose was amongst a party of seven that spent about twenty minutes on Brownsman on 4 October 1994. This had been ringed as an adult in Gipsdalen, Spitsbergen, in July 1993. Fifteen days after its visit to the islands it was seen at Caerlaverock, Dumfries.

Brent Goose *B. bernicla*

Two birds, of the pale-bellied race, were present on North Wamses from 28-30 March and again from 2-3 April. All other records related to the autumn when 1-16 were recorded on seven dates from 7 September-4 December.

Shelduck *Tadorna tadorna*

Nesting was strongly suspected on Brownsman, and possibly on West Wideopen, although no ducklings were ever seen. Four birds were seen regularly from 25 March to mid-August, with four north through Staple Sound on 10 September and finally three records of 1-2 birds on 2, 18 and 24 November.

Wigeon *Anas penelope*

2-4 birds were noted on four dates in March, with 1-3 on six April dates. Five were seen on 11 July, then recorded regularly from late August onwards. Numbers were generally in the region of 1-50, with two counts of 200 and 350. The largest passage movement occurred on 1 October when 1,390 flew north through Inner Sound over a four hour period - the highest count from the islands since 1952.

Gadwall *A. strepera*

A male and a female flew north through the Kettle on 21 April, with autumn records of singles on five days in October.

Teal *A. crecca*

Spring records of 1-8 on sixteen days in April, two on 11 May, two on 10 July and a single on 13 July. Becoming regular from early August in small numbers with a maximum of 200+ on Knoxes Reef on 3 December.

Mallard *A. platyrhynchos*

Recorded in every month although becoming scarce, with just two records of single females, during June. Maximum passage was eighty-one flying north on 2 November, with a peak of over eighty birds on Knoxes Reef on 6 December. For the first time since 1979 there was no evidence of breeding on the islands.

Pintail *A. acuta*

A male and a female flying north through the Kettle on 16 April was the only spring record. In autumn 1-4 were recorded on seven dates from 29 September-2 November.

Shoveler *A. clypeata*

One on Knoxes Reef on 20 April and a male and a female in the Kettle on 23 April were the only spring records. One flew north on 11 June, then 1-2 were recorded on eleven days from 8 September-1 December.

Pochard *Aythya ferina*

Drakes were recorded on 23 and 29 April. Singles and small groups (maximum thirty-five) were then recorded on seven dates between 1 October and 2 November.

Tufted Duck *A. fuligula*

1-3 were recorded on four days in April, two days in May, four dates in August and three dates in October. The final record was of two on 20 November.

Scaup *A. marila*

Two flew north on 1 October and six south on 21 October, one was in Staple Sound on 22 October and two passed north through Inner Sound on 13 November.

Eider *Somateria mollissima*

Birds were prospecting nest sites on Brownsman on 6 April, with the first eggs recorded on West Wideopen on 21 April. 1,462 (1,380) females nested as follows: Inner Farne 1,006 (919), Knoxes Reef 9 (6), West Wideopen 41 (47), East Wideopen 17 (11), Staple Island 41 (30), Brownsman 295 (323), North Wamses 10 (14), South Wamses 24 (14), Big Harcar 8 (7), Northern Hares 1 (2), Longstone main rock 3 (1), Longstone End 7 (6). First ducklings were recorded on 17 May with the last leaving on 12 August. *Ca* 1,100 were around the islands from October-December.

Thirty-eight sight records of ringed birds included one from the Sands of Forvie, Grampian Region. Birds were found dead on the islands (6), Holy Island (2) and Seahouses (3). The oldest bird was fifteen years.

Long-tailed Duck *Clangula hyemalis*

1-8 were recorded on twelve days from 27 March-29 April. A single flew north through Inner Sound on 6 September with birds recorded regularly from 13 October until the end of the season. The largest passage ever recorded from the islands was observed during 2 November when ninety-seven birds passed north through Inner and Staple Sounds.

Common Scoter *Melanitta nigra*

Recorded in every month of the season although becoming scarce during May and June. Recorded on 114 days with the largest count of 213 on 2 November.

Velvet Scoter *M. fusca*

Spring records of single birds on 29 March, 8 and 24 April. One flew north through Staple Sound on 6 July and one on 30 August. 1-4 recorded on thirteen dates from 15 September-5 December with eighteen north on 2 November.

Goldeneye *Bucephala clangula*

1-5 were present daily in the Kettle from 24 March-9 April, with singles on three later dates in April. One flew north on 28 August, with the species recorded on a regular basis from early October onwards. The largest passage of the season was on 2 November when 141 flew north during the day.

Red-breasted Merganser *Mergus serrator*

1-2 were recorded regularly through late March-April, with a single flying south through Staple Sound on 26 July. 1-9 were observed on fifteen days from 15 August-22 November with thirty-one north on 2 November.

Goosander *M. merganser*

Females were logged on 20 April and 3 May, whilst an eclipse female was resident around the inner group from 11 July-8 September. One flew north on 1 October then 1-3 on three dates in early November.

Sparrowhawk *Accipiter nisus*

Singles were recorded on 31 March, four dates in April, two dates in August, two in September, two in October and two in November. The only 'kill' witnessed was that of a redstart.

Osprey *Pandion haliaetus*

On 17 September, whilst the wardens on Brownsman were radioing ashore regarding their lanceolated warbler, an osprey flew over the island en route for the mainland. Despite screamed messages over the radio the Property Manager failed to make it out of his house in Seahouses in time to see the bird! Sixth record for the islands and last recorded in 1991.

Kestrel *Falco tinnunculus*

Singles were recorded on seven dates from 2 April-1 May (possibly just two birds accounting for this spread of records). A female recorded on 23 July was making heavy weather of flying in a force seven westerly. Then 1-2 birds were noted on eighteen dates from 8 August-18 November.

Merlin *F. columbarius*

Singles were seen daily from 26 March-26 April. An 'incredibly tame' first winter female spent 13 April providing the visitors with a rare spectacle - catching turnstone, three during the day, and eating them on the beach in front of her audience. Singles were noted on four dates in August, then 1-2 becoming regular (almost daily) from 2 September-8 December. One was watched pursuing a black tern through Staple Sound on 17 October, whilst the log for 5 December notes: 'chased arctic redpoll across Inner Sound, hope it didn't catch it!'.

Peregrine *F. peregrinus*

All spring records, of singles on six days between 28 March and 25 April, were from the inner group. Singles again on five September dates, then 1-2 almost daily from 1 October-6 December.

Water Rail *Rallus aquaticus*

A visitor came into the Inner Farne information centre on 17 September to enquire about the 'odd bird' found sitting on the altar table in St Cuthbert's Chapel: the warden who went to investigate was somewhat surprised to find a water rail! Singles, in more usual locations on Brownsman, were present on 11-13 November, 23 November and 2 December.

Moorhen *Gallinula chloropus*

One was on West Wideopen on 14 October and one on Inner Farne on 26 November.

Coot *Fulica atra*

One arrived on Brownsman on 24 April after a period of sustained north-easterly winds. Initially found in the sewage pipe! A juvenile was on the sea off Inner Farne throughout the evening of 9 July.

Oystercatcher *Haematopus ostralegus*

Ca sixty recorded in early spring. First eggs were noted on Inner Farne on 6 May, with the first young on the same island on 4 June. 30 (32) pairs nested as follows: Inner Farne 6 (6), Knoxes Reef 2 (4), West Wideopen 5 (3), East Wideopen 2 (2), Staple Island 4 (4), Brownsman 6 (7), North Wamses 1 (1), South Wamses 1 (2), Big Harcar 0 (1), Northern Hares 1 (1), Longstone main rock 1 (0), Longstone End 1 (1). First young fledged on 7 July with the last on 20 August. One 'nearly-fledged' bird was killed by a great black-backed gull on 5 September. Numbers built up throughout the autumn with a maximum of 170 in late September.

Ringed Plover *Charadrius hiaticula*

First eggs were found on Inner Farne on 5 May with first young on Brownsman on 2 June. 12 (12) pairs nested as follows: Inner Farne 5 (6), Knoxes Reef 1 (1), West Wideopen 2 (1), Staple Island 1 (1), Brownsman 2 (2), Longstone main rock 1 (1). First young fledged from Brownsman on 5 July with the last brood of young presumed predated from Inner Farne on 6 August. Maximum count of *ca* sixty on 8 September declined to a maximum of twenty from October to December.

Golden Plover *Pluvialis apricaria*

Ca 150 north over the Kettle on 21 April was the only spring record. There were two records in August of 1-2 birds, then records on eighteen dates between 8 September and 15 October. Generally less than fifty birds were involved but with 270 north-east over the islands on 12 October.

Grey Plover *P. squatarola*

1-3 were recorded on eight dates from 27 March-19 May, with 1-5 on sixteen dates between 17 August and 23 November. From 24 November-8 December there were 1-2 birds daily on Knoxes Reef.

Lapwing *Vanellus vanellus*

1-3 were recorded on six dates in March and April with one north over Inner Farne on 9 May, followed by records on thirty-four days from 12 July-4 December. Numbers were generally 1-30, with the largest count of 102 north-east over Inner Farne occurring on 22 November.

Knot *Calidris canutus*

Four summer plumaged birds were on Knoxes Reef on 3 July, followed by regular records until the end of the season. 1-20 was the norm, with 120 on Knoxes Reef on 17 September being the largest count.

Sanderling *C. alba*

Three summer plumaged birds were on the south end of Brownsman on 24 July followed by singles on Brownsman on 11 August and Inner Farne on 17 August.

Little Stint *C. minuta*

Maximum of three present on Brownsman and Staple Island from 5-10 September and again on 13 September. A juvenile on Inner Farne on 8-9 September may have fallen prey to a merlin. One flying through the Kettle on 27 September was the final record.

Purple Sandpiper *C. maritima*

Maximum spring count of 224 on Inner Farne on 30 April with numbers dropping to just 1-2 by early June. Absent from 2-29 June then numbers slowly built up to give a maximum of 121 on Brownsman on 27 July. Thereafter 80-100 were recorded regularly.

Three colour-ringed birds were recorded. Two of these have yet to be identified and the third had been ringed at Hartlepool, Cleveland, in 1993.

Dunlin *C. alpina*

Recorded throughout the season with 1-8 regularly in spring and up to thirty-five from late July until the end of August. The largest count was of forty north through Staple Sound on 11 June.

Ruff *Philomachus pugnax*

Singles on 3, 8 and 28 September. Two flew over Inner Farne on 8 September.

Jack Snipe *Lymnocryptes minimus*

Singles recorded on seventeen days from 17 September-6 December.

Snipe *Gallinago gallinago*

Spring records of single birds on eleven days from 25 March-24 April. The first autumn bird appeared on 23 August, then 1-7 were seen regularly until the end of the season.

Dowitcher sp. *Limnodromus* sp.

One was seen, in fading light, on Knoxes Reef at 1845 on 27 September. It was watched for fifteen minutes before it flew on to West Wideopen but, despite getting the boat across to that island (in record time!), the bird could not be located. Views were not good enough to make a specific identification. First record for the islands.

Woodcock *Scolopax rusticola*

Singles were on Inner Farne on 25 March and 3 April. 1-8 were noted on twenty days from 12 October-15 November. There were two December records: one on Inner Farne on 5 December, and one on Staple Island on 6 December.

Black-tailed Godwit *Limosa limosa*

One was on West Wideopen on 21 October.

Bar-tailed Godwit *L. lapponica*

There were spring records of 1-4 birds on seven days from 3 April-2 May. The first returning bird was one on Knoxes Reef on 19-20 July, then 1-26 on fifty-seven dates from 19 August-7 December.

Whimbrel *Numenius phaeopus*

1-20 were recorded on nineteen days between 19 April and 28 May. Singles were on the outer group on 10 and 21 June, then 1-6 regularly from 8 July-27 September.

Curlew *N. arquata*

Recorded almost daily throughout the season. Spring counts peaked at 400+ on Knoxes Reef on 19 April, and autumn counts at 500+ on Knoxes Reef on 23 July.

Spotted Redshank *Tringa erythropus*

One flew east over Inner Farne on 14 August, with one through the Kettle on 19 August.

Redshank *T. totanus*

Recorded during every month of the season although scarce in June with single birds recorded on just three days. Generally 1-20 birds with the maximum count on 20 April when 105 roosted on Inner Farne.

Greenshank *T. nebularia*

Singles recorded on nine dates from 20 August-18 October, with three over Inner Farne on 8 September and four flying west over Brownsman on 10 September.

Green Sandpiper *T. ochropus*

One was flushed from Brownsman pond on 22 April. Then singles were seen on five days from 27 July-16 September, with two on Brownsman on 19 August.

Common Sandpiper *Actitis hypoleucos*

Singles were seen on five spring dates from 29 April-1 June. Autumn records were provided by 1-3 almost daily from 3 August-15 October. One bird was resident on Brownsman from 8 September-15 October.

Turnstone *Arenaria interpres*

Present throughout the season. Spring maximum was *ca* ninety decreasing to *ca* forty in mid-June followed by a steady increase thereafter with the largest count of 640+ being in mid-August. 300+ were recorded on a regular basis for the remainder of the season.

Phalarope sp. *Phalaropus* sp.

On 2 October a bird was seen flying from the direction of the Wamses before settling on the sea a hundred metres off the north end of Brownsman. In strong south-westerly winds, and consequently choppy seas, specific identification could not be made. However, a storm petrel flew into view whilst watching the phalarope - 'every cloud ...'.

Grey Phalarope *Phalaropus fulicarius*

Two flew north past Crumstone on 3 November, one was on the sea off Gun Rock on 4 November, one on the sea off Knocklin Ends on 7 November and one in Inner Sound on 8 November.

Pomarine Skua *Stercorarius pomarinus*

1-4 were recorded on twenty-one days from 6 August-11 November. Just one 'big day', on 7 August, when forty-six (forty-four of these adult) were counted from both the inner and outer groups of islands.

Arctic Skua *S. parasiticus*

Single birds recorded on 20 April, 27 May, 9 and 11-13 June. Then 1-57 seen almost daily from 9 July-19 November.

Long-tailed Skua *S. longicaudus*

Recorded on eleven days between 7 August and 4 October, generally 1-3 birds with a maximum of seven on 10 August.

Great Skua *S. skua*

One flew north through Inner Sound on 28 March - the earliest ever record for the islands. Two singles were observed on 10 and 11 May then becoming regular from 8 June-17 November. Numbers only reached double figures on five occasions with the largest count of fifty-five on 28 August.

Mediterranean Gull *Larus melanocephalus*

A first summer bird arrived with an influx of first summer black-headed gulls on Brownsman on 5 June and the same bird was on Brownsman pond on 9 June. A second winter bird was observed feeding with a mixed gull flock in Staple Sound on 31 October. Fifth and sixth records for the islands and last recorded in 1989.

Little Gull *L. minutus*

An adult was on Knoxes Reef and Brownsman on 10-11 April and a first summer bird was over Brownsman cottage on 22 May, followed by singles on twelve days from 11 July-7 November. Two juveniles were in the Longstone tern roost on 16 August.

Black-headed Gull *L. ridibundus*

Birds were displaying from 25 March with the first eggs noted on 3 May. 63 (48) pairs nested as follows: Inner Farne 28 (27), Brownsman 35 (21). First young were recorded on 5 June, with the last fledging on 8 August. Birds were absent from late August-mid October then *ca* 140 were seen daily until the end of the season.

Common Gull *L. canus*

Recorded regularly during the season although becoming scarce throughout June and July. Highest spring count was 200+ on Knoxes Reef on 29 April with 100+ daily from 11 October onwards.

Lesser black-backed Gull *L. fuscus* and **Herring Gull** *L. argentatus*

1,382 (1,193) pairs nested as follows: Megstone 1 (4), Inner Farne 8 (6), Knoxes Reef 40 (29), West Wideopen 245 (243), East Wideopen 169 (119), Skeney Scar 60 (35), Staple Island 75 (46), Brownsman 10 (18), North Wamses 241 (251), South Wamses 180 (169), Roddam and Green 15 (15), Big Harcar 260 (202), Little Harcar 7 (13), Northern Hares 59 (33), Longstone main rock 5 (4), Longstone End 7 (6). First eggs were noted on North and South Wamses on 3 May. Lesser black-backs were last recorded on 18 October whilst herring gull numbers built up to *ca* 2,000 by mid-September.

A Farnes-ringed lesser black-backed gull was found dead at Hartlepool in Cleveland, and one was reported 'alive on ship' at Agadir in Morocco. A herring gull found dead on the islands had been ringed at Pitsea Marshes, Basildon, Essex. The oldest lesser black-backed gull was thirteen years, the oldest herring gull eight.

Iceland Gull *L. glaucoides*

Four sightings make this the best season on record: an adult on 2 April, a third winter/adult and a first summer bird on Knoxes Reef on 23 April, and a second winter bird on Knoxes Reef on 23 November.

Glaucous Gull *L. hyperboreus*

1-3 were recorded on nine days from 26 March-23 April. An adult flew south over Staple Island on 1 May, and a first summer bird north through Inner Sound on 3 June. Then 1-2 were noted on five dates from 6-18 November. On 25 March a bird present on the Bridges may have been a glaucous x herring gull hybrid.

Great Black-backed Gull *L. marinus*

Ca 350 were noted throughout April decreasing to *ca* fifteen by mid-May. 2 (3) pairs nested as follows: East Wideopen 0 (2), North Wamses 1 (0), South Wamses 1 (1). Numbers started increasing from early August onwards with a maximum of *ca* 3,500 by mid-October.

Kittiwake *Rissa tridactyla*

Birds were present on sites on 24 March with nest building activity noted throughout April. First eggs were recorded on Inner Farne, Brownsman and Staple Island on 15 May with the first young on 10 June. 6,313 (5,620) pairs nested as follows: Megstone 49 (31), Inner Farne 1,735 (1,561), West Wideopen 361 (380), East Wideopen 496 (380), Skeney Scar 291 (278), Staple Island 1,613 (1,515), Brownsman 1,459 (1,318), North Wamses 86 (77), South Wamses 118 (56), Roddam and Green 14 (35), Big Harcar 91 (89). The first young fledged on 13 July with the final youngster leaving the cliffs on 23 August. Largest numbers of the autumn were observed on 20 October when a flock of *ca* 3,500 was feeding off Longstone End. 1-50 seen daily for the remainder of the season.

Throughout the season there were sight records of ringed birds including two marked on the

Isle of May, Fife Region. Two Farne-ringed birds were recorded at Dunstanburgh. Recovery sites were the islands, Faroes, Belgium, Netherlands and Spain. The oldest bird was twenty-three years.

Lesser Crested Tern *Sterna bengalensis*

Arriving on Inner Farne on 2 May 'Elsie' was back for her twelfth season - a fairly eventful one as it turned out. Seen intermittently throughout May it had appeared that she might nest (paired with a Sandwich tern) on Brownsman but this came to nothing. Moving to Inner Farne on 31 May she was sitting on a single egg by 4 June. This was lost by 10 June - possibly having been stood on by an eider. Having gone 'walkabout' for the remainder of June she was found incubating an egg on 5 July which hatched on 16 July - there was, however, a strong feeling that this egg probably did not belong to Elsie. The chick vanished on 21 July as did Elsie - only to reappear on 1-10 August intent on feeding any Sandwich tern chick that would accept fish. The log concludes: 'the wardens are all now of the opinion that this bird is either very unfortunate, or just plain stupid!'. She was present, on and off, until 28 August with a final sighting of her roosting on Longstone on 16 September.

Sandwich Tern *S. sandvicensis*

Two flying past Inner Farne on 30 March was the first sighting. Observed daily from 4 April numbers built up throughout the month with the roost on Knoxes Reef holding an estimated 3,000+ birds on 26 April and, having moved to Inner Farne, *ca* 5,000 by 9 May. First eggs were recorded on 14 May with first young on 11 June. 1,837 (1,488, probably nearer 2,000) pairs nested as follows: Inner Farne 1,657 (1,232), Brownsman 180 (256). First fledged young were seen on 5 July with the last on 12 August. Numbers decreased from this date onwards although small numbers were seen almost daily until 26 September. One flying south through Inner Sound on 10 October was the final sighting.

Eight colour-ringed birds were seen - four marked on the islands between 1974 and 1984, one on Coquet Island in 1967 and three on the Sands of Forvie, Grampian Region in 1989. Single birds from Ogilby Island, Down, Northern Ireland and Mulroy Bay, Eire were recorded. Two Farne birds were controlled at Teesmouth, Cleveland with field records of eleven from Griend in the Netherlands.

Recovery areas were Blackhall Rocks, Durham, Redcar in Cleveland, France, Netherlands, Spain, Ghana, Namibia, Sierra Leone, Senegal, and Cape Province, Republic of South Africa. The oldest bird was twenty-eight years.

Roseate Tern *S. dougallii*

First recorded, over Inner Farne meadow, on 8 May. Three pairs were present but only 2 (3) pairs nested as follows: Inner Farne 2 (3). Both pairs laid two eggs and four young were fledged. The car tyre, placed in a suitable site in 1994, was used this season with one pair nesting inside the rim while young from the other pair moved into a nestbox shortly after hatching. Although no birds nested on the outer group 1-3 were seen frequently on and over Brownsman and Staple Island. Birds were observed regularly until early September with a final sighting of two north through Inner Sound on 7 September.

One of the breeding birds was a two year old ringed on Rockabill, Co. Dublin.

Common Tern *S. hirundo*

The first definite record was of a single bird on 29 April. First eggs were noted on 19 May with first young on 11 June. 250 pairs nested as follows: Inner Farne 249 (231) Brownsman 1 (1). The first chick fledged on 8 July with the last on 4 August. Birds were present daily until 29 August with three north through Inner Sound on 13 September being the last record.

Arctic Tern *S. paradisaea*

One north past Crumstone on 27 April was the first record. Eggs were noted on 12 May with first young on 2 June. 3,066 (3,128) pairs nested as follows: Inner Farne 1,895 (1,826) Knoxes Reef 1 (0), Staple Island 4 (3), Brownsman 1,166 (1,299). The first young fledged on 4 July with the last on 16 August. All birds had left the islands by 3 September with the last two seen in Staple Sound on 11 October.

There were sight records of thirteen Farne-ringed birds. In addition ten were found dead on the islands including one ringed on Coquet Island. The oldest bird was twenty-three years.

Little Tern *S. albifrons*

Two flying over Inner Farne meadow on 2 May were the first of the season. The evening roost on the Inner Farne beach, a new occurrence first witnessed in 1992, continued with birds present from 7 May. Building up to a peak of sixty-eight on 19 May this declined to two on 6 June with none thereafter. Seven flew west past Inner Farne on 24 July The only outer group record was one north past Crumstone on 11 May.

Black Tern *Chlidonias niger*

A moulting adult and a juvenile were seen flying north through Staple Sound on 7 August and a moulting adult and juvenile were in the mixed tern flock on Longstone on 15 August. A juvenile flew south past Crumstone on 28 August, with one north through Staple Sound and two juveniles past Crumstone on 29 August. Finally, a juvenile was observed off the south end of Brownsman on 17 October, the latest ever recorded from the islands.

Guillemot *Uria aalge*

Birds were present in large numbers on 24 March although their attendance on the breeding cliffs was erratic until early April. First eggs were seen on 17 April with the first young, on both Inner Farne and Staple Island, on 29 May. 18,994 (17,316) pairs nested as follows: Megstone 91 (86), Inner Farne 2,087 (1,768), West Wideopen 1,086 (812), East Wideopen 1,512 (1,650), Skeney Scar 805 (726), Staple Island 8,625 (8,491), Brownsman 3,823 (3,201), North Wamses 777 (467), South Wamses 180 (115), Roddam and Green 6 (0), Big Harcar 2 (0). The first young was seen leaving the cliffs on 13 June, with the breeding areas deserted by 1 August. A juvenile was heard calling in Staple Sound on 20 August. *Ca* 400 birds were back on the Pinnacles on 22, 23, 25 October and 5 November with the 'full quota' on Brownsman south cliffs and the Pinnacles on 23-24 November. An estimated 10,000 were feeding around the outer group on 9 November.

Nineteen ringed birds were recorded, six as yet unidentified. Ringing sites were Fair Isle, Sumburgh, Shetland, Isle of May, Fife Region, Helmsdale, Highland Region, Skomer, Dyfed, and Wexford in Eire. The oldest bird was nine years.

Razorbill *Alca torda*

Birds were present on 24 March, with the first egg recorded on 24 April and first young on 15 June. The first chick left its ledge on 5 July, with the last on 5 August. 216 (141) pairs nested as follows: Inner Farne 112 (67), West Wideopen 37 (24), East Wideopen 28 (14), Skeney Scar 3 (4), Staple Island 21 (19), Brownsman 2 (1), North Wamses 6 (6), South Wamses 4 (2), Big Harcar 3 (4). Varying numbers of non-breeding birds have been observed around the islands during the last couple of seasons which may help account for the 53% increase in nesting pairs. Birds were scarce throughout August, then 1-40 were seen daily from mid-September onwards.

A bird recorded on Staple Island on 20 July was a three year old ringed on the Isle of May, Fife Region.

Black Guillemot *Cepphus grylle*

The wardens' log for 24 March reads: 'two flew through the Kettle on our arrival - marvellous!'. Single winter-plumaged and summer-plumaged adults were present in Staple Sound from 27-29 March, a summer bird was in Staple Sound on 26 April, then 1-2 were seen regularly from 29 September until the end of October, with 1-6 almost daily from 2 November until the end of the season.

Little Auk *Alle alle*

One flew north through Inner Sound on 27 March. Six birds past the islands on 21 October gave little clue as to what was to follow: continual presence until the season's end and two of the largest counts ever recorded from the islands. 1-80 seen throughout October-early November with *ca* 1,400 an hour south on 12 November and 1,000+ an hour north on 18 November. 1-20 were seen daily thereafter until 8 December. Two birds sitting on Staple Island on 14 November were a novelty, as was the opportunity to drift in the inflatable listening to birds calling across Staple Sound. Many corpses were found, prey of greater black-back gulls. A few birds were seen to fly inland with starling flocks.

Puffin *Fratercula arctica*

Birds were ashore on 24 March but it was not until 9 April that they began to stay throughout the day. The first egg was located on Brownsman on 22 April, with first evidence of young on 27 May. First young fledged, on Inner Farne and Brownsman, on 4 July with just *ca* five pairs still feeding young on 21 August. An adult was last seen entering a burrow on Staple Island on 1 September. Birds were becoming scarce from mid-August onwards with a maximum of three per week observed until the end of the season. No population count was undertaken this year - the 1993 estimate was 34,710 pairs.

There were sight records of thirty-seven ringed birds including one from the Isle of May, Fife Region. Recovery sites were the islands, Coldingham Bay, Border Region, Dunbeath, Highland Region and Finistere, France. The oldest bird had been ringed in 1971 as an adult.

Woodpigeon *Columba palumbus*

One flushed off Brownsman on 20 April flew to Inner Farne. Four flew north over Brownsman on 3 May with one south-west on the same day, then singles were noted on 6 and 26 May. Both autumn records were from Inner Farne with birds west over the island on 1 and 26 October.

Collared Dove *Streptopelia decaocto*

One on Inner Farne on 25 March, with singles on Staple Island on 2 April and Brownsman on 15 May.

Turtle Dove *S. turtur*

One flew west over Inner Farne on 10 October.

Cuckoo *Cuculus canorus*

One flying south over Inner Farne meadow on 4 May was being mobbed by the resident terns.

Long-eared Owl *Asio otus*

A very quiet year for this species with just one record - a single bird on the south-east rocks of Brownsman on 12 October.

Short-eared Owl *A. flammeus*

Four spring records: one flushed from Staple Island on 8 April made landfall on Inner Farne, one flushed from Brownsman on 9 April flew out to Longstone End, and singles were on Staple Island on 13 and 15 April. In the autumn singles were recorded on the inner group on 11, 12 and 31 October, with singles on the outer group on 2, 4 and 5 November.

Nightjar *Caprimulgus europaeus*

A few lucky observers witnessed a unique sight - a female nightjar flying around in the confines of St Cuthbert's Chapel on 3 June. Eighth record for the islands and last recorded in 1983.

Swift *Apus apus*

First sighting was a single bird over Knoxes Reef on 9 May followed by records on thirty days until 8 September. Numbers generally in the 1-14 range with thirty-three north-east over Staple Island in a ten minute period on 20 June.

Wryneck *Jynx torquilla*

A bird arrived on Brownsman on 25 April during a period of north-easterly winds and rain and was heard 'hissing like a snake' when approached by the wardens. It then moved to Inner Farne where it spent the day of 26 April. One 'seen to tumble out of the sky' during poor weather on 2 September spent a couple of hours on Brownsman.

Great Spotted Woodpecker *Dendrocops major*

A male flushed from the lighthouse rubble on Brownsman on 3 May flew out over one of the visitor boats much to the delight of the passengers. It then spent the rest of the day on Brownsman. This is only the second spring record from the islands, the first being on 4 May 1973.

Skylark *Alauda arvensis*

Recorded in every month with 1-5 noted through the spring and summer (although just one bird in August) with numbers increasing from late October to a maximum of 40+ on 29 October.

Sand Martin *Riparia riparia*

1-4 on eight days from 6 April-5 May, then 1-2 on five days from 20 July-12 September. Seventeen south-east through Staple Sound on 21 July was the only large count.

Swallow *Hirundo rustica*

For the sixth year in succession a pair nested in St Cuthbert's chapel on Inner Farne and fledged two broods. Birds were recorded regularly from 5 April (earliest island record) until 7 October with a maximum count of twenty-five feeding over Inner Farne meadow on 20 August.

House Martin *Delichon urbica*

1-5 recorded on ten days from 2 May-24 June, then three on 15 August and one on 4 October. All but two of these records were from the outer group.

Tree Pipit *Anthus trivialis*

There was a single spring record from Brownsman of one on 5 April. Then recorded on eighteen days from 24 August-30 September, generally in single figures with 40+ (previous island maximum ten) during the 'fall' on 8 September.

Meadow Pipit *A. pratensis*

Recorded regularly from 24 March-2 May with a maximum of *ca* thirty on 6 April. One was on Inner Farne on 24 August with three there on 27 August, then seen almost daily in small numbers from 3 September-6 December. 220+ flying north between 0700 and 0900 on 10 September was the largest-ever day-count from the islands.

Rock Pipit *A. spinoletta*

Present throughout the season. 17 (16) pairs nested as follows: Inner Farne 6 (6), West Wideopen 1 (1), Staple Island 2 (2), Brownsman 7 (6), Longstone main rock 1 (1). The first nest was found on Brownsman on 1 May with fledglings noted on 23 May. *Ca* 40 were seen daily from early August onwards.

Yellow Wagtail *Motacilla flava*

Singles were noted on eight dates from 14 April-4 May, with four south over Staple Island on 7 May. Recorded on eight days in September with almost all records related to the nine which appeared on 8 September. Amongst these nine birds were two 'eastern race' individuals.

Grey Wagtail *M. cinerea*

Singles were observed north-east over Brownsman on 1 April and on Inner Farne on 6 April. Autumn records, all of single birds, on eleven days from 1 September-19 November.

Pied Wagtail *M. alba*

Recorded from 24 March-13 November. 5 (4) pairs nested as follows: Inner Farne 2 (2), Staple Island 1 (1), Brownsman 1 (1), Longstone main rock 1 (1). Maximum numbers were recorded in mid-late August with forty-six roosting on Brownsman and Inner Farne on 21 August. Three white wagtails were recorded in spring, followed by two in September and one on 13 November.

Wren *Troglodytes troglodytes*

1-4 seen daily from 24 March-13 May with singles on 20 July and 16 August and 1-11 almost daily from 13 September-7 December.

Dunnock *Prunella modularis*

1-5 noted regularly from 25 March-4 May, with 1-10 almost daily from 17 September-7 December.

Robin *Erithacus rubecula*

1-40 recorded on twenty-four days between 24 March and 22 May, with 1-9 recorded regularly from 29 August onwards.

Bluethroat *Luscinia svecica*

Birds recorded on six days between 17 and 27 May. The maximum number present was five on 23 May with probably ten birds involved in the spread of records.

Black Redstart *Phoenicurus ochruros*

1-2 were seen on eight days from 24 March-2 May. These were followed by a female on Inner Farne on 26 June, a juvenile from 11-13 July, one on Staple Island and Brownsman on 13 October and finally a female on Inner Farne on 12-13 November.

Redstart *P. phoenicurus*

1-2 observed on thirteen dates from 11-30 April. Eight on 3 September were the first of the autumn with further records on seventeen days until 14 October. The 'fall' of 8 September saw at least 150 present, the largest ever count on the islands.

Whinchat *Saxicola rubetra*

Recorded on thirty-one days from 24 April-17 May and 18 July-17 September. 1-2 was the spring norm with 1-12 in the autumn, although 8 September saw a mimimum of eighty. This was the largest ever count on the islands, the former day record being twenty-three.

Stonechat *S. torquata*

A male was on Inner Farne on 2 April.

Wheatear *Oenanthe oenanthe*

1-35 seen regularly from 31 March-23 May, with returning birds from 8 August. 1-13 seen almost daily until 13 October: numbers were generally 1-20 with a minimum of fifty-four on 8 September. A possible Greenland race bird was observed on 3 September and a leucistic bird was present on Brownsman on 12 and 13 September.

Ring Ouzel *Turdus torquatus*

1-3 recorded on nine days from 11 April-1 May. One flying over Knoxes Reef was seen being taken by a herring gull on 30 April. Singles recorded on 13 and 15-17 October.

Blackbird *T. merula*

1-10 observed regularly from 24 March-20 May, then 1-30 almost daily between 11 October and 7 December. Two large day-counts of birds flying over or seen on the islands were *ca* 800 on 30 October and 1,200+ on 31 October.

Fieldfare *T. pilaris*

1-20 were recorded on sixteen days from 2 April-5 May, a juvenile was on Inner Farne on 26 July, then 1-30 were seen on twenty-five days between 29 October and 7 December. 750+ were 'on or over' on 31 October.

Song Thrush *T. philomelos*

1-10 were recorded regularly from 24 March-5 May, a juvenile was on Inner Farne on 20-21 July and then 1-80 were seen almost daily from 3 September-7 December. 215+ were 'on or over' on 31 October.

Redwing *T. iliacus*

1-50 seen on fourteen days from 29 March-5 May, then 1-50 almost daily from 1 October onwards. 4,000+ on 30 October and 5,000+ on 31 October were the largest counts of the season.

Mistle Thrush *T. viscivorus*

One on Brownsman on 23 April, one west over Inner Farne on 28 October and one on Brownsman and Staple Island on 12 November.

Lanceolated Warbler *Locustella lanceolata*

A bird suspected to be this species was found on Brownsman in failing light on the evening of 16 September. Much to the relief of the wardens it was relocated at first light the next morning when positive identification was made; it remained until 1430. First record for the islands.

Grasshopper Warbler *L. naevia*

Singles were noted on 24-25, 29 April and 2 May. Autumn birds were represented by a single on Brownsman on 5 September, four on the inner group on 8 September and singles on Inner Farne on 9 and 11 September.

Sedge Warbler *Acrocephalus schoenobaenus*

1-3 recorded on five dates from 2-23 May with 1-3 on twelve days between 31 August and 20 September.

[**Marsh Warbler** *A. palustris*]

An unstreaked *Acrocephalus* warbler showing some characteristics of marsh warbler was present on Inner Farne on 18 September. Reed warbler was ruled out but marsh warbler not positively identified.

Reed Warbler *A. scirpaceus*

All records relate to the autumn with 1-8 birds recorded on nine days from 3-19 September. The eight arrived on 8 September, the day of the 'fall'.

Icterine Warbler *Hippolais icterina*

One was on Inner Farne during the evening of 12 August. One on 19-21 August was joined by a second on 21 August and the fourth bird for Inner Farne was present on 7 September - a distinctive bird without tail feathers. The fifth for the season was present on Brownsman on 8 September.

Barred Warbler *Sylvia nisoria*

Singles were present on Brownsman on 12-13 and 30 September.

Lesser Whitethroat *S. curruca*

1-3 were present on fourteen days from 24 April-24 May, then 1-6 on nine days from 3-18 September.

Whitethroat *S. communis*

1-2 recorded on seven days from 3-27 May, with 1-12 on fifteen days between 31 August and 14 October.

Garden Warbler *S. borin*

Singles present from 5-7 May, then 1-37 seen on sixteen days from 13 August-13 October. It goes almost without saying that the thirty-seven were on 8 September!

Blackcap *S. atricapilla*

Males were present on 23 and 29 April and 2-3 May. Autumn passage involved 1-7 birds on thirty-two days between 8 September and 28 November.

Pallas's Warbler *Phylloscopus proregulus*

One was present on Inner Farne from 1100 until dusk on 10 November. Fifth record for the islands and last recorded in 1994.

Wood Warbler *P. sibilatrix*

Two on 8 September, one on Inner Farne and one on West Wideopen. The log entry for the Farne bird reads: 'This colourful bird landed on a drab brown background - namely a visitor's corduroy trousers!'. A bird with a damaged wing was on Brownsman on 17-18 September and on West Wideopen on the afternoon of the latter date.

Chiffchaff *P. collybita*

1-6 observed on seventeen dates from 5 April-5 May. Autumn birds were represented by 1-5 on twenty-three days from 23 August-19 November.

Willow Warbler *P. trochilus*

1-12 on twenty-two days from 11 April-30 May. First autumn birds were noted on 3 August with 1-12 seen regularly until 14 October. The 'fall' day of 8 September was exceptional with 260+ birds present - a new record.

Goldcrest *Regulus regulus*

1-5 observed on eleven days from 30 March-29 April, with 1-12 seen regularly from 27 August-15 November.

Spotted Flycatcher *Muscicapa striata*

Singles noted on five dates between 5 May and 28 May, and again singles on eight days from 2-19 September. A minimum of thirty present on 8 September - a new record.

Pied Flycatcher *Ficedula hypoleuca*

No spring records. 1-18 noted on twenty days from 11 August-20 September. The 'fall' on 8 September produced a minimum count of seventy-five, the previous highest count being thirty-six in 1980.

Red-backed Shrike *Lanius collurio*

One was on Staple Island and Brownsman on 11 September and another on Brownsman on 18 September. Both were first winter birds.

Jackdaw *Corvus monedula*

1-5 were over the islands on seven days between 2 April and 12 May with just one autumn record - one west over Brownsman on 22 September.

Rook *C. frugilegus*

Singles and parties of up to five were seen regularly during April with one west over Brownsman on 1 May. Parties of 2-4 were recorded on four dates from 22 September-7 November, with a group of nineteen flying north-east over Inner Farne on 13 October.

Carrion Crow *C. corone*

Recorded throughout the season with numbers from 1-32. Hooded crows were recorded as follows: one on Inner Farne on 9 April, three west over Brownsman on 13 April, one on Roddam and Green on 24 April, one on Inner Farne on 27 April, one west over Brownsman on 1 May and one on Brownsman on 25 May. Carrion crows were regular visitors to Inner Farne from mid-October-late November to feed on dead rabbits.

Starling *Sturnus vulgaris*

For the third year in succession a pair nested in the 14th century window of St Cuthbert's chapel with young fledging on 8 June. Birds were seen almost daily throughout the season - small numbers in spring and summer, with 200-400 present from mid-October onwards. A notable passage was evident on 22 October with 'many hundreds' coming in over the sea. One bird present from 10-24 April was an excellent mimic with house sparrow, chaffinch, brambling and yellowhammer in its repertoire, much to the frustration of the wardens! A leucistic bird was present on Knoxes Reef from 13-15 November.

House Sparrow *Passer domesticus*

A male was on Brownsman when the wardens arrived on 24 March - as the log records: 'what a start!'. Only the tenth record for the islands and last recorded in 1994.

Chaffinch *Fringilla coelebs*

1-4 seen on six days from 24 March-14 April, with 1-7 on thirteen days between 11 October and 7 December.

Brambling *F. montifringilla*

1-10 observed on six days from 23-27 April, then 1-25 on twenty-three dates between 30 September and 17 November, with one on Brownsman on 5 December and one on Inner Farne on 6 December. Largest movements of the season took place on 29-30 October when *ca* eighty were recorded flying west.

Greenfinch *Carduelis chloris*

Three were over Inner Farne on 11 October with one over the same island on 20 October.

Goldfinch *C. carduelis*

Records of 2-5 on five days from 14 April-2 May. Two flew north over Inner Farne on 5 October, four were 'enjoying the thistles' on that island on 10 October, and finally two were seen on 4 November.

Siskin *C. spinus*

Singles on six days from 30 March-28 April with 1-4 on eighteen dates from 28 September-12 November.

Linnet *C. cannabina*

1-22 noted on thirty-eight days from 24 March-23 May, then 2-40 seen daily from 21 September-7 December.

Twite *C. flavirostris*

One on Staple Island on 25 May, with 1-8 on six days from 13 October-3 November.

Redpoll *C. flammea*

1-2 seen on six days from 11 April-2 May. One west over Inner Farne on 20 October gave no clue as to what was to follow - a major eruption of mealy redpoll *C. f. flammea* with birds present daily from 2 November-8 December. Five on 2 November increased to 100+ on 11 November and 120+ on 12-13 November with over forty still present on 6 December. To put this unprecedented influx into perspective mealy redpolls have only been recorded on the islands in seven years since 1970 and then only 1-2 in each of those years.

Arctic Redpoll *C. hornemanni*

One was on Inner Farne for thirty minutes on 5 December, and another from 1430 onwards on 6 December. There was at least one other bird (possibly two) on Brownsman on 5-6 December. The islands had been due to be evacuated on 4 December but this plan was thwarted by the weather and the log for the species reads: 'Being stuck here for a few more days can be worthwhile'. Second-fourth records for the islands and last recorded in October 1989.

Scarlet Rosefinch *Carpodacus erythrinus*

Two were present on Brownsman on 7-9 September, with one remaining until 10 September and one was on Inner Farne on 18 September. All three were immature or female.

Hawfinch *Coccothraustes coccothraustes*

At 1900 on 24 April a female was on the lighthouse cliffs at Inner Farne for only one minute! Third record for the islands and last recorded in 1991.

Lapland Bunting *Calcarius lapponicus*

A male present on Inner Farne during the morning of 19 April was in almost full summer plumage. A 'very approachable' second-spring male was present on the same island on 25 April.

Snow Bunting *Plectrophenax nivalis*

1-7 were noted on seventeen days from 30 September-7 December.

Yellowhammer *Emberiza citrinella*

One on Inner Farne on 28 March, one on Brownsman and Staple Island from 25-27 April and one on Inner Farne on 3 November were all female. An immature was resident on Brownsman from 1-6 November.

Ortolan Bunting *E. hortulana*

A first winter bird present on Brownsman from 2-10 September was joined by another first winter bird from 7-9 September. A different individual from those on the outer group was on Inner Farne on 7-8 September.

Rustic Bunting *E. rustica*

With south-westerly gale force winds blowing, the arrival of one on Brownsman on 1 October was somewhat unexpected. Fourth record for the islands having been recorded annually since 1992.

Little Bunting *E. pusilla*

One was present on Inner Farne from 17-19 September. One on West Wideopen on 18 September may have been a different bird but the possibilty of commuting could not be ruled out.

Yellow-breasted Bunting *E. aureola*

One, a probable first winter bird, spent from 1015 until dusk on Inner Farne on 13 September. Seventh record for the islands and last recorded in 1993.

Reed Bunting *E. schoeniclus*

2-6 were noted on six days from 24-29 April, one was on Inner Farne on 9 May, then 1-10 were seen on twelve days between 17 September and 14 November.

Corn Bunting *Miliaria calandra*

One seen on Inner Farne for three hours on 14 October was one of the biggest surprises of the season. Fifth record for the islands with previous birds in May and September 1952, May 1953 and May 1977.

Feral Pigeon

Ca 120 were present in the spring rising to *ca* 400 from November onwards. Breeding was confirmed on a number of islands.

EXOTICA

Snow Goose *Anser caerulescens*

Six flew over Inner Farne on 25 August.

Large Falcon *Falco* sp.

A bird flushed from the lighthouse cliffs on Inner Farne on 18 November was either a saker, a peregrine/gyr hybrid or a lanner/gyr hybrid. The bird was seen for only a very short time as it flew off the cliffs so these are best guesses only!