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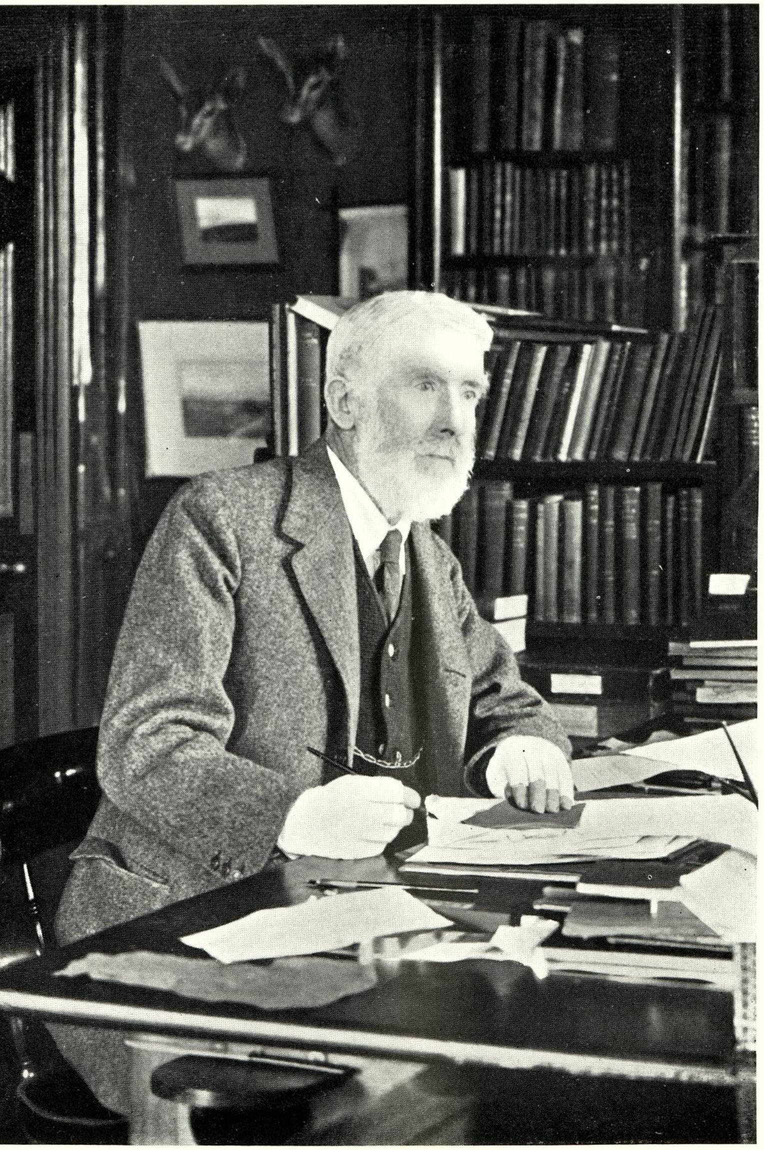


Abel Chapman, M.A.

From a photograph by John Gibson, F.S.A.)

ABEL CHAPMAN

(1851-1929)

Abel Chapman was born at Silksworth Hall, County Durham, on October 4th, 1851. He was the eldest of the family of six sons and two daughters of Thomas Edward Chapman and his wife Jane Ann, who was a daughter of Joseph Crawhall of Stagshaw Close House, Corbridge.

The family of Chapman appears to have been established in Yorkshire for at least six centuries. Abel Chapman was directly descended from Robert Chapman of Whitby, who was born in 1535 and died in 1607, but Chapmans were shipmasters and "seafarers" at Whitby as early as the middle of the thirteenth century, and various members of the family were shipowners until quite recent times.

The original arms of Chapman, which were granted certainly as early as the twelfth century, are "party per chevron argent and gules a crescent counter-charged," and the crest "an arm embowed in armour proper holding a broken spear or encircled by a wreath vert." The motto is *Crescit sub pondere Virtus*.

The first member of the family to become definitely associated with County Durham was Solomon Chapman of Sunderland, who was born in 1684 and died in 1766. His son William had a son by his second wife, Hannah, who was a daughter of John Baynes of Sunderland. This son, who was named Abel, was born at Low Barnes, County Durham, on August 15th, 1769. His second son, Thomas Edward Chapman, was the father of the subject of this memoir.

It is perhaps worthy of comment in passing that the Chapmans were at one time members of the Society of Friends. They afterwards seceded, probably at the time of the Napoleonic War, and tradition gives the following reason: as shipowners they could not charter their vessels for the transport of troops and stores, which was a lucrative business, unless they carried guns. The Society of Friends resolved that the family must give up its guns or the Society. The Chapmans apparently decided to "stick to their guns."[1]

Abel Chapman was educated at Rugby and was there from 1865 to 1869. It was at Rugby he met Frederick Courtenay Selous, whose taste for sport and natural history coincided with his own. The two became intimate friends, and the friendship lasted until Selous was killed in action in 1917. It was at Rugby also that Abel Chapman acquired that love for the classics which he never lost. He delighted in quoting passages from Greek and Latin literature and discussing them with his friends.

When Chapman left school he entered his father's business, which was that of a brewer and wine merchant with headquarters at The Lambton Brewery, Sunderland. Almost immediately he commenced a series of visits abroad, especially to Southern France, Spain and Portugal. These visits were primarily concerned with the business, but Chapman found time to indulge in sporting expeditions and to study and collect birds and beasts in the various districts which he visited. However, he worked hard at the business for nearly thirty years, and eventually sold it in 1897 to Messrs. J. W. Cameron and Co. Ltd. Throughout his commercial career he appears to have spent every moment of his leisure in shooting, fishing and the study of wild nature generally. Up to the time of his retire-

[1] Further interesting details of the family history may be obtained from *Pedigrees of the County Families of Yorkshire*, Vol. II, North and East Riding, compiled by Joseph Foster and published by W. Wilfred Head, London, 1874, and *The History of the Chapman Family*, Vol. I, by Bryan I'Anson, published by the author in London (1918).

ment from business he had written four delightful volumes on sport and natural history, and had amassed extensive and valuable collections of beasts, birds and eggs.

When Abel Chapman first developed a taste for natural history it is difficult to say; it must have been ingrained. He was collecting birds' eggs before he had reached the age of thirteen, as labels in his collection dated 1864 prove. He shot his first grouse on August 12th, 1866, and his career as a writer dates at least from 1869. He was collecting birds in Portugal in 1871, and in Morocco in the spring of 1872. His first essay with big game occurred on March 29th, 1872, when he shot a Wild Boar at Boca de la Foz, Sierra de Ronda, Spain. Having been born and brought up on a country estate, he naturally acquired an interest in wild life, and this was fostered and encouraged by his father and uncles. Chapman himself expresses his gratitude to his uncle, George Crawhall: "a typical sportsman of the old school—the mentor to whom I owe the best of grounding in field-craft."[1] His maternal grandfather's reputation as a sportsman and naturalist also had a great influence upon him. Joseph Crawhall was one of the founder members of the Natural History Society of Northumberland, Durham and Newcastle-upon-Tyne in 1829, and Chapman delighted in exhibiting his grandfather's single barrel flint and steel gun, with which the old man shot twenty-eight brace of grouse on the Hexhamshire moors on August 12th, 1827. This, of course, was before the modern system of driving grouse had been introduced.

Abel Chapman's association with the Natural History Society of Northumberland, Durham and Newcastle-upon-Tyne dates from 1884, when he became a member, and he was present at the opening of the new museum

[1] *Retrospect*, 1851-1928, by Abel Chapman, Gurney & Jackson, London, 1928, p. 9.

building by Their Royal Highnesses the Prince and Princess of Wales on August 20th of that year. A paper by him on "A Voyage to Spitzbergen and the Arctic Seas," with four plates from his own drawings, was published also in 1884 in Vol. VIII, Part 1, of the *Transactions of the Natural History Society*. From that time onwards he frequently presented specimens of birds which were needed for the Museum collections, and he subscribed anonymously to the funds of the Society for many years. When Lord Grey addressed an appeal to the members for increased financial support in 1927, Abel Chapman was in Egypt. As soon as he returned to Houxty the writer received a long letter from him in which he deplored, in no uncertain terms, "that a rich city like Newcastle, and possessed of the finest museum outside of London, should begrudge its upkeep. For the next three years (which will bring me, *si Dios quiere*, to eighty!) I will increase my own subscription to £10, and enclose a cheque for that amount for the present year. . . . I won't write more, as I was a bit of a wreck when I got home on Saturday—these rough and tumble adventures abroad are for the young—but am replying to Lord Grey's appeal amongst the first of a huge pile of letters."

By his will he bequeathed to the Hancock Museum, free of duty, his collection of natural history specimens and big game trophies, together with the sum of £500 for the provision of a glass-fronted wall case to contain the big game specimens. It is a pleasure to be able to place on record his public-spirited feeling in this matter. The writer was in the habit of visiting him every day whilst he was lying in a nursing home just before the close of his life. One evening when he felt that the end was not far off he broached the subject of his will. He said: "You will find that I have left the sum of £500 to provide a case for the big game heads. From the wording of the clause it might be imagined that I was anxious for you to keep everything together as an Abel Chapman collection. I realize quite well that the proper function of a museum is the education of the public and not the erecting of memorials to dead men. Take my money and build a case, and if you have in the Museum better heads in some cases than mine, discard mine and put in the better specimen. I do not wish you to feel that your course of action is restricted in any way whatsoever. If you like, take the £500 and leave the heads. I leave everything to your own judgment." Needless to say, he was assured that his magnificent collection would be valued not only for its great scientific worth, but also because of the patience and enthusiasm which he had expended over many years in bringing it together.

From the time Chapman left Rugby until 1880, his annual expeditions abroad were confined to France, Spain and Portugal, with an occasional visit to Morocco. In 1881, however, he decided to explore the frozen north, and the summer of that year found him in Spitzbergen. He then turned his attention to Northern Europe and embarked upon a series of twenty-three expeditions to Norway, Sweden and Denmark. Nevertheless, he did not lose his interest in Spain, for in 1882 he became joint lessee, with his old friend Walter J. Buck, of the Coto Doñana, a forty-mile stretch of coast forming the delta of the Guadalquivir. This famous hunting-ground occupied much of his time and attention for the next thirty years. In 1899 he was shooting big game in South Africa, and in 1901 he paid a visit to Newfoundland. In 1904 and 1906 he was hunting in British East Africa.

The winters of 1912-13 and 1913-14 he spent in the Sudan, and he returned there again in 1919. Notwithstanding all this foreign travel, he found time to explore many of the lesser-known portions of the British Isles, and sought sporting adventures in the Orkneys, the Shetlands, the Outer Hebrides and various parts of the Highlands of Scotland. Nor did he neglect the county of his adoption, Northumberland: far from it. He was an enthusiastic student of the natural history of the Border Country as early as 1869, and made a permanent home for himself on the North Tyne in 1898. The manner in which he purchased the Houxty estate is worth recounting. He had heard that some sheep farms on the North Tyne were for sale, and in April, 1898, he took his legal adviser with him to view the property. As they were driving along in a dog-cart, Chapman suddenly stood up and exclaimed: "See those birds?" "Yes," said his companion; "crows aren't they?" "No," said Chapman, "they are blackcock, and we'll buy the place." He did, and within forty-eight hours was on the North Sea on a pre-arranged expedition to Norway. As soon as he returned to England building operations were planned and commenced, and gardens and plantations were laid out. Before very long the old dilapidated sheep farm had been converted into an attractive country house. One can hardly say that Chapman settled down there, for he had not then discovered Africa, but it was his home for the remainder of his life, a quiet and secluded retreat. He had blackcock bubbling almost on his doorstep, and from his breakfast table could watch salmon leaping in the river. His *Fauna Houxtiensis*, a private document which has not been published, contains a list of one hundred and thirty-four species of birds observed within a two-mile radius of his house, and a supplementary list, *ex fenestra*, shows that one hundred and ten of these were identified from the windows.

In the preface to *The Borders and Beyond*, which was published in 1924, he says: "The Borders were my first love and to-day, sixty years later, remain my last. Never, during that long period, has the charm

of the Cheviots and of Ettrick Forest, with the far-flung mountain-land that lies between, abated or suffered eclipse."

Chapman's contributions to Science were many and varied. The skins of mammals and birds which he gave to the British Museum provided material for founding one new species and a number of new sub-species or geographical races.[1] He was the first to discover Pelicans in Denmark, and when he published the fact, he was laughed to scorn by the ornithologists of Copenhagen, until he told them where to go and find them for themselves. When in 1893 he informed the world that Camels were living in a feral state and reproducing their kind in the swamps of Southern Spain, many who had "lived in Spain all their lives," some even in Seville, not so far away, suggested that he was bereft of his senses. They did not know, of course, that Chapman never made a statement unless he had absolute proof of its truth. He had studied those camels at close quarters. He was the first ornithologist to discover the breeding grounds of the Flamingo in the marismas of Guadalquiver, and to make known the manner in which the birds disposed their long legs when sitting on their shallow mud nests. The list of such discoveries might be extended considerably, but space will not permit.

As Abel Chapman gained a world-wide reputation as a sportsman and big game hunter there is no necessity to dilate upon his skill with the gun and prowess with the rifle; his books and his extensive collections bear witness to that. It may not be so well known, however, that he was keenly interested in the protection of wild life, if it was undertaken by those possessing knowledge and judgment. He was responsible for the inauguration of the Sabi Game Reserve in South Africa, which is now known as the Kruger National Park. It

[1] The species new to Science is *Lynx pardellus* Miller, the type from Coto Doñana, Huelva, Spain.

was upon his advice also that measures of protection were afforded the Spanish Ibex, which saved this animal from extinction. His remarks concerning the danger threatening the Spanish Ibex and the Reindeer are worth quoting: "Free shooting, unregulated and unlimited, means with modern weapons instant extermination. . . . Then after some creature has perished off the face of the earth, we read a gush of maudlin regret and vain disgust. It is too late; why do not these good folk bestir themselves while there is time to safeguard creatures that yet survive, though menaced with deadly danger? Warnings such as ours pass unnoticed, and platonic tears are bottled-up for posthumous exhibition." He also established a bird sanctuary on his own estate at Houxty.

Abel Chapman's reputation as an author is well known. His first book, *Bird Life of the Borders*, was published in 1889, and it immediately brought him recognition as a writer of outstanding merit. His vivid and characteristic descriptions of bird life on moorland, marsh and sea, at all seasons of the year, have an irresistible charm. A second edition, in great part re-written and enlarged, was published in 1907. *Bird Life of the Borders* is a book to be read again and again. His second book, *Wild Spain*, which was written in collaboration with Walter J. Buck, appeared in 1893. In 1896 *The Art of Wild-Fowling*, an interesting and masterly account of the art and craft of punt-gunning, made its appearance. In the following year *Wild Norway*, one of the finest books ever written on the wild life of the Scandinavian Peninsula, saw the light of day. Then in 1908 came *On Safari*, his first book dealing with African game animals. Two years later, in 1910, *Unexplored Spain*, written conjointly with Walter J. Buck, was published. This is a weighty tome embodying the results of nearly forty years' hunting and exploration in some of the wildest and least known country in

Europe. Following this came a hiatus of a decade, during which Chapman made three separate expeditions to the Sudan. The Great War, and all that it entailed, also came into this period. At length, in 1921, another delightful book entitled *Savage Sudan* was produced to a world which by now was beginning to expect a perpetual and regular flow of literature from the North Tyne. Shortly after this came *The Borders and Beyond—Arctic, Cheviot, Tropic*, published in 1924, and finally in 1928, *Retrospect—Records and Impressions of a Hunter-Naturalist*, 1851-1928. That makes a total of ten lengthy volumes, profusely illustrated with his own drawings produced in forty years. Furthermore, they were not compilations, but faithful and graphic records of his own personal experiences, representing a vast amount of time and labour in the field. However, even those ten volumes were not his sole literary output. Throughout a period of sixty years he contributed papers and articles innumerable to scientific and sporting journals, and was a regular contributor to *The Field*.

His drawings merit a paragraph to themselves. Chapman never claimed to be a trained artist, but whatever may be the judgment of the academician, his drawings possess an inimitable charm. They convey to his readers a true and vivid conception of the habits and movements of live creatures. The drawings were almost invariably made from field sketches. Whether these were made whilst lying frozen stiff in a gunning-punt on Fenham Flats in mid-winter, or whilst suffering torments from the rays of the tropical sun and the attentions of myriads of flies in an equatorial swamp, they were painstaking and accurate records of his observations.

One sometimes wonders how Chapman managed to accomplish so much during his lifetime. It has been said that he never spent an idle moment, and that cannot be far from the truth. His writing materials were frequently handed to him in bed with his early cup of tea, and more than once he has been discovered wielding the pen at daybreak. On one occasion, in his enthusiasm he followed a mighty salmon into the watery depths of North Tyne, and the penalty was a sharp attack of congestion of the lungs. This enabled great progress to be made with *Retrospect*.

In the autumn of 1928 he was suddenly stricken with illness, and an operation was deemed to be necessary and urgent. It is characteristic of him that the morning of the day upon which he had to enter a nursing home, he spent down at the river with a salmon rod. When he arrived at the nursing home in the evening, the matron and her attendants, much to their astonishment, were compelled to remove from the car sundry deed boxes containing manuscript, stacks of virgin paper and other literary paraphernalia before the patient could be extricated. The operation was performed in due course, and, almost as soon as Chapman had recovered from the effects of the anæsthetic, he installed a shorthand-typist by his bedside. He was then engaged upon another book entitled *Memories of Four Score Years Less Two*. This book will be published, it is hoped, before the end of the present year.

In 1922 his contributions to literature were recognized by the University of Durham, and an honorary degree of Master of Arts was conferred upon him.

So much emphasis has been laid upon Chapman's all-absorbing interest in sport and natural history that it appears desirable to interpose here some account of the part he played in human affairs. On August 4th, 1914, England declared war upon Germany, and on August 19th Abel Chapman enrolled as a trooper in the Legion of Frontiersmen for service in Africa. He was then, of course, well over sixty years of age. To his bitter and lasting disappointment, he could not attain the medical standard required for active service

Abel Chapman, Salmon Fishing.

This, the last photograph of him, was taken by the abroad, and he was compelled to stand by, after having been three times rejected, whilst his old schoolfellow and lifelong friend, Selous, was accepted. Chapman, although debarred from "bearing his share" as he put it, did everything in his power to further his country's cause at home. He enrolled as a member of the Special Constabulary, and purchased a fully equipped ambulance wagon, which he presented to the Royal Army Medical Corps. Later, when he heard that there was a great shortage of timber, which was urgently required for military purposes, he gave to the Government without hesitation one of his proudest possessions, namely the Big Wood at Houxty, or at any rate the major portion of it. This portion of the wood contained approximately 5,000 pine and spruce trees, many of them nearly a hundred feet high. Only those who knew the man intimately, and can realize all that the Big Wood at Houxty meant to him, will be able to appreciate the magnitude of his unselfishness. But then Chapman was like that. He always had a clear sense of duty and responsibility, and he never spared himself. When the wood had disappeared, some incompetent official sent him a receipt for £150! As soon as practicable he replanted the ground, and lived to see some of the young trees grow to a height of six feet or so. What is more, he was able to send a cart-load of "Christmas trees" out of the new wood to the Poor Children's Holiday Association year by year.

To each man who left Wark to join any branch of the Service he gave a substantial sum of money, and was ever ready to relieve any case of distress which came under his notice.

Later in the war, when a shortage of food became apparent, he felt it encumbent upon him to bring more of his land under cultivation. Consequently, he gave instructions for another kitchen garden to be made in the paddock between the house and the river. This garden was known as "Mesopotamia," and Chapman used to go down there, take off his coat, and help to dig and plant the potatoes. Furthermore, every member of his staff of servants was expected to take part in this patriotic labour.

In April, 1918, he gave £10,000 5 per cent. War Stock to the Minister of Pensions' Special Fund for the relief of disabled sailors and soldiers.

As Chapman firmly believed that his left hand should never know what his right hand was about, only a small proportion of his good works have seen the light of day. Some things, however, cannot be hidden, and it is well known to his friends that no appeal to his generosity was ever made in vain. If ever a tentative suggestion was made that his charity was becoming somewhat extravagant, and that he was probably being imposed upon, he would say: "I have been given so much, and it is my duty to assist those less fortunately circumstanced than I am myself. I could not bear to turn away from my door anyone who might be hungry or in need of help."

When he lay a very sick man in the nursing home, just before Christmas, 1928, he dispatched a cheque for £1,000 to the Prince of Wales' Fund for the relief of distress in the mining areas, and by his will he bequeathed £5,000 to the Newcastle-upon-Tyne Royal Infirmary, and a like amount to the Sunderland Royal Infirmary.

He was a Justice of the Peace for the County of Northumberland, but sitting on the bench was not a task he relished, and was only undertaken out of a keen sense of duty. Many of the fines he inflicted came out of his own pocket, and he would frequently return from the court at Bellingham and say: "I will never go near the place again! Who am I to sit in judgment upon men who have not enjoyed the advantages which have fallen to my lot?"—or words to that effect.

When talking to the writer a few weeks before the end, he said: "I have had a glorious life. I have been blessed with good health and a strong constitution, and have always been able to do what I wished. I have had a good innings, and when the time comes I shall be ready."

If the writer has allowed his pen to run riot whilst describing Abel Chapman's real character and temperament, his excuse must be his anxiety to do justice to the memory of one who often described himself as a savage living in the wilderness, and whose delight in argument and the caustic criticism of "theorizers" and ignoramuses sometimes led to misunderstanding. It is true that he could bark when the occasion demanded it, and bark furiously, but he was never known to bite. He was very sensitive and tender-hearted, and like some other men who have spent much of their lives in the wild places of the earth, he was of a shy and retiring nature.

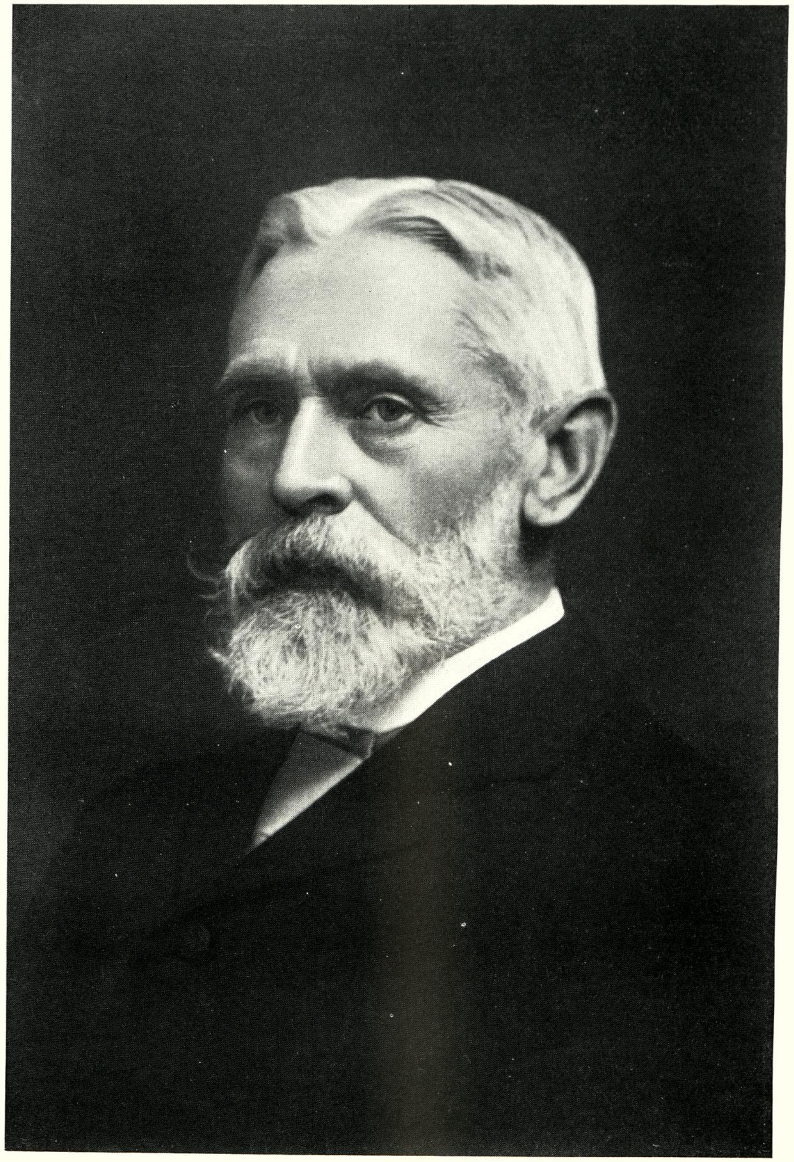
Early in January, 1929, he had recovered sufficiently from his operation to return home to Houxty, accompanied by a trained nurse. He then concentrated every effort upon the completion of the book in hand. A fortnight later, however, he had a relapse, and passed several days in a state of semi-consciousness. It was then realized by his attendants that there was no hope of his recovery.

At 12.45 on the morning of January 23rd, 1929, Abel Chapman passed over the Border into the Beyond. His last words were typical. They were: "Take care of Dash"—his favourite spaniel. When on January 26th he made his last journey from Houxty to the little church at Wark, the ground was bound with an iron frost, and the whole countryside lay under a thin pall of dry, powdery snow. The sky was heavy with more snow as yet unfallen, and the gloom was only occasionally relieved by fitful bursts of pale sunshine. He was laid beside the remains of his mother, whom he loved so well, and so passed from human sight all that was mortal of a great sportsman and naturalist of the old school, nowadays unfortunately so very rare.

Abel Chapman always played the game, and he played it with all his might. His memory will live long in the hearts of his friends, and his life's work remains on record in his books, to be an inspiration, it is hoped, for generations to come.

Bis vivit qui bene vivit.

T.R.G.



Colonel Charles Henry Ellison Adamson.

(From a photographic portrait by Elliott & Fry.)

CHARLES HENRY ELLISON ADAMSON

Colonel Charles Henry Ellison Adamson, C.I.E., who was a Vice-President of this Society, and also one of its honorary curators, died on June 25th, 1930, at his residence, Crag Hall, in North Jesmond.

A love of natural history was implanted in Colonel Adamson from his boyhood. His father, Charles Murray Adamson, who was a close friend of John and Albany Hancock, devoted much of his time to the study of ornithology, and published several volumes of sketches of shore birds, which he was accustomed to draw from life. Mr. Charles Murray Adamson was one of the sons of John Adamson, one of the founders of this Society and an original member of its Committee.

Colonel Adamson, who held a commission in the Royal Artillery, spent the early years of his life in Burma, first in a military capacity and then as Assistant Commissioner and Chief Magistrate in Mandalay, at the taking of which he was present; and he rendered valuable and important service in connexion with the pacification of the country. Colonel Adamson spent, in all, twenty-eight years in Burma, during twenty of which his leisure was occupied in forming a collection of Burmese butterflies, which he presented to the Society in 1902, after he had left the Service and taken up his residence at Crag Hall. Colonel Adamson also wrote a catalogue of Burmese butterflies which was published in Volumes I and III of the new series of the Society's transactions.

Colonel Adamson was a keen gardener, and in his garden at Crag Hall the rock sides of the Ouseburn were skilfully utilized to house many scarce and uncommon plants and flowers, and until a comparatively short time before his death, he gave a large proportion of his time and care to its cultivation.

A.H.D.

A Chemical Study of the Whin Sill

BY J. A. SMYTHE, Ph.D., D.Sc.

CONTENTS

INTRODUCTION

The whin sill of the northern counties of England has been the subject of many studies in its field-aspects, though only one of these, that of Hutton, nearly a century ago, has any pretensions to completeness. On the petrological and chemical sides, our main source of information has been the justly celebrated paper of Teall, now nearly half a century old. Though much has been added to our knowledge of the petrology of the formation since then, and this line is still actively pursued, the chemical side of the subject has been, in great measure, neglected.

The value of Teall's chemical work, to which ample testimony will be given in the following pages, is indisputed. His figures have been frequently checked, during the course of this study, and his findings critically reviewed from many different angles, and the essential soundness of both has been confirmed. Besides its accuracy, Teall's work has the merit of suggestiveness, so that it provokes more extended inquiry; it is also pioneering and leaves much territory unexplored for those who tread his path later.

The immense area over which the whin sill crops out, the general freshness of the rock, the numerous fine natural sections through the formation, the apparent uniformity of the rock over large areas and the variations which a careful scrutiny reveals, and, be it added, the beauty of the rugged country, in which it is always the most prominent feature, all invite to a more thorough study of the subject. One is interested to know whether the rock is so uniform as it appears, whether it undergoes variation in mass, whether the few analyses of hand-specimens which exist can be justly taken as representative of the whole formation, what is the nature of the local variations, and how the rock has been affected by weathering and other agencies since its consolidation.

The answer to these queries has been sought by a survey of the whole formation during the last twelve years or more; much material has been collected for chemical examination, and an attempt has been made to sample the whole outcrop. Many supplementary problems have naturally presented themselves for study, and these will be described in the following pages.

COLLECTION AND GROUPING OF THE MATERIALS

The material collected was in the form of small chips, such as are suitable for grinding into thin sections. These have been taken from practically every exposure where the rock was deemed fresh enough, and, where possible, from various positions across the section of the sill, excluding the selvages, which are often weathered, and even when fresh are difficult to distinguish from the weathered rock. No pains were spared in the field to acquire fresh rock, free from the weathered outside coating. The work of collecting was thus slow, about thirty chips being regarded as a good day's bag. Quarries were not favoured more than natural sections, and, indeed, much of the country in which the whin is exposed is so remote from road and rail that quarries do not exist. There is a natural tendency to collect from the less massive parts of the rock, owing to the greater ease of breaking into these, but this can often be corrected by concentrating on the stream-bed sections. Care was taken not to utilize fallen blocks or boulders—a necessary precaution in a country where glacial erratics are common.

The material assembled for the main part of the work consisted of 2,950 chips, weighing a little over 24 kilograms (53 lb.), the average weight of each chip

being 8 grams. This was combined in 38 groups, the selection of which was somewhat arbitrary, though primarily geographical. Some slight overlapping of groups arose, partly as the result of observation, partly by design. Thus, the collection for Teesdale included, originally, some samples from the neighbouring Pennine escarpment; later, it was thought advisable to make fresh collections for the upper and the lower Tees, the former covering the great gabbro area, roughly down to the High Force. There are also collections for the Pennine escarpment as a whole and for several divisions of it, the object of which was to determine the efficiency of the method of sampling. In upper South Tynedale, the rock of Gilderdale is kept separate from that of the many exposures above Alston, owing to its marked textural difference, and similar considerations apply elsewhere. The list of these groups, arranged in the general order from south to north, and the data, to be discussed later, concerning them are given in Table A. Under the title " Miscellaneous " at the foot of this list are included some larger specimens, formerly collected for other purposes.

PREPARATION OF THE GROUP-SAMPLES AND THE REPRESENTATIVE SAMPLE

The raw material of each group was broken up separately in a large iron mortar, with a heavy iron pestle, until it passed through a sieve having 4 meshes to the linear inch (for shortness, this will be called a 4-sieve and a similar expression will be used hereafter), and was then screened through a 10-sieve. The portion stopped by the latter will be termed " coarse material " (its p.c. amount is given in Table A), that which passed the finer sieve is "dust." Thus there were obtained 38 group-samples of coarse material, which served for the study of variation and also for the

TABLE A

Reference Number	Locality of Group-Samples	Number of Chips	Weight in grams	Coarse Material p.c.	S.G. d. $\frac{t^\circ}{4^\circ}$
1	Lunedale	62	645	53·0	2·940
2	Copthill, Weardale	31	455	48·4	2·915
3	Stanhope (Little Whin Sill) ...	43	430	54·6	2·976
4	Upper Teesdale	141	1200	56·7	2·952
5	Teesdale	240	1330	54·6	2·948
6	Lower Teesdale	23	260	59·6	2·955
7	Upper Tynedale	293	2070	44·7	2·956
8	Gilderdale	53	780	40·4	2·921
9	Harpertown	12	150	53·4	2·956
10	Thinhope	66	550	50·4	2·925
11	Blackburn	60	500	53·8	2·928
12	,, (Lower Sill)	26	210	47·6	2·884
13	Pennine Escarpment	83	500	57·0	2·940
14	,, South (to Mell Fell) ...	42	350	58·6	2·943
15	,, Middle (to Ardale) ...	135	1070	56·6	2·948
16	,, North (to Croglin) ...	100	1480	59·1	2·938
17	,, ,, (Old and New Water)	67	540	56·8	2·938
18	Roman Wall Escarpment. Denton-Cawburn	61	420	57·7	2·935
19	Roman Wall Escarpment. Cawburn-Hotbank	114	1010	59·9	2·948
20	Roman Wall Escarpment. Hotbank-Carrowbrough	117	830	55·2	2·933
21	Bavington E. sheet. Northside-Homildon	74	420	54·7	2·921
22	Bavington W. sheet. Gunnerton-Hawick	83	510	51·6	2·927
23	Kirkwhelpington district	30	180	55·6	2·900
24	Font-Coquet	105	820	57·0	2·929
25	Alnwick Moor	38	400	50·6	2·920
26	Ratcheugh-Howick	84	640	44·2	2·914
27	Cullernose-Dunstanburgh	89	470	54·9	2·871
28	Embleton-Snook Point	99	650	52·3	2·894
29	The Dhu	24	230	48·7	2·920
30	Emblestone	40	500	33·4	2·906
31	Newton-Snook Point	31	230	53·5	2·910
32	Bamburgh-Spindlestone	143	1150	55·6	2·934
33	Farne Islands	37	380	50·8	2·930
34	Spindlestone-Belford	47	410	56·3	2·933
35	Belford-Detchant	38	380	55·3	2·933
36	Detchant district	24	170	65·3	2·936
37	Kyloe Hills	55	490	56·3	2·906
38	Miscellaneous	18	1000	47·0	2·899

preparation of the sample representative of the whole rock, and 38 dusts which (excepting the last, which was used for cleaning out mortars) were combined into 8 new groups, covering larger geographical areas. The products of crushing and screening were weighed on a decimal balance and the result of this first series of operations is as follows:

24,015 grams of chips yielded
12,962 grams coarse material (57·6 p.c.)
9,545 grams dust (42·4 p.c.)

22,507 grams Total

The loss on crushing is 1,508 grams, or 6·3 p.c. Some of this is due to the ejection of fragments from the mortar, though this was lightly covered, but a fair amount must be set down to the escape of fine dust, which arose in clouds from the mortar.[1]

To utilize the coarse material for the preparation of a sample representative of the whole collection, each weighed group-sample was sampled by quartering three times, furnishing thus about 12·5 p.c. of the original weight; 10 p.c. of each was then weighed off and the whole brought together and well mixed.

Thus 12,962 grams of coarse material yielded 1,390 grams (10·7 p.c.) of sample representative of the whole collection. This was crushed to pass the 10-sieve and the following screenings made:

A. Through 10-, stopped by 20-sieve, 732 grams (54 p.c.)
B. Through 20-, stopped by 30-sieve, 120 grams (9 p.c.)
C. Through 30-sieve, 500 grams (37 p.c.)

1,352 grams Total

[1] The labour involved in this crushing was very great, and I wish to thank my laboratory steward, Mr. W. Ryott, for carrying out this part of the work.

This second crushing was more carefully performed than the first, and the loss, 38 grams, or 2·7 p.c., is correspondingly smaller, and a larger fraction of it due to escaping dust. Counting in the loss on crushing, 46 p.c. of the original collection was discarded at the first crushing, and 47 p.c. of the material brought forward at the second. In all, 72 p.c. of the original material was eliminated in the two operations, or, in other words, only 28 p.c. of it was left to furnish the material for the representative sample.

In the final stage of the preparation of this, screening A (732 grams) was twice quartered and a sample of 190 grams obtained. This was washed free from dust, dried and carefully inspected. It appeared to be perfectly clean, and the particles were free from scale; characteristic varieties like the gabbro and the syenitic rock could be clearly discerned. Several counts of 1,000 particles gave an average weight of 4 grams, so that the 190 grams contained 47,500 fragments and, as there were 2,950 chips, each chip contributed 16 fragments to the sample. The whole sample, 190 grams, was now carefully crushed by hand, with an agate pestle in an agate mortar, and ground to a fine powder in a mechanical agate mortar. It will be termed "average whin," and, within the limitations of the methods employed, should be representative of the whole outcrop of the rock. The S.G. of the coarse grade A, from which it is made, is 2·9339; that of the finer grade B, 2·9333. The difference falls within the experimental error, and the S.G. of the average whin, in terms of water at 4° C., may be taken as 2·934.

SPECIFIC GRAVITY OF THE ROCKS

The application of chemical analysis to the study of the assembled material must, from the exigencies of time, be severely restricted. To trace possible variation, some easily applied physical test is desirable, and

the specific gravity is the one that fulfils the conditions of accuracy and quickness of determination most completely. Determinations of this property have been made on all the group-samples and on many other specimens, selected for special reasons. In all these, the bottle-method was used, the samples, usually about 10 grams in weight, being first washed free from dust. Duplicate determinations were made in all cases, and though rapidity of work was a weighty consideration, the results show a sufficient degree of accuracy for the purpose, the average difference between duplicates for the 38 group-samples being 0·0026. All results are calculated in terms of the density of water at 4° C. Those for the group-samples are given in Table A. The extreme range of S.G. is from 2·976 to 2·871, that is 0·105, which greatly exceeds the probable experimental error.

The method of field-sampling can be tested by these figures. Thus, the value for the whole of the Pennine escarpment, 2·940, is almost exactly the mean of the four divisions of it, 2·939, and that for the original Teesdale collection, 2·948, which contains some rock from the escarpment, is just slightly below that of Upper and Lower Teesdale (2·952 and 2·955).

The data fall into several quite well-marked larger groups, which are given, in order of descending value, in Table B.

The Little Whin Sill of Stanhope and Rookhope heads the list, and its S.G. is markedly higher than the highest values for the whin sill proper. For this, the place of honour falls to the eastern part of the Crossfell area, i.e., South Tynedale above Alston, and the neighbouring Teesdale runs close to it. South-west and west of this area come Lunedale and the Pennine escarpment, and the continuation of the escarpment thence to the Tyne, along the line of the Roman Wall, brings but little alteration in value. Then comes a break and high gravities appear again in the northern area (Farnes and Belford), with a relapse in the Kyloe Hills in the extreme north. Low values range in mid-Northumberland, and especially in the coastal region, and the district east and north of Cold Fell, in lower South Tynedale, gives values comparable with these, though there is recovery in the limited exposure near

TABLE B

Locality	Group-samples Ref. No.	Group-samples S.G.	Mean S.G.
Stanhope	3	2·976	2·976
Upper South Tynedale	7	2·956	
	9	2·956	2·956
Teesdale	5	2·948	
	6	2·955	
	4	2·952	2·952
Lunedale	1	2·940	2·940
Pennine Escarpment	13	2·938	
	14	2·943	
	15	2·945	
	16	2·938	
	17	2·938	2·940
Roman Wall Escarpment ...	18	2·935	
	19	2·948	
	20	2·933	2·939
Farnes to Detchant	32	2·934	
	33	2·930	
	34	2·930	
	35	2·933	
	36	2·936	2·933
Mid-Northumberland (N. Tyne to Coast)	21	2·921	
	22	2·927	
	23	2·900	
	24	2·929	
	25	2·920	
	26	2·914	2·918
Lower South Tynedale	8	2·921	
	10	2·924	
	11	2·928	
	12	2·884	2·916
Copthill, Weardale	2	2·914	2·914
Kyloe Hills	37	2·906	2·906
Cullernose Point-Bamburgh ...	27	2·871	
	28	2·894	
	29	2·920	
	30	2·906	
	31	2·910	2·900

Harpertown. The exposure of the whin sill in Weardale, at Copthill, shows a low S.G.

Generally speaking, Teesdale and Alston Moor constitute an area of high S.G. from which diminution takes place towards south, west and north. In the last direction, this is more or less progressive as far as the Farne Islands and Bamburgh, when recovery takes place and the values approach closely to those of the Pennine and Roman Wall escarpments. The exceptions to this arrangement, though significant, are, comparatively speaking, local. It may be remarked that in the low gravity areas there is much greater variation among neighbouring group-samples than in those regions where the S.G. is high.

If the specific gravities of the group-samples be compared with that of the average whin, it will be seen that the northern area (Farnes to Detchant) is almost identical with it; the southern areas, Stanhope, Upper Tynedale, Teesdale, Lunedale, the Pennine and Roman Wall escarpments, are above it, and the long stretch of mid-Northumberland and the coast, together with the smaller patches in the lower South Tyne, Upper Weardale and the Kyloe Hills are below it.

The uniformity of the S.G. in certain areas, where it is high, is striking, and may be illustrated by the data for the Pennine and Roman Wall escarpments. The combined length of these, about 50 miles, afforded 719 chips classified in 8 groups (Nos. 13 to 20). The average S.G. of these is 2·940, and the maximum deviations from this are −0·007 and +0·008. With this may be contrasted the low-gravity coastal reach. The length of this is 5 miles, and 283 chips from it were classified in 5 groups (Nos. 27 to 31). The average S.G. of these is 2·900, and the deviations −0·029 to +0·020.

Where multiple sills occur on a large scale, there is evidence from S.G. both for and against identity of rock. The best investigated case is in the Bavington district, where the sills are thick, about a mile apart, and each forms an almost continuous scarp, the western one 12 miles long, the eastern one 6 miles long. The specific gravities of the two (Nos. 21 and 22) are almost identical. On the other hand, the two sills of the Blackburn (Nos. 11 and 12) show great differences and the like applies to the Little Whin Sill (No. 13) when compared with any of the neighbouring values for the whin sill proper, of which the Stanhope rock is undoubtedly only an offshoot or "split."

Apart from the group-samples, the S.G. of many specimens has been determined, information about which will be given in the appropriate place. Some of the results, bearing on the subject at present under discussion, are given in Table C.

TABLE C

Locality and Nature of the Rock	S.G.	S.G. of group-samples (number in brackets) of the district in which the exposure is situated
Crook. Medium coarse rock from boring...	3·019	—
Teward's Bridge, Harwood Beck	2·951	2·952 (4)
White Force, Teesdale. Contact rock ...	2·947	2·952 (4)
Fontburn. Western sill	2·929	2·929 (24)
Thinhope. Thin sill	2·920	2·924 (10)
Saddle Rock. Dyke offshoot	2·922	2·920 (29)
Snook Point	2·900	2·910 (31)
Gilderdale. Gabbro	2·958	2·921 (8)
Fairnley	2·926	2·900 (23)
Barrasford. Thin sill	2·913	2·927 (22)
Swin Burn. Thin sill	2·905	2·927 (22)
Kirkwhelpington. Lower sill	2·884	2·900 (23)
Kirkwhelpington. Dyke offshoot ...	2·803	2·900 (23)
Winch Bridge. White whin	2·668	2·955 (6)
Tees, near Mattergill Sike. Coarse pink rock	2·907	2·948 (5)
Gilderdale. Coarse pink rock	2·821	2·921 (8)
Snook Point. Inclusions in whin	2·725	2·894 (28)
Cushat Steel. Felsitic rock	2·615	2·871 (27)

The rock from the Crook boring has the highest S.G.

yet observed (omitting a basaltic intrusion at the White Force, to be described later). In the next six rocks in the table, there is good agreement between the values obtained for individual specimens and for the group-samples of the larger areas from which the specimens were taken. In the six following there is no such correspondence, and occasionally there are large discrepancies which, in the case of the thin sills and dykes may be partly ascribed to weathering. The influence of weathering (or metasomatism) is well exhibited in the "white whin" from Winch Bridge, which contains carbon dioxide equivalent to 22·5 p.c. of calcite. The effect of deviation of rock from the normal type on S.G. is illustrated by the last four examples, which all refer to the exceptional rocks, rich in felspathic materials and much lower in S.G.

The recent work of Tomkeieff,[1] in which the S.G. determinations were made on hand-specimens, bears out many of the results related above. The high S.G. of the Crook rock is confirmed, five samples of the medium rock from the boring giving an average of 3·016; a similar number of determinations of the gabbro from the same locality showed the much lower average value of 2·913, and the variations among them were greater. Omitting the data referring to contact rocks (which are always open to the suspicion of weathering) Tomkeieff records 22 determinations of rocks of medium grain, for which the average S.G. is 2·975 and the maximum variation 0·125, and 17 of coarse gabbroid rocks, for which the corresponding figures are 2·958 and 0·241. These may be compared with the data for the group-samples, where the range is 0·105 and the average 2·934. As might be expected, much greater variation is found in the individual sample than in the group-samples, and the lower average value for the whin as a whole is an indication that the average

[1] S. I. Tomkeieff, *Min. Mag.*, 1929, *22*, 100.

whin contains its complement of the exceptional rocks of low specific gravity.

The greater uniformity of the rock in the Teesdale area is well shown in Tomkeieff's results. Thirteen specimens have a range of only 0·097, and an average of 2·953. For the group-samples of this area (Nos. 4, 5, 6) the range is 0·007 and the average 2·952.

To review briefly the results of this work on specific gravity, it would appear that the methods of field-sampling and grouping adopted are adequate to afford rock representative of the areas within the groups, and thus to test uniformity or variation over the whole outcrop. Judged in this way, there is evidence of variation on a large scale, and progressively in direction, as already indicated. The causes of this variation are the subject with which much of the chemical evidence to be detailed later is concerned. So far it is permissible to assume the degree of weathering or other alteration of the rock may be one, and that variation in the felspar-content may be another. To the second of these the anomalous values for Gilderdale and the lower sill of Blackburn may be referred, for inspection alike in the field and of the broken group-samples in the laboratory shows a relatively large content of the pink felspathic rock. The rock from Upper Teesdale is also rich in this variety, so that this factor is not unique in its influence. The high values for the most easterly occurrences in the southern area, viz., those of Stanhope and the boring at Roddymoor, near Crook, suggest that depth of original cover, or nearness to the supposed magma-reservoirs, may also be a factor of importance.[1]

[1] According to Tomkeieff's observations, five specimens from the Crook boring, and one each from Copthill (Weardale), Caldron Snout, Tynehead, Gilderdale and Blackburn have values for S.G. exceeding 3.

HARDNESS OF THE ROCKS

In the last column but one of Table A are given the results of the crushing experiments carried out in the preparation of the group-samples. They are expressed in terms of the amount p.c. of coarse material, that is, rock passing the 4-sieve and retained by the 10-sieve. The figures are obviously related to the resistance to crushing of the rock, and may be taken in that sense as a measure of its hardness. From the nature of the method employed, exact figures are not to be expected, but it may be pointed out that in a long operation of this sort, there is a tendency to work in a uniform manner—so many blows of the pestle being followed by screening, return of the oversize material and feeding of fresh rock in batches, roughly equal in amount.

These crushing results indicate a connexion between hardness, as defined above, and specific gravity. This may be expressed in the following way:

Hardness	No. of Group-Samples	Relation to S.G.
65 to 55	17	14 group-samples have S.G. above 2·933, the remaining 3 are all below.
55 to 50	13	8 group-samples have S.G. 2·933 to 2·920, 3 are above this and 2 below.
50 to 34	8	6 group-samples have S.G. below 2·920, the remaining 2 are above this.

The results may be put in another way:

21 group-samples of high S.G. (2·978-2·928) have high hardness-values, 65-51.

5 group-samples of intermediate S.G. (2·927-2·894) have intermediate hardness-values, 57-51.

10 group-samples of low S.G. (2·927-2·884) have low hardness values, 51-33.

The general relation that high S.G. is accompanied by a great degree of hardness and the converse seems indubitable, and the subject would probably repay investigation under standardized conditions of crushing. It might be expected that grain-size, texture, variation in mineral-content, degree of weathering and the presence of minor joints would all be factors influencing the resistance to crushing, and some of these would undoubtedly exercise an effect on the S.G.; but the experimental data are hardly accurate enough to warrant a full discussion of the subject. Geographically, the northern area and the Pennine and Roman Wall escarpments stand out pre-eminent in hardness. The somewhat low values for Teesdale and Lunedale may be related to the general coarse grain of the rock in these dales. The coastal area and mid-Northumberland are low both in hardness and S.G. South Tynedale is exceptional as being low in hardness and high in specific gravity.

GROUPING OF THE DUSTS

The fine screenings, passing the 10-sieve, from the preparation of the group-samples, were combined, as stated above, so as to cover larger geographical areas. The data relating to this are given below:

Reference Letter	Geographical Area	Reference Number of group-samples from which the dust is obtained	Weight of dust Grams
A	Lunedale and Teesdale	1 to 4	1430
B	Weardale	5, 6	380
C	South Tynedale	7 to 10	1380
D	Pennine Escarpment	11 to 17	1800
E	Roman Wall Escarpment ...	18 to 20	850
F	North Tyne to Coast	21 to 26	1230
G	Coast	27 to 33	1540
H	Northern Area	33 to 37	555
			9165

Each large dust-sample was quartered, in the same manner as described for the group-samples, and 10 p.c. of each sample taken and mixed. The product, 920 grams, was again sampled by quartering and 50 grams obtained, representative of the whole of the finer crushings of the rock. This is termed the " average dust."

CHEMICAL COMPOSITION OF THE WHIN SILL

1. *The Normal Rocks*

For the study of the many problems which have arisen in the course of this work, twelve samples of normal whin have been completely analysed and the results are given in Table D.

The whin sill as a whole is a rock of doleritic aspect. Large collections, like the group-samples, are necessarily derived in the main from this rock of medium grain, though they include all varieties, except the markedly acidic veins, met with in the group-area and in proportionate amount, so far as this can be roughly gauged in the field. Five collections of this type have been analysed. Nos. 1 and 2 are respectively the average whin and the average dust, and thus represent the sampling of the whole outcrop and show the effects of the crushing process. Nos. 3, 4 and 5 represent three geographical areas—Stanhope in Weardale (the Little Whin Sill), Upper Teesdale and the coastal region from Cullernose Point to Dunstanburgh. The S.G. of these samples varies over a wide range. The remaining 7 in the table are from smaller collections of chips (Nos. 6 to 9 and 11), or hand-specimens (Nos. 10 and 12), and they cover the fine-grained varieties (Nos. 6 to 8), those of medium grain (Nos. 9 to 11) and the coarsest variety of all (No. 12).

At the contacts the whin is very fine-grained,

TABLE D—COMPOSITION OF NORMAL ROCKS

	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2 ...	50·32	49·50	49·00	50·25	47·64	50·10	50·50	51·25	49·54	49·70	50·00	50·85
TiO_2 ...	2·48	2·48	2·79	2·40	2·82	2·48	2·48	2·91	2·84	2·73	2·60	2·41
Al_2O_3 ...	15·41	14·51	15·51	15·40	14·74	15·55	15·52	15·19	16·64	15·87	14·97	14·55
Fe_2O_3 ...	3·09	3·62	2·89	3·74	3·95	1·51	1·75	1·91	3·60	2·50	2·39	2·70
FeO ...	8·92	10·11	10·24	9·32	9·19	10·62	10·24	10·30	8·20	10·60	10·52	9·66
MnO ...	0·18	0·18	0·16	0·18	0·16	0·18	0·16	0·15	0·20	0·19	n.d.	0·19
MgO... ...	4·89	4·65	4·58	3·47	4·19	4·71	4·95	4·26	5·51	4·48	4·16	5·08
CaO... ...	8·86	8·82	8·61	8·87	8·69	8·15	7·77	6·40	9·00	8·70	9·20	10·20
BaO... ...	0·03	0·03	n.d.	n.d.	n.d.	0·04	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Na_2O ...	2·03	2·38	2·04	2·39	2·38	2·76	2·38	2·59	2·33	2·54	2·36	1·92
K O... ...	1·06	1·14	0·85	1·35	1·06	0·99	1·14	1·31	0·97	1·33	1·16	0·83
H_2O (+) ...	1·30	1·51	1·40	1·47	2·20	2·10	1·92	1·87	0·47	1·08	1·92 (H₂O + and −)	1·40
H_2O (−) ..	0·75	0·68	0·35	0·61	1·25	0·50	1·05	1·32	—	0·38		0·50
CO_2	0·46	0·46	1·38	0·18	1·35	none	0·14	0·63	0·16	tr.	0·40	tr.
P_2O_5 ...	0·22	0·33	0·38	0·23	0·33	0·31	0·26	0·45	0·28	0·20	0·28	0·25
S	0·15	0·15	0·14	0·09	0·33	0·17	0·14	0·07	0·16	0·08	n.d.	0·08
Less O for S	0·05	0·05	0·05	0·03	0·11	0·06	0·05	0·02	0·05	0·03	—	0·03
Total ...	100·10	100·50	100·27	99·92	100·17	100·11	100·35	100·59	99·85	100·35	99·96	100·59
S.G. ...	2·934	n.d.	2·975	2·952	2·871	2·947	2·891	2·860	2·900	3·019	2·971	2·958

1. Average whin.
2. Average dust.
3. Group-sample 3 (Little Whin Sill).
4. Group-sample 4 (Upper Teesdale).
5. Group-sample 27 (Cullernose-Dunstanburgh).
6. White Force, Teesdale (Lower contact rock).
7. Great Bavington (Basalt).
8. Cullernose Point (Basalt).
9. Snook Point (Dolerite).
10. Crook (Dolerite from boring).
11. White Force, Teesdale (Dolerite).
12. Gilderdale (Gabbro).

bleached in appearance, and sometimes, though not always, weathered. Its appearance is characteristic and enables the upper surface of the rock to be inferred with certainty in many exposures where observation is limited, as in the beds of upland streams in peat-covered country, and in small bosses which have been stripped of their sedimentary cover. As already stated, these selvages were avoided in making the collections for the group-samples; a special collection from the lower contact was made for the analysis No. 6.

The two other fine-grained rocks (Nos. 7 and 8) will be described in greater detail later. It will suffice to state here that, though belonging to the same suite of intrusions, they are probably a little later in age than the whin sill as a whole. Like the contact-rock No. 6 they exhibit the effects of chilling.

Of the medium-grained rocks, that from Snook Point was analysed some years ago;[1] as some of the sample had fortunately been preserved, the opportunity was taken to supply the deficiencies in the old analysis. It may be noted that the analysis of this rock was done on the powder dried at 110° C. The main interest in the dolerite from the White Force comes from its proximity to a basaltic intrusion, as will be explained later, and in that from the Crook boring (No. 10) from its freshness, its high S.G. and its position, some 1,100 feet below the surface.

The very coarse rock of gabbro type is well known, and has long been recognized to occur near the middle of thick sills, though thickness alone does not seem to be the only factor in its generation. It assumes the form of veins, a few inches thick, or of bands or irregular masses, more or less horizontal, of similar thickness, but of no great extension. Contacts with the dolerite are often sharp. It wears and weathers more readily than the dolerite, so that slabs of rock

[1] J. A. Smythe, *Geol. Mag.*, 1914, Dec. 6; Vol. I, 244.

in running water often show a thin surface-covering of gabbro, fringed at the edges, which are more worn, with dolerite. This coarse variety is common in Teesdale, especially above the Harwood Beck and in the Maize and Merrygill Becks. It is also met with in Lunedale (Arngill), South Tynedale (Tynehead, Blackburn, Cash Burn, Gilderdale, Harpertown) and in Weardale (Copthill). It occurs rarely north of the Tyne, and seems to be absent from the Pennine escarpment. The specimen analysed (No. 12) is from Gilderdale, and is very coarse and fresh, with crystals of pyroxene up to 3 inches in length.

Coming now to the discussion of the analyses, the average whin (No. 1) was examined in much greater detail than the other rocks, and the following elements proved, by chemical tests, to be absent, or to occur at most in very minute quantity:—lithium, strontium, zirconium, arsenic and molybdenum. Chlorine, copper and zinc are present in strong traces, and there are small, but determinable, amounts of lead, nickel, chromium and vanadium, the estimated quantities of these elements being:—Pb = 0·0024; NiO = 0·01; Cr_2O_3 = 0·008; V_2O_3 = 0·06 p.c. These are not included among the analytical figures in the above table. None of the sulphur is present as monosulphide (pyrrhotite, pentlandite), and none as sulphate, except possibly an amount equivalent to the barium, i.e., 0·02 p.c., though this is very doubtful, as will appear later. It may be taken to be present entirely as pyrites.

The average dust (No. 2) differs from the average whin chiefly in its lower values for silica (0·8) and alumina (0·9), and its higher values for iron (0·5 and 1·2). With regard to the iron, it must be remembered that the dust contains an appreciable amount of the metal itself, derived during crushing from the mortar and pestle, whereas the other is entirely free from this. The addition of metallic iron to the sample would reduce appreciably the proportion of the constituents present in the largest proportions, namely, the silica and alumina; the latter of these being determined by difference, one factor in which is iron, would become still further diminished. Making these allowances, there would probably be little difference between the composition of the average whin and dust if the iron could be removed from the latter.

The contamination of the dust to the extent indicated by the analyses is not likely to affect the constituents present in small quantity beyond the limits of experimental error. The figures for the alkalies and magnesia might thus be taken to indicate a slight concentration of felspar in the dust, and of pyroxene in the coarser residue. The identity of titania in both cases shows that the relation of the ore-minerals is unaffected by the process. It is significant that water, carbon dioxide, sulphur and barium are identical, or almost so, in both cases, and it is clear from this that weathering, or other alteration, of the whin is of a uniform character, and the products are widely and finely dispersed throughout the rock, otherwise the severe mechanical treatment to which it has been subjected would have led to concentration of the alteration-products in the dust. The effect of the crushing process has thus been essentially that of comminution; the average whin is not, in the mining sense, a concentrate, but represents closely in composition the material from which it is derived.

It has been generally held, since the days of Teall, that the whin sill is remarkably constant in composition. The evidence in favour of this view is partly petrological and partly chemical, for the two analyses of Teall agree fairly well with each other, and with some later analyses which will be considered shortly. Teall's determinations of S.G. were restricted to six specimens and show extreme values of 2·906 and 2·959, which hardly justify his statement that this property is fairly constant.

Inspection of the figures in Table D shows much greater differences than would be anticipated from the general acceptance of this view, and this is all the more remarkable in the group-samples, which represent averages over large areas and are, consequently, free from accidental and local variation. Some of these differences might be ascribed to weathering. It is extremely difficult to get an estimate of the effect of this on the bulk composition of the rock, but if we regard water and calcium carbonate as measures of this change and assume further what, at best, can only be approximately true, that they represent additions to the original rock, then the calculated composition of the residuals, after their subtraction, should give a better estimate of the original, unweathered rocks. The results of these calculations in the case of Nos. 4 and 5 are given below:

	No. 4	No. 5
SiO_2 ...	51·6	51·0
Al_2O_3 ...	15·8	15·9
Fe_2O_3 ...	3·8	4·2
FeO ...	9·5	9·8
MgO ...	3·6	4·5
CaO ...	8·9	6·4
Na_2O ...	2·5	2·5
K_2O ...	1·3	1·1

The agreement now is much closer, especially in silica and alumina, though the values for lime are far apart. The general better agreement may indicate that the original unaltered rocks may not differ so widely in composition as their weathered products may seem to show. There are, however, other facts which may be cited against this view. Thus the differences, especially in silica, between Nos. 3 and 5 are considerable, though the carbon dioxide content has much the same value, and again differences of a similar order are present in Nos. 6, 10 and 12, which are free from carbon dioxide. It would appear, on the whole, that

the observed analytical differences do really express variations in original composition.

If the analysis of the average whin be accepted as a close approximation to the average composition of the whin over the whole outcrop, it is pertinent to inquire to what extent other analyses, whether of extensive though more limited collections, like the group-samples, or of hand-specimens collected and analysed either by one person or by many, or averages of such analyses approach to the true composition of the formation. The data necessary to judge these matters are assembled in Table E, in which only the major constituents are included.

Table E

Comparison of Analyses of the Whin Sill

	A	B	C	D	E	F	G	H	I	J
SiO_2 ...	50·3	49·9	50·3	50·6	3·1	1·3	1·5	+0·4	0·0	−0·3
Al_2O_3 ...	15·4	15·4	15·5	14·4	2·1	2·1	1·9	−0·1	−0·1	+1·0
$FeO+Fe_2O_3$	12·0	12·5	12·3	12·9	1·9	1·3	1·7	−0·3	−0·3	−0·9
MgO ...	4·9	4·6	4·8	4·8	1·6	1·2	2·8	+0·3	+0·1	+0·1
CaO ...	8·9	8·5	8·4	8·6	3·8	3·8	1·4	+0·4	+0·5	+0·3
Na_2O ...	2·0	2·3	2·4	2·7	0·8	0·8	0·6	−0·3	−0·4	−0·7
K_2O ...	1·1	1·1	1·1	1·2	0·5	0·5	0·4	0·0	−0·2	−0·1
H_2O+CO_2 ..	2·5	3·5	2·1	1·9	3·3	3·3	0·9	−1·0	+0·4	+0·6

A. Average whin.
B. Average of 11 normal rocks (all except No. 2 in Table D).
C. Average of 7 normal rocks, not group-samples (Nos. 6 to 12 in Table D).
D. Average of 5 analyses by Teall, Finlayson, Harwood and Herdsman.
E. Maximum differences in the 11 analyses of B.
F. Maximum differences in the 7 analyses of C.
G. Maximum differences in the 5 analyses of D.
H. Difference A—B.
I. Difference A—C.
J. Difference A—D.

The comparison is made between the average whin (column A); the mean (B) of 11 analyses of normal rocks in Table D (that of the normal dust being omitted); the mean (C) of 7 analyses (Nos. 6 to 12), which being of hand-specimens or small collections, and free from admixture with non-normal rocks, are more comparable with the rocks in the next category; and the mean (D) of 5 analyses of other authors, evidently made on small samples. In columns E, F, G are the maximum variations of the constituents in columns B, C and D, and it will be noted that these, on the whole, decrease considerably in order from E to G. In other words, the wider the field of selection and the greater the number of samples analysed, the less uniform in composition does the rock appear.

In columns H, I, J are given the differences between the average whin and the three mean values in B, C and D. These show that the differences between the average whin and the mean of the 7 typical normal rocks (column I) is small; it is somewhat greater between the average whin and the mean of the 11 normal samples (H), clearly since the range of the latter is much greater; and it is highest in J, where the material for comparison is smaller, and where the personal factor of four different collectors and analysts comes into play.

We may conclude, therefore, that in a rock like the whin sill, the average of a few analyses of hand-specimens, made by different authors, may give a reasonably close approximation to the average composition of the whole formation, but it may afford a totally inadequate idea of the variations which the rock exhibits. That four of the analyses of different authors should agree so well may be fortuitous,[1] but it seems more likely due to the fact that the materials analysed are from areas (Nos. 4, 7, 14, 20 of Table A) where the rock exhibits remarkable uniformity in S.G., and that the authors, in collecting their samples, have instinctively selected the same kind of rock, rejecting

[1] Herdsman's analysis of the rock from the Crook boring differs notably in some respects from the four mentioned here.

any which showed even minor deviations from the normal type.

Considering that there is so much variation in composition in the specimens of normal whin which have been analysed, it has not appeared of much value to test whether independent sills differ in composition. The only analyses in the table which can be used for the purpose are Nos. 3 and 10, which refer respectively to the Little Whin Sill of Stanhope and the main sill (the only one) from the Crook boring. Though these are 10 miles apart, the Stanhope sill is clearly a split or offshoot of the main mass. It will be seen, on comparing the analyses, that there is good agreement between the two, except in silica alkalies and carbon dioxide.

The two great sills in the Bavington district are about of equal thickness, and a mile apart. Some determinations in each indicate similarity in composition, though they are too few to carry conviction. They are given here for what they are worth.

	Bavington Eastern sill (21)	Bavington Western sill (22)
S.G.	2·921	2·927
H_2O	2·44	2·20
CO_2	0·40	0·34
FeO	8·87	8·74

The contact rock, No. 6, resembles the average whin very closely, the chief differences being in the relative proportions of the oxides of iron (total iron being almost the same) and in the excess of lime, 0·7 p.c. in the average whin, which is balanced by excess of soda in the contact rock.[1] There is also 0·42 p.c. of carbon

[1] The excess of soda is so marked that if the view, expressed later, that this contact rock represents closely the original magma be accepted, it would follow that this magma contained soda in some form which escaped in the course of consolidation. There are indications from the metamorphism of the sedimentaries that this was the case.

dioxide in the one and none in the other. These relations suggest that the average whin is derived from material of the composition of the contact rock as a result of three reactions: loss of some soda, replacement of the lost material by calcium carbonate, and oxidation of a portion of the ferrous iron. On this view, the contact rock represents closely in composition the original magma, preserved by chilling from the changes accompanying solidification. This is in accordance with Daly's contention that the contact types in intrusives represent the original magma. As a corollary, the differences in composition produced by crystallization of the slowly cooled magma have been compensated by the method of sampling employed in the preparation of the average whin.

The three chilled rocks (Nos. 6, 7, 8) are high in their water-content; in the first two carbon dioxide is low, though, in general, high water accompanies high carbon dioxide. The average water-content of 9 rocks, which contain less than 0·14 p.c. carbon dioxide, is 1·97, whereas in the 3 in question the values are 2·6, 3·0, 3·2. These results may be compared with the Crook rock, No. 10, which is free from carbon dioxide and contains only 1·4 p.c. of water. They suggest that the higher water-content of the chilled rocks is a consequence of their mode of generation, magmatic water being retained under rapid cooling which, under conditions of slow cooling, has opportunity to escape.

These rocks are also low in ferric oxide, the significance of which is not clear.[1] The gabbro of No. 12 is a very fresh rock, free from carbonate and low in ferric oxide, and is comparable, in these respects, with Nos. 6 and 7. It shows, however,

[2] It may be remarked that their finely-ground powders are light in colour, being in fact almost white. Most of the other rocks furnish grey powders; the average whin has a faint brownish tinge, and group-sample 33, from the haematite-stained rock of the Farne Islands, is light brown.

notable differences in composition, and of all the normal rocks is the highest in lime and the lowest in potash.

Little need be said of the elements present in small quantity. Barium has been determined in three rocks, Nos. 1, 2 and 6, and these, along with determinations in the dusts, to be described presently, are sufficient to test its distribution. Its amount is small and constant. Chlorine has been found in several cases, but always in quantity two small for estimation. Manganese is remarkably constant and averages 0·18 p.c. Titanium shows small variation and averages 2·62 p.c. TiO_2. The same may be said for phosphoric acid, the average for which is 0·28 p.c. P_2O_5. Sulphur averages 0·14 p.c., but shows a wider range of variation. There seems to be some tendency for high sulphur and high carbon dioxide to go together, though the indications are not too clear. What appears significant is that there is a minimum value of 0·08 p.c., corresponding to 0·15 p.c. pyrites in the fresh, coarse-grained rocks Nos. 10 and 12. This may possibly indicate the saturation-limit of pyrites in the magma.

Pyrites in the whin is uniformly distributed in small specks, and it is undoubtedly owing to this that two attempts to obtain a sulphide-concentrate from a kilogram or two of the powdered rock, by the method of froth-flotation, failed completely. It is hardly necessary to add that specimens of whin, abounding in pyrites, are not uncommon, especially at the selvages and as an envelope to the main infillings of calcite and quartz in amygdales. Here the material is obviously infiltrated. In the collection of material, all specimens containing visible pyrites were rejected.

2. *The Dusts*

The dusts, or fine material from the crushing of the group-samples, have been grouped, as already mentioned, in larger geographical units. The chemical examination of these has been restricted to the determination of total water, carbon dioxide, sulphur and barium. The data are recorded in Table F, sulphur being given as such, and also as its pyritic equivalent. The figures for the average whin and average dust (from Table D) are added for comparison. To prepare the dusts for analysis, the large collections of material in each group, which includes everything passing the 10-sieve, were sampled by quartering until a sample of convenient size was obtained; this was then screened and the fine powder passing the 100-sieve used for the purpose of analysis.

TABLE F

ANALYSES OF THE DUSTS

Reference letter and area from which the dust is derived	H_2O (total)	CO_2	H_2O+CO_2	S	FeS_2	BaO
A. Lunedale and Teesdale ...	2·12	0·24	2·36	0·128	0·24	0·033
B. Weardale	1·96	1·08	3·04	0·158	0·30	0·049
C. South Tynedale	2·12	0·47	2·59	0·127	0·24	0·036
D. Pennine Escarpment ...	2·10	0·62	2·72	0·120	0·22	0·029
E. Roman Wall Escarpment...	2·07	0·25	2·32	0·134	0·25	0·036
F. North Tyne to Coast ...	2·33	0·49	2·82	0·202	0·38	0·020
G. Coast	2·80	0·59	3·39	0·161	0·30	0·026
H. Bamburgh to Kyloe Hills	2·28	0·33	2·61	0·120	0·22	0·046
Mean (p.c.)	2·22	0·51	2·73	0·144	0·27	0·034
Average whin	2·05	0·46	2·51	0·150	0·28	0·033
Average dust	2·19	0·46	2·65	0·150	0·28	0·033

Water and Carbon Dioxide. Variation of these constituents in the dusts is naturally much less than in the group-samples, since the dusts represent a much larger area and average a greater number of samples than the group-samples. If the figures for the 18 group-samples in Table M be taken as a basis for comparison, the maximum differences in these of water and carbon dioxide are 1·75 and 2·0 p.c.

respectively, whereas for the dusts they are 0·84 in each case, or less than half as much.

The average value for the sum (H_2O+CO_2) in the group-samples is 2·96, and in the dusts, 2·73; the difference here is small, and it would probably be less if the data for all the group-samples, instead of only about half of them, had been available. This average for the dusts (2·73) agrees closely with the value for the average dust (2·65), and both do not differ greatly from the average whin (2·51), thus confirming the view, already advanced, that the crushing process has not altered materially the composition of the coarse rock, from which the average whin was prepared.

The highest values for the sum of these two components are found in Weardale (B) and in the coastal area (G); the south-western area (A and C) and the northern area (H) give relatively low values. This corresponds, in a general way, to the areas of low and high specific gravity, and confirms the conclusions reached as to the relation of weathering to specific gravity.

Sulphur. The mean value of sulphur in the dusts agrees closely with the average whin and the average dust, and confirms the conclusion, already drawn, that pyrites is very finely disseminated and, like calcite, does not exist in strings, for if it did, crushing would inevitably lead to its concentration in the dust. The variations in sulphur are not of great moment, but there is a distinct tendency for high values of sulphur to correspond with high values of water and carbon dioxide. Thus, the three dusts, A, F and G, containing 0·30 to 0·38 p.c. of pyrites, have an average value of 3·08 for (H_2O+CO_2), whilst the five, lower in pyrites (0·22 to 0·25), give an average of only 2·52 for water and carbon dioxide. The pyrites-content thus tends to increase with the degree of alteration which the rock has undergone.

Barium Oxide. The variations in this constituent are small and, as the experimental error is greater than in the other constituents, the figures have not quite the same significance. The mean for the dusts agrees again with the average whin and average dust. The value for dust A has especial interest, for the area from which the dust is derived is one of intense mineralization and is intersected by scores, if not hundreds, of veins carrying barytes, some of which can be seen to cut through the whin sill; yet the barium in the dust has the same value as in the average whin, and is notably less than in that of Weardale, where fluorspar is the main vein-filling mineral, and in that from the northern area, which is not mineralized. The mineralizing solutions of Lunedale and Teesdale have thus been without effect on the whin as a whole, though possibly genetically connected with it.

The average sulphur in the dusts, 0·144 p.c., if present as barytes, would be equivalent to 0·69 p.c. BaO, or twenty times the amount actually present. Though it cannot be stated dogmatically that the whin does not contain barytes, it appears more probable that this is not the case, but that the barium is locked up in the felspars.

3. *The Exceptional Rocks*

Under this heading are grouped those rocks which, for various reasons to be stated presently, depart from the ordinary type. They can hardly be termed abnormal, and the title exceptional is used in the sense of not normal. Analyses of six of these are given in Table G.

At the Ritton White House quarry, Fontburn, there occurs at the base of the whin, here 50 feet thick, an irregular-shaped mass, about 4 feet thick, of soft, greenish-black rock, so friable that it can be crumbled between the fingers. Similar rock has been noted in other places in mid-Northumberland, but in none are these qualities developed in quite the same degree.

It will be noted from the analysis (No. 1) that carbon dioxide is absent (sulphate is also absent) and that the rock contains only the normal amount of water. Though collected as a weathered rock, the analysis fails to show any signs of this and, indeed, it is not very different in composition from the sound

TABLE G

COMPOSITION OF EXCEPTIONAL ROCKS

	1	2	3	4	5	6	7
SiO_2	51·00	50·00	52·20	52·85	56·15	58·10	72·70
TiO_2	2·73	2·41	2·66	3·31	1·74	1·65	0·62
Al_2O_3	16·43	16·66	14·59	13·15	14·78	14·49	13·20
Fe_2O_3	1·69	2·64	2·79	3·90	3·88	n.s.d.	0·37
FeO	9·12	9·35	9·97	9·60	5·65	9·51	2·29
MnO	0·13	0·17	0·15	0·21	0·15	0·16	0·03
MgO	4·94	3·91	2·67	3·02	2·83	3·32	0·55
CaO	8·77	7·96	5·60	6·36	5·00	5·05	1·40
BaO	n.d.	n.d.	n.d.	n.d.	0·08	n.d.	n.d.
Na_2O	1·82	1·98	2·61	2·27	2·47	2·76	2·19
K_2O	0·79	2·13	1·39	1·74	2·22	2·36	5·15
H_2O (+) ...	1·28	1·50	2·60	2·00	1·58		0·65
H_2O (−) ...	0·92	0·60	0·70	0·82	1·63	1·61	0·42
CO_2	none	0·12	1·46	0·08	0·95		0·29
P_2O_5	0·15	0·20	0·63	0·46	0·47	0·73	0·06
Cl	n.d.	n.d.	0·03	n.d.	n.d.	n.d.	n.d.
S	0·15	0·11	0·82	0·12	0.25	n.d.	0·35
Less O for S ...	0·05	0·04	0·27	0·04	0·08	—	0·12
Total ...	99·87	99·70	100·60	99·85	99·75	99·74	100·15
S.G. ...	2·897	2·951	2·821	2·907	2·724	2·725	2·615

1. Ritton White House, Fontburn.
2. Teward's Bridge, Harwood Beck.
3. Gilderdale (coarse pink rock).
4. Tees, foot of Mattergill Sike (coarse pink rock).
5. Inclusions, Snook Point.
6. Inclusions, Snook Point (old analysis).
7. Cushat Steel, Dunstanburgh (Felsitic rock).

normal rocks. The only noteworthy differences are the low values of phosphoric acid and the alkalies. The petrological examination of the rock by Mr. Mockler discloses the fact that the mesostasis has been considerably attacked, and this appears to be the only observable cause of its abnormal physical properties.

Susceptibility to weathering of the mesostasis of the quartz-dolerites of the Kilsyth-Croy district has been noted by Tyrrell,[1] and it would appear, in this case, that the alkali-felspars of the micropegmatite, along with the accompanying apatite, have been partly removed by weathering, and that the withdrawal of this interstitial cement is the cause of the weakness of the resulting rock.

The rock from the limited exposure on the Harwood Beck, at Teward's Bridge (No. 2), is somewhat spotted in appearance, but not markedly different from many other rocks of medium grain. Attention was directed to it by an analysis made in Percy's laboratory and quoted by Clough,[2] in which potash largely exceeds soda, the figures being: $K_2O = 3{\cdot}28$, $Na_2O = 1{\cdot}18$. In order to check this observation, a fairly large collection was made from the locality and, as the outcrop is small and, to the eye, quite uniform, it was hoped that this method would suffice for the purpose. The alkalies found in this sample are: $K_2O = 2{\cdot}13$, $Na_2O = 1{\cdot}98$, so that the preponderance of potash over soda is confirmed, but not the actual amounts of the alkalies.

It is possible that an individual specimen from the locality might yield results in agreement with Percy's, but it is significant that the chloride-equivalent of the total alkalies, which is the form in which they are weighed, is 7·7 p.c. in the one case and 7·1 in the other. From this circumstance, it appears most likely that there is an error in the potassium-determination of Percy's analysts. A similar analysis with respect to alkalies is quoted by Clough, in the same paper, from Tinkler's Sike, Widdybank Fell, not far away from Teward's Bridge, but I have not had the opportunity to check this. With the exception of the highly acidic rocks of the pink veins, this is the only rock of the many analysed in which potash exceeds soda.

[1] G. W. Tyrrell, *Geol. Mag.*, 1909, Dec. 5; Vol. VI, 308.
[2] C. T. Clough, *Geol. Mag.*, 1876, Dec. 2; Vol. VII, 433.

Mr. Mockler reports that the augite in the rock is fresh, but the rhombic pyroxenes are converted into bastite; the felspars show a good deal of sericitization, and there is a fair development of free quartz and micropegmatite, the latter being fine-grained. On the chemical side, the most notable features are the high alkalies and their relationship, just spoken of, high alumina and low magnesia, which indicate a relative abundance of acid felspars. Despite the sericitization of the felspars, the water-content is rather low. This rock represents, in a sense, a transition between the normal whin and the remaining four rocks, and it is of interest to observe that it occurs on the eastern edge of the Upper Tees area, where the pegmatite rocks are so well developed.

The remaining rocks, Nos. 3 to 7, are characterized by abundance of pink felspathic material, which occurs in a variety of forms. Sometimes it is spread locally and irregularly through the coarse rock, giving it, as Garwood observed in the neighbourhood of Ratcheugh, a syenitic appearance.[1] Very fine specimens of this pink gabbro are to be found in Gilderdale, and No. 3 is from this locality. It is relatively abundant in Teesdale, especially on the Tees, from the foot of Greenhurth Sike to Mattergill Sike, and a sample from the latter place (No. 4) has been analysed. Other localities are the upper South Tyne (Tynehead, Cash Burn, Blackburn). Teall's statement[2] concerning the whin sill, that "in no case are there any marked variations from the common type, except such as depend, in all probability, on rapidity of cooling, and these may generally be found in one and the same locality," can hardly be justified in view of the frequency of occurrence of this type of rock, especially in the southern area.

Sometimes the pink matter takes the form of

[1] *County History, Northumberland*, Vol. II, 328.
[2] J. J. H. Teall, *Quart. Journ. Geol. Soc.*, 1884, *40*, 642.

infillings of vesicles, and these may be complete, as in the "pink spots," or partial, that is, forming a fringe to the infiltrated mineral, usually calcite, more rarely quartz and barytes, of the amygdale; or again, it may occur as strings and veins. The range of these is greater than that of the rocks just described; in both cases, the Pennine escarpment, mid-Northumberland (except about Gunnerton and Ratcheugh), and the area north and west of Bamburgh seem to be singularly free from them.

Closely connected with these are the small aplitic "inclusions" in the whin sill at Snook Point, already described by the author.[1] An analysis of these has already been published and is reproduced here (No. 6). As the quantity of the original material was insufficient for a full analysis, the subject was examined afresh on a larger scale. For this purpose, 28 samples, weighing 22 grams, were coarsely crushed, the dust and calcite from the ever-present amygdales separated as thoroughly as possible and the remainder ground. The results are given in No. 5. They confirm the earlier determinations; the slightly lower values for alkalies and phosphoric acid show that the new sample contained a little more of the normal whin, which envelopes the inclusions, than the old one.

On the coast from Cullernose Point to Castle Point, Dunstanburgh, pink veins, up to 2 inches in width, are abundant, but the characteristic occurrence of this acidic rock is in the form of cakes or roundish slabs, several inches wide and up to half an inch in thickness. These are particularly abundant about Cushat Steel, near Dunstanburgh, and analysis No. 7 is of rock from this locality.

Compared with the normal rocks, these rocks rich in felspathic materials show increase in silica, alkalies and phosphoric acid, while lime and magnesia

[1] J. A. Smythe, *Geol. Mag.*, 1914, Dec. 6; Vol. I, 244.

decrease. These changes are progressive in passing from the pink gabbros to the inclusions; in the latter, iron begins to decrease and titanium in sympathy with it. In the felsitic rock, No. 7, silica and alkalies are at a maximum and potash greatly exceeds soda; iron, titanium, lime and magnesia are at a minimum, and even manganese is reduced to one-sixth of its normal value. The only break in the order of change is in the case of phosphoric acid, which suddenly drops to a very low value.

The high value for sulphur in No. 3 is exceptional, and coupled with high values for water and carbon dioxide, and low specific gravity, indicates alteration of the rock by infiltrating waters.

It has already been noted that chlorine has been found in the normal whin in several samples, but always in quantity too small for estimation. In the highly phosphoric rock, No. 3, it is present to the extent of 0·03 p.c. The ratio $P_2O_5 : Cl$ in this rock is 0·63 : 0·03, whereas in chlorapatite it is 0·63 : 0·10. There is present, therefore, only one-third of the chlorine necessary to form this mineral, and it may be inferred from this that the apatite is fluoriferous. This conclusion has not been tested chemically. The rock from Cushat Steel, No. 7, which is exceptionally low in phosphoric acid, contains the merest trace of chlorine—much less than in the normal whin. The latter averages 0·28 p.c. P_2O_5 and should, if the phosphoric acid be present as chlorapatite, contain 0·046 p.c. of chlorine; it certainly does not contain this amount. If the ratio $P_2O_5 : Cl$ is the same in the normal whin as it is in No. 3, then the former should contain 0·014 p.c. of chlorine, which is probably close to the mark. There can be little doubt, therefore, that the chlorine, in all these rocks, is present in the apatite, and that this mineral is composed of one part of chlorapatite and two parts of fluorapatite.

The relation of phosphoric acid to the alkalies is worthy of consideration, and to facilitate this the relevant data are assembled in the following table. In this are included the results of the analysis of pink veins in the Hampeth Dyke, which, as will be shown later, bears the closest resemblance to the whin sill.

WHIN SILL ROCKS.

	P_2O_5	Na_2O	K_2O	SiO_2
A. Cushat Steel (Table G, No. 7) ...	0·06	2·19	5·15	72·70
Pink Veins, Hampeth Dyke (Table N, No. 2)	0·07	2·09	5·44	69·20
B. Average of 11 normal rocks (Table D)	0·28	2·34	1·09	49·90
C. Mattergill (Table G, No. 4)... ...	0·46	2·27	1·74	52·85
Inclusions (Table G, No. 6)... ...	0·47	2·47	2·22	56·15
Gilderdale (Table G, No. 3)... ...	0·63	2·61	1·39	52·20
Inclusions (Table G, No. 5)	0·73	2·76	2·36	58·10

The group of rocks, C, intermediate with respect to silica-content, shows the greatest concentration of phosphoric acid, which, at the maximum, is three times the normal amount, whilst in the highly acidic rocks of group A, the phosphoric acid is only one quarter of the amount in the normal rocks. This amply confirms petrological observations that the micropegmatite of all rocks, except the felsites, abounds in apatite. With increase of phosphoric acid, soda increases slightly, the relationship being almost strictly linear, whereas potash varies irregularly.

Relationships somewhat similar to these have been proved to hold in the gravitational series of the Glen More ring dyke,[1] though the differences are not so striking, as may be seen by comparing with the above

[1] *Mull Memoir*, p. 29.

the four analyses of this suite reproduced in the following table.

MULL ROCKS

P_2O_5	Na_2O	K_2O	SiO_2
0·22	4·15	4·47	68·12
0·20	2·86	0·95	49·90
0·24	3·50	1·16	51·32
0·50	3·82	2·67	56·22

THE VARIATION DIAGRAM

For the further study of the rocks of the whin sill, particularly with a view of exhibiting their genetic relations, reference is made to the variation diagram of Fig. 1.

In constructing this diagram, the complete analyses of nineteen rocks are used, the data being drawn from Tables D, G and O. The analysis of the average dust has been omitted for obvious reasons, also that of the rock from Teward's Bridge. The latter has been stated to be exceptional in many respects, and it shows, in Bowen's words, such "a notable departure from the liquid line of descent" as to justify its omission.[1]

Ten of the 19 analyses plotted are within a silica-range of 2 p.c. (i.e., from 49 to 51 p.c. inclusive) and it is, naturally, within this range that the graphs show the greatest irregularity. Variations of alumina, iron oxides, lime and magnesia of the order of 2 p.c. are quite erratic, though there is some indication of an ill-defined maximum for alumina between the silica-percentages 49 and 51.

Above 51 p.c. of silica a change sets in; alumina,

[1] N. L. Bowen, *The Evolution of the Igneous Rocks*, 1928, p. 113.

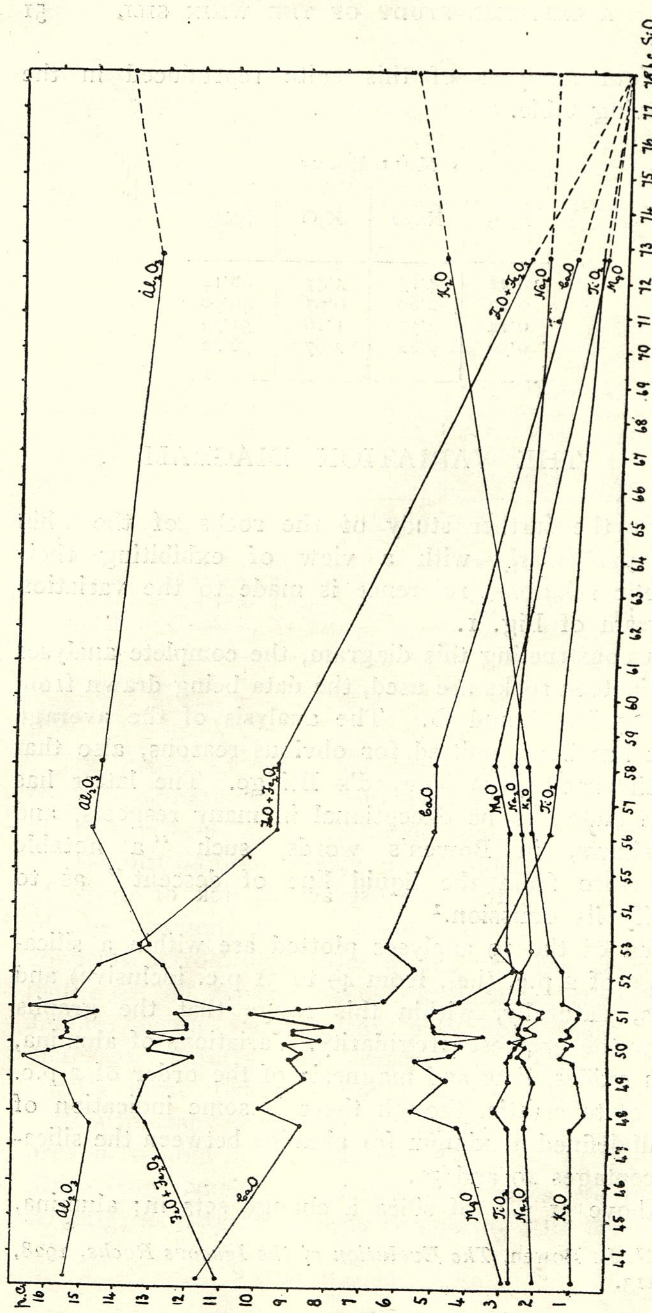


Fig. 1.
The Variation Diagram of Whin Sill rocks.

lime and magnesia begin to fall, the first slowly, the others more rapidly; total iron rises slightly (though ferrous iron shows a slight decrease) and only shows marked diminution beyond 56 p.c. of silica, after which its downward progress is swift, in conformity with the lime and magnesia. Titanium is remarkably constant at first, then rises to a maximum at 53 p.c. of silica (it is closely followed in this reach by ferric oxide). After this, it takes part in the general decrease. In its delayed fall, it resembles the iron oxides, this relation indicating that with advancing acidity of the magma, the ferromagnesian minerals decrease more rapidly than the black ores.

The relation of the alkalies to silica is particularly interesting. Soda is the only constituent which exhibits but little final change, its initial value being 2·02 p.c. and its final 2·19 p.c., and the greatest variation from the mean of these nowhere exceeds 0·6 p.c. Potash remains remarkably constant up to 51 p.c. of silica, its variations being less than those for soda; above this, it participates in the change which affects the other bases, except soda, but in the reverse direction, rising steadily with increasing silica, its final value being five times the initial value.

The prolongation of the graphs beyond the ordinate corresponding to the most acidic rock of the series shows convergence of iron, lime, magnesia and titania approximately at 78 p.c. of silica. The ordinate at this point is cut by the potash curve at 6 p.c., and by the soda curve at 2 p.c. The alumina curve is too indefinite and wavy for prolongation, but it meets the ordinate at about 13 p.c., which is only 1 p.c. below the difference between 100 and the sum of silica, potash and soda. The whole suite, therefore, tends, with increasing acidity, towards a material of the approximate composition: $SiO_2=78$, $Al_2O_3=14$, $K_2O=6$, $Na_2O=2$ p.c.

Confirmation of this and some of the consequences which flow from it will be given later. Meanwhile, it may be pointed out that other series of rocks resemble that of the whin sill in fairly close degree. Perhaps the most striking is the Normal Mull series.[1] The non-porphyritic central type ranges in silica-content from 45 to 73 p.c., and the variation-diagram, based on 29 analyses, shows many points of resemblance to that of the whin sill rocks, despite slight variations in the flexure of the curves. Comparison of the two series is facilitated by drawing them to the same scale, as is done in Fig. 2.

Another example, which may be mentioned, is that of the rocks of Lassen Peak, California.[2] The behaviour in particular of the alkalies in all these cases is very similar, and is held by Bowen[3] to be the result of fractional crystallization, an intermediate degree of "reaction" being indicated.

THE MINERAL CONSTITUENTS OF THE WHIN

1. *The Pyroxenes*

The three main constituents of the whin were isolated by magnetic and flotation methods, and analysed by Teall.[4] The two analyses of pyroxene separated from the rock of Caldron Snout and Tynehead agree closely with one another. The second is probably the better one and runs as follows:

$SiO_2 = 48{\cdot}41$, $Al_2O_3 = 4{\cdot}05$, $Fe_2O_3 = 2{\cdot}36$, $FeO = 15{\cdot}08$, $MnO = 0{\cdot}37$, $MgO = 12{\cdot}14$, $CaO = 15{\cdot}98$, $H_2O = 1{\cdot}19$. Total $= 99{\cdot}58$.

This analysis has been used in many of the calculations

[1] *Mull Memoir of the Geological Survey.*
[2] Harker, *Natural History of the Igneous Rocks*, p. 125.
[3] *Op. cit.*, p. 95.
[4] J. J. H. Teall, *Quart. Journ. Geol. Soc.*, 1884, *40*, 642.

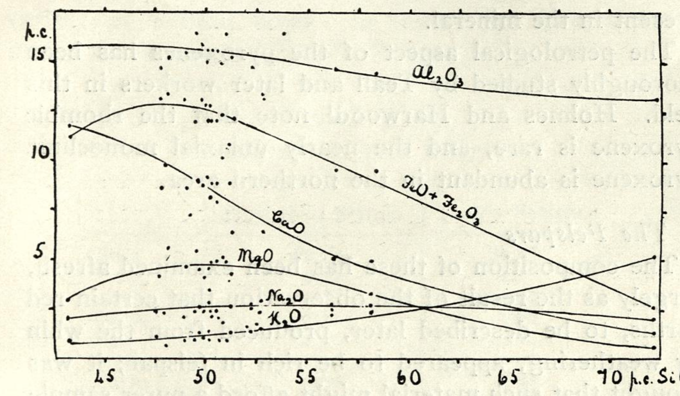
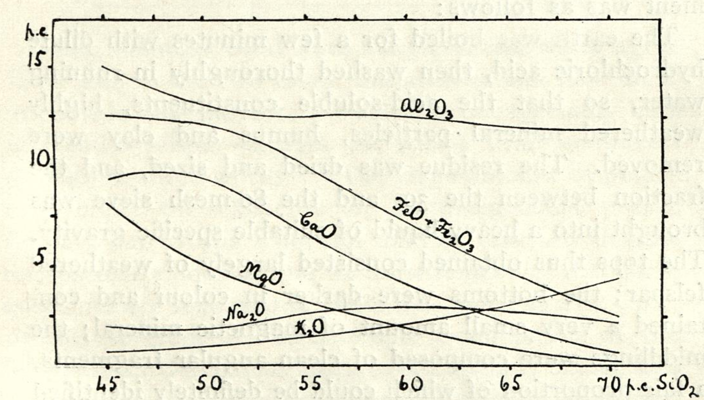


FIG. 2.

Comparison of Variation Diagrams of Whin Sill rocks (above) with rocks of the Normal Mull Magma Series (below). The diagrams are drawn to the same scale.



made in this paper. It was not thought that any improvement could be made on this analysis, though it would be desirable to know whether titanium is present in the mineral.

The petrological aspect of the pyroxenes has been thoroughly studied by Teall and later workers in this field. Holmes and Harwood[1] note that the rhombic pyroxene is rare, and the nearly uniaxial monoclinic pyroxene is abundant in the northern area.

2. *The Felspars*

The composition of these has been examined afresh, largely as the result of the observation that certain red earths, to be described later, produced from the whin by weathering, appeared to be rich in felspar; it was thought that such material might afford a purer sample of this mineral than could be obtained from the crushed rock by Teall's method. Three of these red earths were examined, and all yielded similar material, but only in that from Borcovicus (see Table S) was the process carried to the stage of analysis. The method of treatment was as follows:

The earth was boiled for a few minutes with dilute hydrochloric acid, then washed thoroughly in running water, so that the acid-soluble constituents, highly weathered mineral particles, humus and clay were removed. The residue was dried and sized, and the fraction between the 30- and the 80-mesh sieve was brought into a heavy liquid of suitable specific gravity. The tops thus obtained consisted largely of weathered felspar; the bottoms were darker in colour and contained a very small amount of magnetic mineral; the middlings were composed of clean angular fragments, a fair proportion of which could be definitely identified under the microscope as felspar. Repetition of the separation process with the middle fraction yielded the

[1] A. Holmes and H. F. Harwood, *Min. Mag.*, 1928, *21*, No. 122, 493.

material which was analysed. In the table below, this is termed " Borcovicus Felspar," and Teall's analysis of a preparation from " a moderately coarse-grained variety of normal whin " is given, for comparison, under the heading " Teall's Felspar."

TABLE H

COMPOSITION OF WHIN FELSPARS

	Borcovicus Felspar	Teall's Felspar
SiO_2 ...	62·15	61·18
TiO_2 ...	0·37	n.d.
Al_2O_3 ...	20·43	19·95
Fe_2O_3 ...	0·21	3·20
FeO ...	2·59	n.s.d.
MgO ...	1·22	0·92
CaO ...	7·00	5·45
Na_2O ...	2·96	4·70
K_2O ...	1·12	2·80
H_2O (+)...	1·04	1·13
H_2O (−)...	0·60	—
Total ...	99·69	99·36
S.G. ...	2.715	2·67

Silica, alumina, total iron, magnesia and water agree fairly well in the two cases, but alkalies and lime differ in considerable measure. Potash is unexpectedly high in Teall's felspar—a fact on which Teall comments (p. 646) in these words: " The large amount of potash may imply the existence of an independent potash felspar; but of this I am not able to give any definite microscopic evidence, and we must remember that some andesines are supposed to contain as much as 2 or 3 p.c. of this substance." Microscopic examination of the felspar from Borcovicus failed to disclose any orthoclase.

Teall regarded his preparation as a mixture of felspar, quartz and decomposition products, and we shall probably not be far wrong in assigning the small amount of magnesia, in each case, to chlorite. Allocating the calcium and alkalies to their respective felspars, and the excess of silica to quartz, we obtain the following mineral compositions, from which the composition of the felspars themselves is calculated:

	Mineral Composition		Felspar Composition	
	Borcovicus Felspar	Teall's Felspar	Borcovicus Felspar	Teall's Felspar
Orthoclase	6·7	16·8	10·1	20·0
Albite	25·2	40·1	37·7	47·6
Anorthite	35·0	27·3	52·2	32·4
Quartz	24·7	10·6	—	—
Chlorite	4·3	3·2	—	—
Other Constituents	4·1	2·0	—	—
	100·0	100·0	100·0	100·0

The total felspar-content of the Borcovicus material is 66·9, and of Teall's 84·2 p.c., the difference being chiefly due to the greater quantity of quartz in the former. The composition of the felspathic material in both cases, expressed in analytical terms, is given in the next table, along with the calculated values for andesine and labradorite.

	Borcovicus Felspar	Teall's Felspar	Andesine (Ab_2An_1)	Labradorite (Ab_1An_1)
K_2O	1·7 } 6·1	3·4 } 9·0	—	—
Na_2O	4·4 }	5·6 }	7·9	5·7
CaO	10·5	6·5	6·7	10·4
Al_2O_3	28·3	24·8	25·2	28·3
SiO_2	55·1	59·7	60·2	55·6

Thus, assuming partial replacement of soda felspar by potash felspar, the composition of the Borcovicus preparation agrees with that of labradorite, Teall's with andesine. Variations of a similar order in the whin-plagioclases have been noted by the petrologists. The difference in the proportions of the alkalies in the two cases ($K_2O : Na_2O = 1 : 2·6$ in the first, and $1 : 1·6$ in the second) is significant, and indicates that disintegration

of the whin by weathering has the merit of removing the potash-rich felspar of the micropegmatite, so that the Borcovicus felspar more nearly represents the whin-plagioclase than Teall's felspar.

For this reason the composition of the Borcovicus felspar will be used, in the sequel, in order to study the distribution of alkalies in the whin-rocks, and eventually to arrive at the complete mineral composition of these rocks. It may be objected that the acid-treatment, short though it was, which was part of the method of preparation, would affect the proportion of alkalies in the felspar, but the complete analytical figures for the red earths (Table S), obtained under much more drastic treatment with acid, lend no support to this objection. It may be added that the deduced composition of the felspar, viz., 52·2 An, 37·7 Ab, 10·1 Or, agrees almost exactly with that inferred, from other considerations, by Holmes and Harwood, viz., 52 An, 38 Ab, 10 Or (*op. cit.* p. 501).

Three other preparations were made from the Borcovicus earth, with a view to testing the method and in the hope of achieving a purer felspar. Though, judging by alkali-content, slight improvement was shown in one of these, it was not great enough to warrant more extended trials.

3. *The Iron Ores*

The black ores of iron and titanium were also isolated and analysed by Teall with his usual skill and thoroughness. Owing, however, to some difficulties in the interpretation of his analytical results, it was thought desirable to re-examine the subject.

The material used was the dust from the preparation of the average whin. The portion of this between the 60- and 100-mesh sieve was well washed and searched with a bar magnet. The magnetic portion contained a good deal of metallic iron from the mortar and pestle. This was removed by repeated digestion with carbonic acid, the residue cleaned up with very dilute sulphuric acid (which did not remove more than a trace of titanium), dried and gently crushed in an agate mortar until it all passed the 80-sieve. Repetition of magnetic concentration, washing and crushing was resorted to, until the material passed, successively, the 100- and 120-sieve, and in one case the 200-sieve, and the effect of this treatment was clearly to break up and release fragments of pyroxene and felspar, which contained enough magnetic mineral to be attracted by the magnet, and thus to promote more efficient concentration.

Microscopic examination of the concentrates showed them to contain some, but very little, felspar and pyroxene, though the analyses prove that they are not quite so free from these constituents as they appear to be. The powders are jet-black when finely ground. In the table of analyses below, A and B were prepared in this manner, A having passed the 120-sieve and B

TABLE I

COMPOSITION OF IRON ORES

	A	B	C	D
SiO_2 ...	9·25	8·00	12·16	5·96
TiO_2 ...	23·72	24·80	24·51	20·81
Al_2O_3 ...	8·52	3·34	3·36	9·87
Fe_2O_3 ...	28·58	32·20	24·70	42·13
FeO ...	23·51	24·93	26·54	16·85
MnO ...	0·74	0·90	n.d.	n.d.
MgO ...	0·72	0·90	1·49	0·48
CaO ...	3·12	2·40	4·40	2·52
Na_2O ...	n.d.	0·36	n.d.	n.d.
K_2O ...	n.d.	0·19	n.d.	n.d.
H_2O ...	n.d.	0·55	n.d.	0·75
P_2O_5 ...	0·08	0·20	n.d.	n.d.
S	n.d.	0·08	n.d.	n.d.
Less O for S	—	0·03	—	—
Total ...	98·24	98·82	97·16	99·37

A. From Whin Sill. Through 120-mesh sieve.
B. From Whin Sill. Through 200-mesh sieve.
C. From Whin Sill. Analysis by Teall.
D. From Budle Sands.

the 200-sieve. C is Teall's analysis of the black ores from the whin sill, and D is of a similar magnetic mineral, separated from a very rich garnetiferous sand, which occurs on the shore at Budle and in the immediate vicinity of the whin. It was originally analysed to test its possible derivation from the whin sill; though this appears unlikely, the analysis is included for purposes which will be explained later.

In calculating the mineral composition from these figures, we may rule out the possibility of sphene being present, and the visible presence of pyroxene requires that the magnesium should be allocated to that mineral and not to ilmenite. Phosphoric acid, as usual, goes to apatite, and the substantial amount of manganese must be reckoned as pyrophanite, isomorphous with ilmenite, rather than referred to pyroxene. Iron, manganese and titanium are grouped together, constituting the ore proper. The potash and soda are naturally reckoned as the corresponding felspars, and also that portion of the lime not already allocated. In A and D the quantity of material at disposal did not allow of determination of the alkalies, so that the felspars are lower than they should be,[1] and the remainder of the unassigned constituents too high. It may be noted that the effect of extreme comminution in the preparation of B has been to reduce the felspar content of the magnetic powder and to raise the proportion of black ores quite appreciably. The figure 81·6 for the latter may be taken as the approximate limit of concentration by this method, whether from the artificially- or naturally-disintegrated rock.

[1] This is compensated to a slight extent only by reckoning some lime as felspar which should appear as apatite.

The mineral composition, thus calculated, is as follows:

IRON ORES

	From the Whin Sill			From Budle Sands
	A	B	C (Teall)	D
Apatite	0·18	0·43	n.d.	n.d.
Pyroxene	5·81	7·29	12·03	4·76
Felspar: Potash ...	n.d.	1·13	n.d.	n.d.
Felspar: Soda ...	n.d.	4·92	n.d.	n.d.
Felspar: Lime ...	10·30	3·05	12·13	9·40
Black Ores	75·52	81·60	73·61	78·26
Remainder ...	6·43	0·40	−0·61	6·95
	98·24	98·82	97·16	99·37

The analytical composition of the iron ores themselves, calculated to 100 p.c., is:

	A	B	C	D	Mean of A and B.
MnO ...	1·0	1·1	—	—	1·0
FeO ...	30·0	29·2	33·5	20·8	29·6
Fe_2O_3 ...	37·6	39·3	33·2	52·7	38·5
TiO_2 ...	31·4	30·4	33 3	26·5	30·9
	100·0	100·0	100·0	100·0	100·0

In the three specimens from the whin sill, there is a fair general agreement, the errors inherent in the preparative and analytical work, and in the method of calculation, being represented by the differences between A and B. The difference between C and either of these is much greater, and may be partly due to the personal factor; but it is not unlikely that it indicates actual variation in composition of the ores from different localities. D differs so much from the others that it cannot be regarded as derived from the whin sill, until, at any rate, we know more about the uniformity in composition, or otherwise, of the black ores in that formation.

From the mean of the analyses in column 6 of the above table, and from the titania-content of the rocks in tables D and G, we can calculate the ore-content of these rocks. The results will be given later. The mean value for the normal rocks is 8·5, and the maximum variation 1·6 p.c., which is much less than for any of the other important mineral constituents of the whin sill.

Teall is somewhat vague about the constitution of the black ores. He states (p. 651) that "the analysis and also the physical properties . . . agree with the assumption that we are here dealing with a mixture of magnetite and ilmenite." Evidence of such mixtures is quoted from foreign sources, and this, along with the observation that alteration of the ore into leucoxene takes place along two sets of parallel planes, appears to convince him that the ore is an intergrowth of magnetite and ilmenite. In the description of the plates, however, he speaks of "magnetic titaniferous iron-oxide, consisting of a framework of ilmenite lamellæ, with interspaces occupied by a different substance, probably magnetite," and elsewhere of forms "which are supposed to indicate ilmenite."

In describing the ores in the quartz dolerites of Croy, Tyrrell[1] remarks that "the form of this framework shows that this mineral belongs to the ilmenite group," and later, without deducing further evidence, that "the iron ore is made up of an intergrowth of magnetite and ilmenite." This view is also maintained by Bailey[2] for the iron ores in the similar quartz dolerites of the Glasgow district, and it is stated that the action of cold, concentrated hydrochloric acid removes the magnetite, leaving the brown-coloured ilmenite. It is, however, doubtful whether much importance could be attached to such a reaction.

[1] G. W. Tyrrell, *Geol. Mag.*, 1909, Dec. 5; Vol. VI, pp. 308, 365.

[2] E. B. Bailey, *The Geology of the Glasgow District*, 1925.

Despite some vagueness, the concensus of opinion as to the nature of the iron ores in the quartz dolerites is that they consist of mixtures or intergrowths of ilmenite and magnetite. The analytical results, however, do not lend support to this view in the case of the whin sill, as may be seen from Teall's own figures; for, supposing the titania to be completely present as ilmenite, it would take up 29·9 p.c. of ferrous oxide, leaving only 3·6 p.c. of this oxide to form magnetite. There would result from this 11·8 p.c. of magnetite and a residue of 25 p.c. of ferric oxide, presumably present as haematite. If, on the other hand, the ferric oxide be present as magnetite, and its equivalent of ferrous oxide be deducted from the total of that constituent, then, after forming ilmenite, there will be a residue of 12 p.c. of titanium oxide, presumably present as rutile.

Considering the four cases in this way, then of the four possible minerals, viz., magnetite, haematite, ilmenite and rutile, all the four possible combinations, taken three at a time, occur, and thus the chemical evidence is at variance with the assumption that the ores are mixtures of magnetite and ilmenite.

A way out of this difficulty can be found by assuming that ferric oxide, ordinarily regarded as a basic oxide, may function, perhaps only under magmatic conditions, or alternatively when in solid solution with a titanium derivative, as a ferrous ferrite, as symbolized by $FeO.FeO_2$ or $Fe''(FeO_3)$ and that, in such guise, it mixes isomorphously, or forms solid solutions, with ilmenite, $FeO.TiO_2$ or $Fe''(TiO_3)$.[1] The justification

[1] The formulation of oxides as salts, the basic and acidic components of which consist of oxides of the same metal in different stages of oxidation, is common enough. Thus, red lead, Pb_3O_4, is regarded as lead orthoplumbate, $2PbO.PbO_2$, or $Pb_2(PbO_4)$ and corundum as a kind of spinel, $Al(AlO_2)_3$. Even ferric oxide has been regarded as a ferric ferrite, $Fe'''(FeO_2)_3$.

of this assumption would be that the analyses of such titaniferous iron ores as are here under consideration should conform to the formula $FeO.(Fe,Ti)O_2$, or, if these ores be manganiferous $(Fe,Mn)O.(Fe,Ti)O_2$; in other words, the molecular ratio of the components, dualistically represented, should be unity.

It is necessary to observe that analysis of ferrous ferrite would not disclose its existence, since half the contained iron is oxidized as much above the tervalent stage as the other half is below it, and solution in acid would therefore yield only the ordinary ferric salt; but the relation, expressed symbolically as $Fe_2O_3 \rightarrow FeO + FeO_2$ is sufficient for the purpose in hand, namely, to calculate from the analyses of the ores the amount of FeO_2 equivalent to the ferric oxide which has been determined experimentally.

To take an example: In A, 37·6 p.c. Fe_2O_3 is equivalent to 16·9 p.c. FeO and 20·7 p.c. FeO_2. The former, added to 30·0 p.c. FeO actually found by analysis gives a total of 46·9 p.c. FeO. The molecular proportions of the four oxides concerned are now: — $MnO : FeO : FeO_2 : TiO_2 = 0·014 : 0·652 : 0·235 : 0·392$; or the sum $MnO + FeO = 0·666$ and $FeO_2 + TiO_2 = 0·627$; thus the ratio of the two is 1 : 0·94.

The results of similar calculations in the four cases, taken in order, expressed in molecular proportions, are: $(Fe,Mn)O : (Fe,Ti)O_2 = 1 : 0·94$; 1 : 0·94; 1 : 0·92; 1 : 1·07; that is, the ratio is close to unity in all cases as required by the hypothesis.

A number of published analyses of similar ores have been calculated in this manner and with satisfactory results, but many such are incomplete, and to extend the test, more analyses *ad hoc* are required. The ore D, from the Budle Sands, is especially valuable in this connexion, for it differs so greatly in composition from the other three and yet gives almost the same molecular ratio of constituents. This suggested constitution of the iron ores thus evades the analytical difficulties which arise when they are regarded as mixtures of magnetite and ilmenite, and it allows of considerable variation in composition of the ores, within the limits of the type. It is evident on this assumption that vicarious replacement of titanium by iron in ilmenite brings with it great increase in magnetic susceptibility, and it may be noted that the observed patterns which the leucoxenic bands display, on weathering of the ore, are not incompatible with this view.

Some other results come from the consideration of the analyses and may be briefly noted. The phosphorus-content in A is almost certainly low, as there was but little of the sample available for the determination; that in B is probably accurate, and it shows that the iron ores contain just about as much phosphorus as the whole rock from which they are derived. This result may be regarded as, in part, supplementary to the notable solubility of apatite in felspathic magmas, which has been already recorded.

The case is different with manganese and, indeed, the iron ores are the only whin-materials so far examined, with the exception of the pectolite from Caldron Snout (*v.* Table Q), which show any particular concentration of this element. The distribution of manganese in the rock may be calculated from the following data: The average whin contains 0·18 p.c. of manganese oxide and 8·0 p.c. of iron ores, and the ores themselves contain 1 p.c. of manganese oxide.

Hence the whin is made up of 8 p.c. of ores, containing 0·08 p.c. of manganese oxide and 92 p.c. of materials not ore, containing 0·18—0·08=0·1 p.c. of manganese oxide, both quantities of oxide referring to the whole rock. This gives a ratio of actual distribution of oxide of manganese between the ores and the rest of the rock of 1:1·25; or a ratio, calculated on equal weights of the two rock-constituents,

of 9·2:1. This latter ratio is the co-efficient of distribution of manganese oxide between the iron ores and the rest of the rock.

There can be little doubt that the 0·1 p.c. manganese oxide, not present in the ores, is a constituent of the pyroxenes, which are present in the whin to the extent of 37 p.c. These pyroxenes, therefore, contain 0·27 p.c. of manganese oxide, or just a quarter of the amount in the ores. In Teall's two analyses of pyroxene, the values found for manganese oxide are 0·22 and 0·37 p.c., which are in excellent agreement with this. In his table showing the composition of the whin (*op. cit.* p. 655), 0·13 p.c. of manganese oxide is ascribed to augite, none to titaniferous ore, and 0·03 p.c. to the remainder (unallocated constituents). A slight correction is obviously necessary here, in accordance with the above calculations.

THE COMPOSITION OF THE MICROPEGMATITE

The occurrence of micropegmatite in the mesostasis of the whin sill was described by Teall.[1] It is an invariable constituent of the coarser-grained rocks. As the grain diminishes, the typical structure becomes obscure and passes eventually into a crypto-crystalline mass in which the components, quartz and felspar, cannot be recognized. A like phenomenon has been encountered in similar rocks, such as the granophyric diabases of Dumbartonshire.[2]

The greatest concentration of this acidic material is met with in the pink veins and similar felsitic rocks of Cushat Steel. Though the former have not been

[1] J. J. H. Teall, *Quart. Journ. Geol. Soc.*, 1884, *40*, 642.
[2] G. W. Tyrrell, *Geol. Mag.*, 1909, Dec. 5; No. VII, 259 and 299.

analysed, an analysis of similar veins in the Hampeth Dyke (Table N, No. 2) has been made and this, together with the analysis of the felsitic rock of the whin sill (Table G, No. 7), may be used in order to calculate the composition of the micropegmatite.

The mineral composition of the two rocks is calculated on the ordinary assumptions with respect to the allocation of constituents for the formation of calcite, apatite, iron ore, pyrites and the felspars; magnesia is allocated to chlorite, using Wager's estimated composition of this mineral,[1] residual alumina to kaolinite, and silica to quartz. The results are:

	Felsitic Rock (Cushat Steel)	Pink Veins (Hampeth Dyke)
Calcite	0·7	2·8
Apatite	0·1	0·1
Iron Ore	1·8	1·3
Pyrites	0·7	0·6
Chlorite	4·1	5·4
Kaolinite	3·7	8·3
Albite	18·6	15·9
Orthoclase	30·5	29·6
Anorthite	4·4	3·8
Quartz	35·4	32·2
	100·0	100·0

The sum of the micropegmatitic constituents in the first is 88·9 p.c., and in the second, 81·5 p.c.

Calculating these to 100 p.c. we obtain:

	Cushat Steel	Hampeth	Mean
Albite	20·9	19·5	20·2
Orthoclase ...	34·4	36·3	35·4
Anorthite ...	4·9	4·6	4·7
Quartz	39·8	39·6	39·7
	100·0	100·0	100·0

[1] L. R. Wager, *Geol. Mag.*, 1929, Vol. LXVI, 226.

The composition of the micropegmatite, in analytical terms, is thus:

	Cushat Steel	Hampeth	Mean	Convergence Value
Na_2O ...	2·4	2·3	2·4	2
K_2O ...	5·8	6·1	5·9	6
CaO ...	1·0	0·9	1·0	—
Al_2O_3 ...	12·3	12·2	12·3	14
SiO_2 ...	78·5	78·4	78·4	78
	100·0	100·0	100·0	100

In the last column are given the convergence-values of the whin-suite, as deduced roughly from the variation diagram (*q.v.*). The correspondence between the analytical and the convergence value is strikingly close, and it seems legitimate to conclude from this relation and other observations already detailed, that the consolidation of the whin-magma results in the formation of an acidic mother-liquor, rich in albite, orthoclase and quartz, and carrying also a little anorthite, which tends to the composition given under the mean value in the last table; this is, approximately, 20Ab, 5An. 35Or.40Q.

This is the material which normally appears as micropegmatite but which, as already mentioned, may pass into an indeterminate assemblage of its constituents in the fine-grained rocks, or, when greatly concentrated, may shade into a crypto-pegmatite in spherulitic form. This magmatic mother-liquor is undoubtedly an eutectic in the etymological sense, but some hesitation may be felt as to whether it conforms to this title, as understood in the sense of the law of phase-equilibrium. With this reservation, there can be little objection in describing it as an eutectic mother-liquor.

THE MINERAL COMPOSITION OF THE WHIN SILL

The composition of the plagioclase felspars, the black ores and the micropegmatite having been determined with some degree of probability, it is now possible to go a step further and to calculate the mineral composition of the rocks from the analytical data.

As the plagioclase and the micropegmatite are the only constituents which carry alkalies, their proportions in any rock-sample can be determined from the alkali-content by a simple algebraical method. The relevant data may be repeated; they are:—for micropegmatite (Mp), $Na_2O = 2{\cdot}4$, $K_2O = 5{\cdot}9$; for plagioclase (F), $Na_2O = 4{\cdot}4$, $K_2O = 1{\cdot}7$ p.c. The proportions of these constituents in any whin-rock are thus given by the formulæ:

$$F = 27{\cdot}0 \times \text{p.c. } Na_2O - 11{\cdot}0 \times \text{p.c. } K_2O$$
$$Mp = 20{\cdot}1 \times \text{p.c. } K_2O - 7{\cdot}8 \times \text{p.c. } Na_2O$$

On applying these equations to the analytical material, it is found that a small negative value is obtained for the micropegmatite of the contact rock from White Force. This may be due either to errors in the composition of the mineral constituents in question, or to errors in the alkali-determinations of the rock, or to both causes. Assuming an experimental error of only 0·1 p.c. in the alkalies (that is, taking the values to be $Na_2O = 2{\cdot}66$, $K_2O = 1{\cdot}09$, instead of $Na_2O = 2{\cdot}76$, $Na_2O = 0{\cdot}99$), then the value for the micropegmatite becomes positive and equals 1·2 p.c. This example shows how sensitive the calculation is to experimental error, and this particular rock will be omitted in the subsequent calculations.

Apart from experimental error, however, the second

of the above formulæ implies that a certain minimum proportion must be maintained between the soda and the potash in order that the micropegmatite should be capable of formation; for when Mp = O, then the ratio of soda to potash (termed later the alkali-factor) equals 2·58. When this value is exceeded and the magma solidifies in the normal manner, then the potash felspar is completely taken up in the crystallization of the plagioclase, and none is left for the formation of micropegmatite.

The content of iron-ore is reckoned on the basis of the analysis of the isolated ores given above, and the titania-values of the individual rocks.

Minerals present in small quantity, like apatite, pyrites and calcite, are calculated from the content of the rocks in phosphoric acid, sulphur and carbon dioxide. They are grouped under the heading "Calcite, etc.," in the tables below.

For the estimation of the pyroxenes the analytical data are useless, partly because the only analyses of the mineral (those of Teall) do not contain titania, and so the mineral cannot be gauged as to its content of iron-ore, but chiefly on account of the complexity subsisting among the pyroxenes themselves, as recognized by Teall and emphasized in the later work of Holmes and Harwood.

It might appear, at first sight, that the relationship between felspar, F, and pyroxene, P, expressed by the equation $\frac{F}{F+P} = k$, would be of service. If k were really a constant, this would be the case, for putting the expression in the form $\frac{P}{F} = \frac{1-k}{k}$, it is apparent that the pyroxene bears a fixed proportion to the felspar.

In the micrometric measurements of Holmes and Harwood (*op. cit.* p. 509), the values of k differ by 10 p.c. To illustrate the effect of this deviation from constancy, suppose $k = 0{\cdot}5$, then P = F. If now k varies from 0·45 to 0·55, then the value of P changes from 1·22 F to 0·82 F; that is, the first is 50 p.c. greater than the second. Such a relationship is therefore useless for the purposes of the present problem.

The only method remaining is to estimate the pyroxene by difference. For this, the sum of the other four constituents is subtracted from the analytical total (in no case far from 100 p.c.), and then all five constituents are calculated to 100 p.c. The available data are given in Table J.

TABLE J

MINERAL COMPOSITION OF WHIN SILL ROCKS

Rock	Reference to Analysis	Felspar	Micro-pegmatite	Iron Ore	Pyroxene	Calcite, etc.	S.G. (found)	S.G. (calculated)
Average whin ...	Table D, No. 1 ...	43·1	5·5	8·0	39·6	3·8	2·934	2·952
Group-sample 3...	,, ,, 3 ...	45·5	1·3	9·0	38·2	6·0	2·975	2·926
,, 4...	,, ,, 4 ...	49·7	8·6	7·8	30·8	3·1	2·952	2·914
,, 27...	,, ,, 5 ...	52·4	3·3	9·1	27·3	7·9	2·871	2·830
Bavington Basalt	,, ,, 7 ...	51·3	4·5	8·0	32·1	4·1	2·891	2·909
Cullernose Basalt	,, ,, 8 ...	55·0	6·2	9·4	23·6	5·8	2·860	2·853
Snook Point ...	,, ,, 9 ...	52·3	1·4	9·2	34·6	2·5	2·900	2·980
Crook	,, ,, 10 ...	53·7	7·0	8·9	28·4	2·0	3·019	2·944
White Force ...	,, ,, 11 ...	51·0	4·9	8·4	32·9	2·8	2·971	2·946
Gilderdale ...	,, ,, 12 ...	42·4	1·8	7·8	45·4	2·6	2·958	3·018
Teward's Bridge	Table G, No. 2 ...	30·1	27·5	7·8	31·6	3·0	2·951	2·906
Gilderdale ...	,, ,, 3 ...	54·8	7·7	8·5	19·7	9·3	2·821	2·790
Mattergill ...	,, ,, 4 ...	42·2	17·4	10·7	25·5	4·2	2·907	2·901
Snook Point Inclusions ...	,, ,, 5 ...	42·5	25·6	5·6	19·5	6·8	2·724	2·724
do. do. ...	,, ,, 6 ...	49·7	26·1	5·3	15·7	3·2	2·725	2·776
Cushat Steel ...	,, ,, 7 ...	2·6	86·5	2·0	5·6	3·3	2·615	2·630
Group-sample 1...	Alkalies in Table K	36·5	6·4					
,, 7...	,, ,,	38·1	10·1					
,, 12...	,, ,,	45·4	9·3					
,, 19...	,, ,,	49·2	7·7					
,, 23...	,, ,,	40·3	5·1					
,, 26...	,, ,,	38·6	5·8					
,, 36...	,, ,,	41·2	7·7					

Though great accuracy cannot be claimed for these figures, the results, on scrutiny, appear to be consistent, and to have, at least, comparative value. It

is satisfactory to note that, for the normal rocks, the mean values for 17 estimations of plagioclase and 10 of pyroxene, respectively 46·2 and 33·3, are in close agreement with the mean of 10 micrometric determinations of Holmes and Harwood, viz., 46·3 and 35·8 p.c. Variations from the mean are naturally greater in the former case than in the latter, corresponding to the wider range of selection of material. There is also fair agreement between the values determined for group-sample 4 (Upper Tees) and Teall's calculations for the rock of Caldron Snout, the latter made by different methods from his own chemical data.

	Felspar	Micro-pegmatite	Ores	Pyroxene	Calcite, etc.	Remainder
Group-sample 4...	49·7	8·6	7·8	30·8	3·1	—
Caldron Snout (Teall)	40·0	—	7·3	36·2	1·7	14·3

It is apparent that the chief variable is micropegmatite, which, when all rocks are considered, ranges from 1·3 to 86·5 p.c., having a mean value 5·68 p.c. for the normal rocks, which is close to that of the average whin (5·5). Arranging the figures in the order of increasing micropegmatite and calculating this constituent as constant, then its relation to the plagioclase and pyroxene is seen in a clearer light, as appears in the table on p. 74.

While felspar and plagioclase vary greatly in their relation to micropegmatite, their variation with respect to each other, though by no means negligible, is very much less, the ratio of the two averaging 1·5 : 1 for all rocks. In the normal rocks, the ratio is distinctly less in those containing the smaller amounts of micropegmatite.

The magma contains, potentially, 5·5 p.c. of eutectic mother-liquor, for this is the average amount of micropegmatite in the whin. Extreme concentration of this is met with in the rock of Cushat Steel and reaches 86·5 p.c. From these figures, a simple calculation shows that to produce unit weight of the Cushat Steel rock, 15·7 units of magma are required, or 100 parts by weight of magma yield 6·4 parts by weight of the acidic derivative.

Relations of Chief Mineral Constituents in Whin Sill Rocks

Mp. (p.c.)	Mp.	: F	: P	F	: P
1·3	1	35·0	29·4	1·2	1
1·4	1	37·4	24·7	1·5	1
1·8	1	23·6	25·2	0·9	1
3·3	1	15·9	8·3	1·9	1
4·5	1	11·4	7·1	1·6	1
4·9	1	10·4	6·7	1·5	1
5·5	1	7·8	7·2	1·1	1
6·2	1	8·9	3·8	2·3	1
7·0	1	7·6	4·1	1·9	1
7·7	1	7·1	2·8	2·8	1
8·6	1	5·8	3·6	1·6	1
17·4	1	2·4	1·5	1·6	1
25·6	1	1·7	0·8	2·2	1
27·5	1	1·1	1·1	1·0	1
86·5	1	0·03	0·06	0·5	1

It might be expected from this that the pink differentiates would bulk largely among the whin-rocks, instead of constituting, as they do, only a very small fraction of them. The conditions of generation, however, are such that residual crystallization-liquor is entrapped in a mesh of interlocking crystals, and its separation and concentration is at best a partial process, the general nature of which will now be considered.

THE DIFFERENTIATION PROCESS

The genetic connexion of the various rocks of the whin sill has now been made abundantly manifest. Any attempted explanation of their derivation must take account of the variations, especially in felspar and pyroxene, of the normal rocks; the production of the exceptional varieties, their small quantity and the differences in their apatite-content.

Though there is some evidence, as will be seen later, of difference in composition of the magma, it may be assumed that this was slight. The progress of crystallization is attended by the formation of a mother-liquor, of ever-increasing acidity, containing the constituents of orthoclase, albite and quartz, with a little anorthite, together with apatite and, presumably, the volatiles. If we adopt the hypothesis that this mother-liquor possessed some freedom of motion throughout the whole course of solidification of the magma, then most, if not all, of the observations can be satisfactorily accounted for. The physical cause of the movement of mother-liquor is to be sought mainly in differential pressure, itself a resultant of the mode of intrusion of the magma, as described in a later chapter.

Movement of liquor at an early stage in the consolidation of the magma will result in increase of concentration of felspathic and quartzose constituents in the region invaded by the liquor. Further crystallization should increase the proportion of felspar, relatively to pyroxene, in this region, as compared with the locality which has been partly drained of its mother-liquor, and, provided no further movement of mother-liquor takes place, there should be more micropegmatite formed at the last stages of consolidation. Thus, the variations in felspar and pyroxene, and the relative increase of the felspar with rising micropegmatite, can be explained.

The data for the neighbouring rocks in Gilderdale, the dark gabbro and the coarse pink rock, are illuminating in this connexion.

	Mp.	Mp. : F : P	F : P
Gabbro	1·8	1 : 24 : 25	0·9
Coarse pink rock ...	7·7	1 : 7 : 3	2·8

Similar relations hold for group-sample 4 (Upper Tees) and the rock from Mattergill Sike.

At a later stage in the consolidation of the magma, the liquor available for transport was much more acidic and approaching the presumed eutectic composition. In addition it was saturated with volatiles and had dissolved most of the potential apatite in the magma, except the small amount carried down in the crystallization of the iron ores. This apatite obviously crystallized at a late stage, and is found in abundance in the micropegmatite of the mesostasis, the pink spots, inclusions and pink gabbroid rocks. Its proportion in the micropegmatite of any particular rock can be calculated as follows, assuming, as is likely from petrological evidence, that its solubility in the rock-constituents other than micropegmatite and iron ore is very small or nil. Five examples will be given, the data being taken from Tables D, G and J.

	Mineral Composition p.c.			Apatite p.c.			
	Micro-pegmatite	Iron Ores	Remaining Rock Constituents	Total in Rock	Total in Iron Ores	Difference	Present in Micro-pegmatite
1. Average whin (D, No. 1) ...	5·5	8·0	86·5	0·52	0·04	0·48	8·7
2. Gilderdale (G, No. 3) ...	7·7	8·5	83·8	1·50	0·04	1·46	18·9
3. Mattergill (G, No. 4) ...	17·4	10·7	71·9	1·10	0·05	1·05	6·0
4. Inclusions (G, No. 6) ...	26·1	5·3	68·6	1·74	0·02	1·72	6·6
5. Inclusions (G, No. 5) ...	25·6	5·6	68·8	1·12	0·03	1·09	4·3

The result for the average whin may be taken as standard and as representing the maximum solubility of apatite in the eutectic mother-liquor. Nos. 1 and 2, containing almost the same amounts of remaining rock-constituents, in which apatite is probably insoluble, are strictly comparable, and it is evident that the micropegmatite in No. 2 contains a large excess of apatite. From this one may conclude that eutectic liquor has been drained off from the rock after the partial solidification of the apatite. The remaining three contain less than the normal apatite, and presumably represent translocated liquor from which the apatite has been partly deposited. They might thus be derived from the draining of a rock like No. 2. The data for the two inclusions (Nos. 4 and 5) are of interest as showing the variations possible in different samples of the same rock.

These results therefore indicate that movement of mother-liquor was taking place continuously during the stage of crystallization of apatite from liquid residues which were rapidly approaching their ultimate composition.

In the final stage of the process, the apatite had separated almost completely,[1] and the drained-off liquor constituted the material from which the pink veins and felsitic rock of Cushat Steel are derived. It is of interest to note that a similar chain of events has been traced in the case of the gravitational series of the Glen More ring-dyke. In Bailey's words: "It is clear that much of the crystallization of the apatite occurred during the migration of the acid residuum."[2]

It is probable that the movement of mother-liquor during the process of crystallization of the whin sill magma was, in general, partial and extended to no

[1] Actually 0·16 p.c. of apatite is present in this liquor; this is, presumably, the solubility of the apatite at the freezing point of the eutectic.

[2] *Mull Memoir*, p. 329.

great distance. Most of it solidified *in situ*, forming the mesostasis, and this may well account for the small quantity, relatively speaking, of the micropegmatitic rocks which are found in the whole formation. The finer the crystal-grain of the rock, the more difficult would it be to remove the acidic liquor.

The intimate association of the coarse gabbroid rock, poor in micropegmatite, with the coarse pink rocks, rich in this constituent, has already been noted. These rocks occur in some profusion in positions usually a little higher than the middle of thick sills in the southern districts (Tees, Wear and Tyne), that is, in areas probably near to the source of the magma and in which the metamorphic action of the whin on the sedimentaries is a maximum. This is possibly the joint-effect of high magma-temperature, passage of much hot magma on its journey to distant places, and sill-thickness. The moulds in which the whin was cast were therefore well heated, and the intruded magma was forced to cool slowly. The conditions were thus eminently favourable to the segregation of acidic mother-liquor in the position in which the coarse rocks occur.

Tomkeieff[1] has given cogent reasons for concluding that the gabbro owes its origin to crystallization from a magma, the viscosity of which was low, on account of the presence of water and other volatiles, and he regards its formation as due to "a sort of liquation-differentiation within the body of the magma, prior to its injection into the strata."

The difficulties in the way of accepting this view are many, and it would appear that the conditions sketched above are competent to explain the origin not only of the gabbro but also of the associated coarse pink rocks or dolerite pegmatite. The segregated acidic liquor contained the necessary volatiles to reduce the

[1] S. I. Tomkeieff, *Mineralogical Mag.*, 1929, Vol. XXII, No. 125, p. 117.

viscosity and slow crystallization from this, coupled with local concentration of eutectic liquor by filter-press action, seems to be sufficient to account for the coarse rocks of both types and their juxtaposition in the same locality.

The generation of the spherical inclusions of Snook Point involves a greater translocation of mother-liquor than the case just considered. Though at first sight it might appear otherwise, there is no evidence here of immiscibility of magmas; rather must we regard the squeezed-out liquor, rich in the constituents of micropegmatite and apatite, as so placed, fortuitously, that it escaped into a fluid, though viscous, part of the mass, assumed the drop-like form as the result of surface-tension and rose through the liquid, partly by reason of its specific lightness, partly by the bubbles of steam and hydrogen sulphide generated within the drops by the release of pressure.

Though differential pressure has been invoked as one of the chief agents in the generation of the differentiated rock, it need not always arise in the same way. The pink spots or amygdales, either partially or entirely filled with micropegmatite, are obviously the result of injection of mother-liquor into gas-cavities, after the gases have lost their elasticity by cooling. The stresses set up by uniform contraction of the rock on solidification are enough for this purpose. The formation of the pink slabs and veins, again, may be due to the action of similar stresses, the still molten residue being forced into such cracks and fissures, produced by the contraction of the rock, as were in a position to receive it. It is noted by Tomkeieff (*op. cit.* p. 110) that the veins "show a definite intrusive relation to the normal dolerite . . . but there is no distinct marginal chilling," from which it would appear that the rock invaded by them was still hot. The same author has described an interesting observation from Tindal quarry of a pink vein, apparently issuing from a region of coarse pink rock and passing into the ordinary dolerite. This gives support to the close relationships among these pegmatitic rocks just described. It may be noted also, in this connexion, that inclusions of the Snook Point type have been found at Scrog Hill and Queen Margaret's Cove, both in the immediate neighbourhood of Cushat Steel, where the pink veins and slabs (especially the latter) are so abundantly developed.

CONNEXION BETWEEN CHEMICAL COMPOSITION AND SPECIFIC GRAVITY

In the early part of this paper, many determinations of specific gravity are recorded, and much evidence brought forward of considerable variation in this property. The cause of this variation was not obvious *a priori* and, on the generally accepted belief in the uniformity of chemical composition of the rock, was not lightly to be referred to a chemical origin. Extended chemical work, however, has disclosed greater differences than were anticipated, and it was decided to test the possible connexion between chemical composition and specific gravity.

For this object many of the analytical results given in tables D and G are available; in addition, a large number of determinations have been made *ad hoc*. With respect to these, the difficulty met with has been the selection of constituents which can be determined with accuracy in a reasonably short time, the analytical figures for which serve as criteria of the quantity of some important mineral constituent. The alkalies, ferrous oxide, water and carbon dioxide were chosen as conforming best to these conditions.

The alkalies have the merit of indicating uniquely the content of soda and potash felspars, but the number of determinations is necessarily limited by the great length of time which the process of their estimation demands. The results obtained render it doubtful whether the

expenditure of more time in this direction would be justified.

Ferrous oxide can be determined accurately and with much more expedition than the alkalies. Though not unique in its indications, since it is a constituent both of the pyroxenes and the black ores, yet as the latter are remarkably constant in quantity, any large variation in ferrous oxide may be ascribed mainly to variation in ferromagnesian minerals.

Carbon dioxide and water are both determined quickly and accurately, and they serve, in general, as criteria for the weathering and similar changes which the rock has undergone.

In the following description of this branch of the subject, analytical information concerning the accuracy of determinations is given (as was done in the case of specific gravity) wherever it appears necessary for the appreciation of the argument.

1. *The Alkalies*

The alkalies have been determined in 26 specimens, of which 17 are of normal rocks; these include the average whin and 10 group-samples. Duplicate determinations were made in 9 cases and the mean difference in these is 0·08 p.c., Na_2O, and 0·07 p.c., K_2O; the extreme variations being 0·11 p.c., Na_2O, and 0·13 p.c., K_2O. The experimental error in any determination probably does not exceed 0·15 p.c. The data are given in Table K, the arrangement being that of increasing alkali-content.

Consider first the average whin and the group-samples. The average for the latter, viz., $Na_2O = 2·08$, $K_2O = 1·13$, agrees well with the average whin, in which $Na_2O = 2·03$, $K_2O = 1·06$, but the extreme variations in the group-samples, viz., $Na_2O = 0·62$, $K_2O = 0·50$, greatly exceed the probable experimental error.

In the last column of the table is given the ratio

Na_2O/K_2O, which we may call the alkali-factor. This is very sensitive to experimental error, as may be illustrated in this way. Its value for the average whin is 2·03/1·06 = 1·92. If the soda were 0·1 p.c. high and the potash 0·1 p.c. low, then the quotient

TABLE K

ALKALIES

Locality (Group-sample numbers in brackets)	Na_2O p.c.	K_2O p.c.	Na_2O+K_2O p.c.	Na_2O/K_2O Alkali Factor	S.G.
Ritton White House	1·82	0·79	2·61	2·30	2·897
Gilderdale (Gabbro)	1·92	0·83	2·75	2·31	2·958
Lunedale (1)	1·76	1·00	2·76	1·76	2·940
Ratcheugh-Howick (26) ...	1·84	1·00	2·84	1·84	2·914
Stanhope (3)	2·04	0·85	2·89	2·40	2·976
Kirkwhelpington (23)	1·91	1·02	2·93	1·87	2·900
White Force (Basalt)	2·30	0·63	2·93	3·65	3·043
Scrog Hill (Basalt)	2·02	0·95	2·97	2·13	2·734
Average Whin	2·03	1·06	3·09	1·92	2·934
Detchant (36)	2·00	1·16	3·16	1·73	2·936
Upper Tynedale (7)	1·92	1·25	3·17	1·54	2·956
Snook Point	2·36	0·97	3·33	2·43	2·900
Cullernose-Dunstanburgh (27) ...	2·38	1·06	3·44	2·25	2·871
Bavington (Basalt)	2·38	1·14	3·52	2·09	2·891
White Force (Dolerite) ...	2·36	1·16	3·52	2·03	2·971
Blackburn (12)	2·27	1·34	3·61	1·70	2·884
Cawburn-Hotbank (19) ...	2·35	1·29	3·64	1·82	2·948
Upper Teesdale (4)	2·37	1·35	3·72	1·75	2·952
White Force (Contact rock) ...	2·76	0·99	3·75	2·79	2·947
Crook	2·54	1·33	3·87	1·91	3·019
Cullernose Point (Basalt) ...	2·59	1·31	3·90	1·97	2·860
Gilderdale (Pink rock) ...	2·61	1·39	4·00	1 88	2·821
Mattergill (Pink rock) ...	2·27	1·74	4·01	1 31	2·907
Teward's Bridge	1·98	2·13	4·11	0 93	2·951
Snook Point (Inclusions) ...	2·47	2·22	4·69	1 11	2·724
do. do. ...	2·76	2·36	5·12	1 17	2·725
Cushat Steel	2·19	5·15	7·34	0·42	2·615

would be 2·13/0·96 = 2·22, whilst, if the experimental errors were reversed, it would be 1·93/1·16 = 1·66. Now the average alkali-factor for the 10 group-samples is 1·86, the extremes being 2·40 and 1·54, which are almost the limits given in the above

example. It may be inferred, then, that the ratio of soda to potash in these rocks is constant, though the quantities of the two show considerable variation.

To take an extreme case, the total alkalies in the Crook rock, 3·87, are 50 p.c. greater than in the Gilderdale rock, 2·75, yet the alkali-factors in the two cases, 1·91 and 2·31, are not very different. It may be remarked, too, that the alkali-factor for the felspar separated from the whin by Teall is 1·66, whilst that from Borcovicus is 2·6, and these ratios are within the limits of the rocks here described.

The other normal rocks display, as might be expected, greater divergencies, extreme variations being Na_2O = 1·00, K_2O = 0·56, but the mean for all normal rocks, viz., Na_2O = 2·16, K_2O = 1·09, Na_2O/K_2O = 2·02, is close to the average whin. This confirms previous observations that the method of group-sampling eliminates local differences and is competent to disclose large-scale variation.

It is evident from the Table K that there is no simple relation between alkali-content and specific gravity in the case of the normal rocks, and this is borne out by the graphs (Fig. 4) on which these results are plotted. Though it cannot be doubted that variation in felspar-content has an effect on the specific gravity, this effect is obviously masked by other factors. No connexion between alkali-content of the rocks and their geographical position can be detected, and attempts to correlate it with other analytical data have not been successful.

The high alkali-content of the exceptional rocks in the lower part of Table K has already been commented on. One may note here that the alkali-factor is low, and in two cases is even less than unity. The end members, richest in alkalies, show a great diminution in specific gravity, part of which, at least, must be referred to their high felspar-content. This is illustrated in Fig. 3.

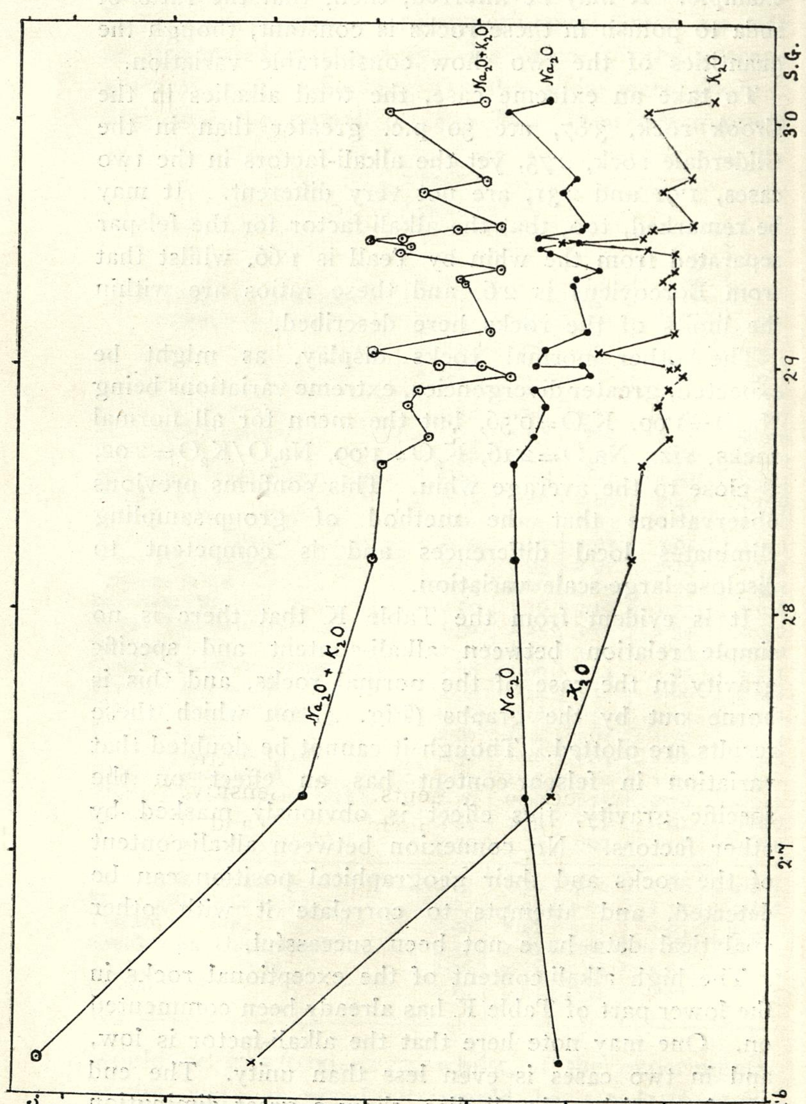


Fig. 3.
Showing the relationship between Specific Gravity and Alkali-content, both for normal and exceptional rocks.

Before leaving this subject it may be noted that the approximate constancy of the alkali-factor in the normal rocks indicates a simplicity of relationship between the felspars which does not extend to the rock-constituents in which these felspars occur. From the alkali-content of the plagioclase felspars (F) and the micropegmatite (Mp) we can represent the alkali-factor by the expression:—

$$\text{Alkali-factor} = \frac{4{\cdot}4\ F + 2{\cdot}4\ Mp}{1{\cdot}7\ F + 5{\cdot}9\ Mp}$$

From this we can calculate the ratio of the two rock-constituents corresponding to the mean and the extreme values of the alkali-factor of the group-samples. The figures are:—

Alkali Factor	F/Mp
2·4	39·0
1·8	6·1
1·5	3·4

A relatively small change in alkali-factor may be accompanied by a large change in the ratio of the alkali-bearing rock-constituents. The sensitiveness of the alkali-factor to experimental error, and its note-worthy approximation to constancy, are therefore liable to detract attention from large variations in the proportions of important rock-constituents, consistent with small changes in the alkali-factor.

2. *Ferrous Oxide*

Determinations of this constituent in 31 normal rocks are recorded in Table L, in which they are arranged in descending order of specific gravity of the rocks examined. These embrace 19 group-samples, the average whin and 11 other rocks. Duplicate determinations were done in 13 cases, and the average difference of duplicates is 0·09 p.c.; extreme values of ferrous oxide range from 11·90 to 8·09, or 3·81 p.c. The average of the 19 group-samples is 9·04 p.c., which agrees, within experimental error with the figure for the average whin, 8·92. The average of all the rocks is somewhat higher, 9·3, showing that the selected rocks, other than the group-samples, deviate more from the mean value, as was noted, too, in the case of the alkalies.

TABLE L

FERROUS OXIDE

Locality (Group-sample numbers in brackets)	FeO (p.c.)	S.G.
White Force (Basalt)	11·90	3·043
Crook	10·60	3·019
Stanhope (3)	10·24	2·976
White Force (Dolerite)	10·52	2·971
Gilderdale (Gabbro)	9·66	2·958
Upper Tynedale (7)	9·41	2·956
Harpertown (9)	9·44	2·956
Upper Teesdale (4)	9·32	2·952
Cawburn-Hotbank (19)	8·91	2·948
White Force (Contact)	10·62	2·947
Pennine Escarpment (15) ...	9·20	2·945
Lunedale (1)	9·16	2·940
Detchant (36)	9·06	2·936
Average whin	8·92	2·934
Belford-Detchant (35)	8·96	2·933
Farne Islands (33)	8·29	2·930
Bavington, Western Sill (22) ...	8·74	2·927
Fairnley	8·84	2·926
Bavington, Eastern Sill (21) ...	8·87	2·921
Copthill (2)	9·57	2·914
Ratcheugh-Howick (26)	9·22	2·914
Kyloe Hills (37)	8·22	2·906
Kirkwhelpington (23)	8·55	2·900
Snook Point	8·20	2·900
Ritton White House	9·12	2·897
Embleton-Snook Point (28) ...	8·34	2·894
Bavington (Basalt)	10·24	2·891
Blackburn (12)	9·03	2·884
Cullernose-Dunstanburgh (27) ...	9·19	2·871
Cullernose Point (Basalt) ...	10·30	2·860
Scrog Hill (Basalt)	8·09	2·734

It is evident from the tabulated data (see also Fig. 4) that ferrous oxide tends to decrease with the specific gravity, and this relationship is more strongly marked in the rocks of higher specific gravity than the average whin. Of 8 group-samples, having S.G. above the average whin, 7 have a higher content of ferrous oxide, the remaining one being almost identical; of 11 group-samples with a lower S.G. than the average whin, ferrous oxide is lower in 6, equal in one and higher in 4. These relationships are not much altered when all specimens are considered, but they have greater significance in the case of the group-samples, which are more strictly comparable with each other.

It is thus difficult to escape the conclusion that one factor affecting the specific gravity of the rocks is variation of ferrous oxide, which implies that the pyroxene-content differs from sample to sample and that density-changes are, to some extent, dependent on this. Other influences are at work which tend to mask the relationship, though this stands out more clearly than in the case of the alkalies.

The only exceptional or abnormal rocks to be considered here are the coarse, pink, granophyric rocks from Gilderdale, and from the Tees near Mattergill Sike (see Table G, Nos. 3 and 4). These contain respectively 9·97 and 9·60 p.c. of ferrous oxide, about 1 p.c. above the average whin. Some of the group-samples, notably Nos. 12 and 26, contain a fair proportion of this pink rock, the effect of which will be to raise their content of ferrous oxide. The low value for the whin from the Farne Islands, No. 33, is possibly connected with the red staining which the rock from that district exhibits, and may indicate that some of its ferrous constituents have been oxidized. It is noteworthy that three of the chilled rocks, namely the basalts from Great Bavington and Cullernose Point, and the contact rock from the White Force, are anomalous in position and have high values for ferrous oxide. The remaining chilled rock, the basalt from White Force, has the highest ferrous oxide content of all the rocks. This is conceivably due to the preservation, by a kind of quenching action, of a state of equilibrium between oxides of iron and silica, different from that attained when the magma cools slowly in the normal manner.

In considering the data geographically, stress must be laid upon those referring to the group-samples. The highest values for ferrous oxide are in Weardale (10·2, 9·6) and in the Upper Tees (9·3), Tyne (9·4) and Lune (9·2), and the Pennine escarpment comes close to these (9·2). There is a slight fall along the Roman Wall (8·9), and the same value is found in the Bavington district (8·9, 8·7); the fall becomes pronounced at Kirkwhelpington (8·5), and more so towards the coast (8·3, 8·3), though broken between Ratcheugh and Dunstanburgh by much higher values (9·2, 9·2). Slight recovery takes place around Belford and Detchant (8·9, 9·1) and there is again a fall at the most northerly part of the outcrop, in the Kyloe Hills (8·2).

Thus, with the exception of the district between Ratcheugh and Dunstanburgh, the changes in the ferrous-oxide content correspond with those in specific gravity, and this relationship points to original difference in the composition of the magma.

3. *Water and Carbon Dioxide*

These constituents have been determined in 28 specimens, viz.: the average whin, 18 group-samples, and 9 other rocks. The average difference in 6 duplicate determinations of water was 0·08 p.c., and in 9 of carbon dioxide, 0·05 p.c. The results are given in Table M (and are plotted in Fig. 4), in which hydroscopic water, given off at 110° C., is marked $H_2O(-)$, and combined water, lost on ignition, is marked $H_2O(+)$. It is impossible to separate in function the hydroscopic from the combined water, and it is,

analytically, undesirable to do so, for one determination follows the other on the same sample, and any deficiency in hydroscopic water is carried forward to the credit of combined water. Hence, though each is given separately in the table, it is the sum of the two, the total water, which is particularly important.

TABLE M

WATER AND CARBON DIOXIDE

Locality (Group-sample numbers in brackets)	$H_2O(+)$	$H_2O(-)$	Total H_2O	CO_2	$H_2O + CO_2$	S.G.
White Force (Basalt)	—	—	1·30	0·40	1·70	3·043
Crook	1·08	0·38	1·46	tr.	1·46	3·019
Stanhope (3)	1·40	0·35	1·75	1·38	3·13	2·976
White Force (Dolerite)	—	—	1·92	0·40	2·32	2·971
Gilderdale (Gabbro)	1·40	0·50	1·90	tr.	1·90	2·958
Upper Tynedale (7)	1·55	0·65	2·20	0·24	2·44	2·956
Harpertown (9)	1·62	0·55	2·17	0·13	2·30	2·956
Upper Teesdale (4)	1·45	0·61	2·06	0·18	2·24	2·952
Teward's Bridge	1·50	0·60	2·10	0·12	2·22	2·951
Cawburn-Hotbank (19)	1·32	0·82	2·14	0·14	2·28	2·948
White Force (Contact)	2·10	0·50	2·60	none	2·60	2·947
Lunedale (1)	1·70	0·50	2·20	0·42	2·62	2·940
Detchant (36)	1·65	0·20	1·85	0·08	1·93	2·936
Average whin	1·30	0·75	2·05	0·46	2·51	2·934
Belford-Detchant (35)	1·21	1·02	2·23	0·12	2·35	2·933
Farne Islands (33)	0·95	0·75	1·70	0·10	1·80	2·930
Bavington, Western Sill (22) ...	1·22	0·98	2·20	0·34	2·54	2·927
Bavington, Eastern Sill (21) ...	1·52	0·92	2·44	0·40	2·84	2·921
Copthill (2)	1·50	0·78	2·28	1·06	3·34	2·914
Ratcheugh-Howick (26)	1·88	1·12	3·00	0·54	3·54	2·914
Kyloe Hills (37)	1·38	1·20	2·58	0·54	3·12	2·906
Kirkwhelpington (23)	1·55	0·85	2·40	1·04	3·44	2·900
Embleton-Snook Point (28) ...	1·50	1·28	2·78	0·75	3·53	2·894
Bavington (Basalt)	1·92	1·05	2·97	0·14	3·11	2·891
Blackburn (12)	2 15	0·75	2·90	2·18	5·08	2·884
Cullernose-Dunstanburgh (27) ...	2·20	1·25	3·45	1·35	4·80	2·871
Cullernose Point (Basalt) ...	1·87	1·32	3·19	0·63	3·82	2·860
Scrog Hill (Basalt)	2·12	2·07	4·19	5·05	9·24	2·734

From inspection of the analytical data there appears to be no simple relation between total water and carbon dioxide; in this connexion, it has already been observed (p. 40) that the conditions under which the magma solidifies may exercise an effect on the water-content of the resulting rock. Nevertheless, it is apparent that, in a general way, those rocks which are low in carbon dioxide are also low in water, and those in which carbon dioxide exceeds, say 0·5 p.c., have a high water-content. It may be accepted that alteration (whether hydrothermal or by weathering) of the gentle character to which these rocks have been subjected will result in their hydration and carbonation, and the effect of both of these changes is to reduce specific gravity. An extreme case of carbonation has already been mentioned in the white trap from Winch Bridge, which contains 9·9 p.c. of carbon dioxide, equivalent to 22·5 p.c. of calcium carbonate, and has a specific gravity, 2·668.

From a consideration of the data in Table M it is apparent that there is a tendency for both water and carbon dioxide to increase as the specific gravity is diminished. This is best seen by directing attention to the sum of the two constituents ($H_2O + CO_2$). The average of this for all specimens is 2·8 p.c., and of the 17 rocks, having specific gravity over 2·921, only one exceeds this average value, whilst the 10 of lower specific gravity have all a higher content of total water and carbon dioxide.

Another way of exhibiting the relationships is to divide the rocks into three groups (omitting the first two rocks and the last), each having the same difference of specific gravity, and to compare the average values of total water, carbon dioxide, and the sum of these two in each group. The results are given below.

S.G. of Rock	Number of Analyses	Mean Values in each Group		
		H_2O (Total)	CO_2	H_2O+CO_2
2·98 to 2·94 ...	10	2·17	0·29	2·46
2·94 to 2·90 ...	10	2·27	0·47	2·74
2·90 to 2·86 ...	5	3·58	1·01	4·59

The general relationship thus appears indisputable, though, as in the other cases studied, there are many anomalies, among which may be mentioned the high value for carbon dioxide in group-sample 3 and the low value for the same constituent in group sample 36.

The data relating to alteration of the rock, as measured by the values for ($H_2O + CO_2$), though only about half as numerous as those concerning specific gravity, are yet sufficient to trace, in a general way, the changes which take place in passing from one locality to another. Weardale gives high values (3·13 and 3·34). The Lune, Tees, South Tyne (including Harpertown) and the Roman Wall escarpment average 2·38 (the extremes being 2·22 and 2·64): Blackburn, 5·08, is an exception here, as it is in the matter of specific gravity. In mid-Northumberland a rise takes place, 4 group-samples averaging 3·09 (extremes 2·54 and 3·54), and this rise is accentuated on the coast, two values there being 4·8 and 3·53. Reversion to lower values sets in on the Farnes and continues to Detchant, three group-samples giving an average of 2·09, and, finally, there is a slight rise in the most northerly exposure of the Kyloe Hills (3·12). Traced thus topographically, it is evident that specific gravity varies inversely as the sum of total water and carbon dioxide, that is, as the degree of alteration which the rock has undergone. Some part of this alteration is to be credited to weathering, the remainder to anterior metasomatic processes.

The results of this study may be summarized in a few words. Variation in alkali-content has no observable effect on specific gravity until the quantity of alkalies exceeds the normal and the group of exceptional rocks is entered. When this happens, high alkali-content is combined with low specific gravity. There is a more obvious connexion between specific gravity and content of ferrous oxide, the relation being a direct one, i.e., high values of the one corresponding to high values of the other, and the reverse. The differences are mainly to be ascribed to variation in pyroxene-content, and this would appear to be original, that is, owing to lack of uniformity of the magma. Between specific gravity and content of water and carbon dioxide, the connexion is otherwise, high values of the one corresponding to low values of the other.

Both in the case of ferrous oxide and water and carbon dioxide, anomalies are encountered and the problem is a complex one. The relationships, just described, for the normal rocks are plotted in Fig. 4.

MINERAL COMPOSITION AND SPECIFIC GRAVITY

From the above, there appears to be an undisputable relation between the amounts of certain constituents of the rocks, expressed analytically, and their specific gravity. To examine the subject more closely, three group-samples (Nos. 3, 4 and 5 in Table D) were fully analysed, but the results, from this point of view, are disappointing, for increase in the number of variables renders it all the more difficult to select a datum line for comparison. A more hopeful line of attack presents itself by way of mineral composition, as given in Table J.

Here there are five constituents, and a fair estimate of the specific gravity of four of these can be made, both by calculation and experiment. These four constituents and their accepted gravities are: felspar (F), 2·7; micropegmatite (Mp), 2·62; iron ore, 5·5; pyroxene (P), 3·3. The constituents grouped under "Calcite, etc.," in the table include calcite, apatite, pyrites and water, and it is the presence of the water which presents

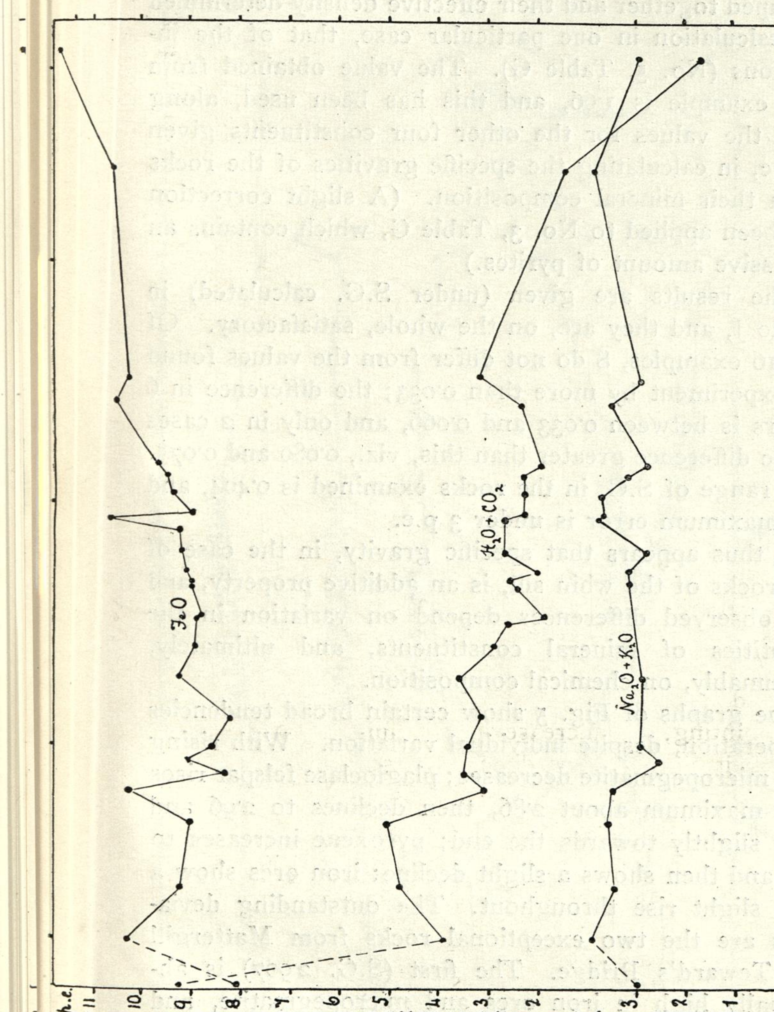


FIG. 4.

Showing the relationship, in normal rocks, between specific gravity and content of ferrous oxide, alkalies, water and carbon dioxide. (Note that the rock of lowest specific gravity (2·734) should be some distance to the left of the diagram. The connecting lines with the next member should thus be less steep than the broken lines.)

the difficulty in estimating their influence on specific gravity. For the purpose in hand, they have been grouped together and their effective density determined by calculation in one particular case, that of the inclusions (No. 5, Table G). The value obtained from this example is 1·66, and this has been used, along with the values for the other four constituents given above, in calculating the specific gravities of the rocks from their mineral composition. (A slight correction has been applied to No. 3, Table G, which contains an excessive amount of pyrites.)

The results are given (under S.G. calculated) in Table J, and they are, on the whole, satisfactory. Of the 16 examples, 8 do not differ from the values found by experiment by more than 0·033; the difference in 6 others is between 0·033 and 0·066, and only in 2 cases is the difference greater than this, viz., 0·080 and 0·075. The range of S.G. in the rocks examined is 0·404, and the maximum error is under 3 p.c.

It thus appears that specific gravity, in the case of the rocks of the whin sill, is an additive property, and the observed differences depend on variation in the quantities of mineral constituents, and ultimately, presumably, on chemical composition.

The graphs of Fig. 5 show certain broad tendencies in operation, despite individual variation. With rising S.G. micropegmatite decreases; plagioclase felspar rises to a maximum about 2·86, then declines to 2·96 and rises slightly towards the end; pyroxene increases to 2·95 and then shows a slight decline; iron ores show a very slight rise throughout. The outstanding deviations are the two exceptional rocks from Mattergill and Teward's Bridge. The first (S.G. 2·907) is abnormally high in iron ores and micropegmatite, and low in pyroxene; the second (S.G. 2·951) is high in micropegmatite, and low both in felspar and pyroxene.

This method of calculating S.G. has been applied to the analyses of other authors, and the results, given in

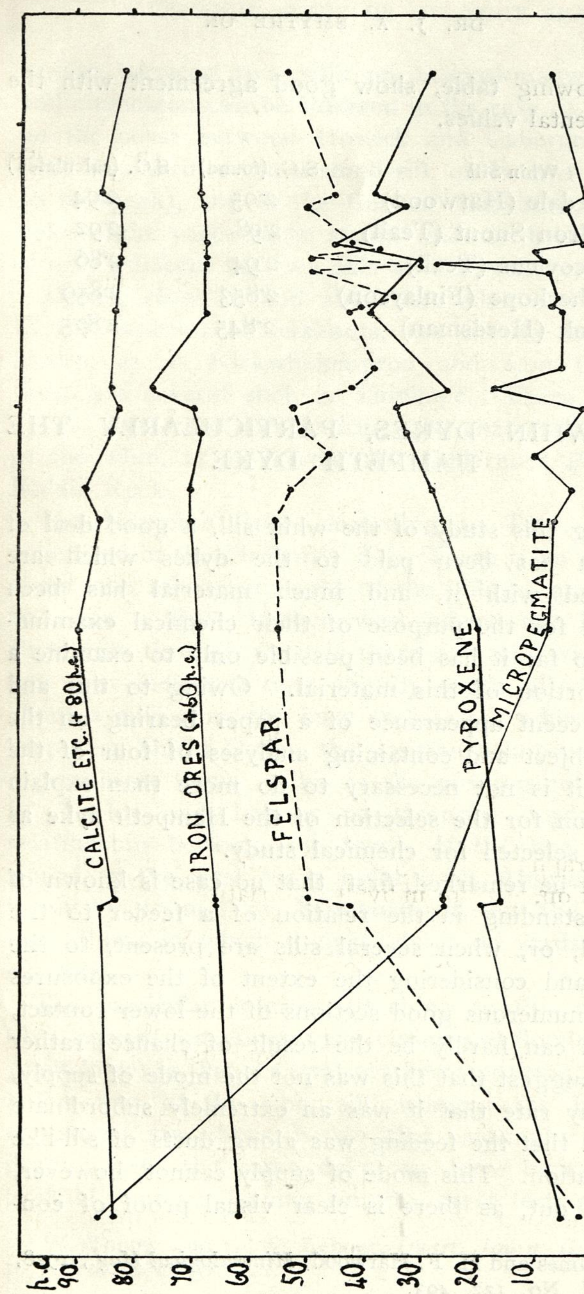


FIG. 5. Showing the relationship between specific gravity and mineral composition.

the following table, show good agreement with the experimental values.

Whin Sill	S.G. (found)	S.G. (calculated)
Scordale (Harwood)	2·95	2·94
Caldron Snout (Teall)	2·98	2·92
Borcovicus (Teall)	2·94	2·86
Rotherhope (Finlayson)	2·853	2·859
Crook (Herdsman)	2·845	2·875

THE WHIN DYKES, PARTICULARLY THE HAMPETH DYKE

During this study of the whin sill, a good deal of attention has been paid to the dykes which are associated with it, and much material has been collected for the purpose of their chemical examination. So far it has been possible only to examine a small portion of this material. Owing to this and to the recent appearance of a paper bearing on the same subject and containing analyses of four of the dykes,[1] it is not necessary to do more than explain the reason for the selection of the Hampeth dyke as the one selected for chemical study.

It may be remarked, first, that no case is known of a dyke standing in the relation of a feeder to the whin sill, or, when several sills are present, to the lowest, and considering the extent of the exposures and the numerous good sections of the lower contact, this fact can hardly be the result of chance; rather does it suggest that this was not the mode of supply, or at any rate that it was an extremely subordinate one, and that the feeding was along ducts of sill-like configuration. This mode of supply cannot, however, be ruled out, as there is clear visual proof of connexion between two sills on Scarrowmanwick Fell, and connexion can be inferred in the case of the dyke on the coast between Howick and Cullernose Point (this also throws out a small sill, on its own account, so to speak), and at the Butt of Blackburn, where a dyke eight yards wide stands midway between, and closely adjacent to, two sills at different horizons.

[1] A. Holmes and H. F. Harwood, *Mineralogical Mag.*, 1928, Vol. XXI, No. 122, 493.

Dykes, close to and above the whin and standing in the relation of offshoots, are known in various places, as at Kirkwhelpington and Loo Gill, and there are several such in Thinhope. There are also dykes, connected with faulting and change in horizon of the whin, as at Raven Gill, Cullernose Point and Saddle Rock.

The Hampeth dyke, according to Tate, was encountered in the Shilbottle Pit. There is an exposure about one mile south-west of the village, and a very fine one a little farther west where the Hampeth Burn cuts through it; it is there 22 yards wide. The line thus indicated runs slightly south of west, and about a mile from the burn crosses the whin sill outcrop near Shield Dykes, the position being marked by a prominent hump. This is the position referred to by Topley and Lebour as strongly suggesting a relationship between the two.[1] If the line be continued to the west for 3 miles, over Alnwick Moor, a quarry is met at Flamborough, on the Edlingham Burn, in which a dyke about 20 yards wide is exposed.

The particular interest attaching to this exposure (first opened out about 1920, closed and flooded a few years later) is that its stratigraphical position is much below that of the whin sill, whereas the Hampeth exposures are above it; so that, assuming we are dealing with the same dyke, we have here a case, probably unique (leaving out the great tertiary dykes

[1] W. Topley and G. A. Lebour, *Quart. Journ. Geol. Soc.*, 1877, Vol. XXXIII, 421.

of Acklington and Cleveland, which are obviously unconnected with the whin sill), of a dyke, either later in age or contemporaneous with the sill; in the latter case, the whin sill would be, locally at least, a lateral extension of the dyke.

The rock of this dyke is undistinguishable from the whin sill and, in its exposure on the Hampeth Burn, contains pink veins half an inch wide. Analyses of the dyke rock and pink veins from Hampeth are given below.

TABLE N

ANALYSES OF THE HAMPETH DYKE

	1	2	3
SiO_2	49·60	69·20	44·30
TiO_2	2·60	0·43	3·34
Al_2O_3	14·75	14·32	16·52
Fe_2O_3	2·36	0·19	9·08
FeO	9·66	2·48	4·29
MnO	0·15	0·03	n.d.
MgO	5·34	0·71	5·00
CaO	8·30	2·50	6·25
BaO	n.d	n.d.	0·05
Na_2O	2·32	1·88	1·79
K_2O	1·08	4·97	0·60
H_2O (+) ...	1·52	1·02	2·39
H_2O (−) ...	1·18	0·30	4·82
CO_2	0·32	1·22	none
P_2O_5	0·31	0·07	0·20
Cl	tr.	tr.	none
S	0·26	0·26	0·09
SO_3	n.d.	none	1·41
Less O for S ...	0·08	0·08	0·03
Total ...	99·67	99·50	100·10
S.G. ...	2·955	2·602	n.d.

1. The dyke-rock.
2. Pink veins.
3. Altered rock.

The dyke-rock shows differences in composition from the average whin of the same order as other samples of the whin. In many respects, it resembles very closely the Little Whin Sill (Table D, No. 3), but the high degree of carbonation of that rock obscures somewhat the relationship. Perhaps it is best compared with the Bavington basalt (Table D, No. 7), where the only differences of note are in silica and iron, and these are compensatory.

The pink veins are closely related to the felsitic rock of Cushat Steel (Table G, No. 7), the differences in lime and silica being largely accounted for by the high content of calcite, 2·8 p.c., in the Hampeth rock. Especially noteworthy are the normal soda-content, the high potash and the almost complete absence of phosphoric acid. Detailed calculations on this rock have already been made, and its practical identity with the Cushat Steel rock established. Taking the dyke-rock and the acid veins together, their resemblance to the whin sill and its differentiates is such that it is almost inevitable to conclude that both dyke and sill have sprung from the same magma which, by the operation of the same process of differentiation, has furnished the same acidic mother-liquor in each case.

The recent work of Holmes and Harwood has extended our knowledge of the dykes and brought out the similarity in composition between those at Holy Island, Elsdon, St. Oswald's Chapel, Wackerfield and Hett, and the Whin Sill. If we assume these dykes to be constituted like the whin sill, and apply the methods of calculation already described to the analytical results, the proportions of plagioclase and pyroxene, in all but the Holy Island dyke, come out close together. This is confirmed by the results of 17 micrometric measurements, given in their paper, which show less variation in these minerals than in the case of the whin sill, and the mean of which, incidentally, is very close to that of the whin sill.

The results of the calculations in question are given below, along with those for the Hampeth dyke and the basalts of Cullernose and Bavington (the last two repeated for reasons explained in the next chapter). The results for the Hett and Wackerfield dykes are incomplete since the calculations yield small negative values for the micropegmatite, the possible reasons for which have already been stated.

Mineral Composition and Specific Gravity of Dyke Rocks

	Felspar	Micropegmatite	Ore	Pyroxene	Calcite, etc.	S.G. (calculated)	S.G. (found)
Elsdon Dyke	51·1	0·6	8·4	35·8	4·1	2·94	3·01
St. Oswald's Chapel Dyke	51·5	2·0	8·5	34·3	3·7	2·94	2·99
Holy Island Dyke ...	63·3	1·8	8·1	23·7	3·1	2·89	2·97
Hett Dyke	54·4		7·0	31·3	7·3		
Wackerfield Dyke ..	54·9		7·2	34·0	3·9		
Hampeth Dyke	51·0	3·6	8·4	32·9	4·1	2·92	2·95
Bavington Basalt	51·3	4·5	8·0	32·1	4·1	2·91	2·89
Cullernose Basalt	55·0	6·2	9·4	23·6	5·8	2·85	2·86

Judging by these results it would seem that the conditions under which the magma became consolidated in the dyke-fissures were more favourable for the production of a uniform rock than was the case in the sill-fissures. Stated in terms of the hypothesis sketched in a former chapter, there was less free movement of molten material during the period of freezing, which may be ascribed to the conditions in the dyke-fissures being unfavourable to the establishment of differential pressure.

Alteration of the rock of the Hampeth dyke has some points of interest. Patches of fibrous chloritic material are fairly common. Though this has not been analysed, it does not differ in appearance from the chlorite associated with the whin sill. There is,

however, another alteration product which, though resembling somewhat the rock from Ritton White House, is very different in composition from any of the whin sill rocks. It is a friable, greenish-brown material which, on rubbing in the hands, all passes the 80-mesh sieve, and on further screening gives a large yield of dust passing the 120-mesh sieve. This dust on grinding furnishes a brown powder the analysis of which is given in the table above under the head of " altered rock."

Perhaps the most striking feature of this material is the high content of sulphate ($SO_3 = 1{\cdot}41$ p.c.) which is present chiefly as ferrous sulphate (with some ferric salt) and calcium sulphate, the relative proportions of the hydrated salts being about 4 : 1. Comparing the analysis with that of the dyke-rock, it is seen that total iron and magnesium are hardly affected, though the proportion of ferric to ferrous iron is greatly increased in the altered rock; lime and soda are slightly reduced, potash largely reduced, and there is a considerable gain in water.

From this it would appear that sulphuric acid was an important agent in altering the dyke-rock, and the percolating solutions probably contained a limited amount of oxygen, whereby ferrous oxide, set free by the action of the acid on the iron ores, was partly oxidized, while the more stable ferrous sulphate was preserved. Of the other minerals, potash felspar would seem to have been most easily attacked; this was followed by plagioclase felspar, while the pyroxene was relatively stable. There is nothing to indicate the source of the sulphuric acid. As only 1·8 p.c. of the water occurs in the hydrated salts, it is probable that extensive kaolinization of the rock has taken place.

Another alteration product found in pockets between the whin-columns is a brownish-yellow ochre, which is turned a rich brownish-red on ignition. This is remarkably rich in hydrated ferric oxide, and free from other bases soluble in acid, as the following analysis indicates:

Insoluble in acid	17·45
H_2O	12·63
Fe_2O_3	66·40
Al_2O_3	3·70
CaO	trace
MgO	none
	100·18

BASALTIC INTRUSIONS IN THE WHIN SILL

Fine-grained basaltic rock, weathering with a cherty appearance, has been observed in the mass of the whin sill in five localities: near the White Force in Teesdale; near the Vicarage Burn, a little north of Great Bavington (this occurrence was discovered by Mr. Mockler in the author's company); at Cullernose Point; Scrog Hill, just west of Dunstanburgh Castle, and on the Thirlwall Crags, along the line of the Roman Wall. The exposures are in all cases obscure, and especially so on Scrog Hill and Cullernose Point. At the White Force there are well-marked veins of dark basalt, 1 to 3 inches thick, showing sharp contacts with the medium-grained rock. On the Thirlwall Crags, the basalt is in the form of ramifying tongues of unknown thickness and thin strings. The exposure at Bavington is apparently in the form of a dyke, about 3 feet wide and more or less vertical. In no case can the basalt be traced for more than a few feet.

Four of these basalts have been analysed, as well as the dolerite in immediate contact with the basaltic strings at the White Force. The analyses of those

from Bavington and Cullernose have already been given as examples of the fine-grained whin rocks (Table D, Nos. 7 and 8), and that of the dolerite from White Force as an example of the medium-grained rocks (Table D, No. 11). The last-mentioned shows only small and unimportant differences from the other normal rocks, especially the average whin and group-sample 4 from the district in which it is found. The analytical data are assembled in Table O.

TABLE O

ANALYSES OF INTRUSIVE BASALTS

	1	2	3	4	5
SiO_2	50·50	51·25	43·25	48·10	50·00
TiO_2	2·48	2·91	2·73	3·22	2·60
Al_2O_3	15·52	15·19	15·45	15·16	14·97
Fe_2O_3	1·75	1·91	3·05	1·56	2·39
FeO	10·24	10·30	8·09	11·90	10·52
MnO	0·16	0·15	n.d	n.d.	n.d.
MgO	4·95	4·26	2·92	5·58	4·16
CaO	7·77	6·40	11·70	9·90	9·20
Na_2O	2·38	2·59	2·02	2·30	2·36
K_2O	1·14	1·31	0·95	0·63	1·16
H_2O (+) ...	1·92	1·87	2·12	1·30 (+ and −)	1·92 (+ and −)
H_2O (−) ...	1·05	1·32	2·07		
CO_2	0·14	0·63	5·05	0·40	0·40
P_2O_5	0·26	0·45	0·36	0·22	0·28
S	0·14	0·07	0·42	n.d.	n.d.
Less O for S ...	0·05	0·02	0·14	—	—
Total ...	100·35	100·59	100·04	100·27	99·96
S.G. ...	2·891	2·860	2·734	3·043	2·971

1. Basalt, Great Bavington (quoted from Table D, No. 7).
2. ,, Cullernose Point (quoted from Table D, No. 8).
3. ,, Scrog Hill, Dunstanburgh.
4. ,, White Force, Teesdale.
5. Dolerite immediately adjacent to the basalt of White Force (quoted from Table D, No. 11).

The Bavington basalt conforms closely in composition to the average whin. The Cullernose basalt is rather low in lime and high in alkalies and phosphoric acid, but on the whole does not differ more from the normal rocks than they do from one another.

The basalt from Scrog Hill is, unfortunately, hardly comparable with the others, owing to its advanced state of alteration, which is reflected in the low specific gravity and attested by the high values for water, carbon dioxide, lime and ferric iron, and its low content in magnesia. There is, however, nothing to indicate that the rock when fresh would have differed much in composition from the normal.

The White Force basalt differs fairly widely from the dolerite in immediate contact with it. Titania, iron, magnesia and lime are all high, potash, water and silica low. It is a more basic rock, richer in iron ores and pyroxene, and poorer in orthoclase felspar, and it is distinguished by having the highest specific gravity and the highest content of ferrous oxide of all the rocks examined. By the methods already described it can be calculated that the dolerite contains 5 p.c. of micropegmatite. If we imagine this to be removed, and the composition of the residue be then calculated to 100 p.c., a fairly close approximation to the composition of the basalt is obtained, as the following figures indicate:

	Basalt	Dolerite (less 5 p.c. of Micropegmatite)
SiO_2	48·1	48·5
TiO_2	3·2	2·7
Al_2O_3	15·2	15·1
$FeO+Fe_2O_3$ ...	13·5	13·6
MgO	5·6	4·4
CaO	9·9	9·6
Na_2O	2·3	2·4
K_2O	0·6	0·9

On the other hand, the Cullernose basalt contains about twice as much micropegmatite as the normal whin. Whatever be the source of these basalts, it is clear that the magma has undergone the same process of differentiation as has taken place in the sills themselves. The main difficulty now is to account for the intrusion of a magma which is much the same in composition as the early crystallization-product of the whin magma. The simplest explanation is that this product, drained free from acidic mother-liquor, has been liquefied before intrusion.

The petrological study of these basalts has been undertaken by Mr. Mockler. Pending his detailed account of them, it will suffice to say here that those from White Force and Bavington are markedly porphyritic in texture, the former showing phenocrysts of plagioclase and hypersthene, with groups of monoclinic pyroxene in a fine groundmass of the normal whin constituents, the latter showing phenocrysts of basic plagioclase, and of pseudomorphs after olivine and polysomatic groups of pyroxenes in a cryptocrystalline base. On the other hand, the Cullernose rock is almost non-porphyritic, except for a few augites. Apatite is abundant, as indicated by the chemical analysis. At the contacts with the medium-grained whin, these basalts are very fine-grained. In the Bavington rock, this is easily visible to the naked eye, and the basalt passes, an inch or so from the contact, into a dolerite, not quite so coarse as the surrounding whin.

Bailey[1] has described dark and light segregation-patches as occurring in the quartz-dolerites of the Kilsyth district. These are complementary in composition with respect to the main bulk of the rock, and are presumably differentiation-products derived from this.

The rocks under consideration do not appear to be of this character. That from Bavington (and possibly also that from Scrog Hill) has a normal composition; the

[1] E. B. Bailey, *Geology of the Glasgow District*, *Mem. Geol. Soc.*, 1925, p. 185.

Cullernose basalt is slightly more acidic, and the White Force basalt somewhat more basic than it. The extreme range of composition is not great, and both petrological and field-evidence indicate that they are later intrusions, dating from a time when the sills had become consolidated and cold.

The Bavington occurrence is interesting, in connexion with the origin of the basalts, since it is in the upper of two thick sills, which are remarkably constant in this area. One is tempted to infer that the basalt in this case may be derived from the lower, still molten sill, at a period when the upper sill had become solid. In the other cases, such conditions do not appear to exist, and one is driven to assume that the magma came from some reservoir, presumably that which supplied the material of the sill itself.

Though the quantity of the basalt so far detected is small, it may be remarked that its discovery is very largely a matter of chance, and there must be very many occurrences as yet undetected. It is also by no means improbable that some of these may be much thicker than would be gauged from the above descriptions. It has been noted that the Bavington example passes, within an inch or so of the contact, into a dolerite hardly distinguishable from the main mass of the whin sill. Detection of a thick, dyke-like mass of the basalt would thus involve the discovery of the two narrow selvages far apart, and this would be a task of the greatest difficulty in the field.

The problem of these basalts is one which demands much more field-search, thorough and fortunate, and laboratory investigation before a definite statement of their origin can be given. At present they appear to differ in no wise from the whin-dykes, and the data concerning composition, both chemical and mineral, given in the last chapter, are significant in this connexion. It may be assumed, provisionally, that there were two phases of igneous activity, the first resulting in sill-formation, the later one in the injection of the dykes and basaltic intrusions in the whin. The magma in each case came from the same reservoirs, and its composition remained fairly constant over the period covered by these two phases, such variations as did occur being readily accounted for as the results of fractional crystallization.

ALTERATIONS OF THE WHIN

1. *Chloritization*

Under the comprehensive term alteration are included changes, many of them obscure, which the dolerite has undergone, after its consolidation, by the action of magmatic and other solutions, and the ordinary weathering agents.

Chloritization is a common form of alteration, and is especially displayed, though not universally, along vertical joints. The change does not usually extend far on either side of the joint, but, on occasion, thick bands of the altered rock are encountered. The example selected for study was from the old quarry at Spindlestone, a few miles west of Bamburgh, where the bands are several feet wide and are associated with dirty, rubbly rock, in an advanced stage of weathering, and with thin veins of well crystallized calcite and quartz. The quartz sometimes encloses exceedingly delicate feathery crystals of a cinnamon colour, which are possibly rutile; if so they are of interest as indicating the removal of titanium in solution from the whin, but this could not be confirmed chemically, owing to the small amount at disposal. The rock adjacent to the dirt bands is weathered spheroidally, and passes, in a short distance, into the fresh columnar rock.

The chloritized rock breaks easily into angular fragments, each with a coating of the greenish chloritic mineral, nacreous to the touch, and having the appearance of slickensiding, owing to the regular disposition of the fibrous mineral. At first sight the whole rock seems to be made of chlorite, but more careful examination discloses the fact that the rock, as a whole, is dull and greenish, and it is only the surfaces of the fragments, into which it breaks so readily, which have the bright appearance of the crystalline mineral.

Two samples were analysed: A, the rock as a whole; B, scrapings from the surface of broken fragments of A. The amount of the latter did not permit of a full analysis. An analysis of a chloritic alteration-product of the whin from Middleton quarry, in Teesdale, recently reported by Wager,[1] is given under C, Table P.

TABLE P

ANALYSES OF CHLORITIZED ROCKS

	A	B	C
SiO_2	45·05	42·45	36·98
TiO_2	2·34	1·60	3·53
Al_2O_3	16·20	12·61	15·02
Fe_2O_3	1·82	n.d.	2·34
FeO	11·26	13·43	18·33
MnO	0·11	n.d.	tr.
MgO	6·09	9·92	9·78
CaO	4·93	4·23	2·25
Na_2O	0·67	n.d.	0·55
K_2O	0·89	n d.	0·18
H_2O (+) ...	4·00	{ 13·74	7·75
H_2O (−) ...	6·25		2·60
CO_2	none	none	0·38
P_2O_5	0·28	n.d.	0·27
S	0·08	n.d.	tr.
Less O for S ...	0·03	—	—
Total ...	99·94	97·98	99·96
S.G. ...	2·671	n.d.	2·84

A. Chloritized whin from Spindlestone.
B. Scrapings from A.
C. Chloritized whin from Middleton-in Teesdale. Anal., W. H. Herdsman.

[1] L. R. Wager, *Geol. Mag.*, 1929, Vol. LXVI, No. 779, p. 221.

Total iron in B, 10·45 p.c., is reckoned as ferrous oxide, and is only slightly higher than in A (10·03 p.c.). Assuming the same proportion between ferrous and ferric in both cases, the figures for B would be: $Fe_2O_3 = 1·89$, $FeO = 11·74$. This would bring the total to 98·18, leaving 1·82 p.c. to cover the constituents not determined. The total of these in A is 2·03, so it is evident that the constituents not determined in B are present in much the same proportions as in the whole rock.

Considering analysis A, the combination of excessive hydration and low S.G. is noteworthy, and adds force to what has already been said on that point. Apart from the high water-content, the rock does not differ so greatly in composition from the normal whin. This is rendered clearer by recalculating A on the basis of 2·1 p.c. total water (the amount in the average whin), and considering only those constituents which differ by more than 0·2 p.c. The results are:—

	Average Whin	Spindlestone A	Difference
SiO_2 ...	50·3	49·0	+1·3
CaO ...	8·9	5·4	+3·5
Na_2O ...	2·0	0·7	+1·3
Al_2O_3 ...	15·4	17·6	−2·2
FeO ...	8·9	12·2	−3·3
MgO ...	4·9	6·6	−1·7

Apart from the hydration, the Spindlestone rock differs from the normal whin in having lost 6·1 p.c. of silica, lime and soda, and in having gained but a little more, 7·2 p.c., of alumina, ferrous oxide and magnesia, the chief loss and gain being in lime and ferrous oxide respectively. The relatively-low magnesia in the Spindlestone rock precludes the possibility of much true chlorite, so that the results are significant rather as an illustration of chloritizing conditions, and it would appear that the chloritizing process consists mainly in attack on the soda-lime felspars of the normal rock by watery liquors rich in ferrous oxide and magnesia, resulting in their replacement by hydrated ferro-magnesian minerals. The reacting solutions are presumably derived from the solution of pyroxenes at some place remote from that of chloritization, and their high content of ferrous oxide indicates that they are possibly magmatic in origin.

Changes of this character have lately been postulated by Wager[1] to account for the metamorphism of shale below the whin sill, the active agent being assumed to be solution of alkali-carbonate produced in the chloritization process.

In connexion with these changes it is significant that when the Spindlestone rock is repeatedly extracted with hot water and the filtrate evaporated, a liquid is obtained having a marked alkaline reaction and containing iron, calcium, magnesium and probably silica. In agreement with this observed alkalinity, the pH value, determined on the powdered rock, is high (8·2). These observations support the above contention as to the liberation of alkaline liquors during chloritization, but they suggest that the alkalinity is due rather to easily-hydrolysed salts of sodium, like the silicates, than to alkali-carbonate.

If analyses A and B are compared, it will be seen that the scrapings have gained quite considerably in water, ferrous oxide and magnesia (7·8 p.c. in all), and this gain is offset by loss in silica, titania, alumina and lime. These results reinforce the conclusions already drawn, and show the scrapings to be much richer in chlorite than the bulk of the rock. The smooth chloritic films are obviously much thinner than they appear to be, and the scraping, gentle though it was, has removed much of the chloritized rock below

[1] L. R. Wager, *Geol. Mag.*, 1928, LXV., 91.

the films. The sharp drop in titania in the scrapings is somewhat surprising, as it appears to be greater than can be accounted for by increase in chlorite. It possibly indicates the removal of titania in solution, produced from the decomposition of the iron ores, and may be connected with the mineral, presumed to be rutile, in the quartz veins associated with the chloritic rock.

The chloritized rock from Middleton, described in detail by Wager, has many points of resemblance to the Spindlestone rocks. Whether compared with the normal whin by the method used above, or by Wager's method (in which no loss of alumina during the changes is postulated), the results indicate in general the same changes to have taken place, but to a much larger extent. The much lower value for potash in the Middleton rock agrees with Wager's petrological determinations that orthoclase is the last mineral to suffer change in chloritization, though one would expect the soda to be decreased more in sympathy with this. The high value for titania is difficult to understand, for if it be an effect of concentration, caused by the removal of part of the rock in solution, one would expect a corresponding increase in phosphoric acid, since apatite is unaltered in the chloritizing process.

There would appear to be a difference in the composition of the chlorites at Middleton and Spindlestone, the former being, relatively, much richer in ferrous constituents. The observed difference in water-content of the two minerals is in agreement with this.

2. *Pectolitization*

Pectolite is found in the whin sill in numerous places, generally in the form of thin veins, associated with calcite, at times in small amygdales. It is relatively abundant over a stretch of about two miles from Cawburn to Peel, on the Roman Wall escarpment, and it occurs here as an infilling of blow-holes, as large as two inches in diameter. These are surrounded by a band or aureole, up to half an inch in thickness, of altered dolerite, light green in colour and coarse-grained, in which small nests of pectolite can sometimes be discerned, even with the naked eye. A specimen of this altered rock, selected by crushing and careful hand-picking, has been analysed, as well as the pectolite which it surrounds; another specimen of pectolite from a thin vein at Caldron Snout has also been analysed.[1] Both pectolites were of dazzling whiteness and apparently homogeneous.

TABLE Q

PECTOLITE AND ALTERED ROCK IN CONTACT WITH IT

	1	2	3
SiO_2	52·16	55·00	57·95
TiO_2	n.d.	n.d.	0·99
Al_2O_3	0·62	tr.	14·47
Fe_2O_3	n.s.d.	n.s.d.	1·17
FeO	0·22	0·69	3·70
MnO	1·40	0·31	0·11
MgO	none	4·79	0·84
CaO	32·64	26·83	10·10
Na_2O	7·02	6·20	7·54
K_2O	1·52	tr.	0·27
H_2O (+) ...	4·14	5·96	1·35
H_2O (−) ...			0·32
CO_2	n.d.	n.d.	0·17
P_2O_5	n.d.	n.d.	0·55
S	n.d.	n.d.	0·31
Less O for S ...	—	—	0·10
Total ...	99·72	99·78	99·74
S.G. ...	2·736	2·761	2·715

1. Pectolite, Caldron Snout, Teesdale.
2. Pectolite, Cawfields near Haltwhistle.
3. Altered whin around the pectolite at Cawfields.

[1] The analyses of these pectolites first appeared in *The Vasculum*, 1924, Vol. X, No. 4, 100.

The analyses show the pectolites to be essentially hydrated soda-lime silicates, interesting points of difference being the high manganese-content of 1, and the high magnesium-content of 2. The ratio of lime to soda is 4·1 : 1 in the former, and 4·3 : 1 in the latter, or very much the same as in the average whin, viz., 4·4 : 1.

The altered dolerite, No. 3, shows notable differences in composition as compared with the normal rock; silica, lime, soda and phosphoric acid are increased, while iron oxides, magnesia, potash and titania are diminished in amount. The increase in apatite is probably a residual effect, and indicative of its very slight solubility in the pectolitizing liquors. The low value for water is at first surprising, especially since, as shown below, the rock contains over 20 p.c. of pectolite, which alone contributes 1·2 p.c. of water. The small amount of pyroxene in the rock is probably sufficient to account for this.

Microscopic examination reveals the presence of some pyroxene, a large amount of acid felspar, and a fair amount of pectolite, finely dispersed in the mesostasis.[1] In computing the mineral composition of the rock, magnesia is reckoned as pyroxene, potash as orthoclase, and residual lime, after deducting the quantity necessary for calcite, apatite and pyroxene, together with all the soda, have been allocated to anorthite, albite and pectolite. The result is given below; the composition calculated from it agrees closely with that of the rock itself.

Calcite	0·4
Pyrites	0·6
Apatite	1·2
Iron Ore	3·0
Pyroxene	6·8
Orthoclase	1·5
Anorthite	9·9
Albite	54·1
Pectolite	22·7
	100·2

[1] Since this was written, the rock has been described petrologically by Mr. S. I. Tomkeieff, *Mineralogical Mag.*, 1929, XXII, 125, p. 112.

Comparison of this altered rock with the normal whin is facilitated by recalculating these figures, omitting calcite and pyrites, on the basis of rock free from pectolite, and by utilizing Teall's estimate of the mineral composition of the whin sill—both calculated to 100 p.c. The results are:

	Normal Whin	Altered Whin
Apatite ...	0·6	1·6
Iron Ores ...	8·7	3·9
Pyroxene ...	43·0	8·9
Orthoclase ...	8·8	1·9
Albite ...	25·7	70·8
Anorthite ...	13·2	12·9
	100·0	100·0

This method brings out clearly the main changes which have taken place. Anorthite is almost unaltered, pyroxene and orthoclase are greatly reduced, iron ores are decreased in lesser degree, and these deficiencies are made good by a large increase in albite.

These facts, combined with the observation that the rock contains a good deal of pectolite, finely crystallized and occupying the spaces between the felspar-groups, suggests the following mode of alteration of the whin and derivation of the pectolite amygdales.

After the consolidation of the magma, and while the rock was still hot, it was traversed by aqueous solutions of the whin-plagioclase, a gentle flow being maintained, by the agency of joints and capillary channels, through such blow-holes as are now filled with pectolite. The liquors attacked, differentially, the minerals of the whin in immediate contact, the action spreading slowly inwards as the rock was opened up by the solvent action of the solution. The solution being, by supposition, one of plagioclase, would not affect the plagioclase felspars, but would be able to dissolve

pyroxenes and orthoclase, and even iron ores. Alumina from pyroxene and orthoclase however, could not enter the solution except by compensation, and this was afforded by its immediate precipitation, along with its equivalents of soda and silica, as albite.[1]

This still left the liquor supersaturated with lime and silica, and these, with their equivalent of soda and water, were thrown out as pectolite. This mineral was deposited partly in the interspaces left by the solution of pyroxenes and ores; partly the constituents diffused into the vesicular cavity, and the pectolite crystallized on the wall, growing inwards towards the centre. The mother-liquors, after the separation of albite and pectolite, were now charged with potash, magnesia, ferrous oxide, titania, but contained only a small concentration of soda, lime, and possibly silica, corresponding to saturation in albite and pectolite. They passed away in the general circulation, being gradually replaced by fresh plagioclase solution. The effect of the potash in these waste liquors is perhaps indicated by the not uncommon sericitization of felspars, and in the alterations produced by vein-solutions, to be mentioned shortly.

Such a process as sketched above would obviously proceed until the original gas-cavity became blocked with pectolite, so that the depth of alteration of the whin is determined by the size of the cavity. It is probably this circumstance which accounts for the visual alteration of the whin around the large amygdales. Careful examination would probably show it to exist at the edges of thin pectolite veins and around small amygdales.

The reactions conceived as being involved in the process of pectolitization and chloritization appear to

[1] It may be noted, in this connexion, that sedimentary albite, but not anorthite, is stated to occur in limestones. See *Treatise on Sedimentation*, W. H. Twenhofel, 1926, p. 428.

be complementary. If this be so, the question as to which starts the cycle is bound up with the origin of the liquors. If magmatic, then the difficulty is encountered that the differentiation-process, which results in the pegmatites and felsites, does not appear competent to furnish residual watery solutions of either type. If meteoric in origin, then it would appear that influences are at work, in the shape of selective solubility and preferential precipitation, which ensure that small initial differences, accidentally set up and intensified by repetition, will lead to wide variation of resulting solutions in composition and mineralizing action.

This view, therefore, on the whole commends itself, with the qualification that the solvent and mineralizing action of the meteoric waters was particularly active at a period when the rock was still hot, and that, indeed, these waters began their attack immediately conditions of temperature and pressure made it possible for them to come in contact with or, better, to permeate the igneous rock.

Under such hydrothermal conditions, pectolite and chlorite are the analogues of plagioclase and pyroxene in magmatic circumstances.

3. *Alteration by Vein Solutions*

It is impossible to draw the line between meteoric waters, juvenile waters of magmatic origin, and such solutions as are responsible for the infilling of vein-fissures and alteration of the neighbouring rock. Presumably they may become mixed at some level, and thus introduce complexity in the order of ore- and spar-deposition, as well as in the metasomatism of the rocks around them.

Two examples of the effect of vein-solutions on the whin sill have been studied, viz., in connexion with a barytes-lead vein at Force Burn, and a pyrites-quartz vein near Cross Fell.

In Upper Teesdale there is a fine section of the whin sill exposed in the Force Burn. A barytes vein, carrying some galena, several feet thick, cuts through the dolerite, and the direction of the burn is accurately determined by the erosion of the vein, so that it flows for half a mile, with many falls or forces, in a straight line, without meanders.

The dolerite in contact with the vein is slightly bleached for a short distance, and forms a light grey powder on grinding. The sample collected was made up of many specimens taken within half an inch of the vein. Under the microscope, the pyroxenes are seen to be largely replaced by carbonates, and the iron ores are converted into leucoxene, but the felspars are fresh.

The analysis of this rock is given in the following Table R, and with it analyses of two similarly altered whin-rocks which have been studied by Finlayson[1] and Wager.[2]

When the Force Burn rock is digested with acetic acid, it yields in solution 2·7 p.c. of ferrous oxide and 7·2 p.c. of calcium oxide, and a mere trace of magnesium. As the carbon dioxide equivalent of these bases, viz., 7·3 p.c., is identical with the amount determined, it is clear that this carbon dioxide is entirely present as chalybite (4·35 p.c.) and calcite (12·86 p.c.).

Contrary to expectation, the amount of barium in the rock is no greater than in the normal whin, and as it is equivalent to 0·015 sulphur trioxide, there is an excess of this constituent of 0·035 p.c. The rock contains 0·006 p.c. of lead, which is notably greater than the average whin (0·0024 p.c.). Zinc is present in strong trace (greater than in the whin); there is also a trace of copper, but no nickel. Sulphide sulphur is very high.

[1] A. M. Finlayson, *Quart. Journ. Geol. Soc.* 1910, LXVI, 299.

[2] L. R. Wager, *Geol. Mag.* 1929, LXVI, 97.

Comparing the main basic and acidic constituents with the normal whin, and allowing for the 7·2 p.c. of lime present as calcite, and 2·7 of ferrous oxide present

TABLE R

WHIN ALTERED AT CONTACT WITH MINERAL VEINS

	1	2	3	4
SiO_2	48·90	62·29	35·10	38·20
TiO_2	2·60	1·13	2·31	3·08
Al_2O_3	17·04	12·27	18·09	20·95
Fe_2O_3	0·53	1·29	tr.	18·93
FeO	5·35	8·65	3·74	1·59
MnO	n.d.	0·27	n.d.	n.d.
MgO	1·43	2·45	5·79	tr.
CaO	9·45	3·29	11·89	0·15
BaO	0·03	n.d.	n.d.	n.d.
Na_2O	2·34	0·23	1·03	0·16
K_2O	1·82	2·66	1·60	0·81
H_2O (+) ...	2·12	{ 1·65	{ 4·18	8·70
H_2O (−) ...	0·45			7·50
CO_2	7·30	4·34	16·12	0·05
P_2O_5	0·29	0·32	n.d.	0·27
S	1·21	n.d.	none	none
SO_3	0·05	n.d.	none	tr.
Less O for S ...	0·40	—	—	—
Total ...	100·51	100·84	99·85	100·39
S.G. ...	2·79	2·65	2·73	n.d.

1. Force Burn, Teesdale. Rock altered in contact with barytes vein.
2. Rotherhope, South Tynedale. Rock altered in contact with lead vein. Anal., A. M. Finlayson.
3. Winch Bridge, Middleton-in-Teesdale. White whin in contact with chalybite vein. Anal., L. R. Wager.
4. Aglionby Beck, Cross Fell. Whin in contact with the Great Sulphur Vein (quartz-pyrites).

as chalybite, there is seen to be a large decrease in iron, magnesium and calcium, and a marked increase in alkalies, particularly potash.

The mineral composition of the rock, calculated in the usual manner, gives the following result:

Barytes	0·4
Pyrites	2·3
Apatite	0·6
Calcite	12·9
Chalybite	4·4
Anatase	2·6
Orthoclase	10·8
Albite	19·8
Anorthite	9·5
Kaolinite	19·4
Quartz	15·2
	97·5

The main loss is in pyroxene, and the gains are in pyrites, carbonates, kaolinite, quartz and orthoclase. The relation of the felspars in the altered and original rocks is interesting. Using Teall's estimate of them in the fresh rock, and assuming that albite has remained unchanged, then the following comparison shows that anorthite has suffered but little reduction, whereas orthoclase has increased by 60 p.c.

	Ab.	An.	Or.	Ab.	An.	Or.
Whin Sill ...	21·6	11·1	7·4	1·0	0·51	0·34
Altered Rock ...	19·8	9·5	10·8	1·0	0·48	0·54

Summarizing all these facts, it is apparent that the vein solutions have been rich in barium, lead, potassium, carbon dioxide, sulphide and sulphate. Solubility-relations among these have been such that all the barium has been deposited as sulphate in the vein, along with most of the lead (and zinc) as sulphide; a little lead and zinc were able to diffuse into the surrounding rock, along with excess of sulphate and sulphide, and, there being no opportunity for the precipitation of the other constituents in the vein-fissure, they were in a position to attack the dolerite walls of the fissure. The chief agent in the metasomatizing action on the whin was thus a solution charged with carbon dioxide, and containing the carbonate, sulphide and sulphate of potassium (with a little sodium), and possibly smaller amounts of other elements which have left no trace behind them.

The main chemical actions have resulted in the removal of pyroxene, the extraction of iron from the ore-minerals, and the filling of the cavities, left after solution of the pyroxene, by calcite, chalybite, pyrites, kaolinite and quartz. Of the materials removed in solution magnesium is the most important, though a good deal of iron has accompanied it.

From the point of view of the mineral changes, it would seem that these are in a much less advanced stage than those studied by Wager in the case of the White Whin from Winch Bridge, and the degree of metasomatism corresponds to that occurring in a band 3 to 6 cm. from the limit of altered dolerite in his example.[1]

The active chemical agent is assumed to be a solution of carbonic acid containing potash; that is, then, carbonic acid, potassium carbonate and potassium bicarbonate. This attacks preferentially the pyroxenes which contain, according to Teall's analysis, 15 p.c. of ferrous oxide, 16 p.c. of lime, and 12 p.c. of magnesia, and the predisposing cause of the reaction is undoubtedly the solubility of the bicarbonate of these three bases; as a secondary effect of this reaction, alumina (4 p.c.) and silica (48 p.c.) are liberated.

[1] Wager, *Op. cit.*, p. 106.

As a result of this attack, the vein-liquor becomes charged with bicarbonates of iron, calcium and magnesium, in addition to that of potassium (and sodium), and the concentration of carbonic acid is greatly reduced. The combined effect of increase of calcium, potassium and sodium salts, and decrease of carbonic acid, is to stabilize the felspars, and indeed their quantity is added to by new formation from the elements in solution, viz., potassium, alumina and silica, the last two being liberated from the pyroxene. Probably at this stage, too, alumina and silica combine in part to form kaolinite, and excess of silica from these reactions passes partly into solution as alkali silicate, and is partly deposited as quartz.

The rapid inflow of bicarbonates into the solution, with the reduction of concentration in carbonic acid, brings about conditions approaching or even attaining equilibrium in which the normal carbonates are precipitated. The problem here is a complicated one, about which little appears to be known. Magnesium bicarbonate is twenty-five times more soluble than calcium bicarbonate, and ferrous bicarbonate is slowly precipitated as the normal carbonate by calcium carbonate, this reaction being retarded by the presence of soluble sulphates. These relationships are consistent with the observation that little or no magnesium carbonate is precipitated, a fairly large amount of the iron and much more of the lime. The waste liquors must thus have been rich in magnesium and fairly rich in iron salts.

If the metasomatic reactions be conceived, for the sake of simplicity, as occurring intermittently, then after the first attack, a narrow band of rock will be altered in the manner just described. A fresh flow of vein liquor will permeate this band in part, and begin a similar attack upon the fresh rock beyond; in part it will set up fresh changes in the altered band. The carbonic acid, being no longer quickly absorbed by the pyroxene, has opportunity for a more leisurely attack, especially on the lime felspar, the potash and soda felspar being now slowly transformed, by combination with water and alumina liberated from the lime-felspar, into muscovite and paragonite. Some calcium and ferrous carbonates, deposited in the first attack, will go into solution and possibly be made up again in the return of waste liquor from the zone of active reaction beyond, and a certain amount of iron will be precipitated as disulphide, by reaction of ferrous bicarbonate with alkali sulphide and sulphur, the latter being liberated by reduction of ferric oxide, both in pyroxene and ore, with hydrogen sulphide.

Some such reactions are suggested by the chemical investigation of the contact-rock. Wager, who has studied the metasomatism of the whin sill in contact with a chalybite vein at Winch Bridge in Teesdale, postulates changes which, on the whole, are not at variance with the above, though they do not appear to stress sufficiently the equilibrium reactions between bicarbonate, normal carbonates and carbonic acid.

The analysis of the dolerite, altered by lead vein solutions at the Rotherhope Mine, Alston Moor, is given in Table R, No. 2, and of the White Whin from Winch Bridge (No. 3). Though the latter is a chalybite vein, it is considered by Wager as similar in its metasomatizing action to the lead veins.

These three analyses, considered together, disclose such variations that one might well despair of being able to correlate the changes which have taken place. There are, however, certain features common to all three rocks: potash is high, and the dibasic metals, or those quantities of them not present as carbonates, are low. All three show a high degree of carbonation, and it is by consideration of this that a suitable basis for comparison is found.

It may be assumed that the degree of alteration of the whin is proportional to the extent of carboniza-

tion. If, then, we deduct the amount of carbonate in each case from the analytical figures, and calculate the residues to 100 p.c., the result should afford some idea of the changes which have taken place. The results of this procedure, arranged in order of increasing carbonation of the rocks, are as follows:

	Rotherhope	Force Burn	Winch Bridge
Total Carbonate ...	10·6	17·2	35·8
Residue not Carbonate:			
SiO_2	69·6	60·5	51·9
Al_2O_3	13·9	21·1	26·8
Oxides of Fe, Mg, Ca ...	10·0	6·6	7·8
Na_2O	0·2	2·8	1·5
K_2O	3·0	2·2	2·4
H_2O	1·8	3·2	6·2
TiO_2	1·2	3·2	3·4
P_2O_5	0·3	0·4	n.d.
	100·0	100·0	100·0

From these figures it follows that with increasing carbonation, silica is reduced and there is a fall (not quite uniform, possibly owing to uncertainty with respect to the allocation of the carbon dioxide to the bases in question) in the bivalent bases. Water and alumina are increased, and this may be taken as an index of the formation of kaolinite and increase in the sericitization of the felspars. The alkalies in the Rotherhope rock are outstanding, quantitatively speaking, though they show loss of albite to accompany increase of orthoclase; in the other two this behaviour of these felspars is evidently the result of increasing metasomatic action. The increase of titania throughout would appear to be a residual effect, that is, one depending on excess of removal over accretion of minerals. Such an effect should be indicated by the content in phosphoric acid, but unfortunately the vital datum in the case of the Winch Bridge rock is missing.

All things considered, these three analyses point to the same conclusions as were reached in the study of the contact rock from Force Burn. The lead vein solutions would appear to have had a similar composition, qualitatively but not necessarily quantitatively, in all cases, and its influence on the dolerite, with which it came in contact, was largely conditioned by the length of time in which it was active.

The other example of alteration of the whin sill at the contact with a mineral vein is on Alston Moor. Here is a vein of considerable scientific, but of little economic value, known as the Great Sulphur Vein, or, in the miners' phrase, the Backbone of the Earth. It is several miles long and of great width, and the weather-resisting quartz of which it is composed causes it to stand out in bold relief over most of its course. The chief ore in it is iron pyrites, and in some places there is a notable amount of chalcopyrite. The vein occupies a fault, and the whin sill is exposed in numerous places on its southern cheek. In the Aglionby Beck, high up on the flank of Cross Fell, the whin, in contact with the vein, is greatly altered, being converted into a light brown, friable material which, in places, is so ferruginous that it has been worked as an iron ore.

The sample analysed was of the friable, less ferruginous material, and the results are given in Table R, No. 4.

When this rock is boiled with hydrochloric acid and thoroughly washed in running water, a residue is obtained of small, angular fragments, chiefly quartz and felspar, obviously doleritic in origin. Titania is extracted quantitatively with hot, dilute sulphuric acid, and, at the same time, there passes into solution most of the iron, a little silica and one-third of the alumina.

After heating the rock to 500° C., the amount of soluble alumina is doubled.

The analysis indicates very thorough removal of lime, magnesia and soda; iron has been liberated, oxidized and hydrated; titania set free (as rutile or anatase) and somewhat concentrated by the loss of other constituents. Alumina appears, from the above observations on its solubility, and from the high degree of hydration of the rock, to be largely present as kaolinite. Potash felspar has proved to be relatively stable.

From this the mineral composition of the rock is calculated to be:

Calcite	0·1	
Anatase	3·1	
Felspars	6·6	
Quartz	10·3	
Oxides of Iron	20·5	29·7
Water of Hydration	9·2	
Kaolinite	50·5	
	100·3	

The almost complete absence of carbonation of this rock marks it off clearly from the white whins considered above. The low silica and the lack of any signs of silicification indicate that the vein-solutions have added little or nothing of their chief mineral constituent. The absence of more than a mere trace of sulphur points in the same direction, and it also suggests that the intense alteration of the dolerite has not been produced, as was at first thought probable, by the action of sulphuric acid, generated by oxidation of pyrites in the adjacent vein.

The results, on the whole, point rather to attack on the whin by meteoric agents than by vein-solutions, though they are different in some important respects from the examples of weathering to be described next. It is possible that vein-solutions have initiated metasomatic changes and opened up the rock to weathering agencies, the attack of which has been so drastic that all trace of earlier stages has been lost.

It seems reasonably certain that a solution of carbonic acid, saturated with oxygen, was the chief agent operative in producing these changes. The soluble bases were removed as bicarbonates in such circumstances that insoluble normal carbonates were not formed, and this implies continued percolation of the rock by the solution. The presence of oxygen has conditioned the oxidation of the ferrous bicarbonate and the precipitation of the iron as the hydrated ferric oxide. Kaolinization is so extensive that probably all the alumina in the rock was converted into this mineral. This involves concentration, by loss of soluble products, of the original alumina by about one-fifth, which is the same order of concentration as that of the titania.

The survival of a mere trace of magnesia, a little lime and soda and most of the potash, indicates that the order of attack was first the pyroxenes, then the soda-lime felspars, and lastly the potash-felspar. The position of the iron-ore in the sequence is not certain, but it probably followed the pyroxenes.

4. *Outcrop Weathering of the Whin*

A common form of weathering at the outcrop is that indicated by spheroidization. Though so well known and widely observed, the study of this form of weathering in the field discloses many difficulties, some of which may be briefly mentioned in passing. The effect is generally observed in columnar rock, and alteration works inwards from the vertical joints, but examples are not uncommon where massive and spheroidal rock are juxtaposed, with a horizontal plane of junction. Where the length of time can be appraised, during which the rock has been exposed to the air, the results are sometimes contrary to expectation. In the old Roman fosse about Limestone Bank and Carrowbrough, the whin is still fresh and shows only in isolated places the beginnings of spheroidization, and the huge excavated blocks at the side of the trench are fresh and angular and only covered with a thin weathered coating.

Some disused quarries of comparatively recent date, like that at Coldside, near Ward's Hill, show the process in an advanced stage, though the rock in the neighbourhood is quite fresh. Similarly, some of the old mining hushes, which cut through the whin, give sections of highly spheroidalized rock, in areas where it does not occur in natural sections. A striking case of this is at the Birkdale Hush in Teesdale, and another example, good, but in less degree, at the Silverband Hush in Knocker Gill, on the Pennine escarpment. It seems possible, from such observations, that rapid removal of bearing has relieved stresses and caused the rock to split, thus opening it up to the action of the atmosphere and percolating waters.

From the chemical point of view, this form of weathering seems, admittedly from few observations, to be associated with carbonation and to be a localized and advanced form of the change which the rock over the whole outcrop (with few exceptions) has experienced, and which is indicated by its content of carbon dioxide: 0·46 for the average whin, equivalent to 1 p.c. of calcium carbonate.

It has been pointed out by Wager[1] that "the minerals which give any slice of the whin sill a weathered appearance are the same as those which result from the action of the hydrothermal solutions present in the early joints," and from this it is argued that a portion of these solutions did not escape into the joints, but remained in the mass of the rock and produced the effects usually ascribed to weathering.

Though there is probably some truth in this, it does

[1] L. R. Wager, *Geol. Mag.*, 1929, LXVI, 229.

not appear that this mode of alteration is competent to account for many of the observations on this subject which can be made in the field. The difficulty possibly resides in the similarity in chemical composition of hydrothermal and meteoric waters and the frequent superimposition of true weathering upon hydrothermal alteration.

A different type of alteration, one indisputably due to weathering, is that in which carbonic acid has been active, but the product is not carbonated; oxygen, too, has taken part in the process, and the resulting iron oxides tint the residues yellow, red or brown.

It has been pointed out by Lebour[1] that this form of weathering is much less often associated with the whin sill than with the local dykes, and it may be added that, in the case of the whin sill, it is much more frequently seen in the northern part of the field. It does not appear to be in any way connected with spheroidization, and it is always quite localized. At the Dhu, near Dunstanburgh, pillars of massive rock, fresh to the edges, stand isolated in these red earths.

The Geological Survey[2] have observed in Mull that spheroidal weathering, with the formation of red loams, is characteristic of the region outside that in which pneumatolytic action has occurred. No such correlation is yet possible in the case of the whin sill, but the greater frequency of the red earths over the outcrop north of the Roman Wall escarpment suggests the possibility that this escarpment is a rough dividing line, marking the northern limit of pneumatolysis.

Three samples of these earths were taken for analysis: A, of rich, dark-brown colour from the Kyloe Hills; B, brown, from Scrog Hill, near Dunstanburgh; C, brownish-yellow from the neighbourhood of the Roman camp of Borcovicus. All consisted of loamy

[1] G. A. Lebour, *Outline of the Geology of Northumberland and Durham*, 1886, p. 8.
[2] *Mull Memoir*, p. 94.

material which, on rubbing between the hands, passed the 30-sieve, leaving only a small residue of vegetable fibre. They all occurred near the top of the escarpment, and had evidently been accumulated in vertical joints in the solid rock; this was free from drift and partly bare on top, partly covered with thin soil and vegetation. The analyses are given below:

TABLE S

ANALYSES OF RED EARTHS

	A	B	C
Moisture (110° C.)	5·20	2·90	2·97
Insoluble in HCl (dried at 110° C.) ...	69·74	79·12	79·50
Soluble in HCl :—			
SiO_2	0·05	n.d.	0·05
TiO_2	2·73	2·73	2·23
Al_2O_3	3·18	1·62	3·26
Fe_2O_3	12·96	8·94	7·01
FeO	0·80	1·37	1·74
MnO	0·31	0·19	0·19
MgO	1·31	1·56	0·87
CaO	0·67	0·60	0·65
Na_2O	n.d.	n.d.	0·12
K_2O	n.d.	n.d.	0·30
P_2O_5	0·21	0 24	0·26
Organic matter, loss, etc.	2·84	0·73	0·85
Total	100·00	100·00	100·00
pH	5·4	4·6	5·3

A. The Kyloe Hills.
B. Scrog Hill, Dunstanburgh.
C. Borcovicus.

In all three earths, carbonate, sulphate, chloride and nitrate were either absent or present only in traces; they contain organic matter and, on warming with alkalies, give a peaty smell, along with ammonia. The nitrogen-content of C is 0·07 p.c., which is equivalent to 0·44 p.c. of protein matter.[1] The presence of this organic matter undoubtedly maintains some of the iron in the ferrous condition.

[1] For the determination of nitrogen and of the pH values, I am indebted to my colleague Dr. A. A. Hall.

The general similarity in composition of these earths is apparent. Titania, phosphoric acid and manganese oxide preserve the same relation as in the whin from which they are derived, the average for the three earths being 2·56 : 0·24 : 0·23, and in the whin 2·48 : 0·22 : 0·18. Soluble bases, with the exception of iron and, to a less extent, alumina, are small in amount. The material, insoluble in acid, is rich in felspar and clay, and lacking in ferromagnesian constituents. Thus the earths represent a stage in the decomposition of the whin, in which the iron ores and pyroxene have been broken down to a very large extent, and the felspars, relatively speaking, slightly attacked.

They are, indeed, soils in the making, and much of their interest in this regard arises from the fact that they are quite unmixed in origin, being derived entirely from the whin; they have never been tilled, and, occurring as they do, high above the water-table, they are uncontaminated by drainage from other areas. As might be expected, they are sour, their solutions have a high hydrogen-ion concentration (their pH values are low), and, in agreement with this, they are free from carbonate. In the acid-soluble portion, magnesia is in excess of lime and potash of soda, thus reversing the order in the whin. Even though this portion were derived entirely from pyroxene, lime would be liberated in excess of magnesia, for, according to Teall, the ratio of the two constituents in the pyroxene is CaO = 5·8, MgO = 4·4; the decomposition of plagioclase would naturally increase the proportion of soluble calcium salt. The proportion of the four bases in the acid-soluble portion of sample C, expressed per cent. is: $MgO : CaO : K_2O : Na_2O = 44{\cdot}9 : 33{\cdot}5 : 15{\cdot}5 : 6{\cdot}1$, and this may be compared with the figures for the exchangeable and acid-soluble bases in a soil, as quoted by Hissink,[1] viz.: 51·6 : 28·2 : 13·1 : 7·1.

[1] D. J. Hissink, *Base Exchange in Soils, Faraday Soc.*, 1924, 555.

It is now possible to sketch, at least in outline, the course of the changes whereby the red earths are produced from the whin. The weathering agent is carbonic acid, acting under conditions of free aeration, and the solubility of the bicarbonates of the divalent metals must be looked upon as the main predisposing cause of the disintegration and chemical decomposition of the rock, particularly of the pyroxenes and iron ores. From these iron, manganese, calcium and magnesium are leached, iron and manganese immediately precipitated by oxidation, and titania and apatite liberated. Partial attack on the felspars liberates soda, potash and lime in a soluble form, alumina and some silica forming a clay-like colloid which, with the humus from vegetable matter, exercises selective action on the soluble products of decomposition, retaining or adsorbing these in part and giving rise to the phenomena of base-exchange. Much silica, from these reactions, is doubtless removed in solution, but some is left as quartz in the insoluble residue.

The red earths thus consist of particles of felspar, some fresh and some weathered, quartz and the colloidal, hydrated alumino-silicic acids and humus, the last two retaining the acid-soluble bases magnesium, calcium and the alkalies; in addition, there are present apatite, rutile or anatase, and hydrated oxides of manganese, iron and possibly aluminium. The calculated proportions of these last are:

		A		B		C	
Apatite		1·8		2·9		3·1	
Rutile		10·6		14·9		12·4	
Manganese Peroxide		1·5		1·3		1·3	
Hydrated Oxides of Iron and Aluminium	Fe_2O_3 ...	50·4	86·1	47·8	79·9	28·9	73·2
	FeO ...	3·1		7·5		9·7	
	Al_2O_3 ...	12·4		8·8		18·1	
	H_2O ...	20·2		15·8		16·5	
		100·0		100·0		100·0	

These represent, in the main, the residues from the pyroxene and iron ore, and it is to this portion of the earths that the colour is due. The main factor in this is evidently iron, not manganese, and it is not unlikely that the presence of ferrous oxide brings about darkening of the ferric oxide, as is the case when the mixed hydrated oxides are precipitated from solution.

METAMORPHISM OF SEDIMENTARY ROCK BY THE WHIN SILL

The metamorphic action of the whin on its associated sedimentaries is met with over the whole outcrop, though its effects are most marked, as noted by Hutton, in Teesdale. A very thorough study of the subject, both chemical and petrographical, has been made by Hutchings,[1] and little more than passing reference will be made to it here.

The purer limestones are rendered saccharoidal, sometimes to a distance of 50 feet from the contact, as may be seen below the whin at the White Force, and above it at Widdybank Fell, in Teesdale. By this action the bedding is obliterated, and the limestone weathers in pillowy masses, with the production of so much marble sand that large areas, as at Thistle Green, are devoid of vegetation. These pure white, saccharoidal limestones contain a notable amount of monosulphidic mineral, a sample near the Maize Beck Force yielding 0·0075 p.c., and one from Queen Margaret's Cove, Dunstanburgh, 0·003 p.c. of sulphur in this form. The former, on carefully dissolving in

[1] W. M. Hutchings, *Geol. Mag.*, 1895, Dec. 4, Vol. II, 1; 1898, Dec. 4, Vol. V, 69, 123. Also L. R. Wager, *Ibid.*, 1928, Vol. LXV, 88.

acid, left a residue of pyrrhotite, the latter only pyrites. The ordinary dark, unmetamorphosed limestones of the district seem to contain much less sulphur, only 0·0007 p.c. being found in the Tynebottom Limestone of Maize Beck, and the same amount in the Scar Limestone of Dry Burn, Alston Moor.

The shales are affected, in the typical locality of the Falcon Clints, to a distance of 80 feet below the whin, spots and nodules and a suite of new minerals being developed. Spotted shales also occur above the whin at several places in Tynedale, notably in Thinhope, Crossgill, and on the South Tyne near Garrigill, and at the last place there are large nodules.

From the chemical side, the interesting feature of these metamorphosed shales is their increased content in alkalies, especially soda, the ordinary proportion of these in the shales being often reversed. Hutchings' numerous alkali-determinations, however, show that this change is erratic, some highly altered beds maintaining the ordinary alkali-ratio, whilst adjacent beds show a large accession of soda. In his words, "it is difficult to explain the fact that such soda-rich alteration-products alternate with others, derived apparently from quite similar original rocks, in which soda has not increased, or has increased in far less degree." On the general question of the origin of the soda-bearing liquors, the suggestion of Wager that they are connected with chloritization seems a feasible one, and this has been discussed above (p. 110), along with its possible connexion with pectolitization. It is conceivable that differences in permeability to alkaline liquors of the shales concerned may be at the root of the observed variations in impregnation.

Metamorphism of coal by the whin sill has attracted very little attention, though many pits have been worked in its proximity in the coals of the Scremerston series, and some are still active in the Shilbottle, Little Limestone and other coals associated with these. In a recent paper, Trotter and Hollingworth[1] state that the Little Limestone coal at Tows Bank is "completely coked" by a sill 20 feet thick, which overlies it at a distance of 30 feet, and they give a proximate analysis of the same coal from the Venture Pit, at least 1,000 feet from the whin, and one from Gair's Pit, where the coal is 350 feet below the whin. The volatile matter (including moisture) in the latter case is only one half what it is in the former, the values for the two (calculated on ash-free material) being 17·3 and 35 p.c.

Cinder coals are not often encountered in the field. Three thin ones, all showing the typical prismatic structure, have been observed. One occurs on top of a thin sill in Thinhope, another is associated with the thin sill exposed in the North Tyne below Barrasford, and the third forms a coating on top of a dyke-like intrusion of the whin, just north of the Saddle Rock, Dunstanburgh.[2] The last two have been analysed with the following results:

CINDER COALS

	Barras-ford	Saddle Rock	Calculated free from Ash and Moisture	
			Barrasford	Saddle Rock
Fixed Carbon ...	59·9	58·6	94·8	90·5
Volatile matter ...	3·3	6·2	5·2	9·5
Ash	35·7	33·6	—	—
Moisture	1·1	1·6	—	—
	100·0	100·0	100·0	100·0

They are singularly alike in composition and greatly impregnated with mineral matter. Volatiles are low, indicating a high temperature of coking. The organic

[1] F. M. Trotter and S. E. Hollingworth, *Geol. Mag.*, 1928; LXV, 772, p. 433.

[2] J. A. Smythe, *The Vasculum*, 1929; XV, No. 2, p. 56.

matter in both cases is nitrogenous, and no tar or combustible gas is evolved when the cinders are ignited. A partial analysis of the ash from the Saddle Rock coke (which is covered by the sea at high water) gave the following figures, which indicate the presence of quartz, clay, pyrites and dolomitized calcite in the cinder coal:

$$SiO_2 = 47{\cdot}5;\quad Al_2O_3 = 22{\cdot}5;\quad Fe_2O_3 = 6{\cdot}7;\quad CaO = 13{\cdot}4;$$
$$MgO = 5{\cdot}0;\quad TiO_2 = 0{\cdot}2;\quad \text{Alkalies and loss} = 4{\cdot}7.$$

THE PROBLEM OF ASSIMILATION

The question as to whether the whin sill can dissolve or assimilate the sedimentaries which it traverses has been raised several times in the past, and has been studied, in a small scale manner, by the petrological examination of contact-specimens, and, on the large scale, by the consideration of its relations to the adjacent sedimentary beds.

In the former respect, the work of Hutchings[1] is extensive but indecisive. He found in some places, as at Middleton, near Belford, that contact rocks had a band of tachylite-looking material, containing garnets, and he observed that "As no garnet occurs in the altered limestone, except at the actual contact, and as it occurs in the tachylite band, it seems likely to be the product of the interaction of limestone and whin. No garnet seems ever to occur in the normal whin sill rock." In many other sections examined there was no evidence of assimilation, fine-grained whin coming right up to the contact on one side, and crystalline limestone on the other. The evidence did not carry conviction to Hutchings one way or the other, and the best one can say of it is that it may

[1] W. M. Hutchings, *Geol. Mag.*, 1898, Dec. 4; Vol. V, 69 and 123.

indicate a slight localized contact-effect of assimilation, on a scale vastly different from that imagined by Clough.

Clough[1] contemplated wholesale assimilation of sedimentaries by the magma, and he was led to this view, in the first instance, by the notable absence of mechanical disturbance in Teesdale, attention to which had already been drawn by Hutton. From quotations in Clough's paper, it appears that this view was supported by Goodchild, from his extensive acquaintance with the Pennine sections. D. Burns[2] has put it on record that the little whin sill of Stanhope, intruded in the Three Yard limestone, has in places only two feet of limestone above it and one foot below it. This would imply replacement of a portion of the limestone by its own thickness of whin, or as the author puts it, "the whin, in some way, has destroyed a fathom of it" [the limestone].

Unfortunately, this observation cannot now be confirmed, though, of course, there is no reason to doubt its accuracy. No similar replacement is observable in the great boring at Roddymoor, near Crook,[3] where the whin sill, 187 feet thick, is embedded in the Scar limestone, there being 7 feet 3 inches of limestone above it and 15 feet 6 inches beneath. The total thickness of limestone, 22 feet 9 inches, corresponds closely with its thickness in Teesdale and Weardale.

Clough's main arguments in favour of assimilation are of the same character as in the case of the Stanhope sill, just cited, and the field-evidence on which they are based cannot be gainsaid. At the High Force, a bed of shale 6 feet thick, when traced a short distance, is found to be replaced by a similar thickness of whin. A better example is described from the north

[1] C. T. Clough, *Geol. Mag.*, 1876, Dec. 2; Vol. VII, 433.
[2] D. Burns, *North of England, Min. Inst. Proc.*, 1878, XXVII.
[3] D. Woolacott, *Geol. Mag.*, 1923, LX, 50.

flank of Meldon Fell, a few miles above Caldron Snout, at a height of some 1,700 feet. Here three sikes, flowing to the Tees, expose sections of the strata along a line running W.N.W.-E.S.E., the distance between the first and second being 100 yards, and between the second and third 400 yards. The sections are as follows in the order just mentioned:

Lodge Gill Sike	Rowantree Sike	Cockle Sike
Limestone	Limestone	Limestone
12 ft. Beds	12 ft. Sandstone	30 ft. Beds (some limestone near top)
4 ft. Limestone	5 ft. Limestone	17 ft. Sandstone
16 ft. Shale and Sandstone	25 ft. Sandstone	3 ft. Shale
41 ft. Whin	21 ft. Whin	4 ins. Coal
3 ft. Shale	14 ft. Shale (altered)	30 ft. Shale
2 ft. Whin	3 ft. Shale (calcareous)	
10 ft. Shale (calcareous)		
Limestone	Limestone	Limestone

The top limestone, in the three sections, is the second thick limestone under the Tynebottom.

The essence of this evidence is that between the same two limestones there are, in Cockle Sike, 80 feet of sedimentaries; in Rowantree Sike, 59 feet of sedimentaries and 21 feet of whin (total 80 feet); and in Lodge Gill Sike, 45 feet of sedimentaries and 43 feet of whin (in two sheets), the total thickness being 88 feet. The intruded sheets, in the two gills in which they occur, thus replace their own thickness of sedimentary beds, and the conclusion drawn by Clough is that the vanished sedimentaries have been dissolved and replaced by the magma.

The physical difficulties in the way of this hypothesis are very considerable, and were not discussed by Clough, nor was the hypothesis applied to explain the sharp vertical junctions of whin and sedimentaries which are common in Teesdale and which greatly impressed this acute observer. Clough sought chemical evidence in two directions: first, from analysis of the whin at Teward's Bridge (where the rocks presumably assimilated were limestone) and at Tinkler's Sike (where they consisted of equal amounts of limestone, sandstone and shale). The two analyses are very much alike, and do not show the expected influence on the whin of the difference between the composition of the dissolved sedimentaries.[1] The second direction of attack was to calculate the composition of the melt which would be produced from the vanished sedimentaries at Tinkler's Sike (the proportions of the components of which may be taken to represent the whole region), in the belief, evidently, that the whin is the actual representative of these rocks, and foreseeing the difficulty of reconciling a vast intrusion, of uniform composition, with a magma which was being continually altered in composition by the act of assimilation.

The composition of the melt, thus calculated, is ludicrously inadequate for the purpose; ferrous oxide being only 1·8 p.c., and magnesia 0·9; on the other hand, lime is 19·3 p.c., and the ratio of soda to potash is 1 : 10. Clough was thus driven to the position that the possibility of assimilation had to be faced, though the chemical evidence was completely against it.

With a view to obtaining further chemical evidence on the subject, the analysis of the contact whin (Table D, No. 6) was undertaken. The chips, from which the sample was prepared, were carefully selected within an inch of the actual lower selvage, from the neighbourhood of the White Force, in Teesdale, where the whin is very thick and the metamorphism of the sedimentaries is at a maximum, the limestones being completely recrystallized up to a distance of 40 feet or more below the whin, and a thin band of intercalated shale,

[1] These analyses differ so materially from the more modern ones, beginning with Teall's, that they only possess value for comparative purposes.

35 feet below the contact, showing a high degree of metamorphism. Here, then, one might expect conditions to be favourable for the absorption, at least, of some lime by the magma; the white appearance of the rock seemed to indicate this, but the analysis does not afford confirmation. The amount of lime is actually slightly less than in most of the other whin-samples analysed, and, indeed, this particular rock has been chosen as the one which, in all probability, most nearly approaches in composition the original magma. This line of evidence, then, like the others of a chemical nature, fails to support the hypothesis of assimilation.

Though somewhat outside of the scope of this paper, it may be permissible to point out, since the subject is important and has not been discussed by most recent authors, that Clough's field-observations, characteristically accurate and on the significance of which he so rightly insists, can be readily explained in terms of a mechanism of intrusion, sometimes exhibited by the whin-dykes, and without the necessity of involving such reactions as are involved in the conception of assimilation.

To be brief, we may consider the crust under the influence of tensional forces, by the relief of which fissuring, guided by the planes of stratification, with occasional leaps to higher, or even possibly lower, horizons occurs. Into these fissures the magma, from sub-crustal reservoirs, is immediately injected, the rate of its flow keeping pace with the propagation of the fissure. In places where the stresses were great, the opening of the fissure would be accompanied by considerable displacement, laterally, of the strata above and below it; in any case, some shifting would take place and the upper mass or settling would no longer come back to its original position, relatively to the lower, for at the breaks in horizon step-like masses of the lower beds would act as supports for the upper beds. Pools of magma would thus be left, more or less isolated, to consolidate as sills, and the ducts connecting them would have the magma, sometimes completely, sometimes partially squeezed out of them during the settlement of the beds above the fractured plane, so that no evidence, or but little, of connexion would remain.

The process is illustrated, in broad outline, by the three sectional diagrams in Fig. 6. The top diagram represents, roughly to vertical scale, the 80 feet of sedimentaries lying between the two thick limestones which serve as guiding beds. This mass of strata is under tensional stress, acting along the line of the section. Relief is afforded by the development of a horizontal crack, at the east end, which follows the bedding planes of the shales, 17 feet above the lower limestone, and, in its progression westwards, along the line of section, makes two jumps, respectively of 21 and 20 feet, to higher horizons. The state of things at the initiation of this crack is shown in this diagram, the thick stepped line in the sedimentaries representing the crack.

The crack now widens to a fissure, owing to the lateral displacement of the beds above the crack in an easterly direction. The east end of the fissure is connected with a reservoir of magma, and this is injected into the fissure. The magma here is conceived to be very fluid (there are other places where it seems to have been viscous at the moment of intrusion), and the filling of the fissure to have followed immediately on its formation. Fissuring and magma-invasion would thus be propagated westwards at a speed partly determined by the friction between liquid and solid, that is, by the height of the fissure.

The middle diagram represents conditions when the stress has been relieved and the ruptured sedimentaries have experienced their maximum displacement, both vertically and horizontally. At this stage the pressure of the superincumbent beds on the pool of intruded

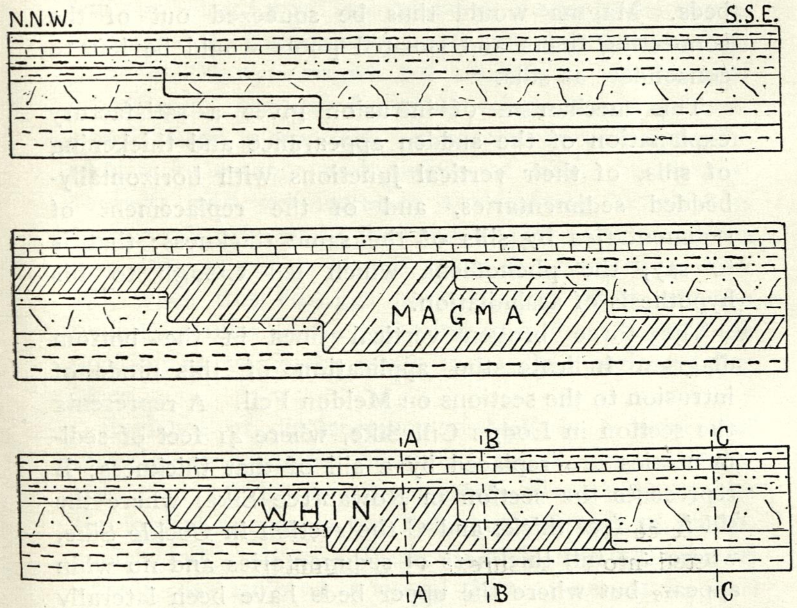


FIG. 6.

Illustrating the Mode of Intrusion of the Whin Sill. Magma and whin are shaded; sedimentaries shown conventionally. Explanation in the text.

magma would be very great. These beds would tend to sink, under gravity, thereby transmitting intense pressure through the magma in a horizontal direction. The effect of this would be to extend the fissure farther to the west, and for the magma pool to contract, the excess of magma feeding the advancing fissure. The upper beds would sink until, as represented in the bottom diagram, they became supported on the lower beds. Magma would thus be squeezed out of the connecting ducts and isolated pools would be left to consolidate as sills.

This mechanism of intrusion gives a satisfactory explanation of the sudden appearance and thickening of sills, of their vertical junctions with horizontally-bedded sedimentaries, and of the replacement of sedimentaries by sills of the same thickness; that is to say, the phenomena which led Clough to his hypothesis of assimilation.

The three broken vertical lines in the bottom diagram indicate the application of this mode of intrusion to the sections on Meldon Fell. A represents the section in Lodge Gill Sike, where 41 feet of sedimentaries are replaced by a sill of that thickness; B represents the section in Rowantree Sike, where the sill is 21 feet thick; and C the section in Cockle Sike, where the full thickness of sedimentaries and no whin appear, but where the upper beds have been laterally displaced, to the east, along a plane 19 feet above the lower limestone.

One important result of this mode of intrusion is that the thickness of the sills equals the vertical height of the jump in horizon, so that, in particular sections, the whin appears of equal thickness to the sedimentaries which have apparently been assimilated, but which, in reality, have only been displaced laterally.

Clough (p. 439) evidently considered the possibility of injection of magma into fissures, for he says: "I do not think that any theory of pre-existing fissures will help to explain facts like these." He was, however, clearly thinking of solution-fissures, as the context proves, which are radically different from the kind of fissures postulated here.

This hypothesis of intrusion avoids the difficulty of explaining how a great sheet of molten rock, probably hundreds of square miles in extent, could sustain the weight of an enormous mass of superincumbent rocks without being forced into countless cracks in the strata. It is capable of accounting easily, not only for observations of the type which led Clough to his view of assimilation, but also for many others which are constantly made in the field. Examples of such are: the sudden appearance and ending of sills; the vertical contacts with sedimentaries, the bedding of which is horizontal right up to the igneous rock; the numerous thin sills which shoot out from the base of a thick sill, when this changes horizon, and which are the obvious results of the extension of a crack beyond the position at which the break to another horizon takes place.

Evidence of displacement of beds in a horizontal direction is, naturally, difficult to prove, but a remarkable case of this has been lately discovered by the Geological Survey in the Ratcheugh district of Northumberland,[1] where a tract of land, several miles in extent, has suffered a lateral shift of one and a half miles. As the whin sill is extensively developed in this area, it may be assumed that this huge displacement is intimately bound up with its intrusion. Another observation, possibly bearing on this subject, may be cited. At Dunstanburgh, sedimentary beds in contact with a thin sill-offshoot of the main mass of whin, at a break in horizon of the latter, are horizontally slickened. The whin of the offshoot is not slickened, though there would appear to be no reason why the

[1] Summary of Progress for 1923, *Mem. Geol. Survey*, 1924, p. 84, and *Geology of the Alnwick District*, 1930, p. 84.

markings should not be preserved. This points to horizontal movement of the sedimentaries before the injection of the magma. It is conceivable that the horizontal slickening observed on some of the dykes, intimately connected with the whin sill, are indications of the last stages of release of strain, equilibrium being only attained after consolidation of the molten rock.

Perhaps the best test of the validity of the hypothesis of intrusion which could be applied would be to find traces of whin, in such sections as those on Meldon Fell, in a position corresponding to the plane of fissuring, from which the magma, owing to imperfections of the fissure, or a slight permanent tilt of the sedimentaries, had not been entirely squeezed out, when the beds re-adjusted themselves after the magma invasion. Consideration of the sike sections shows that this should be in Cockle Sike at a position corresponding to the base of the sill in the neighbouring sike, that is, 17 feet above the lower limestone. The chance of discovering what would almost certainly be a very thin band of much decomposed whin are not very great, for the length of section available in these steep, narrow gills is small. Unfortunately, at present, Cockle Gill is so much obscured with slipped drift and talus that the outlook is hopeless. The other two gills are remarkably clean, and Clough's sections can be verified in detail, and it may be added that the sudden thickening of the whin in passing from Rowantree Sike to Lodge Gill Sike, over the 100 yards of moss and peat which separate them, is very striking. Though this trial has been unsuccessful, it is not unlikely that careful search in other parts will disclose evidence of the kind sought here.[1]

[1] The displacement, without appreciable absorption, of sedimentary by igneous sills, has been studied by Cadell and Dinham in the Edinburgh district, and conclusions drawn somewhat similar to those above. See C. H. Denham, *Proc. Geol. Assoc.*, 1927, XXXVIII, p. 478.

CONCLUSION

From the evidence which has been presented in the foregoing pages, a mental picture of the magma and its transformations is evoked which, though lacking somewhat in definition, may deserve consideration as a means of unifying many diverse observations.

There are reasons for thinking that the magma, when intruded, was not of uniform composition throughout, for the facts concerning the variation of ferrous oxide indicate progressive change from south to north, greater richness in this constituent characterizing the southern area, which was, almost without doubt, nearer to the source of the magma. It may be accepted, however, that the magma in any particular area, more or less limited in extent, was substantially uniform, and that the magma as a whole, with few exceptions which do not concern us here, was of good fluidity, and was drawn or injected into horizontal fissures as the result of earth-movements intimately connected with the Pennine and Holborn folding.

The mechanism of injection is of importance, in so far as it is bound up with the question of assimilation and of influences which bear on the final composition of the consolidated magma. Evidence has been adduced that the magma invasion followed on the release of crustal stresses of a tensional nature, in which relative displacement of the beds above and below the stepped planes of fissuring took place. Gravitational adjustment, following the release, resulted in the isolation of pools of magma, some self-contained, others connected in places by ducts, more or less horizontal, but all so disposed that the weight of the superincumbent sedimentaries was in large measure borne by the beds below the plane of fissuring.

Though other modes of intrusion are not excluded, this one may, perhaps, be regarded as normal, and two important consequences follow from it. First, the field evidence for assimilation falls to the ground, and, as a result, the chemical and petrological evidence against it acquires new force; secondly, conditions were established which appear competent to account for some of the changes which the magma undergoes during its consolidation.

There can be little doubt that many of the dykes, in local association with the whin sill, are intimately connected with it, in the sense that they are derived from the same magma reservoirs. Though one cannot rule out the possibility of some of the dykes acting as feeders, there is little or no indication that this is the case; the dyke phase of intrusion must rather be regarded as somewhat later than the sill phase, and, possibly, as representing the release of residual crustal stress by the opening of vertical fissures.

Once the magma has been brought into position, influences making for heterogeneity of product become operative. The apparent uniformity of the whin sill is deceptive, for the more measurements of a quantitative nature are made on it, the more, within limits, are its variations disclosed. Most of these can be ascribed to changes which take place during consolidation, in virtue of which even a uniform magma yields products varying widely in composition.

During consolidation the magma-filled caverns were subjected to differential pressure, the load over the central portions being necessarily greater than at the sides, where the roof had effective support. In consequence of this, there was a tendency to migration of liquor, during the process of freezing, from areas of high to those of low pressure, and, as a result of this and the ever-changing composition of the mother-liquor, the balance between the earlier-formed minerals was disturbed. Thus, the varying ratios between the plagioclase felspars and the pyroxenes can be accounted for.

The change in the composition of the mother-liquor during the process of consolidation was in the direction of enrichment in quartzose and felspathic constituents and apatite. The limiting composition of this (eutectic) liquor is: albite, orthoclase, quartz = 25, 35, 40 (albite being replaced, possibly, by anorthite, in quantity up to 5 p.c.). The concentration of apatite in this is of the order of 0·16 p.c. at the freezing point, and it seems likely that its solubility increased largely with the temperature, reaching a limit of 8·7 p.c.

The normal yield of eutectic mother-liquor from the magma is 5·5 p.c.; its variability is independent of the other mineral constituents, and indicates the operation of the same process of migration as was active at an earlier stage. Its movements, during the course of its cooling to the eutectic freezing point, can be traced partly from its position in the enveloping rocks, partly by means of its varying apatite-content.

The first stage involves but little translocation and was favoured by positions where cooling of the magma was slowest, that is, a little above the middle of thick sills in regions where metamorphism of the sedimentaries is at a maximum. This might arise either by the "super-heat" of the magma, owing to its nearness to the feeding reservoirs, or by reason of the passage of a vast quantity of magma on its journey to distant places. The characteristic coarse, pink, granophyric rocks of Upper Tees and Tyne are the chief representatives of this stage.

To a slightly later period must be ascribed the inclusions at Snook Point. Here the conditions were different, for the eutectic liquor, having deposited some 30 p.c. of its apatite, has been apparently squeezed out of the rock-sponge, in which it was enmeshed, and risen in drop-like form through the viscous material of a slightly later intrusion.

The next stage is marked by the partial or complete filling of the blow-holes in the rock. By this time the rock was well consolidated and the extent to which the cavities were filled would depend upon the relative pressure of the vapours within them, and that acting on the circumambient rock and tending to strain off the still-molten residuum from the main crystalline mass. The filling of the cavities was, in general, only partial, and the completion of the process dates from a much later period, when infiltration of pyrites, calcite and quartz and, more rarely, barytes and fluorspar took place. The acidic mother-liquor injected into these blow-holes contained a fair amount of apatite, but the quantity of this has not yet been determined, owing to the lack of suitable material.

The last stage is that in which the mother-liquor, now near its freezing point and having deposited most of its apatite, was extruded from the rock and injected into such cavities as were available for its reception. These were vertical and horizontal cracks and fissures, produced by the shrinkage of the rock and not differing essentially in temperature from the invading eutectic liquor.

After cooling somewhat, the whin sill was then invaded by basalt, possibly to a much larger extent than the present evidence would lead one to infer. This basalt, in part, closely resembles the whin sill in composition; in part it shows differences of the same order as are encountered among the rocks of this formation. These intrusions may be correlated with the whin-dykes associated with the whin sill, both being regarded as derived from the same magma-reservoirs which supplied the sills. In the case of the dykes, conditions were naturally such that there was little opportunity for migration of mother-liquor during their solidification and, consequently, they show less variation in mineral-composition than the whin sill. That the process of differentiation, caused by crystallization, followed the same course as in the sills is proved by the identity of the pink veins in the Hampeth dyke, with the similar material derived from the whin sill.

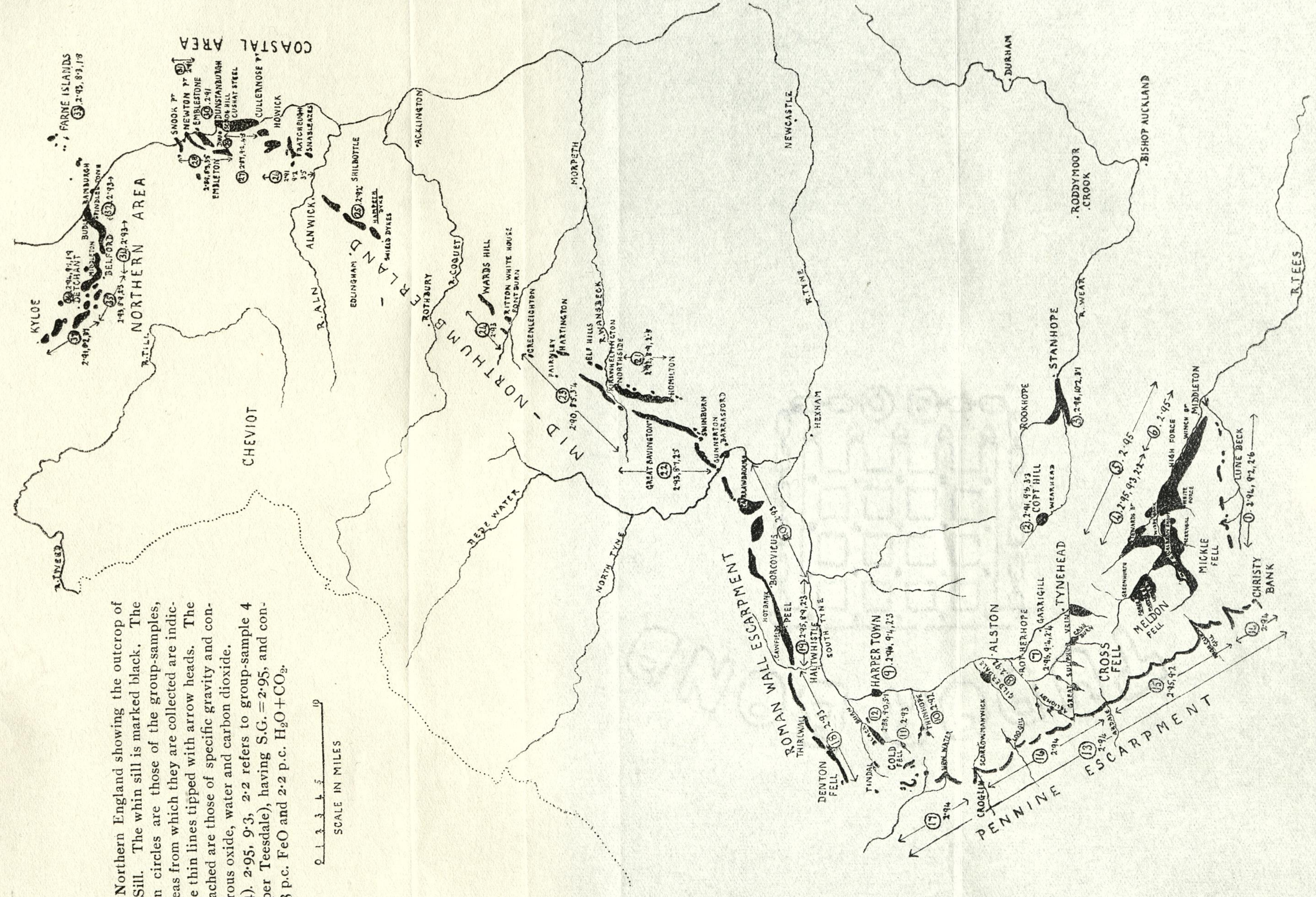
The other phases of activity, of which we have record, are concerned with the circulation of magmatic and meteoric waters and vein-solutions, and their effect on the consolidated rock. It is impossible at present to separate satisfactorily the effects of these solutions, and it is not unlikely that they were, on occasion, greatly mixed. Wager[1] has recognized an early jointing system, developed in the rock, after the solidification of the mesostasis, along which alteration by hydrothermal solutions took place, resulting in the chloritization of the rock. The deposition of pectolite has been referred, in this paper, to the same period the chlorite and pectolite being regarded as complementary in their formation, and as the analogues of pyroxene and plagioclase under magmatic conditions. An important by-product of these reactions is the metamorphism of the surrounding sedimentary beds, especially the shales, in which the chemical constituents and mineral assemblages are particularly suitable for registering the resulting changes.

Further cooling of the rock probably brought about columnar jointing, and this was succeeded by tectonic movements which opened up part of the country to the invasion of mineralizing solutions. These solutions, of unknown origin, were rich in carbon dioxide, and in the constituents of the vein-filling minerals: galena, blende, pyrites, fluorspar, barytes, etc., and they altered profoundly the whin sill wherever they came in contact with it, producing the carbonated "white whin."

[1] L. R. Wager, *Geol. Mag.*, 1929, Vol. LXVI, pp. 97, 221.

Lastly among the agencies affecting the whin sill are those of weathering. It is perhaps a moot point how far the small departure from freshness, which so much of the rock exhibits, is due to weathering or to antecedent attack by hydrothermal solutions. In the formation of the loams or red earths, however, there can be little doubt that atmospheric agencies predominate, though the results are modified by the complicated processes of soil-formation. Under these conditions, the pyroxenes are readily attacked and the felspars prove relatively stable. Much more work must yet be done before the chemistry even of these common processes is placed on a sound footing.

The author wishes to acknowledge his great indebtedness to his colleague, Mr. G. S. Mockler, for the petrological examination of a number of rocks, the results of which are briefly quoted in this paper; also for the help he has received from him in the discussion of many of the problems which have arisen during the course of this work.



Map of Northern England showing the outcrop of the Whin Sill. The whin sill is marked black. The numbers in circles are those of the group-samples, and the areas from which they are collected are indicated by the thin lines tipped with arrow heads. The figures attached are those of specific gravity and content of ferrous oxide, water and carbon dioxide.

Thus (4). 2·95, 9·3, 2·2 refers to group-sample 4 (from Upper Teesdale), having S.G. = 2·95, and containing 9·3 p.c. FeO and 2·2 p.c. H_2O+CO_2.

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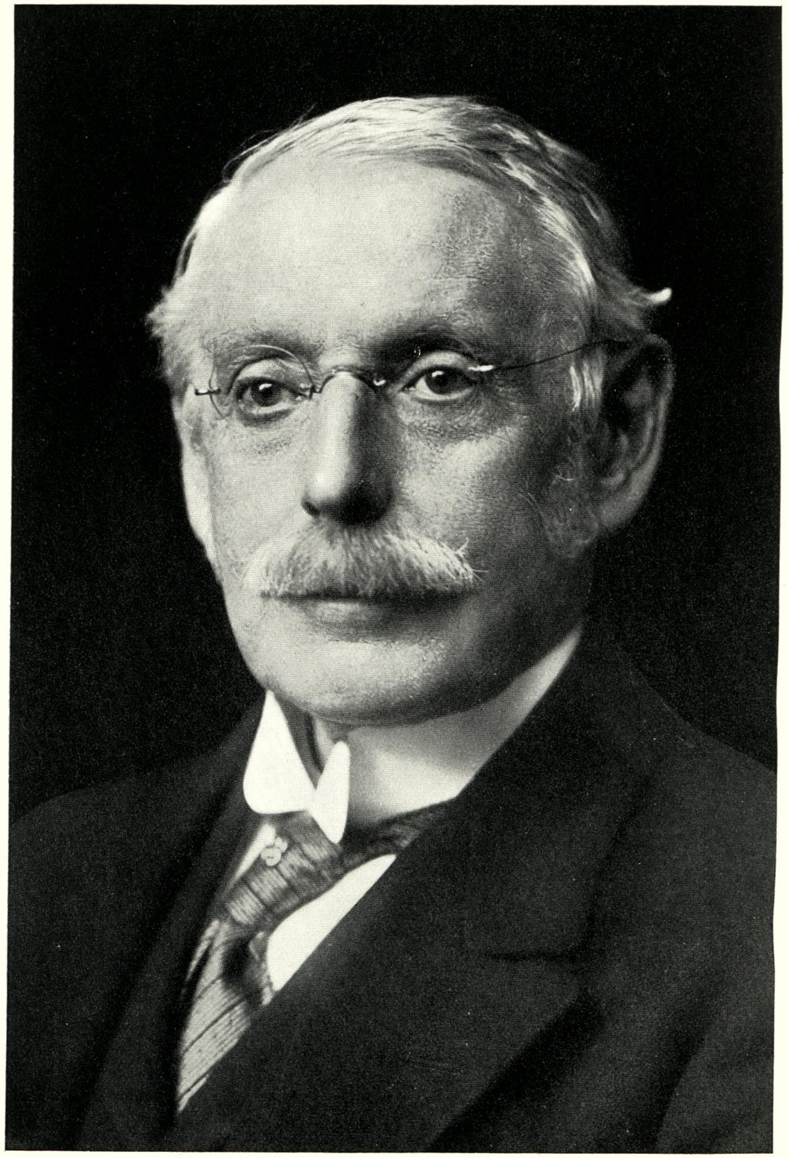
SCALE IN MILES



THE HON. SIR CHARLES A. PARSONS

THE HON. SIR CHARLES A. PARSONS

O.M., K.C.B., F.R.S., D.SC., LL.D., M.A., VICE-PRESIDENT

By the death of the Honourable Sir Charles Algernon Parsons, the nation has lost one of the greatest pioneers in the whole history of the engineering industry and one whose life was devoted to the development of the steam turbine, of which he was the originator, and which in its influence on commercial and industrial progress is probably the most important invention of modern times.

Sir Charles was taken ill whilst on a cruise to the West Indies, and after an illness lasting only a few days he died on board at Kingston, Jamaica, on February 11th, 1931.

Born in London on June 13th, 1854, Sir Charles was the fourth son of William, third Earl of Rosse. His early life was spent at Birr Castle, his father's seat in Ireland. His education was at first under the care of a private tutor, later he took a course at Dublin University, and in 1873 entered St. John's College, Cambridge, graduating three years later as eleventh Wrangler in the Mathematical Tripos. In 1884 Sir Charles married Katherine, daughter of Mr. W. F. Bethell, of Rise Park, East Yorkshire. He had one son, who lost his life in France in 1918, and one daughter.

After leaving Cambridge he served his apprenticeship with Sir W. G. Armstrong & Company, from there he went to Messrs. Kitson, of Leeds, and in 1883 became a partner in the firm of Messrs. Clarke, Chapman & Company, of Gateshead. About this time his experiments with the steam turbine were commenced, and these led to the founding, in 1889, of the Heaton Works of Messrs. C. A. Parsons & Company, for the commercial development of the turbine and its electrical equipment. Five years later, in 1894, a pioneer company was formed to carry out experimental work in connection with the application of the steam turbine to marine propulsion. The first experimental vessel—*The Turbinia*—achieved a remarkable success, which led immediately to the formation of the Parsons Marine Steam Turbine Company, whose Works are situated on the river at Wallsend.

The turbine is essentially a high speed and high efficiency engine, and with it new conditions were introduced which required the solution of many problems besides those involved in the development of the turbine itself. Electric generators suitable for the high speeds had to be designed. Condensing plant had to be improved to enable higher vacua to be obtained. Gearing for transmitting the power of the turbine to ships' propellers had to be developed. Such phenomena as cavitation had to be investigated and efficient propellers evolved. To all these and many other similar problems Sir Charles applied himself with the same brilliance and resource as characterized his work on his original invention, and each was in its turn brought to a successful solution.

Sir Charles was also actively interested in other branches of engineering and science. More than forty years ago he produced a method of making searchlight reflectors which was far superior to the processes then known, and a department was established at Heaton Works for the manufacture of reflectors. As a result of the difficulties experienced during the War, when this country was cut off from the usual supplies of high-class optical glass, he determined to develop its production as a British industry, and for this purpose he took over the Crown Glass Works at Derby, and also acquired a controlling interest in Messrs. Ross

Limited, whose optical works are situated at Clapham. More recently, he purchased the works of Sir Howard Grubb, maker of astronomical telescopes, at St. Albans, and transferred the plant to Newcastle.

The importance of the services rendered by Sir Charles in the advancement of science and in industrial progress was appreciated all the world over, and he was the recipient of honours and distinctions from Institutions and Universities in many countries. He was appointed a K.C.B. in 1911, and in further recognition of his work he was created a Member of the Order of Merit in 1927, and had the distinction of being the first engineer on whom this honour had been conferred.

The success which he achieved was due to a combination of qualities which but few are privileged to possess. He combined an inventive genius with a personality capable of controlling the commercial development of his ideas. Endowed with untiring energy, he was always ready to attack a fresh problem. He was gifted with the most remarkable insight into the real nature of problems by which others were baffled, and to their solution he applied methods, the simplicity and logic of which frequently became apparent to others only when the solution was reached. Above all, he had a driving force and determination to carry through his convictions in the face of opposition and obstacles that would have overwhelmed most men.

Outside his work Sir Charles was a keen observer of all that went on in the world around him. Scientific subjects interested him particularly. Amongst his many activities he found time for some recreation and used to enjoy a day's fishing in Sweethope Lough, or shooting over the moors about Ray Demesne, his country residence near Kirkwhelpington. At such times, and during his travels abroad, he found many opportunities of studying nature, and he was especially interested in that aspect of natural history which concerns the methods by which animals, birds or insects deal with their own peculiar mechanical problems. The manner in which natural history appealed to him can perhaps be best illustrated by the following anecdote. A party of naturalists visiting his estate at Ray were examining a wasps' nest that had been dug up, and were puzzled as to the purpose of a thick layer of pebbles at the bottom of the nest. Sir Charles at once suggested the explanation that in excavating the earth from the hole the wasps could not remove the pebbles, which therefore accumulated at the bottom.

Sir Charles was a generous supporter of the Natural History Society, of which he was a Vice-President. His membership of the Society dates back to 1903.

F. W. GARDNER.

BIRDS OF HURWORTH BURN, COUNTY DURHAM, 1910-1929

BY REV. GEORGE F. COURTENAY

Hurworth Burn is a railway station lying between Sunderland and Stockton-on-Tees, about eighteen miles from the former and nine miles from the latter. It is merely a railway station. There is no village, or even hamlet, near it; there are not half a dozen houses within view. Close to it is a reservoir belonging to the Hartlepools Gas & Water Company. It has been formed, apparently, by the damming of the little river Skerne, a tributary of the Tees. It is of irregular shape, about one and a half to two miles round; five miles from the sea as the crow flies; eight or nine miles from Teesmouth. The country around it is open; most of it rough, some cultivated. About three miles from this reservoir, in a south-easterly direction, there is another, Crookfoot, made more recently by the same Water Company. It is, I should estimate, smaller than the Hurworth reservoir; certainly so in circumference, but it is of more regular, oblong shape. The country round it, too, is open and rough, except on one side, where a fair sized wood comes down to the water's edge. Crookfoot is also some five miles from the sea as the crow flies, and about seven and a half miles from Teesmouth.

The road between these two sheets of water runs both through open country, rough and arable, and also through, or alongside, a fair amount of wood—some pine, some mixed. It has wide grass borders, with good hedges, and much furze, wild rose bushes, etc.

Thus, the area comprising the two reservoirs and the country between them, though small, is of very varied character from the bird point of view. And it was within this area that the observations recorded in the following notes were made, with the exception of a rare digression once in a way eastward towards Elwick Hall and Hart, or southwards towards Wynyard.

It is always to be borne in mind that these notes are the notes of an occasional visitor and not of a resident. Between 10th March, 1910, and 21st May, 1929, one hundred and forty-nine visits were paid. The great bulk of these fell between October and May. In fact, only sixteen were paid in the remaining four months. In July and August the foliage was too thick, the waters too empty of birds, and the flies too insufferable, to make a visit worth while. In September I was usually away from home.

The time spent in the district on each visit was from 11 a.m. to 3.45 p.m., with usually an extension on one day, or perhaps two, in the year (in May or June) to 7 p.m.

There is a table at the end of the paper showing how the visits of each year were distributed over the months.

Throughout the years 1918-1929 I kept a register of all the species seen on each visit. These twelve years comprised seventy-seven visits. In the following list the numbers in brackets denote the number of times each species was seen or heard. House Sparrow (75), Chaffinch (74), Rook (72), Blackbird (70), Mallard (69), Starling and Moorhen (67), Peewit and Crow (65), Yellow Hammer (63), Magpie (61), Wood Pigeon (59), Skylark (58), Hedge Sparrow (57), Common Gull (55), Robin (50), Dabchick (49), Coot and Blackheaded Gull (48), Tufted Duck and Greenfinch (44), Teal (42), Meadow Pipit (39), Herring Gull (38), Blue Tit (36), Partridge and Pied Wagtail (35), Pochard (34), Curlew

(32), Marsh Tit (30), Wren (27), Jackdaw (23), Reed Bunting and Redshank (22), Mistle Thrush (20), Thrush and Snipe (18), Heron and Lesser Blackbacked Gull (17), Coal Tit (16), Great Tit (15), Tree Sparrow, Kestrel and Stockdove (13), Linnet (10), Sparrow Hawk (9), Lesser Redpoll (6), Treecreeper (5).

There are one or two points illustrated by this list that are worth noticing. One is the remarkable preponderance of Blackbirds over Thrushes. I saw a Snipe as often as a Thrush! It was quite a usual experience not to see a single Thrush in the course of the day. It was almost a rarity! Whereas there were only three birds more frequently seen than the Blackbird. The Song Thrush was not even as often seen as the Mistle Thrush, and neither of them as often as the Fieldfare, with only half the year in which to make its appearance. Then, contrary to what I think is generally the case, the Marsh Tit would seem to be more abundant in the district than the Coal Tit, and increasingly so. Thus, in the eight years preceding 1918, Marsh Tits were seen or heard on twenty-eight occasions, Coal Tits on twenty-one. In the next twelve years the disparity had grown wider: Marsh Tits thirty, Coal Tits sixteen. To put it another way, more strikingly, in the five years 1913-17 Marsh Tits were seen or heard on twenty occasions, Coal Tits on nineteen. Ten years later, in the five years 1923-27, Marsh Tits were seen or heard on sixteen occasions, and Coal Tits had fallen to eight. In the last three years I have not seen or heard a Coal Tit at all. It is not that Marsh Tits are on the increase, but that Coal Tits would appear to be decreasing in the district.

Some Notes on Particular Species

Blackbirds and Thrushes. Comparative scarcity of latter, see page 157.

Fieldfares and Redwings. Fieldfares always showed a marked preponderance over Redwings in number. I do not know whether this is usual, but it was certainly the case in the Hurworth area in the past twenty years. I have seen Fieldfares more than four times as often as I have seen Redwings. There was only one year in which I failed to come across a Fieldfare—there were nine in which no Redwing appeared.

Wheatear. The Hurworth district does not seem to lie in the Wheatear's track. I have only three times met with them; on each occasion in the spring.

Whinchat. A by no means abundant visitor. There were almost as many years in which I failed to meet with one as those in which I came across it.

Redstart. This is a bird that seems to have forsaken the Hurworth district in its yearly visits. In the first half of the period covered by these notes, while I did not meet with it every year, I used to see it from time to time; usually in May, twice in July with youngsters. In three consecutive years it made its appearance in the same neighbourhood. Since 1919, however, I have missed it altogether.

Garden-Warbler. Though I should not describe it as numerous in the district, yet hardly a year passed without my coming across the Garden-Warbler. As regards its commonly regarded "opposite number," the Blackcap—in all my twenty years I never once saw or heard one. This is in accordance with my customary experience throughout the county of Durham. I can recall but one spot where I have met with the Blackcap.

Goldcrest. Not as often met with as one would expect from the favourable conditions the district provides. Thus, from 1916 to 1919 (both included), and

again from 1925 to 1929, I did not happen to observe a single Goldcrest.

Wood Wren. Only casually met with, there being little of the kind of timber that attracts Wood Wrens.

Sedge-Warbler. The Sedge-Warbler was an intermittent visitor in my experience, turning up in some years, absent in others, with a gap of sometimes as many as four years between its appearances.

Coal Tit and Marsh Tit. See page 157.

Long-tailed Tit. In the course of close on twenty years I have come in contact with this wanderer on only two occasions, and these within six months of each other, October, 1926, and February, 1927.

Treecreeper. As there is not much old timber in the district, it is perhaps not surprising that this retiring little bird was but seldom seen—just five times, at various seasons of the year, in the whole period of my observations.

Pied Wagtail. Pied Wagtails become scarce in winter, but do not always disappear. Although, more often than not, I have failed to see them throughout the winter, I have come across them more than once in each of the months November, December, January and February.

Grey Wagtail. The Hurworth district is, of course, nowhere the kind of country for Grey Wagtails, but I happened on two occasions to come across them. On one day (3rd March, 1911) I actually came across two at widely separated points in the area; and on 27th September, 1918, I saw one again by Hurworth reservoir.

Yellow Wagtail. A very occasional visitor to the district, and, like the Redstart, it would seem to have left it altogether since 1919. I saw it in 1915. I did not see it, but feel sure that I heard it in 1916. I saw it again in 1919. That is my whole record in brief. To quote my notes made at the time: "1915, May 14th—A Yellow Wagtail in ploughed field on north side of

Hurworth reservoir." "June 25th—At same spot as on May 14th—a pair of Yellow Wagtails." "1916, July 27th—Heard distinctly, but did not see, Yellow Wagtail in same immediate neighbourhood as last year." "1919, May 27th—Yellow Wagtails following a man working in field next Hurworth reservoir, again in same neighbourhood as in 1915 and 1916." "July 11th—Yellow Wagtail and, if I mistake not, a young one in same neighbourhood again."

Tree Pipit. A regular visitor, though it was curiously absent (so far as my observation went) in the three successive years 1923, 1924, 1925.

Spotted Flycatcher. Nothing has surprised me more at Hurworth than the almost complete absence of so common a bird as the Spotted Flycatcher. Amid the abundant variety that the district presents there is no lack of suitable stations. And yet it was not until the thirteenth year of my visiting the area that I ever came across one. Two years later I saw a pair much about the same spot, and on the same day a single individual not very far from it. That is the complete record of my observation of this bird in the course of twenty years.

Tree Sparrow. It is pleasing to note that this bird is decidedly and steadily on the increase in the district. In my first eleven years I saw it on eight occasions. In the next eight years I saw it on eleven. In the last four years seven times. It has made its appearance at various points scattered over the whole area; and ever, as the years went on, in larger parties. Thus, "a party of four," "a party of four (if not five)" are entries in my notes of recent years. On 26th February, 1926, there were no less than three little companies (of six or so in each) met with. And on the same day, strange to relate, I did not see more than half a dozen House Sparrows altogether. A more curious experience was on 31st May, 1920, when the only sparrow of any kind I saw all day was a solitary Tree Sparrow.

Up to 1919 it was always in late autumn or winter that I met with them. Since then it has as often been between mid-March and the end of May. And a pair seen on 26th April, 1928, at a certain spot, and (presumably the same pair) seen at the same spot a month later, would certainly seem to indicate their nesting in the district. One day, in the early part of 1929, there was quite a little colony down at stack-yard corner of reservoir, and some more were to be seen at a point a mile or two off.

Brambling. Not often seen. Sometimes a gap of eight or nine years between their appearances. On the other hand I saw them three times in the twelve months March, 1920, to March, 1921. It was in March that I most often came across them; and more than once in the stackyard at the corner of Hurworth reservoir.

Linnet. It was not often that I came across Linnets at Hurworth—only eleven times in all. When I did, curious to relate, it was always either between May 2nd and July 2nd, or between October 2nd and December 2nd. Every appearance fell within one or the other of these two periods.

Lesser Redpoll and Mealy Redpoll. Not as often seen as one would expect from the conditions; only six times in the course of my observations. Always in the winter half of the year; never in spring or summer. They usually occurred in small parties, apparently in the course of their winter wanderings. On one occasion there was with them a larger bird, very grey in appearance, that I took to be a Mealy Redpoll (21st November, 1913).

Bullfinch. Considering the large amount of undergrowth here and there over the whole district, it is surprising that Bullfinches were not more in evidence. Only twice did I see them in the course of my visits. On one of these occasions, 1st December, 1911, I had the pleasure of seeing three or four together; and on the 20th November, 1914, a fine cock revealed himself by the roadside. In the fifteen years following that date I never saw one, though an odd time or two I have thought that I heard their note.

Corn Bunting. Hurworth district is not one of the localities favoured by this very local bird. I only came across it three times, and that in three successive years —1911 (May), 1912 (April), 1913 (May). I have neither heard nor seen it since.

Reed Bunting. This bird was met with all the year round, but more than twice as frequently in the months March to July as in October to February, with an equal number of visits paid in each of these periods, or, to be quite precise, with one more paid in the latter period.

Jay. I have but once seen this bird in the district —a passing glimpse, 29th July, 1918. Before that I had twice heard it in 1910 and 1914. Since these dates I have not even heard it. This is rather surprising, as the area seems left very much to itself as regards gamekeeping.

Magpie. A very common bird at Hurworth. Indeed, there were only ten species more frequently seen. An unusual sight to me, I do not know whether it is generally so, was on one occasion to see two Magpies perched together on a sheep's back. When disturbed, they calmly mounted together on the back of another.

Hooded Crow. This bird seems to have disappeared from the district in a mysterious and remarkable way. From 1910 to 1919 on a winter's day visit to Hurworth it was almost a matter of course to see Hooded Crows. Since 1919, however, I have only seen them twice. Once in 1921—a single one (November 10th), and once in 1922—two pairs at different points (October 10th). I have never seen them since. From 1910 to 1919 seen on thirty-three occasions; from 1920 to 1929 seen on but two occasions!

Green Woodpecker. From 1910 to 1917 it was a comparatively common experience to hear the Green

Woodpecker, at various times of the year, more especially in April and May, and in various parts of the district, more especially in the woods about Crookfoot. I only saw it, however, three times. The first occasion was while I was sheltering in a wood on a hopelessly wet day (18th May, 1910). I had some compensation in obtaining an excellent view of a Green Woodpecker as it flew past quite near me. The next glimpse was on 29th November, 1912, when one flew across the road between Hurworth and Crookfoot. The third and last glimpse was in a wood at Wynyard on 5th February, 1915. I heard it subsequently, once in 1916 and twice in 1917. But since 4th July, 1917, I have neither heard nor seen the bird in the district.

Great Spotted Woodpecker. It was a great delight to come across this bird, and get an uncommonly good view of it, on 13th February, 1922. It was on the top branches of two oaks, since cut down, standing together close to the roadside. "Much struck," I noted at the time, "by the vivid red of hinder under parts. As I did not notice any red about the back of the head, I presume it was a female. After obliging me with an excellent view, it flew across the road into a fir plantation."

Kingfisher. Only once seen, and that not until 2nd December, 1927, when I had long come to think that there were none in the locality.

Barn Owl. On the afternoon of a mild, cloudless day in January, 1923, with the sun still up, it was very interesting to see a Barn Owl come across the road and begin quartering the rough ground adjoining it, every now and then dropping to earth and up again. I watched it for a good while, and sometimes it flew past me so closely that I concluded it was either indifferent to, or unconscious of, my presence.

Sparrow Hawk. Unlike the Kestrel, the Sparrow Hawk seems to hold its own in the Hurworth area, neither more nor less. Its appearances were pretty much the same in frequency all through the period of my visits. One did not see it very often, but sometimes an excellent "close up" view was to be had. A Sparrow Hawk mobbed by a crowd of Peewits was an item in one day's "bag."

Kestrel. The Kestrel would appear to be waning as a bird of the district. In the years 1910 to 1919 I saw it on twenty-three occasions. In the following ten years on only twelve. In the earlier days I used to see them three, five, or even six times in a single year: in the last ten years never more than twice, and not often that. For the last twelve months and more I have not seen one at all. Again, in the earlier years, it was no uncommon thing to see more than one in the day, on occasion three, or even four; in the latter years never more than one. I do not know whether it is unusual or not, but it struck me as strange, one day, to see a Kestrel perched on the telegraph wire. I had seen it on an insulator, but never before on the wire. More than once I have noticed a Kestrel driven off by a Rook.

Cormorant. On 20th May, 1926, a Cormorant (the first and only one I have seen here) got up from Hurworth reservoir and flew off, rising higher and higher. It then flew round in circles, until I lost sight of it, as if out of its bearings and looking for the best direction to take; its flight quite different from its usual direct course over the sea.

Heron. So far as I am aware, there is no heronry anywhere near Hurworth. I have no notion how far one would have to go to reach the nearest. But Herons put in an appearance from time to time; usually single birds, but occasionally two, or even three, at once. These visits were much more frequent in the latter half of the year than in the earlier, and were most frequent of all in the last three months of the twelve.

Whooper Swan. One would not expect to see much

of wild swans in the Hurworth area, so that I deem myself very fortunate indeed to have come in for the following experiences:

On the 10th November, 1921, Hurworth reservoir was frozen over except for one small patch in the centre. Sometimes resting on the ice, and sometimes drifting about the open patch, were four Whooper Swans. I was able to see the details of head and bill excellently. They kept very close together, so that sometimes two birds appeared as one. I noticed also the constant turning of the head from side to side while swimming, and how distinctly the black butt of the tarsus showed. They gave the impression of being two pairs. An hour or so later, while sitting by Crookfoot reservoir, which, by the way, was quite open, four large white birds appeared flying over the trees towards it, evidently the some four swans again. They flew backwards and forwards over the water, sometimes coming very low down, as if inspecting it. Apparently not satisfied with it, they rose higher and higher, and finally flew back over the trees by the way that they had come. While flying about over the water they more than once passed very close to me—I feel sure they had not observed me—and I could hear a frequent note—like a subdued crowing (very well syllabled by H. A. Macpherson as *hoop-hooper-hoop*) softly uttered.

On another occasion, 4th April, 1924, there were two swans on Hurworth reservoir. I took them to be immature Whoopers. Their upper parts were washed with buff. The yellow at the base of the bill was not at all bright, the rest of the bill black or greenish black.

The Ducks. Taking one time with another, I have seen nine species of Duck on Hurworth reservoir. Six of these are either residents or regular visitors—Mallard, Tufted Duck, Teal, Pochard, Goldeneye and Wigeon. I have named them in the order of the frequency with which I have seen them. Three more are casual visitors—Shoveler, Smew (seen four times) and Scaup (once). Wigeon seemed to be visiting Hurworth more frequently in the last ten years than in the previous ten, Shoveler less frequently. The high-water mark in the display of Ducks generally was reached as a rule in March. In the following two months they tapered off, until in June they had practically disappeared. I have only twice seen a duck on the water in June—two Tufted Drakes on 3rd June, 1927, and three Mallard on 25th June, 1915. In July they begin to reappear, especially Mallard. Mallard certainly nest at Hurworth, and the Shoveler has done so. I have no direct evidence of the nesting of the Tufted Duck, but I should be immensely surprised to learn that it did not. Circumstantial evidence seemed very strong. The Ducks in general showed a curious but very noticeable preference for Hurworth reservoir over Crookfoot—a preference most marked in the case of Tufted Duck, and, strange to say, about least so in another diving duck, the Pochard.

It was a somewhat remarkable experience on 4th January, 1923, to see on the water at Hurworth, Teal, Wigeon, Pochard, Tufted Duck and at least one Goldeneye, and not a single Mallard! Much the same happened on 15th December, 1916, when there were four species represented, all the last named except Wigeon, but no Mallard. It was nothing unusual to see five species of Duck in the course of the day, sometimes all together on the same piece of water. Very occasionally six were to be seen; once all six at the same time—on 16th March, 1922, when on Hurworth reservoir there were a sprinkling of Mallard, five Wigeon, three Tufted Duck, five Pochard, three Goldeneye and a Smew. Sometimes it was the number of individuals that was remarkable. Such an entry as the following does not stand alone in my notes: "6th February, 1925, Hurworth reservoir literally swarming with ducks; uncounted Mallard, Teal liberally distributed among them; a company of about fifty Pochard, and quite two dozen Wigeon.

Mallard. The Mallard was, of course, the commonest duck on both reservoirs by a long way. Like the rest, it was to be seen much more frequently and in far larger numbers at Hurworth than on Crookfoot. It was only in a small minority of visits that one failed to see a Mallard, and of these a full half were in May and June when the birds were in nesting seclusion. Indeed, only once did I see a Mallard in June, while in the ninety-seven visits paid in the six months October to March there were only eight occasions on which I failed to see one. There was no doubt about the nesting of the Mallard at Hurworth. As early as January pairing was noticeable, becoming more and more conspicuous as the season advanced. Then in May small parties of drakes would be in evidence, cruising or flying about, the ducks out of the picture. On 27th May, 1919, I noticed four drakes flying about over the reservoir. Very shortly after, I put up two ducks from the water's edge, almost certainly from nests. Later in the same year (July 11th) I surprised and disturbed in a stream part of the reservoir a family party. The young ones, though looking as if able to fly, scuttled down stream as fast as they could; the duck zig-zagged across it, as if lamed or in difficulties of some sort, giving the others time to get safely out of harm's way, and then flew off after them. In winter there were often enormous numbers of Mallard, more especially on Hurworth reservoir—even when it was covered with ice, and when, as was very commonly the case, there was open water on Crookfoot.

Shoveler. The Shoveler made its appearance not quite a dozen times in the course of my observations, much less frequently in the last ten years than in the preceding ten; in fact, in the last ten years I have seen it but twice, in May, 1919, and in October, 1925. The last week in February and the first week in November were the earliest and latest dates of my seeing it. May and October were the months in which it was most often observed. It certainly nested at Hurworth in 1914, for in May of that year I saw one accompanied by eight youngsters.

Teal. The Teal is of very common occurrence at Hurworth, being only surpassed in this respect by the Mallard, and very slightly by the Tufted Duck. It is a little interesting to compare the appearances of this last and the Teal. They present a curious contrast. Though much the same in total for the year, there is a striking difference in the way in which these appearances are distributed.

No. of visits.	In Quarter.	No. of times seen Teal.	Tufted Duck.
45	Oct. to Dec.	40	23
52	Jan. to March	26	28
41	April to June	6	25
138		72	76

Thus, it will be seen that Teal were most in evidence in the last three months of the year. Probably the more severe weather that commonly comes in the first three months accounts for the drop in that quarter. Again, in contrast to the marked preference shown by the Tufted Duck for Hurworth reservoir, no duck showed a larger proportion of appearances at Crookfoot than the Teal. It usually occurred in small parties, often as a sprinkling among a larger number of Mallard. The greatest number I have seen is sixty in January. In view of the Teal's impatience of cold, it is worth noting that on a day in February, when both reservoirs were almost completely frozen over, there was a party of nineteen on Hurworth. On my single September visit to the district, apart from three

Mallard, the only ducks seen were a party of a dozen to twenty Teal.

Wigeon. In most winters Wigeon were to be seen at Hurworth, on one or more occasions, between the second week in November and the second week in May. But some half-dozen seasons passed without my seeing one at all, notably the three successive winters 1918-19, 1919-20 and 1920-21. March was the month in which they occurred most frequently. Hurworth reservoir, though farther from Teesmouth, whence it is to be presumed they came, seemed much to be preferred to Crookfoot. Twice I have observed as many as fifty on the water, and on three occasions from ten to two dozen, but mostly they occurred singly or in pairs, with now and again three to half a dozen.

Pochard. From October to March the Pochard was a common visitor to both reservoirs. Between November and February it was not unusual to find them in parties ranging from twenty to upwards of fifty—more often than not simply resting on the water. In March the brilliant, clean-cut plumage of the drakes was always very noticeable and gave them a very attractive appearance.

Later than March I only met with them five times—once in April, once in May, and thrice in July. On 16th July, 1912, a solitary Pochard was the only duck seen all day on either reservoir. On 1st July, 1918, there was again a single Pochard "lazing" in a corner of Hurworth reservoir, quite apart from the dozen to twenty other ducks (Mallard and Teal) on the water. Once more, on 18th July, 1922, there was again a single bird on Hurworth reservoir, and a pair resting on Crookfoot. On 27th May, 1919, a fine drake settled on the water at Crookfoot quite close to where I was sitting.

Tufted Duck. Except the Mallard, no duck is to be met with at Hurworth more frequently that the Tufted, though the Teal runs it pretty closely. I have seen it ten months in the year, and have little doubt that I should have come across it in the remaining two (August and September) if I had visited the district during these months with anything like the frequency with which I visited it for the rest of the year. Unlike the Pochard and Goldeneye, the Tufted Duck showed a curious, but quite marked preference for Hurworth reservoir as compared with Crookfoot. And of its much fewer appearances on the latter, a good proportion were due to the fact that in time of frost there is usually a good deal more open water on Crookfoot than on Hurworth. Tufted Duck occurred mostly in small parties from a pair up to half a dozen, but occasionally singly, and three or four times I have seen as many as a dozen together. Now and again one or two might be seen showing white about the base of the bill.

Goldeneye. Goldeneye were regular winter visitors to both reservoirs. I saw them every season except in my last winter, 1928-29, when I was only able to pay a very few visits. The first arrivals were in October. Immature birds figured largely throughout the season, but now and again a resplendent drake in full array would be seen among them—or rather, as often as not, by himself, aloof from all other ducks on the water. Very frequently they occurred singly, never in more than very small parties; seven is, I think, the largest number I have seen together. They showed a distinct predilection for keeping to themselves. March was the month in which they appeared at their best and most frequently. Twice I have seen them in April, immature birds both times, and once an adult drake as late as 25th May, 1928.

Smew. It was a piece of good luck to see this rare bird on no less than four occasions, and under somewhat unusual circumstances. It is usually well on in winter that the Smew makes its appearance, and its

visits are commonly associated with severe weather. But it was on 10th November, 1920, a fine, mild, open day, that I came across a pair, quite to themselves, on Hurworth reservoir. They flew off, but returned to the same spot. On flying off again, they settled on a different part of the reservoir, where I afterwards came upon them. Just a month later, December 9th, a fine, cloudless day, with a touch of frost over night, and all day in the shade, I again visited Hurworth, and found the Smews in the same corner of the reservoir where I had first seen them. This time I had them in such an excellent light that I was able to note every detail in duck and drake. Both were in splendid plumage. I assume, of course, that they were the same pair as in November, for it seems beyond the limits of coincidence that another pair of such rare birds should be in the same spot on my second visit. On the other hand, it is certainly remarkable, and seems strange that they should hang about the place so long —especially as the weather for the month had been open and free from severity. The next occasion was fifteen months later, 16th March, 1922, a glorious day of bright and warm sunshine, when I found a Smew in the same corner of the reservoir where I had seen them the previous winter. This time it was a duck, alone, in very good plumage. I had to wait seven years for my next glimpse. It was on 4th January, 1929, a skin of ice, sufficient for Gulls to stand on, almost covering the reservoir. There, in the same corner as before, where the water was freer from ice, was a Smew again. It was a female in beautiful plumage—well named "Weasel Duck," with its clean-cut brown and white on head and neck—the white in this one extraordinarily pure.

Corncrake. I had that rare experience, a glimpse of a Corncrake, by the roadside, on 19th May, 1911. It ran at once through the grass and hedge into the adjoining field. Since then—that is over a period of eighteen years—I have never so much as heard one in the district.

Coot. The Coot is, of course, a common bird on the reservoirs, especially Hurworth, but at the same time its appearances were distinctly capricious. At times only an odd two or three were to be seen; perhaps on the next occasion there would be quite a flock of them, spread out like poultry along the margin of the lake. Then again for a long spell there would not be one visible. Thus, for two periods of over eighteen months each I never saw a single Coot: from October, 1917, to May, 1919, and from March, 1923, to October, 1924. It was the same for the thirteen months October, 1919, to November, 1920. On the other hand, for the last three years of my visits to Hurworth there was not a single occasion on which I failed to see them.

Ringed Plover. A single Ringed Plover put in an appearance on 15th May, 1914, the occasion when I had for the first time the satisfaction of seeing upwards of forty species in one day. On 25th June, 1915, there was again a solitary one feeding along the edge of Hurworth reservoir. Once more, on 16th March, 1922, a pair of Ringed Plover were playing about the waterside.

Oystercatcher. Once, and once only, have I seen an Oystercatcher in the district—a single one, standing by the edge of Crookfoot reservoir, on 19th January, 1912.

Snipe. Snipe were to be met with all the year round, but especially in May. There is some boggy ground in which I have no doubt they nested. On 7th October, 1921, when the water in Hurworth reservoir was very low and left much mud exposed, I had an excellent view of a party of ten or twelve feeding, and watched them for a long while. They never went off very far when disturbed, and kept fairly together. It was an exceptional opportunity for observing their beautiful characteristic markings.

Dunlin. It was only in the fall of the year that Dunlin put in an appearance at Hurworth, and not always then. I saw them there on six occasions; five times on Hurworth reservoir and once on Crookfoot. The first I came across were a party of three, on 12th August, 1910—perhaps rather early to be described as in the fall of the year, but all the other dates, it will be observed, are well within that season. In the following year, on October 6th, there were seven or eight; and on December 1st, half a dozen flying about over the reservoir. On 8th October, 1915, when the water was very low, and consequently a good deal of mud exposed round the edges, there was a large flock of Dunlin. On the same occasion, but apart from them, there was a solitary Godwit feeding—the only one I have ever seen in the district. In the following month, November 5th, there was a party of fourteen on the edge of Crookfoot. Six years later, 7th October, 1921, when the water was again very low, as much land as water in the usual water area, a small party of Dunlin were to be seen.

Redshank. From March to July Redshanks were always in evidence, especially about a rough, tussocky piece of ground where, although I never came across a nest, I have little doubt they nested. On 4th July, 1917, there were nine Redshanks about Hurworth reservoir. In the remaining seven months of the year I have only once met with them, in December, 1913.

Godwit. On 8th October, 1915, there was the unusual spectacle of a Godwit (presumably Bar-tailed, I was so taken aback at seeing such a bird at all that details were lost upon me) feeding by the edge of Hurworth reservoir. On the same day there was also a large flock of Dunlin. The Godwit, however, was not with them, but kept to itself.

Common Tern. On Crookfoot two birds settled side by side on the stump of a tree projecting above the water a foot or two from the shore on May 25th, 1928.

Gulls. The Gulls most commonly seen at Hurworth were the Common, Blackheaded, Herring and Lesser Blackbacked, and in that order of frequency; the first being seen more than three times as often as the last, the second nearly three times, and the third more than twice. The numbers seen on different days, even at the same time of year, varied very considerably—according to circumstances, I should suppose; weather conditions, for example, and, I should imagine, the state of the tide, the sea being only five miles off. But a general trend of frequency or infrequency was very observable. In October there was a growing increase in numbers. In November and December the high-water mark was reached. Such expressions as "very numerous," "large company," "immense number," "a host," "a crowd," figure in my notes. January, and still more February, saw a gradual decline; and in March, while a good sized company might be come across now and again, the entry more usually was "a small party," "a few," "under six," "three," or even "not a single Gull seen all day." In April, May and June this last was not at all an uncommon entry, and "one," "two" or "three" quite frequent.

Great Blackbacked Gull. It seemed somewhat startling to come across this fine bird amid the quiet, rural conditions of Hurworth; and yet it was not really surprising considering that the sea was only five miles off. I found it on six occasions, always on Hurworth reservoir, not Crookfoot. The first was on an intensely cold day in January, 1914, when there were a pair on the water. In December of the same year, on a calm, mild day, there were three amid a numerous company of Herring Gulls. A year later, almost to a day (December, 1915), there was a single one among a large crowd of smaller species. On a fine, calm day in the following month (January, 1916) there was again

a Great Blackbacked among the gulls on the water. I did not see another for six years, when I came across three resting on the ice that almost entirely covered the reservoir. The next and last occasion was nearly five years later (December, 1926), when on a calm, bright day there were again three, a pair and an odd one, on the water.

Blackthroated Diver. I have only once seen a Diver of any kind on the waters at Hurworth, and then I had the satisfaction of a close view, with plenty of time to observe, of a pair of Blackthroated Divers (15th February, 1924).

Great Crested Grebe. My first contact with this bird in the Hurworth district was on 31st March, 1916, when I had a splendid view of one, at close quarters and in perfect light, as it passed, swimming and diving, down a tributary stream into Crookfoot reservoir. I did not see another until four and a half years later, when a Great Crested Grebe turned up on Hurworth reservoir on 10th November, 1920. Close on two years after this, on 10th October, 1922, I saw one again at almost the same spot. These were the only occasions on which I came across it.

Sclavonian Grebe. Twice I had the good luck to see this bird—once on each reservoir. First on Crookfoot, 15th February, 1924. A little later in the same year (April 4th) there was one on Hurworth reservoir. I was so occupied, however, with two Swans on the water at the same time that I paid little attention to the Grebe beyond noting its presence.

Dabchick. Hurworth reservoir is well frequented by Dabchicks, more so than Crookfoot. March, April and May were the months in which they were always most in evidence; January and February least so.

It is a matter of much surprise to me that I have never once met with any one of the following birds in the long course of my visits to Hurworth: Stonechat, Goldfinch, Blackcap, Chiffchaff, Water Rail, Woodcock.

As to the Blackcap, see page 158. The Chiffchaff I have always found to be a curiously rare bird in the county of Durham—almost non-existent so far as my personal experience goes. I have never met with it at all on the eastern side of the county, and but once in the west. Why this should be so I have no notion. It seems puzzling.

Following is a list of ninety-seven species I have seen at Hurworth: Mistle Thrush, Song Thrush, Redwing, Fieldfare, Blackbird, Wheatear, Whinchat, Redstart, Robin, Whitethroat, Garden-Warbler, Willow Wren, Sedge-Warbler, Wood Wren, Goldcrest, Hedge Sparrow, Long-tailed Tit, Great Tit, Coal Tit, Marsh Tit, Blue Tit, Wren, Treecreeper, Pied Wagtail, Grey Wagtail, Yellow Wagtail, Tree Pipit, Meadow Pipit, Spotted Flycatcher, Swallow, House Martin, Sand Martin, Greenfinch, House Sparrow, Tree Sparrow, Chaffinch, Brambling, Linnet, Mealy Redpoll, Lesser Redpoll, Bullfinch, Corn Bunting, Yellowhammer, Reed Bunting, Starling, Jay, Magpie, Jackdaw, Crow, Hooded Crow, Rook, Skylark, Swift, Green Woodpecker, Great Spotted Woodpecker, Kingfisher, Cuckoo, Barn Owl, Sparrow Hawk, Kestrel, Cormorant, Heron, Whooper Swan, Mallard, Shoveler, Teal, Wigeon, Pochard, Tufted Duck, Scaup, Goldeneye, Smew, Wood Pigeon, Stock Dove, Partridge, Corncrake, Moorhen, Coot, Ringed Plover, Peewit, Oystercatcher, Snipe, Dunlin, Sandpiper, Redshank, Godwit, Curlew, Common Tern, Blackheaded Gull, Common Gull, Herring Gull, Lesser Blackbacked Gull, Great Blackbacked Gull, Blackthroated Diver, Great Crested Grebe, Sclavonian Grebe, Dabchick.

Of these birds the following were seen but once: Blackthroated Diver, Common Tern, Kingfisher, Cormorant, Mealy Redpoll, Barn Owl, Godwit, Oystercatcher, Corncrake, Great Spotted Woodpecker, Jay (heard on two other occasions), Scaup, Wood Wren (heard on nine other occasions).

Of birds that would appear to be on the increase in the district I can only name two. The Tree Sparrow has certainly come much more into evidence, and the Wigeon is now a more frequent and abundant visitor to the reservoirs than in my first years at Hurworth. On the other hand, of those birds that would seem to be decreasing or to have disappeared altogether, there are unfortunately many more to be named: Corn Bunting, Yellow Wagtail, Green Woodpecker, Bullfinch, Hooded Crow, Kestrel, Redstart, Shoveler, Corncrake. (See notes on these particular birds.)

TABLE OF VISITS PAID SHOWING NUMBER IN EACH MONTH

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals
1910			1	1	2		1	1		1	1	1	9
1911	2		1	2	1					1	1	1	9
1912	1	1	1	1	1		1				1	1	8
1913	1	1	1	1	2					1	2	1	10
1914	1		1	1	1					1	1	1	7
1915	1	1	2	1	1	1				1	1	1	10
1916	1	1	3		2		1			1		1	10
1917		2	1		2		1			1	1	1	9
1918	1		1	1	1		2		1				7
1919		1	1		1		1			1			5
1920	1		2	1	1	1					1	1	8
1921	1	1	1							1	1	1	6
1922	1	1	1		1		1			1	1		7
1923	1		1	1	1						1	1	6
1924	1	1		1		1				1	1	1	7
1925	1	1	1	1		1				1		2	8
1926		1	1	1	1					1		2	7
1927		1	1		1	1				1		2	7
1928		1	1	1	1		1						5
1929	1		1		2								4
Totals	15	14	23	14	22	5	9	1	1	14	13	18	149

TABLE SHOWING THE NUMBER OF TIMES THE VARIOUS DUCKS WERE SEEN IN THE DIFFERENT MONTHS OF THE YEAR

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals
Mallard	14	11	22	13	12	1	5		1	13	12	17	121
Shoveler		1	1		3		1	1		3	1		11
Teal	9	8	9	5	1		2		1	10	12	18	75
Wigeon	1	2	8	2	3						1	3	20
Pochard	7	10	13	1	1		3			8	10	11	64
Tufted Duck	9	6	13	10	14	1	1			7	5	11	77
Scaup											1		1
Goldeneye	8	6	13	2	1					6	7	8	51
Smew	1		1								1	1	4
Visits Paid	15	14	23	14	22	5	9	1	1	14	13	18	149

THE STRATIGRAPHY OF THE BERNICIAN AND MILLSTONE GRIT OF SOUTH NORTHUMBERLAND

By W. Percy Hedley

Certain lithological divisions of the Carboniferous in Northumberland have been widely used for some time. The divisions used by Lebour[1] in 1886 were five in number, viz.:

1. The Coal Measures.
2. The Millstone Grit.
3. The Bernician Series.
4. The Tuedian Series.
5. The Basement Beds.

This paper is only especially concerned with the Millstone Grit and the Bernician Series. The boundaries of these divisions have been fixed in quite an arbitrary manner, and in fact any boundaries which might be taken, other than on purely palæontological lines, must be arbitrary, for each division constitutes a perfect transitional series between the divisions above and below. The base of the Bernician has been taken as the Redesdale Limestone, and the top as the Harlow Hill (Felltop) Limestone. The beds between the Harlow Hill Limestone and the Brockwell Coal constitute the so-called "Millstone Grit" Series of Northumberland. The term Millstone Grit is used not in a lithological sense, but as a term to define the beds lying between the Lower Coal Measures and the Lower Carboniferous. The fact that the Millstone Grit of Yorkshire is ten times the thickness of the corresponding beds in Northumberland does not preclude the use of the same term to define both.

The Bernician Series and the Millstone Grit together make up the greater part, if not all, of the Dibunophyllum zones of Vaughan[2] and Garwood,[3] and the succeeding goniatite zones up to the top of G, established by Bisat.[4] In 1927 Allan[5] placed the Scremerston Coal Group, the equivalent in North Northumberland to the Carbonaceous Series, in Zone S; the Fell Sandstones in C; and the Cementstone Group in Z. These three sub-divisions together make up the Tuedian. This correlation will be to reconsider at some later date, when the fauna of these beds has received further study. Clough[7] records *Zaphrentis phillipsi* from a thin impure limestone in the east bank of the North Tyne, 300 yards south-east of Wellhaugh. This is in the Carbonaceous Series.

The Redesdale Limestone is certainly in D1, and the underlying Redesdale Ironstone Shale and Shell Bed may well be the equivalent of the Bryozoa Band of the Westmorland Pennines, which is taken by Garwood[6] as the base of D1. The top of D1 ends below the level at which *Girvanella* reaches its maximum. This horizon is well known in the north of England. In North Northumberland it is in the Oxford Limestone; in the Upper Wansbeck valley it is in a limestone outcropping at Raechester and Ferneyrigg. In the North Tyne valley a recent boring for water at Barrasford Sanatorium reached, at a depth of 80 feet, a limestone containing *Girvanella*. In West Northumberland *Girvanella* occurs in the Bankhouses or Smiddy Limestone. In Yorkshire we find the Girvanella Band in the Great Star Limestone.

We have thus an excellent base for D2, but unfortunately the top is not nearly so clear. D2 was defined by Vaughan[2] as the sub-zone of *Lonsdaleia floriformis* Mart., and by Garwood[3] as the zone of *Saccamina carteri* Brady. *Lonsdaleia floriformis* is recorded by Turner[8] from the Lower Little, the Jew, and the Great Limestones of Westmorland, and it occurs in the Great Limestone of South Northumberland. *Saccamina carteri* has a similar vertical range (Lower Little, Jew, Tynebottom and Single Post Limestones of Westmorland; Tynebottom, Scar, Four-fathom and Great Limestones of West Northumberland; Oxford, Acre and Sandbanks Limestones of North Northumberland). In South Northumberland it is so plentiful in the Four-fathom Limestone that this limestone is sometimes known in the Lead Mining District as the "Spotted Post." If we were only to consider the range of D2 by the definitions of Vaughan and Garwood we should have to include in it all beds from the Oxford Limestone up to and including the Great Limestone. The report of the British Association in 1925[9] advised that D2 should terminate below the horizon at which *Orionastræa phillipsi* McCoy reached its maximum development. In the Ingleborough sequence of Yorkshire[10] the Orionastræa Band occurs above the Simonstone Limestone, which is some distance below the Main or Great Limestone. Turner[8] in Westmorland discovered *Orionastræa* in the Single Post Limestone and suggested that it was the equivalent of the lower part of the Orionastræa Band of Ingleborough. If this is a correct identification, D2 includes all the beds from the Oxford Limestone at the base up to the Single Post Limestone at the top. The exact identification of the Single Post Limestone in South Northumberland is not known, but it would appear to be one of the two thin limestones outcropping across the Watling (Dere) Street south of "The Five Lane Ends."

In 1924 Bisat[4] re-defined D3 as the zone of *Prolecanites compressus*, *Beyrichoceras hodderense*, *B. micronotum* and *Beyrichoceratoides implicatum*, and added above D3 a zone P *Goniatites crenistrea*. In North Northumberland *G. crenistrea* occurs in the shale overlying the Budle Limestone. In South Northumberland the Budle Limestone may be looked for above the horizon of the Single Post Limestone, perhaps at the level of the Scar Limestone. Owing to the unfortunate scarcity of goniatites in Northumberland we have to fall back on zonal fossils which take into consideration the coral-brachiopod phase, which is so much better developed here than the goniatite-lamellibranch or culm phase.

Notwithstanding the apparent difficulty which confronts us in attempting to find zonal values between Northumberland and the districts to the south, we have two well-defined horizons, viz.:

1. The Oxford Limestone—the maximum development of *Girvanella*.
2. The Great Limestone—the last appearance of both *Saccamina carteri* and *Lonsdaleia floriformis*.

We have seen that the Oxford Limestone can be taken as the dividing line between D1 and D2. The Great Limestone has been taken as the division between the Upper and Lower Limestone Groups into which the Bernician has been divided.

The whole of the Bernician Series and the Millstone Grit of South Northumberland represent a phase similar to the Yoredale phase of Yorkshire. Reynolds[11] defined this phase admirably as follows: "The standard limestone fauna may be a coral-brachiopod assemblage, or may be mainly a brachiopod fauna, or mainly a coral fauna. The fauna of the associated shale may be very much that of shales of the Zaphrentid phase, but sometimes bands with the Goniatite-lamellibranch fauna occur."

All the beds possess a regular rhythmic succession such as that described by Hudson[12] and Brough.[13] Brough showed that the base of a rhythmic unit should be taken at the base of a limestone and not at the

base of a shale. The perfect rhythm includes the following series:

1. Coal.
2. Fireclay or Ganister.
3. Sandstone.
4. Shaly Sandstone.
5. Sandy Shale.
6. Unfossiliferous Shale usually with ironstone.
7. Calcareous Shale with marine fossils.
8. Limestone.

These eight units are not always present. One or more units may be missing from the top or from the base of a rhythm. Close under almost every limestone in the Bernician Series of South Northumberland occurs a coal, a fireclay, a ganister, or at least a sandstone with rootlets. This would suggest that the appearance of a land surface normally preceded the subsequent downward movement of the basin of deposition. This confirms the suggestion made by Brough[13] that rhythmic succession bears a definite relation to wet and dry periods. Whatever the cause of the downward movement and the transgression of the sea, it was widespread in its action. The Limestone Series of Scotland, the Bernician of Northumberland, and the Yoredales of Yorkshire all show this feature. In view of the obvious breaks between the deposition of coal and the deposition of the overlying marine deposits, any boundary which may be taken between series of beds should be taken at the base of such marine deposit.

Returning to the further consideration of the D zones, we have seen that the limestones between the Single Post and the Great cannot be fitted into the zones adopted in other parts of England.

D3 was defined by Vaughan[2] as the sub-zone of *Cyathaxonia cornu*. *C. cornu* is recorded (*Summary of Progress*, 1923, p. 84) from the Acre Limestone of North Northumberland (equivalent to the Three Yard

Limestone of South Northumberland) and by Turner[8] from the shales immediately above the Scar Limestone in the Westmorland Pennines. D3 was defined by Garwood as the zone of *Phillipsastræa*. So far as I am aware, this has not yet been recorded from Northumberland.

The Great Limestone is the highest horizon from which *L. floriformis* and *S. carteri* have been recorded, and if we were to use these two fossils for the defining of a zone, we should include in their zone all the beds from the Great Limestone (and including it) to the base of the Oxford Limestone. The top of this division would be the base of the next marine horizon above the Great Limestone. This underlies the Little Limestone Coals. In West Northumberland it is represented by the Snope Burn Marine Band of Trotter and Hollingworth[14] and in South Northumberland by a thin limestone in the bed of the South Tyne below Allerwash and in the Silly Burn, north-east of Haydon Bridge.[1]

The succeeding beds of the Bernician Series, in upward succession, include the Lower Oakwood, Middle Oakwood, Upper Oakwood, Corbridge, Thornbrough and Harlow Hill Limestones, besides several thin limestones and marine horizons which are more particularly set out in the paper given by Waite and myself to the Durham University Philosophical Society in 1928.[15] In these beds few fossils have been recognized as of zonal value. In the Corbridge Limestone we have an abundance of *Buxtonia scabricula* Mart. and *Edmondia sulcata* Flem. and an apparent absence of Dibunophyllid corals, such as occur in the two limestones above. The Thornbrough Limestone almost invariably contains *Productus latissimus* and *Pustula punctata*. Underlying the Thornbrough Limestone, a recently discovered plant shale has yielded *Sphenopteridium dissectum* Gopp., *Sphenopteris cf. falkenhaini* Stur., *S. dicksonoides* Gopp. and *Calamites sp.*

Sphenopteridium dissectum extends from the Oil Shale Group of the Calciferous Sandstone Series to the top of the Carboniferous Limestone Series. Kidston recorded it from various localities in the Lower Limestone Group, the Limestone Coal Group and the Upper Limestone Group of Scotland. This is believed to be the first record of its occurrence in England.

Sphenopteris dicksonoides is restricted to rocks of Lower Carboniferous age, and, according to Kidston, is rare in Britain. It occurs in both the Carboniferous Limestone Series and the Calciferous Sandstone Series. It is recorded from the shore section west of Budle in Northumberland, and from three horizons in the Limestone Coal Group of the Carboniferous Limestone Series of Scotland.

Sphenopteris falkenhaini has only been recorded from the Upper Limestone Group of the Carboniferous Limestone Series of Scotland.

This assemblage shows that the Thornbrough Limestone is definitely Lower Carboniferous in age.

A goniatite from the Thornbrough Limestone in the South Tyne area, and rather diffidently referred to *Eumorphoceras*, has been given more prominence than its mutilated state deserved, but even without this assistance we should have to consider the Thornbrough Limestone as in Bisat's zone E.

The Thornbrough Limestone contains an abundance of Dibunophyllid corals, including the following:

Aulophyllum var. towards *pachyendothecum* S. Smith.
Campophyllum cf. ciliatum Garwood.
Dibunophyllum y var. muirheadi.
Aspidophyllum cf. huxleyana Thomson.

The Harlow Hill Limestone is the last "important and recognizable band of limestone,"[1] and the base of the Millstone Grit was at one time taken at this horizon. This limestone had always previously been referred to as the "Felltop" Limestone, but in 1928 Waite and myself made use of the name Harlow Hill Limestone for the first time.[15] The term "Felltop" had been applied to limestones of different horizons in different districts. In this respect it may be mentioned that Trotter and Hollingworth[14] referred the "Felltop" Limestone of the Alston district to the horizon of the Lower Oakwood Limestone. The presence of *Tylonautilus nodiferus* Armstrong under the name *Pleuro-nautilus nodoso-carinatus*, has been already recorded in the Harlow Hill Limestone, and the Styford Shale above. Pringle and Jackson have shown[16] that *T. nodiferus* can be used as a useful index to Upper E and Lower H, and we may therefore consider the Harlow Hill Limestone and the Styford Shale as in Upper E or Lower H. R. G. S. Hudson, in a recent paper to the Yorkshire Geological Society, has suggested that Harlow Hill Limestone = Shunner Fell Limestone = Cayton Gill Beds = top of E2.

The beds of the "Millstone Grit" form a perfect transitional stage between the Bernician Series below and the Coal Measures above. There is no great lithological or faunal break. We can, however, define the "Millstone Grit" of Northumberland as the beds between the lowest "Mussel Band" of the Coal Measures and the top calcareous member of the Upper Limestone Group containing a true coral fauna. If we are to use this definition for the "Millstone Grit," we must take the base of the series at the base of the Styford Shale, which represents the next marine horizon above the Harlow Hill Limestone. This bed may represent the Upper Felltop Limestone (Upper Foxton) of Central Northumberland. A calcareous shale in the bed of the March Burn, near Dipton Foot, and proved in borings as far apart as Chopwell and Horsley, lies

a short distance above the Styford Shale. Above the Dipton Foot Marine Band is the horizon of the Upper Shilford Coal, which is now being worked south of Riding Mill. Below the Dipton Foot Marine Band are three other coal horizons. Some of these coals have been worked at Nafferton and Horsley, and coals near this horizon have been proved in borings near Belsay and Felton.

In the new drift south of Riding Mill a plant shale immediately above the coal has yielded:

Neuropteris schlehani Stur.
Lepidodendron cf. obovatum Sternb.
Cordaites principalis German.
Calamites cf. suckowi Brongt.
Callymatotheca stangeri Stur.
Asterophyllites longifolius Sternb.

Several of these species are of good zonal value. *N. schlehani* occurs frequently in the lower part of the Ovalis zone of Davies and Trueman (i.e. Upper Millstone Grit and Lower Coal Measures—goniatite zones of Upper R and G) in a number of British coalfields, including Scotland, Lancashire, Staffordshire, North Wales and South Wales. It is also found at a comparable horizon on the Continent. *Callymatotheca stangeri* has only been recorded in Britain from the Upper Limestone Group of the Carboniferous Limestone Series of Scotland, and from the Yoredale Beds of Grassington, Wharfedale, Yorkshire; the latter, according to Kidston, representing an horizon in the Upper Limestone Group, but according to Wheelton Hind representing an horizon low in the Millstone Grit. *A. longifolius* often occurs with *N. schlehani* in various coalfields, but has a fairly long range, occurring as high as the top of the Modiolaris zone of Davies and Trueman.

The whole assemblage of plants from Shilford undoubtedly represents an horizon in the Millstone

Grit of other areas—in most coalfields found in the goniatite zones of R and base of G. Bertrand has made use of *N. schlehani* and *Pecopteris aspera* to define two zones of the Millstone Grit. A boring at Horsley in 1930 produced *P. aspera* from one of the coals below the Dipton Foot Marine Band, so that the division between Bertrand's zones must be at the base of this Marine Band, and we may conveniently take this as the division between the goniatite zones of R and H. The division between the goniatite zones of H and E appears to be at the base of the Styford Shale, leaving the Harlow Hill Limestone in zone E. Owing to the almost complete absence of goniatites below this we cannot distinguish the zones of E, P and D3.

In his presidential address to the British Association in 1926, Reynolds adopted the term Yoredalian for the beds lying between the top of D2 and the base of the Millstone Grit. The value of the D zones is very strictly limited in an area where we have rhythmic succession as opposed to solid limestone formation, so that we cannot use them to any advantage above the Orionastræa level. Until the goniatite zones of D3, P and E can be defined in terms of a coral-brachiopod phase, it is perhaps better to accept Reynolds' scheme and use the term Yoredalian for all beds between the top of D2 and the base of the Millstone Grit.

In conclusion, I wish to place on record my particular indebtedness to Mr. James Brough (University of London), who gave me considerable assistance in the field work necessary, and to Miss Emily Dix (Bedford College for Women), who has kindly identified the plants from the Upper and Lower Shilford Coal horizons. I am also especially grateful to Mr. G. A. Burnett (H.M. Geological Survey) for much helpful criticism, and through him to Dr. R. Crookhall for identification of the plants from below the Thornbrough Limestone. I am indebted to Professor H. G. A.

Hickling and Dr. A. Raistrick (University of Durham) for great encouragement and considerable advice, without which this work would not have been completed.

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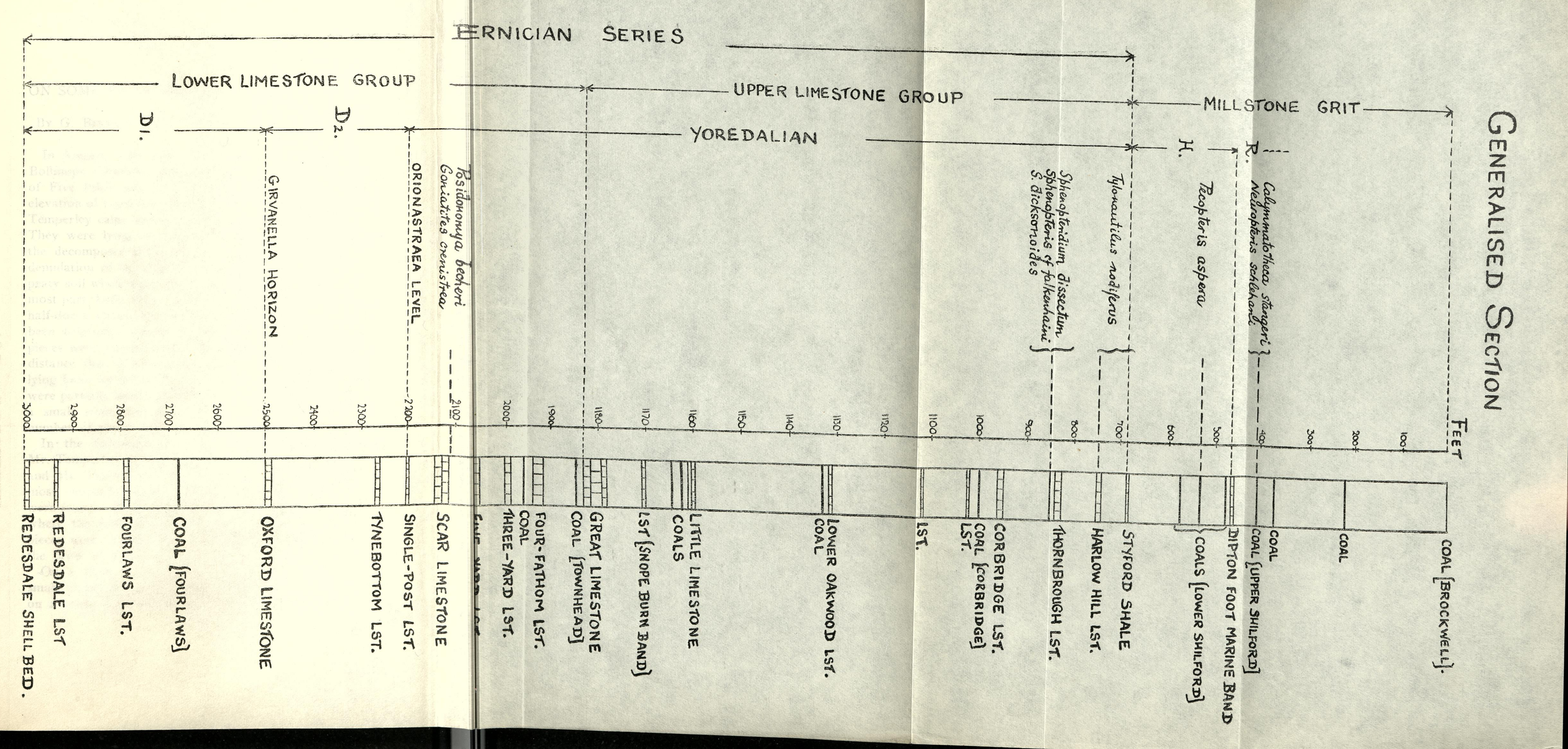

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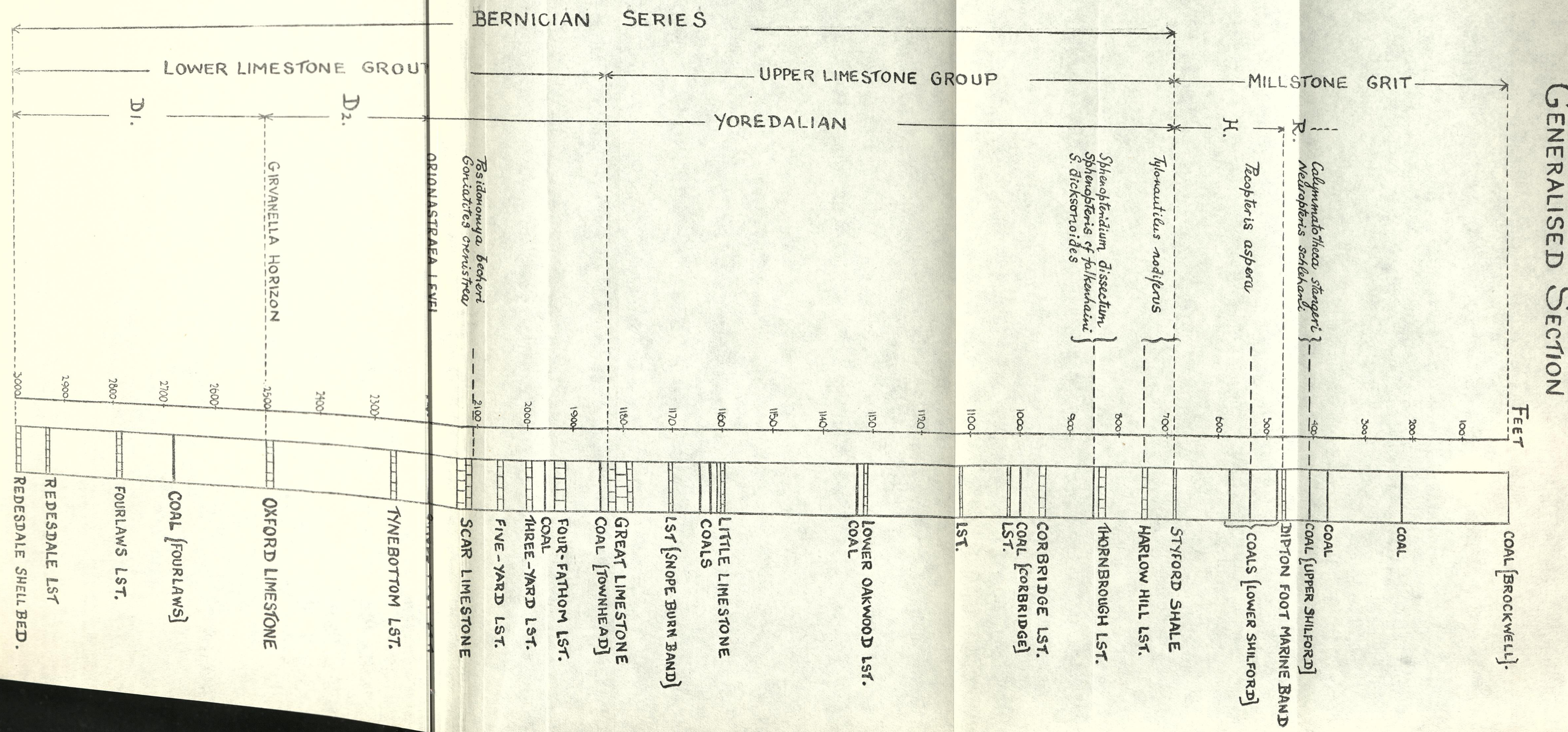


ON SOME FLINT FLAKES FROM WEARDALE

By G. Bennett Gibbs and George W. Temperley

In August, 1928, while crossing a northern slope of Bollihope Common, Weardale, just below the summit of Five Pikes and west of Wager Head, and at an elevation of 1,500 feet, Mr. R. B. Cooke and Mr. G. W. Temperley came across a large number of flint flakes. They were lying on a small patch of ground where the decomposed gritstone sand had been exposed by denudation of the vegetation and of the thin layer of peaty soil which supported it. The flakes were, for the most part, lying close together, within an area of some half-dozen square feet, almost suggesting that they had been originally thrown down in a heap. A few odd pieces were found farther afield, but none at a greater distance than a few yards. Most of the pieces were lying loose on the surface of the ground, though a few were partially buried, and one at least was found below a small stone embedded in the ground. The total number of pieces collected was between 120 and 130.

In the following year the site was revisited by Mr. Temperley, accompanied by Mr. G. Bennett Gibbs and Mr. Patrick B. Gibbs, when, as the result of a most thorough search, about fifty additional pieces were found. Most of these were on the identical patch where the first lot had been found, but a few odd pieces were collected nearer to the "stone man" on the brow of the hill.

On a third visit paid by Mr. Gibbs, only a few small fragments were found on the original site; but on a lower slope of the same fell, marked Whitfield

Brow on the Ordnance Map, a number of interesting flakes were picked up, evidently of similar date.

The total number of pieces collected were:

Wager Head site	190
Whitfield Brow site	30

The flints may be roughly classified as follows:

	Wager Head	Whitfield Brow
Arrowhead flake	1	1
Cores	6	—
Scrapers	3	3
Flakes showing secondary chipping	28	5
Flakes serrated, possibly by use	21	9
Other flakes, showing "bulb of percussion"	36	5
Odd chips, broken blades, etc.	63	—
Odd fragments showing signs of fire	32	7
	190	30

An interesting feature of these collections of flint flakes, etc., is that the material of which they are made varies so much in colour. While the majority of the fragments are of a pale grey, with, where remaining, a thick white "crust," there are a number of others which are pale light red, with grey or white mottling; some are darker red, two or three are nearly black, one is brown, another is nearly black with a dark red streak across a clear portion, and one is transparent.

The specimens have been examined by Dr. A. Raistrick, Mr. George Coupland and others. The general opinion is that the fragments indicate a Tardenoisean Chipping Site, deriving from Azilian culture. Flints of this type have been found in the Yorkshire caves associated with the bones of animals which lived in Britain after the close of the last Ice Age. It is believed that the artificers were a race of hunters and fishermen who came north as the ice-

cap retreated, living normally in caves during the winter months, but inhabiting the hill-tops during the summer. Other Tardenoisean sites in County Durham, at Wrekenton and on the coast near Ryhope, have been investigated by Mr. G. Coupland. "Pigmy" flints have also been found at other places on the coast.

For previous discoveries of chipping sites on the higher moorlands of Durham and South Northumberland, the following papers should be consulted:

"Notes on a Find of Prehistoric Implements in Allendale, with Notices of Similar Finds in the Surrounding District," by Rev. W. Howchin, F.G.S. *Natural History Transactions of Northumberland, Durham and Newcastle-upon-Tyne*, Vol. VII (1880), p. 210.

"Notes on Neolithic Chipping Sites in Northumberland and Durham," by Dr. C. T. Trechmann. *Transactions of the Natural History Society of Northumberland, Durham and Newcastle-upon-Tyne (New Series)*, Vol. IV (1914), p. 67.

PLATE I

WAGER HEAD FLINTS

1. Core. Grey.
2. Core, made into pointed scraper. Grey.
3. Core, made into pointed scraper. White and grey.
4. Core, flake scraper. Black and grey.
5. Flake, artifact. Mottled, light red.
6. Flake, artifact pointed. Mottled, grey.
7. Flake, artifact pointed. Mottled, light red.
8. Flake, push plane point. Mottled, light red.
9. Flake. Light grey.
10. Flake. Light grey.
11. Flake, blade. Nearly black.
12. Flake, three-faced blade. Light grey.
13. Microlith, tool. Light grey.
14. Microlith, tool. Light grey.
15. Microlith, broken. Light grey.
16. Microlith, imperfect. Darker grey.
17. Flake, rounded point. Darker grey.
18. Microlith, imperfect. Light grey.
19. Microlith, imperfect. Light grey.
20. Microlith, imperfect. Light grey.
21. Microlith, chip. Light grey.

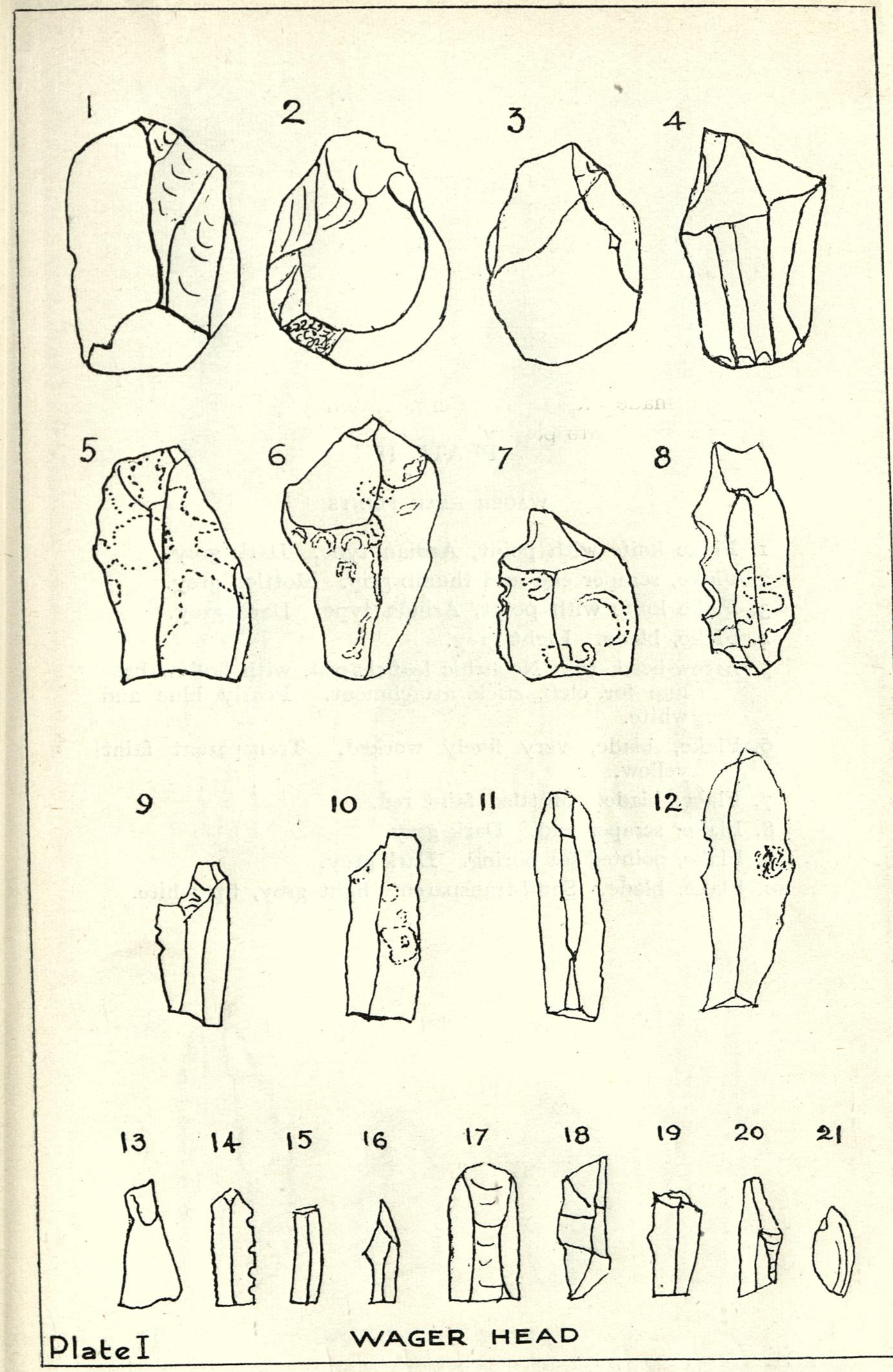


PLATE II

WAGER HEAD FLINTS

1. Flake knife with point, Azilian type. Dark grey.
2. Flake, scraper end and thumb grip. Mottled grey.
3. Flake knife with point, Azilian type. Dark grey.
4. Flake, blade. Light grey.
5. Arrow-head, thin Neolithic leaf-shaped, with hollow base line for cleft stick attachment. Pearly blue and white.
6. Flake, blade, very finely worked. Transparent faint yellow.
7. Flake, blade. Mottled faint red.
8. Flake, scraper end. Dark grey.
9. Flake, pointed for boring. Dark grey.
10. Flake, blade. Semi-transparent, light grey, tip white.

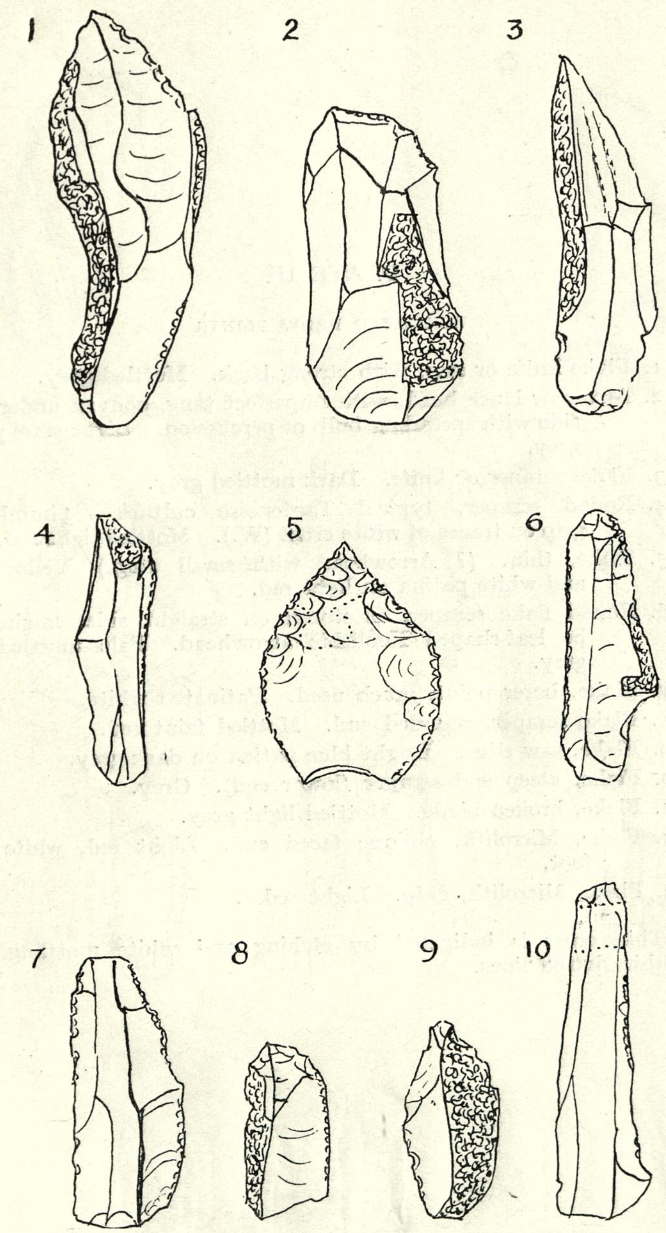


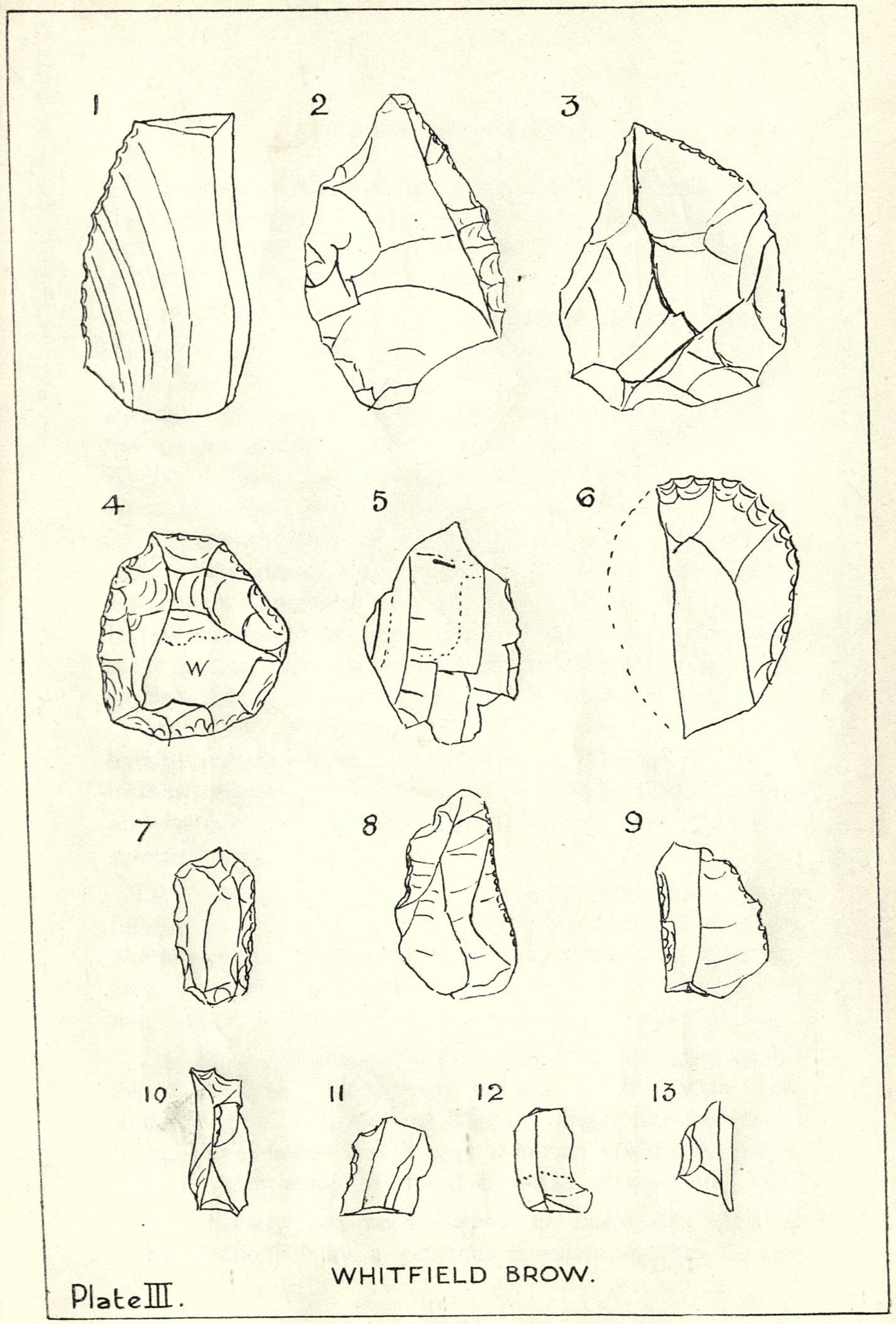
Plate II WAGER HEAD

PLATE III

WHITFIELD BROW FLINTS

1. Flake knife or saw, with strong back. Mottled grey.
2. Arrow or lance head, with imperfect tang, convex underside with spreading bulb of percussion. Light smoky grey.
3. Flake scraper or knife. Dark mottled grey.
4. Round scraper, typical Tardenoise culture. Thumb grip on traces of white crust (W.). Mottled light red.
5. Flake, thin. (? Arrowhead with small tang.) Yellow and white patina on light red.
6. Round flake scraper, fractured on straight side; might be leaf-shaped Neolithic arrowhead. Pale mottled grey.
7. Flake, borer point, much used. Patinated white.
8. Flake scraper, rounded end. Mottled faint red.
9. Flake, saw edge. Bright blue patina on dark grey.
10. Flake, steep end scraper (lower end). Grey.
11. Flake, broken blade. Mottled light grey.
12. Flake, Microlith, oblique faced end. Light red, white foot.
13. Flake, Microlith, chip. Light red.

Thin crust is indicated by etching and white mottling within dotted lines.



PREFACE TO PART III

In issuing the following papers the Society is resuming one of its most notable functions, begun more than a century ago, that of publishing Catalogues of the Fauna of the Counties of Northumberland and Durham.

Nearly forty years ago, the Society published " Durham Diptera " by the Rev. W. J. Wingate (" Transactions," new series, Vol. II.), a work which is still in constant use by dipterists on account of its excellent analytical keys to the genera and species. The following paper, by the late Dr. W. J. Fordham, amplifies Wingate's work on the Diptera of County Durham, whilst extending the area covered to include the County of Northumberland. Dr. Fordham compiled this List mainly during the years 1921 to 1928, while he was resident in Gateshead and an active collector of material. It was completed in 1932. Since then, changes have been made in the classification and nomenclature of some of the species and the Society is greatly indebted to Mr. J. E. Collin, F.E.S., the well-known authority on the Diptera, for having undertaken the work of bringing the List up to date in these respects. Mr. Collin also very kindly read the proofs and for this valuable assistance the Society here records its sincere thanks.

Like Wingate's " Durham Diptera," this paper has an interest for dipterists far beyond the confines of the two Northern Counties, as each species has a note on its frequency and distribution in Britain and the months in which the fly may be taken, with occasional notes on its normal habitat.

The Society is glad to be able to publish the paper on the Aphididæ of Northumberland by Mr. R. A. Harper Gray and Mr. J. P. Rogerson of King's College, Newcastle upon Tyne. It is hoped that it may stimulate a wider interest in and a closer study of the distribution of the Plant Lice.

The Society has been helped to make this issue of " Transactions " by a generous donation towards its cost from Mr. H. Tully, M.B.O.U., who is interested in the local diptera.

In issuing this, the third and final part of Volume VII of its "Transactions," the Society would draw attention to the fact that Volume VIII has already been published. It consisted of "A Catalogue of the Birds of Northumberland" by the late George Bolam, issued in 1932. Volume IX will follow when circumstances permit.

A PRELIMINARY LIST OF THE DIPTERA OF NORTHUMBERLAND AND DURHAM (excluding the CECIDOMYIDÆ).

W. J. FORDHAM, M.R.C.S., L.R.C.P., D.P.H.

INTRODUCTION.*

It is twenty-six years since the Rev. W. J. Wingate published his "Preliminary List of Durham Diptera" (now out of print) and since that date numerous other records have been made. In order to stimulate interest in the two-winged flies in the two counties it has been thought advisable to publish another preliminary list bringing the records up to date.

The Bibliography of the Diptera in Northumberland and Durham is scanty and consists mainly of the following:—

(1) "Durham Diptera," by the Rev. W. J. Wingate. "The Naturalist," 1903, pp. 269-288.

(2) "A Preliminary List of Durham Diptera with analytical tables," by the Rev. W. J. Wingate. Transactions of the Natural History Society of Northumberland, Durham and Newcastle upon Tyne, 1906.

(3) "Notes on some Durham Diptera," by W. J. Fordham. "Vasculum," 1926, pp. 71-76, 84-85.

(4) Various notes and records in the "Vasculum." By R. S. Bagnall, W. J. Fordham and J. W. H. Harrison.

A few other references are given in the text.

The arrangement of families is that of Hendel as given in "Die Tierwelt Deutschlands; Diptera; Allgemeiner Teil." Jena, 1928, with the exception of lumping all the Mycetophilid families under Mycetophilidæ.

*** This Introduction was written in 1932, four years after Dr. Fordham had left County Durham and settled in Yorkshire and ten years before his lamented death in 1942. Ed.**

Meigen's " 1800 " names have not been used as their use is still under official consideration.

Following the name is given a note on the frequency and distribution in Britain and the months in which the fly has been taken in Northumberland and Durham.

The writer is greatly indebted to Mr. J. E. Collin, J.P., F.E.S., for much kind help in revising the manuscript of this list and making various suggestions as to alterations and additions; in fact without his help this list could never have been attempted. All critical species recorded by the writer have been either named or confirmed by Mr. Collin.

Letters in brackets following the records in the text refer to the following collectors:—

B. = R. S. Bagnall.
H. = J. W. H. Harrison.
F. = W. J. Fordham.
W. = W. J. Wingate.

TRICHOCERIDÆ.

A small family of flies allied to the Tipulidæ and formerly considered to be a sub-family of Limnobiidæ. They are known as " Winter gnats " and are found in swarms flying a variable distance from the ground in the winter months. The larva lives in rich humus or toadstools.

Trichocera annulata Mg. Widely distributed. Larvæ in leaf mould in open woodlands. Nov. Bishop Auckland (W.).

T. hiemalis DeG. Common, larvæ in decayed vegetable matter. Oct.-Feb. Very common in winter (W.). Low Fell. Ravensworth. Larvæ in owl castings (F.).

T. regelationis L. Common, flying in swarms. Jan. Very common in winter (W.). Low Fell, abundant (F.).

T. saltator Harr. Widely distributed. Common at Bishop Auckland in winter (W.).

TIPULIDÆ.

Large flies with long legs, " Daddy-long-legs " or " Craneflies." Head round, prominent. Hind-body long. Distinguished from Limnobiidæ by greater length of palpi and difference in venation. Larvæ aquatic or terrestrial (" Leather-jackets ") in soil or rotten wood.

Nephrotoma analis Schum. Widespread but not common. July. Bishop Auckland (W.) most northerly record.

N. cornicina L. Not very common. June. Bishop Auckland, Harperley (W.) most northerly records.

N. crocata L. Widely distributed but uncommon. July. Bedburn (W.).

N. flavescens L. (*histrio* F.) Widespread and common. Larva in rotten wood. A woodland species. June, July. Harperley (W.). Low Fell, sparingly (F.).

N. flavipalpis Mg. (*crinicauda* Riedel.) Recorded as British as *imperialis* Mg. Common in damp woods. Larva in rotten stumps. June, July. Low Fell, not uncommon, males slightly predominating (F.). Fallodon (H. B. Herbert).

N. guestfalica Westh. Not common. July. Bishop Auckland (W.) most northerly record.

N. lunulicornis Schum. Widespread but uncommon. June, July. Bishop Auckland, Harperley (W.). Ravensworth (F.).

N. maculata Mg. " Spotted Crane Fly." Very common. Larva at grass roots and infesting crops. June, July. Bishop Auckland, Bollihope (W.). Low Fell, Ravensworth (F.).

N. quadrifaria Mg. Widely distributed and common, June-Aug. Bishop Auckland, Hesleden, commonest species in district (W.). Ravensworth, Low Fell, males greatly predominating (F.).

N. scurra Mg. Widely distributed but scarce. July. Low Fell (F.) most northerly record.

Tanyptera atrata L. Uncommon in damp woods in May and June. Larva in decaying wood. Chopwell Woods (G. B. Walsh).

Tipula cava Riedel. Widely distributed and not uncommon in woods in summer. July. Low Fell, occasional (F.).

T. cheethami Edw. A northern species occurring among damp mossy rocks on mountains. Described as new in 1924. June. Middleton-in-Teesdale (F.).

T. czizeki de Jong. Separated in 1925 from the common *oleracea L.* May prove to be fairly common. Newcastle. (H. Audcent, *Trans Ent. Soc. S. Eng.*, 1932.)

T. fascipennis Mg. Fairly common in damp places in woods. June-Aug. Hesleden, Harperley (W.).

T. fulvipennis DeG. (*lutescens* F.). Widespread in woods in summer and autumn. June-Aug. S. Durham, Gibside, Bishop Auckland, Harperley, Hesleden (W.). Low Fell (F.).

T. hortulana Mg. A woodland species. April-June. Bishop Auckland, Raby, Harperley, Waskerley (W.). Low Fell (F.) most northerly records.

T. lateralis Mg. Widespread and common in damp meadows. July-Aug. Bishop Auckland, Bollihope, Harperley, Waskerley, Hesleden, Wearhead (W.).

T. luna Westh. (*lunata* Auct.). Fairly common in summer in marshy fields. June. Harperley (W.). Low Fell (F.).

T. lunata L. (*ochracea* Auct.). Widely distributed and common in woods and hedges in early summer. June. Bishop Auckland, males very common. Barnard Castle (W.).

T. marmorata Mg. (*confusa* Wulp.). Widespread and common in spring and autumn. Aug.-Oct. Shull, Wearhead (W.). Low Fell, common on walls (F.).

T. maxima Poda (*gigantea* Schrk.). Fairly common in woods. The largest British crane fly. June, July. Harperley, Shull (W.). Prestwick Carr (F.).

T. montium Egg. Fairly common in hilly districts. June. Middleton-in-Teesdale (F.).

T. oleracea L. The "Common crane fly." Very common in fields in May and June and again in Sep. and Oct. Larva ("leather jackets") destructive to grain and other crops. Bishop Auckland, Hesleden (W.). Low Fell, males flying in at open windows (F.).

T. pagana Mg. Fairly common in late autumn in woods and hedge banks and on walls. The female is practically wingless. Sep.-Nov. Shull (W.). Low Fell, abundant on house walls, the females a few inches from ground, males higher up. Barrasford (F.).

T. paludosa Mg. Very abundant in fields in autumn. The larva attacks roots of oats, turnips, mangolds and potatoes. Hesleden, Wearhead (W.). Low Fell (F.).

T. peliostigma, Schum. Uncommon in summer. Has been bred from an old thrush's nest at Oxford. June. Bishop Auckland, ? this species (W.).

T. scripta Mg. Very common in autumn. Aug., Sept. Harperley (W.). Low Fell (F.).

T. signata Staeg. (*marmorata* Verr. list.). Not common in woods in autumn. Oct. Low Fell, a few on house walls. Barrasford (F.).

T. subnodicornis Ztt. (*plumbea* Auct.). Occurs in Cotton grass bogs. May-July. Harperley, Bedburn (W.). Middleton-in-Teesdale (F.).

T. truncorum Mg. Not common in woods. June. Bishop Auckland. "The thoracic stripes are peculiar" (W.).

T. unca Wd. (*longicornis* Schum.). Fairly common and widely distributed in marshy places. June. Bishop Auckland, Harperley (W.).

T. variicornis Schum. Fairly common in woods often by the sides of streams. June. Harperley (W.). Middleton-in-Teesdale (F.).

T. variipennis Mg. Not common in damp woods. June. Barnard Castle, Wearhead (W.). Low Fell (F.).

T. vernalis Mg. Common in meadows in spring and autumn. Harperley, Bollihope, Waskerley, Belburn, Bishop Auckland (W.). Low Fell (F.).

T. vittata Mg. Uncommon in damp woods. May-June. Belburn, Harperley, Raby (W.).

LIMONIIDÆ.

Moderate sized flies with well marked thoracic suture, short palpi, large wings and long legs. Allied to the Tipulidæ of which sometimes given as a subfamily. Larvæ aquatic or terrestrial, some in rotten wood, a few in fungi.

Austrolimnophila ochracea Mg. A widespread lowland species. Larva in decayed wood and detritus. July, Aug. Bishop Auckland, Hesleden (W.).

Dactylolabis transversa Mg. (*gracilipes* Lw.). Widespread but local. June. Harperley (W.).

Dicranomyia chorea Mg. Common. Larva in moss (*Bryum, Hypnum*). Swarms in autumn. Very common everywhere (W.).

D. dumetorum Mg. Common in damp woods. Larva in stumps and under bark. Aug. Hesleden (W.).

D. mitis Mg. Widely distributed and abundant. Aug., Sept. Bishop Auckland (W.). Low Fell, very common on yew, rhododendron and holly, flying out in numbers on shaking trees (F.).

D. modesta Mg. Widely distributed. June, July. Bishop Auckland, Brancepeth (W.). Low Fell (F.).

Dicranota bimaculata Schum. Widespread. Larvæ in ponds and streams. Apl. Hesleden (W.).

D. pavida Hal. Widely distributed. Aug. Howick (W.).

Empeda cinerascens Mg. (*nubila* Schum.). Not uncommon in woodlands. Larvæ in leaf mould. May. Bishop Auckland (W.).

Epiphragma ocellaris L. (*picta* F.). Widespread. June. Deepdale (W.).

Erioptera flavescens Mg. Common. Larva in moist humus. June. Aug. Wearhead, Brancepeth (W.).

E. fuscipennis Mg. Common. Larva in damp soil. May., Aug. Bishop Auckland, Hesleden (W.).

E. divisa Wlk. (*macrophthalma* Lw.). Probably fairly common and widespread. June. Hesleden (W.).

E. lutea Mg. var. *taenionota* Mg. Common in wet situations, ditches, marshes and stream sides. May. Bishop Auckland (W.).

E. trivialis Mg. Widely distributed. Larva in marshes. June-Aug. Hesleden, Wearhead (W.). Middleton-in-Teesdale (F.).

Gonomyia alboscutellata v. Ros. Rare. Aug. Hesleden (W.) ? this species.

Gonempeda flava Schum. Not uncommon. June, Aug. Bishop Auckland, Hesleden (W.).

G. tenella Mg. Widespread. Larva in moist leaf mould. Aug. Hesleden (W.).

Idioptera pulchella Mg. Apparently not recorded north of County Durham. Aug. Wearhead (W.).

Ilisia (*Acyphona*) *maculata* Mg. Common and widespread. Aug. Hesleden (W.).

Limonia flavipes F. Not very common but widespread. May, June. Shipley Moor, Hesleden (W.).

L. nubeculosa Mg. Very common and widespread. Frequents damp shady places. Larva in moist humus. May, June, Aug., Sept. Harperley, Barnard Castle, Bishop Auckland, Raby, on yew (W.). Low Fell, flying out in myriads on beating yew, holly and rhododendron (F.).

L. quadrinotata Mg. Widely distributed. County Durham, no locality. "I am almost sure it was at Gibside in 1896." (W.).

L. tripunctata F. Probably common as far north as Forth district. Larva in leaf mould. May-Aug. Shipley Moor, Hesleden, Bishop Auckland (W.). Hamsterley (F.).

L. trivittata Schum. Widely distributed. July, Aug. Hesleden (W.). Low Fell (F.).

Limnophila dispar Mg. Not common. June. Harperley (W.) apparently most northerly record.

L. fulvonervosa Schum. Widely distributed. July, Aug. Wearhead, Bedburn (W.).

L. lineola Mg. A lowland species occurring as far north as Aberfoyle. Larva in moist humus. Aug. South Durham, Howick (W.).

L. lucorum Mg. Not uncommon. July. Bedburn (W.) apparently most northerly record.

L. nemoralis Mg. A very variable species, the type commonest in the south of England. July, Aug. Wearhead, Bishop Auckland, Shull, Hesleden (W.).

L. phaeostigma Schum. Occurs on moors. July. Waskerley (W.).

Lipsothrix errans Wlk. A widely distributed delicate looking fly found under trees by water. June. Belburn (W.).

Molophilus appendiculatus Stg. Common. Occurs all over North and Central Europe. June, Aug. Brancepeth, Harperley, Hesleden (W.).

M. griseus Mg. (*bifilatus* Verr.). Apparently common.

Aug. Hesleden (W.).

M. obscurus Mg. Widely distributed. Aug. South Durham. Hesleden (W.).

M. propinquus Egg. Common. June-Aug. South Durham, Brancepeth, Hesleden (W.). Low Fell, abundant (F.).

Ormosia lineata Mcq. Widespread. Larva in wet mud. May. Stanhope (W.).

O. nodulosa Mcq. Common. May, Aug. Bishop Auckland, Hesleden, Stanhope (W.).

Oxydiscus senilis Hal. Widely distributed, the larva in submerged mud. Gibside (B.).

Pedicia rivosa L. Widely distributed and common. A woodland and heath species. May-July, Sept. Gibside, Hesleden (W.). Fallodon, Middleton-in-Teesdale, Waldridge Fell (F.).

Pilaria discicollis Mg. Widespread. Larva in wet mud and decaying vegetable matter. July. Bedburn (W.).

Rhipidia maculata Mg. A common species attracted to light. May-July, Sept. Bishop Auckland, Shull, Raby (W.).

Rhypholophus hæmorrhoidalis Ztt. Distributed from Dorset to Clyde and Forth. Larva in wet soil under leaves. Aug. Wearhead (W.).

R. varius Mg. Widely distributed. Aug. Wearhead (W.).

Taphrophila vitripennis Mg. A summer species locally abundant resting under leaves and vegetation beside waterfalls. Bishop Auckland. June. (W.).

Tricyphona immaculata Mg. Common. Larva in wet soil, leaf mould, dung, etc. May, June. Shipley Glen, Bishop Auckland (W.). Middleton-in-Teesdale (F.).

T. unicolor Schum. A rare species. June. Harperley (W.).

Ula sylvatica Mg. (*macroptera* Mcq. *pilosa* Schum.). Not very common. Larva in fungi (*Tricholoma*, etc.). May, June. Stanhope, Harperley (W.).

PSYCHODIDÆ.

" Owl Midges." Small flies with broad wings covered with scales, giving a moth-like appearance. Very fragile. Plentiful in damp places. Larva in damp detritus. The female of *Phlebotomus* in Southern Europe and Egypt sucks blood and transmits " Sandfly Fever."

No local species recorded but several species of *Pericoma* and *Psychoda* should occur.

PTYCHOPTERIDÆ.

Medium sized blackish flies, like small craneflies, common among reeds and water plants. Strong cross suture on thorax. Larva lives in mud.

Ptychoptera albimana F. Common in damp places in summer. Larva has long tube at end of body and lives in stagnant water. June, July. South Durham, Bishop Middleham (W.). Waldridge Fell, Low Fell (F.).

P. contaminata L. Common along ditch sides. Larva aquatic, rat tailed. April, Aug. Hesleden, Waskerley (W.).

P. lacustris Mg. Widely distributed. July. Bedburn (W.).

P. paludosa Mg. Widely distributed. May, July. Low Fell, Ravensworth (F.).

P. scutellata Mg. Common and widespread. June. Bishop Auckland, Bishop Middleham (W.).

ANISOPODIDÆ (RHYPHIDÆ).

Small gnat-like flies, often found on windows. Thorax without cross suture. Antennæ moderately short and stout. Larva in rotting vegetable matter.

Anisopus (*Rhyphus*) *fenestralis* Scop. " Window Gnat." Common. April-Aug. Bishop Auckland, Hesleden (W.). Low Fell (F.).

A. punctatus F. Common. Males swarm in the evenings under trees. May-Sept. Bishop Auckland, Hesleden, Shull (W.). Low Fell (F.).

MYCETOPHILIDÆ.

" Fungus Gnats." A large family whose larvæ live mainly in fungi. They are humpbacked in appearance and have long legs with spurred tibiæ. They are easily bred out from fungi containing the larvæ and a considerable number of species new to the counties should be obtained by this method. The family is exceedingly numerous and world wide in its range.

Allodia griscicollis Staeg. (*caudata* Winn.). Fairly common everywhere. July. Fatfield (B.).

Boletina trivittata Mg. Fairly common everywhere in damp woods. May, June, Aug. Gateshead, Low Fell, Middleton-in-Teesdale (F.).

Boletophila cinerea Mg. The commonest of the genus everywhere. Bred from *Hypholoma velutinum*. May, June. Bishop Auckland, Harperley (W.).

B. hybrida Mg. (*fusca* Mg.). Not uncommon. Larva in *Paxillus involutus*. May. Stanhope (W.).

Cerotelion lineatum F. A large dark coloured species with yellowish brown striped thorax and blotched wings. Rare and often found on windows. Larva feeds on bark fungi. Dr. Sharp has found it in dry rot fungus. July. Low Fell, on window (F.).

Delopsis aterrima Ztt. Rare with few records. July. Gibside (B.) most northerly record.

Diadocidia ferruginosa Mg. A small reddish fly common in most parts of the country. July. Low Fell, on window (F.).

Exechia trivittata Staeg. A common species, the males hovering over horse dung. Sept. Low Fell, on fungus (F.).

Isoneuromyia flava Macq. Rather rare. July. Gibside (B.) apparently most northerly record.

Leia subfasciata Mg. Rare but widely distributed. Teesdale (F. W. Edwards, *Trans. Ent. Soc.*, 1924, 580).

L. fascipennis Mg. A common red bodied species. July, Sept. Bishop Auckland (W.). Low Fell (F.).

Macrocera centralis Mg. Common and widespread. Aug. Hesleden (W.).

M. fasciata Mg. The largest of the genus. Fairly common and well distributed. July. Gibside, Bishop Auckland (W.).

M. lutea Mg. Widely distributed but not very common. Aug. Hesleden (W.).

M. stigma Curt. Common and widespread. June, Sept. Harperley, Bishop Auckland (W.).

Monocentronota lundströmi Edw. Very rare. Described by Edwards on a specimen from Northumberland. Also occurs in Finland (F. W. Edwards, *Trans. Ent. Soc*, 1924, 527).

Mycetophila cingulum Mg. Fairly common everywhere. Larva on *Polyporus squamosus*. Oct., Nov. Bishop Auckland (W.).

M. fungorum DeG. Everywhere abundant. Occurs in North America, Amur and Assam. Its natural food is *Armillaria mellea* and numerous other fungi. The larva makes an earthy cocoon in the ground. May, Aug. Common in Durham (W.). Low Fell (F.).

M. ocellus Wlk. Common everywhere. Feb. Low Fell, on window (F.).

M. signata Mg. Rare but widely distributed. Aug. Hesleden, Wearhead (W.).

Mycomyia ornata Mg. Rare. Sept. Shull (W.).

Rhymosia macrura Winn. Widespread and not uncommon. June. Low Fell (F.).

Sciara præcox Mg. Probably abundant. Common in Durham (W.).

S. Thomæ L. A gregarious fly common in summer in most districts on flowers of Umbelliferæ. Larva feeds on plant roots or fungi and decaying vegetation. Aug. Waldridge Fell (F.).

Sciophila hirta Mg. Common, the larva feeding on *Daedalia, Poria, Polysticus, Herniola, Lactarius* and green algæ on rotting stumps. May. Bishop Auckland (W.).

S. lutea Mcq. A very variable species. Larva on *Polyporus giganteus*. Aug. Bishop Auckland (W.).

Trichonta hamata Mik. Widespread but uncommon in some places Teesdale. (F. W. Edwards, *Trans. Ent. Soc.*, 1924, 620).

BIBIONIDÆ.

Small or medium sized blackish flies with large round hairy eyes. Legs long with spurred tibiæ. Short thick straight antennæ. Larvæ caterpillar like with horny head, living in decomposing vegetable matter. Most of the species fly in April and May.

Bibio johannis L. An abundant spring species preyed upon by Empids. April-June. Common in Durham, Witton, Escomb, Belburn, Gibsonees, Harperley, Hesleden (W.). Gibside, Low Fell (F.).

B. lacteipennis Ztt. Widely distributed. May, June. Low Fell. Middleton-in-Teesdale (F.).

B. laniger Mg. Common especially near the coast. April-June. Common in Durham with *johannis* from which its pale hairs and faint stigma distinguishes it. Belburn, Shull, Escomb, Harperley (W.). Ravensworth, Low Fell, males common on *Heracleum* (F.).

B. lepidus Lw. A late autumnal species. Oct. Barrasford, common flying over heather (F.).

B. leucopterus Mg. Widely distributed. May. Gibside (F.).

B. marci L. "St. Mark's fly." Very common flying about hawthorn hedges and over moorland. Appears in the South of England about St. Mark's day (April 25th.) later in the North. Larvæ breed in decaying vegetable matter and often occur in masses at the roots of meadow grasses. April-June. Common in Durham especially along the willow bordered banks of streams. Escomb, Evenwood, Bishop Auckland (October, a remarkably late date) (W.). Low Fell, Chopwell, Gibside, Ebchester (F.).

B. nigriventris Hal. Widespread. May, June. Bishop Auckland (W.). Low Fell (F.).

B. pomonæ F. Occurs mainly in hilly districts. Double brooded. Flies singly. (Most other species single brooded and gregarious.) July-Sept. Shull, Wearhead, Harperley. "I have also picked it up on the coast washed up by the waves" (W.).

B. varipes Mg. Chiefly a woodland species. May. Gibside (F.).

Dilophus febrilis L. "Fever Fly." Abundant everywhere in spring, apparently several broods. Fond of flowers of Umbelliferæ. Larvæ injure roots of garden crops and damage

hop roots in Kent and Surrey. May-August. Common everywhere in Durham, Hesleden, Bishop Auckland, Evenwood, Bollihope, Wearhead (W.). Low Fell (F.).

D. femoratus Mg. Almost as common as *febrilis* but rather later in appearance. June. Evenwood (W.).

D. humeralis Ztt. Widespread in South of England. August. Howick (W.) apparently most northerly record.

SCATOPSIDÆ.

Small black shining flies somewhat resembling *Bibionidæ*. Legs rather short, no spurs on tibiæ. Larvæ in decayed vegetable matter.

Scatopse notata L. The commonest of the genus. Occurs in most parts of the world. Plentiful on windows. Larvæ in dung and decaying matter. May, August. Common in Durham, Bishop Auckland, Hesleden. The larvæ were abundant in the museum macerating tub in the autumn of 1904 (W.). Low Fell, common (F.).

S. pulicaria Lw. Rare but widely distributed. July, Bedburn (W.).

Swammerdamella brevicornis Mg. Abundant in Britain and through Europe and also found in Asia Minor and North America on flowers of Umbelliferæ. August. Hesleden (W.).

CULICIDÆ.

"Mosquitoes." A family of world wide distribution containing bloodsucking flies, some of which transmit disease. Only the females are biters. The body, wings and legs are hairy and the antennæ are long and hairy. The palpi of the male are long. Larvæ aquatic and active, with large head and thorax and slender hind body.

Aëdes punctor Kirb. (*nemorosus* Mg.). A persistent biter. Very common. Sometimes swarms of males. July. Bishop Auckland (W.).

Anopheles claviger Mg. (*bifurcatus* L.). Common in many inland localities. Bites freely and conveys malaria. Sept. Hexham (F. V. Theobald).

A. maculipennis Mg. Common. Enters houses freely.

Carries malaria in Europe and North America. Females hibernate. Larvæ in stagnant water overgrown with vegetation. Sept. Hexham (F. V. Theobald).

Culex pipiens L. The common "Gnat." Widespread from South of England to Shetlands. Jan.-Nov. Bishop Auckland, Hesleden (W.). Low Fell, abundant in house in Oct. and Nov. (F.).

C. pipiens var. ciliaris L. May, Aug. Bishop Auckland, not uncommon (W.). (Not now recognized.)

Taeniorhynchus richiardii Fic. Local. Bites at dusk. Larvæ attached to plant roots in water. Gibside (B.).

DIXIDÆ.

A small family related to the Culicidæ with which they are sometimes united. Both sexes have long slender antennæ and bare wings. Head rounded. Ocelli wanting. Larvæ aquatic.

Dixa aestivalis Mg. Common. Dances in swarms in air in damp places. Apl. Gibside (W.).

CHIRONOMIDÆ.

Moderate sized or small slender flies with long narrow wings, known as "Gnats" or "Midges." Antennæ feathered in the male. No cross sutures on thorax. World wide distribution, some marine. Larvæ in mud of ponds, "Bloodworms" containing Hæmoglobin. Imago often dances in swarms in evenings round lofty towers or trees.

Anatopynia nebulosa Mg. Rather common and widespread. May-Sept. Hesleden, Bishop Auckland (W.) Penshaw (B.).

A. varia F. Common. Apl., Aug. Hesleden (W.).

Cardiocladius capucinus Ztt. Rare. Larva lives on rocks in waterfalls. Teesdale (F. W. Edwards, *Trans. Ent. Soc.*, 1929, 317).

Chironomus annularis DeG. Widespread. May, Aug. Harperley, Hesleden (W.).

Chironomus dispar Mg. Common as far north as Forth district. Gibside (B.).

C. dorsalis Mg. Common and variable. Gibside, Penshaw, Fatfield (B.).

C. flaveolus Mg. Uncommon. July. Bishop Auckland (W.).

C. nervosus Stæg. (*brevitibialis* Ztt.). Common. May, June. Bishop Auckland (W.).

C. nubeculosus Mg. Common. Apl.-June. Bishop Auckland (W.).

C. nubilus Mg. Uncommon. Fatfield, Penshaw (B.). (? = *Pentaneura id.*).

C. pedellus DeG. Common and variable. Swarms in the late dusk. Bishop Auckland (W.). Fatfield (B.).

C. pictulus Mg. Rather common. May. Bishop Auckland (W.).

C. pilicornis F. (*dolens* Wlk.). Locally common near water. Apl. Gibside, flying over lily pond (W.).

C. plumosus L. Abundant and variable. Never forms large swarms. Aug. Very common in Durham. Hesleden, females abundant over farm pond, males in swarm 100 yards away (W.).

C. tentans F. Widely distributed. Bishop Auckland, common (W.).

Clunio marinus Hal. A marine species with vistigial mouth parts. Skims over the surface of rock pools. June. Beadnall, males common on rock pools (W.). Roker, Cresswell, Bamburgh (B.).

Corynoneura clavicornis Kf. Widely distributed by hill streams. June. Upper Teesdale, numerous (J. W. Edwards, *Ent. Ms. Mag.*, 1924, 185).

Cricotopus bicinctus Mg. Common. May-July. Bishop Auckland, very common in spring (W.). Fatfield (B.). Low Fell (F.).

C. motitator L. Very common. May-June. Bishop Auckland, very common in spring Escomb (W.). Fatfield (B.).

C. sylvestris F. Common and variable. April. Bishop Auckland, common in spring (W.).

C. tremulus L. Common in hilly districts. June. Escomb, Bishop Auckland (W.). Middleton-in-Teesdale (F.).

C. triannulatus Mcq. Widely distributed. Fatfield (B.).

Metriocnemus fuscipes Mg. Abundant everywhere. Bred from larvæ in moss on ground in woods. Mar.-May. Bishop Auckland (W.). Ravensworth, Low Fell (F.).

Pentaneura carnea F. Common. May. Bishop Auckland (W.).

P. divisa Wlk. Widely distributed. Teesdale (F. W. Edwards, *Trans. Ent. Soc.*, 1929, 294).

P. melanops Mg. A pretty pale yellow species, usually common. May. Belburn (W.).

P. northumbrica Edw. Described as new by F. W. Edwards in *Trans. Ent. Soc.*, 1929, 291, on a male from Crag Lough, 28th July, 1923. Also occurs in Mull and at Malham, Yorks.

Procladius choreus Mg. Common. Aug. Hesleden (W.).

Spaniotoma aterrima Mg. Very common. May. Bishop Auckland (W.).

S. minima Mg. Very common. Fatfield (B.).

S. minor Edw. Described as new by F. W. Edwards in *Trans. Ent. Soc.*, 1929, 348, from Teesdale. Also occurs in Yorks and Derbyshire.

S. nitidicollis Goet. A species with few records. Fatfield (B.).

S. ornaticollis Edw. Described as new by F. W. Edwards in *Trans. Ent. Soc.*, 1929, 359. Fatfield, 14th August, 1916 (B.). Also occurs in Lancs. and at Killarney.

S. stercoraria DeG. Abundant everywhere. Larva in dung. Apl., May, Aug. Gibside, Bishop Auckland, Hesleden. Very common in Durham (W.). Gibside, Fatfield (B.).

S. thalassophila Goet. Common on coasts between tide marks. See Bagnall, *Vasculum*, III, 91.

Tanytarsus flavellus Ztt. In train between Penshaw and Newcastle. ? this species (B.).

T. flavipes Mg. Widely distributed. Apl., May, Gibside, Hesleden, Harperley, Bishop Auckland (W.). Penshaw (B.). (? =*Pentapedilum id.*)

T. gregarius Kf. Widely distributed. Crag Lough (F. W. Edwards, *Trans. Ent. Soc.*, 1929, 411.).

T. tenuis Mg. Common. May, Oct. Belburn, Bishop Auckland (W.).

T. viridulus L. Few records. Fatfield (B.). (? = *Chironomus id.*)

ORPHNEPHILIDÆ.

Small rather stout flies with broad wings. Very large eyes. Legs and antennæ short. Found near streams in which the larvæ live. No local species as yet. *Thaumalea testacea* Ruthe. Should occur as it is widely distributed.

CERATOPOGONIDÆ.

Small black midges with wings folded at rest. Hind legs longest. Naked wings. Blood suckers, attacking mammals (including man), birds and other insects. Larvæ in decomposing vegetable matter or aquatic like small slender leeches.

Culicoides obsoletus Mg. (*varius* Winn). Abundant. A vicious biter. Bred from fungi and dung. Penshaw, Gibside, Fatfield (B.).

C. pulicaris L. Common and very variable. A vicious biter. Penshaw, Gibside, Fatfield (B.).

Johannsenomyia nitida Mcq. Locally common. June. Shull, Bedburn (W.).

Palpomyia distincta Hal. A variable species. Gibside (B.). (*Trans. Ent. Soc*, 1926, 420.)

P. flavipes Mg. Common. Gibside (B.).

Serromyia femorata F. Common, especially in hilly districts. June. Fatfield (B.). Middleton-in-Teesdale (F.).

SIMULIIDÆ.

" Sand Flies." A small family of small humpbacked black flies. Broad wings, short legs and antennæ. Females are biters and troublesome to horses and cattle. Nearly cosmopolitan. Larvæ attached to stones in running water.

Simulium latipes Mg. Perhaps the commonest species. May, Nov, Bishop Auckland (W.). Low Fell (F.).

S. ornatum Mg. Common and widespread. Apparently does not bite. Less frequent in Scottish Highlands. May. Ravensworth, Middleton-in-Teesdale (F.).

S. variegatum Mg. Occurs in mountainous districts. Apl., Oct. Ravensworth, Gateshead, on window (F.).

XYLOPHAGIDÆ.

A small family of moderately large flies with elongate body, formerly included in the Leptidæ. Larvæ carnivorous, preying on larvæ under bark of dead trees, especially those of wood-borong Coleoptera. No species as yet found in Northumberland and Durham. *Xylophagus ater* F., from its known distribution, should occur.

STRATIOMYIDÆ.

Stout flies, often brightly coloured. Head broad. Antennæ erect, 3rd joint ringed with a style. Larvæ in water or decaying plants. Imago frequents flowers near water.

Beris chalybeata Forst. Widespread and common. May-July. Bishop Auckland, common (W.). Low Fell, abundant, males preponderating at first, the females later, Ebchester, Gibside, Waldridge Fell, Middleton-in-Teesdale (F.).

B. geniculata Curt. Not common. June-Aug. Bishop Auckland, Hesleden (W.). Low Fell, scarcer and later than *chalybeata* (F.).

B. vallata Forst. Fairly common. Mimics certain sawflies with its orange abdomen. June, July. Bishop Auckland (W.). Low Fell (F.).

Chloromyia formosa Scop. Common on leaves and flowers. Larva lives in garden mould. July. Low Fell (F.).

Chrysonotus bipunctatus Scop. An autumn species, widespread. Larva said to live in cow dung. Aug., Sept. Hesleden (W.). Gateshead, Low Fell (F.).

Microchrysa cyaneiventris Ztt. Not uncommon in the north. July. Low Fell (F.).

M. flavicornis Mg. Not uncommon. Sometimes with *polita*. June, July. Bishop Auckland (W.). Low Fell (F.).

M. polita L. Very common on leaves of shrubs in gardens.

Bred from cow dung and decaying vegetable matter. June-Sept. Hesleden, Bishop Auckland (W.). Low Fell (F.).

Nemotelus uliginosus L. The commonest of the genus, especially in saltmarshes. Greatham, by sweeping (H.).

Oxycera morrisii Curt. Rather rare in marshes. Castle Eden Dene (J. C. Dale, Verrall British Flies, V, 101), the most northerly record.

O. pygmæa Fln. Local but common where it occurs. Aug. Hesleden (W.).

Sargus cuprarius L. Widespread but not as common as *iridatus*. A garden species also in small woods, fond of sitting on large leaves in hot sun. Larva in mould, dung and vegetable refuse. June-Aug. Bishop Auckland, Hesleden (W.). Low Fell (F.).

S. iridatus Scop. Rather common though seldom abundant. June-Aug. Bishop Auckland, Waskerley, Evenwood (W.). Low Fell, Hamsterley (F.).

S. flavipes Mg. Not so common as the last two but widespread. A rather late species, generally in or near large woods. Aug. Hesleden (W.). Low Fell (F.).

Stratiomys furcata F. Rather local on *umbelliferæ*. Aug. Fallodon (H. B. Herbert).

S. potamida Mg. Uncommon in marshes and fens. Billingham (H.).

LEPTIDÆ.

"Snipe flies." Moderate sized flies with long and stout hind body and slender legs. Occur in woods and shady places. Feed on other flies. Larva carnivorous in damp soil.

Atherix ibis F. Widespread. The females form clusters on bushes overhanging streams and rivers and deposit eggs in water. Northumberland (C. Robson).

Chrysopilus auratus F. Common in marshy places. June-Aug. Hesleden, Shull, Belburn, Bishop Auckland (W.). Alnwick (F.).

Leptis lineola F. Not uncommon, especially in the North, on shrubs in glades in woods and in gardens. July-Sept. "Apparently rare. I have only taken one male in this district." South Durham (W.). Low Fell, frequent (F.).

L. nigriventris Lw. (*conspicua* Mg. of Wingate). Not uncommon; perhaps a form of *tringaria*. Aug. Hesleden, common (W.).

L. scolopacea L. The "Down-looker Fly." Common. Fond of sitting on tree trunks facing head downwards. Larva in earth, attacking earthworms and grubs. June, July. Gibside, Bishop Auckland, Wearhead, Waskerley (W.). Ebchester, Low Fell, Ravensworth, Blanchland, Hamsterley (F.).

L. tringaria L. Common and variable. Among shrubs in damp places. Larva carnivorous in earth. June-Aug. Hesleden, Bishop Auckland (W.). Croft (F.).

Symphoromyia crassicornis Pz. A montane species. Larva beneath turf. July. Bishop Auckland, Rowley (W.). Blanchland (F.).

TABANIDÆ.

"Breeze Flies, Gadflies or Horse Flies." Robust flies with broad head. Antennæ 3 jointed with terminal segment ringed. Eyes large. Hind body broad. Bloodsuckers in female. Males hover over mountains and rest on tree tops, trunks, palings, etc., near water. Larvæ carnivorous on small crustaceans in marshy ground and small insects and slugs in damp earth.

Chrysops caecutiens L. Common in the South, scarcer in the North. Bites viciously. Males rare. Larva in mud. July. Aug. Escomb. Witton. Bishop Auckland (W.).

C. relicta Mg. Uncommon but widely distributed. Greatham (J. Gardner).

Hæmatopota crassicornis Whlbg. Local, commoner in Scotland. July. Blanchland (F.).

H. pluvialis L. The "Cleg." Very common. A biter. Frequents damp places. Females much commoner than males. Larvæ in damp sand and mud. July. Aug. "Very common in Durham." Wearhead, Waskerley (W.) Blanchland (F.).

Tabanus autumnalis L. Not uncommon in South, rarer

in North. Bites horses and cattle and rarely man. On trees and posts in and near woods. June, July. Bishop Auckland, Harperley (W.) most northerly records.

Therioplectes montanus Mg. A rare montane species. July. Waskerley (W.) ? this species.

T. solstitialis Mg. Not abundant. Larva in mud and rotting leaves, feeding on worms and other insects. Bishop Auckland, one female, Mr. Greenwell. (Probably = *distinguendus* Verr.)

THEREVIDÆ.

A small family of medium sized flies with hairy bodies. They sit on the ground or on shrubs in the sun and prey on other insects. Larva elongate and worm-like in fungi and rotting wood, carnivorous.

Thereva annulata F. A silvery fly, common on sand dunes and occasionally inland in sandy places. Aug. Hart Sands (W.).

T. nobilitata F. Not really common. Often in gardens on leaves of plants. Larva carnivorous in earth and decaying wood. July, Aug. Hart Sands (W.). Low Fell (F.).

SCENOPINIDÆ.

"Carpet Flies." Rather small, narrow, oblong and dark flies with simple neuration. Larvæ carnivorous on the larvæ of fleas and tineid moths. Imago not common, often on windows.

Scenopinus fenestralis L. Not uncommon on windows. July. Gateshead (F.) most northerly record.

S. niger DeG. Not common. July. Gateshead (F.).

ASILIDÆ.

"Hawk" or "Robber Flies." Large robust flies with powerful wings, and strong spiny legs. Found in open sunny places. Prey on other insects. Larvæ in earth, feeding on detritus and other insects.

Dioctria rufipes DeG. Common in meadows near streams. Preys on Hymenoptera, especially *Ichneumonidæ*, and

Diptera. June, July. Bishop Auckland, Barnard Castle, Harperley (W.). Waldridge Fell, Ravensworth (F.).

Dysmachus trigonus Mg. Widespread on sandy areas on coast and inland. Prey chiefly Diptera. July, Aug. Hart (W.).

Philonicus albiceps Mg. On coastal sand dunes and occasionally inland in sandy localities. Very shy, with acute vision. Preys on various insects, particularly Diptera. Aug. Hesleden. " It is common on the sandhills below Hart station, where it lies in bare patches among the bent grass, looking like a piece of broken twig, and so is easily overlooked. When disturbed it only flies a few yards and then settles again. The males are much commoner than the females." (W.)

BOMBYLIIDÆ.

Medium sized flies with long proboscis and hairy bodies. Very bee-like. Hover in spring in the sun over primroses and other flowers. Larva in nests of wild bees and wasps.

Bombylius major L. Not uncommon in early spring. Hovers over primroses and ground ivy. Larva in nests of *Andrena* Spp., etc. Apl., May. Gibside, Hesleden. " Common on warm sunny days about the end of April, hovering over labiate flowers and primroses. It disappears instantly at the slightest movement but if perfect stillness be observed, it will often return to the same spot." (W.) Low Fell, Gibside (F.).

ACROCERIDÆ.

" Bladder Flies." Small flies with small head. Large globular abdomen. Wings small with large squamæ. Flies sluggish. Larva parasitic inside spiders. No local species as yet. *Paracrocera globulus* Pz. possibly occurs as it is found in Yorkshire and Lancashire.

EMPIDIDÆ.

A large family of moderate sized or small flies with slender bodies and long legs. Terminal joint of antennæ long and pointed. Long slender beak. Feed on other insects in woods or near water. Larvæ in earth, carnivorous.

Bicellaria pilosa Lndbk. Comparatively common. May. Middleton-in-Teesdale (F.).

B. spuria Fln. Widely distributed. June-Aug. Harperley, Bishop Auckland (W.).

B. sulcata Ztt. Widespread with two forms (*vana* southern, *sulcata* ver. Northern). June. Low Fell (F.).

Chelifera (*Hemerodromia*) *precatoria* Fln. Common in grassy spots, preying on minute Diptera. Aug. Hesleden (W.).

Chersodromia arenaria Hal. A species with few records. Aug. Hesleden. " Common, but very difficult to catch as they run rapidly among the stones and sand." (W.)

Dolichocephala irrorata Fln. Frequent in damp shady places. June. Bollihope (W.).

Empis aestiva Lw. Common. Aug. Low Fell on ragwort (F.).

E. borealis L. A northern species. June . Wearhead (W.).

E. chioptera Fln. Widespread as far north as Perthshire. May. Bishop Auckland (W.).

E. grisea Fln. Widespread as far north as Forth district. June, July. Low Fell, not uncommon (F.).

E. livida L. Very common. July, Aug. Hesleden (W.). Alnmouth, Ravensworth, Team Valley (F.).

E. lutea Mg. Distribution as *grisea*. Aug. Hesleden (W.).

E. nuntia Mg. (*pennaria* Brit. Coll.). As the last. June. Low Fell.

E. opaca F. Widespread, commoner in the North. June. Croft, Forest of Teesdale (F.).

E. pennaria Fln. (*vernalis* Mg.). Widely distributed. June. Hesleden, Harperley, Bishop Auckland (W.).

E. pennipes L. Somewhat uncommon. June. Bishop Auckland, Brancepeth (W.) apparently most northerly records.

E. punctata Mg. Common. May, June. Bishop Auckland, Harperley, Escomb (W.).

E. stercorea L. Not uncommon. June, July. Harperley, Shipley, Shull, Hesleden (W.). Ravensworth (F.).

E. tessellata L. Very common on Umbelliferæ and May blossom. Larva in earth especially under dead leaves. June, July. Common everywhere in Durham (W.). Croft, Low Fell, Chopwell, Ebchester, Ravensworth, Hamsterley (F.).

E. trigramma Mg. Very common on Umbelliferæ. May, June. Common everywhere in Durham (W.). Low Fell, Gibside, Hamsterley, Middleton-in-Teesdale (F.).

E. vitripennis Mg. A species with few records. Sept. Shull (W.) most northerly record.

Hilara canescens Ztt. A northern species. June-Aug. Harperley, Bishop Auckland, Hesleden (W.).

H. chorica Fln. Not uncommon. May, June. Escomb (W.).

H. interstincta Fln. Widely spread. June, Low Fell (F.).

H. litorea Fln. Widely distributed. July. Low Fell, not uncommon (F.).

H. longevittata Strobl. Common and widespread on Umbelliferæ. June. Low Fell (F.).

H. manicata Mg. A species with few records. July. Bishop Auckland (W.).

H. maura F. Common, dancing in swarms over water. May, June. Common everywhere in Durham (W.). Middleton-in-Teesdale (F.).

H. quadrivittata Mg. Widespread to the Forth district. June. Bishop Auckland (W.).

H. thoracica Mcq. Widely spread but uncommon. June, Aug. Bishop Auckland, Hesleden (W.).

Hybos culiciformis F. Common and widespread. Confused by Wingate with *grossipes*. July. Gibside, several (B.).

H. femoratus Mull. Common and widely distributed. Aug. Wearhead (W.).

H. grossipes L. A northern species. Hesleden, Shull, Wearhead, Bishop Auckland. " Males common, I have not as yet taken the female " (W.)

Hydrodromia fontinalis Hal. Widely distributed in the North of England and Scotland. June. Bollihope (W.).

H. stagnalis Hal. A northern species occurring practically all the year round. Low Fell, January, on a pond (F.).

Microphorus holosericeus Mg. (*velutinus* of list). Common. May. Wynyard (W.).

Ocydromia glabricula Fln. Abundant by sweeping herbage. Apl.-Sept. Bishop Auckland, Hesleden, Shull (W.). Low Fell, Ravensworth, Waldridge Fell (F.).

Œdalea holmgreni Ztt. Common. June. Bishop Auckland (W.).

Rhamphomyia barbata Mcq. (*pennata* Mcq.). Not common. June. Bishop Auckland (W.) apparently most northerly record.

R. dentipes Ztt. Not uncommon. May-July. Bishop Auckland (W.). Middleton-in-Teesdale (F.).

R. flava Fln. Widely distributed. July, Aug. Hesleden (W.).

R. geniculata Mg. (*plumipes* Fln. nec Mg.). Not uncommon. May. Middleton-in-Teesdale (F.).

R. negripes F. Common. June-Aug. Evenwood, Harperley, Wearhead (W.).

R. sulcata Mg. Common. May-July. Bishop Auckland, Hesleden, Escomb, Waskerley (W.). Middleton-in-Teesdale, abundant, Low Fell (F.).

R. sulcatina Coll. A northern species. May. Middleton-in-Teesdale (F.).

R. tibialis Mg. Another northern species. May. Middleton-in-Teesdale (F.).

R. umbripennis Mg. Not common. June, July. Brancepeth, Bishop Auckland (W.).

R. variabilis Fln. Widely distributed. Aug., Sept. Shull, Wearhead (W.).

Tachista arrogans L. Widely distributed. Aug. Howick (W.).

Tachydromia agilis Mg. Widespread. May. Middleton-in-Teesdale (F).

T. bicolor F. (of Auct.). Widely distributed. Aug. Hesleden (W.).

T. ciliaris Fln. Widely distributed. June. Low Fell (F.).

T. cursitans F. Widely distributed. July, Aug. Hesleden, Bishop Auckland (W.).

T. fasciata Mg. Seldom recognised. On Umbelliferæ. June, Sept. Low Fell, occasional (F.).

T. flavipes F. Not very common. May. Stanhope, Bishop Auckland, Evenwood (W.).

(*T. interstincta* Coll. A fairly common species which has been much confused with *flavipes* F. should occur.)

T. longicornis Mg. Widespread. Has been bred from a rotten willow log. May. Hudeshope Beck, Middleton-in-Teesdale (F.).

T. lutea Fln. Widespread on Umbelliferæ. June. (Low Fell, on *Heracleum* in some numbers (F.).

T. nigritarsis Fln. Widely distributed. June. Low Fell (F.).

Tachypeza nubila Mg. Common. June. Low Fell (F.).

Trichopeza longicornis Mg. Widely distributed. June, July. Low Fell, abundant (F.).

Wiedemannia bistigma Curt. A species with few records. Aug. Wearhead (W.).

DOLICHOPODIDÆ.

A large family of moderate sized or small flies with long legs with bristles on thorax and legs. More or less metallic. Predaceous, often near water. Larva carnivorous, in damp earth or decayed wood.

Argyra argentina Mg. Widely distributed. July, Aug. Belburn, Wearhead (W.). Blanchland (F.).

A. argyria Mg. Less common than the last. June. Low Fell, several (F.).

A. diaphana F. Fairly common all over Britain. July, Aug. Bedburn (W.). Blanchland, Low Fell, Waldridge Fell (F.).

A. leucocephala Mg. Our commonest species. June-July. Low Fell, Ravensworth (F.).

Campsicnemus curvipes Fln. Commonest of the genus. March, July, Aug. Hesleden (W.). Low Fell, several, Ravensworth (F.).

Chrysotus gramineus Fln. Common in dry places. Aug. Hesleden (W.).

Dolichopus atratus Mg. Common in forest or marshy districts, often on alders by side of streams. July, Aug. Waskerley, Bedburn (W.). Waldridge Fell (F.).

D. atripes Mg. Not uncommon. July, Aug. Waskerley, Hesleden (W.). Waldridge Fell (F.).

D. brevipennis Mg. Local. July. South Durham (W.). Low Fell (F.).

D. claviger Stan. Not common except locally. Sunderland (G. H. Verrall, *Ent. Mo. Mag.*, 1904, 199).

D. discifer Stan. Common. June, July. Low Fell, Blanchland (F.).

D. griseipennis Stan. Common. July, Aug. Hesleden, Bishop Auckland (W.).

D. migrans Ztt (*confusus* Ztt.). Not common. June. Low Fell (F.).

D. pennatus Mg. Common. June. Harperley (W.).

D. picipes Mg. Widely distributed. Aug. Bedburn (W.). Waldridge Fell (F.).

D. plumipes Scop. Very common. June-Aug. Hesleden, Bishop Auckland, Wearhead, Waskerley (W.). Low Fell, common, Ravensworth, Blanchland (F.).

D. popularis W. Local in numerous localities. June, July. Bishop Auckland, Bedburn (W.). Ravensworth (F.).

D. simplex Mg. Not uncommon. July. Ravensworth, several males (F.).

D. trivialis Hal. Very common. June-Sept. Hesleden, Bishop Auckland, Waskerley, Bedburn, Wearhead, Embleton (W.). Low Fell, Falloden (F.).

D. ungulatus L. (*æneus* DeG.). Universally distributed and very abundant. June, July. Hesleden, Harperley, Bishop Auckland, Bedburn (W.). Low Fell, Ravensworth, Waldridge Fell (F.). Fallodon (H. B. Herbert).

D. urbanus Mg. Moderately common. July. Bedburn (W.).

D. vitripennis Mg. Common everywhere in marshy places. June, July. Waskerley (W.). Low Fell (F.).

Gymnopternus aerosus Fln. Common. July. Waskerley, Bishop Auckland (W.).

G. cupreus Fln. Common. Aug. Bedburn (W.).

Hercostomus nigripennis Fln. Common. Aug. Wearhead (W.).

Hydrophorus oceanus Mcq. (*bisetus* Lw.). Apparently common especially on coast. June-Aug. Hesleden, Wearhead (W.).

H. nebulosus Fln. Not uncommon. May. Waskerley (W.).

H. praecox Mg. Not uncommon on coast and on inland pools. Aug. Hesleden (W.).

Liancalus virens Scop. Common at waterfalls and where-ever water trickles down a perpendicular surface. Aug. Wearhead (W.).

Neurigona quadrifasciata F. Not common. June. Barnard Castle (W.).

Poecilobothrus principalis Lw. Rare. June. Hamsterley (F.).

Scellus notatus F. Probably not rare. Sometimes abundant among marshy herbage. June, Aug. Bishop Auckland, Hesleden (W.). Low Fell F.

Sciopus (*Psilopus*) *platypterus* F. Fairly common on tree trunks and palings, and by general sweeping. June-Aug. Bishop Auckland, Hesleden (W.). Low Fell (F.).

S. wiedemanni Fln. Not uncommon usually near coast. Aug. Hesleden (W.).

Sympycnus Desoutteri Par. (*annulipes* Mg.). Common July. Low Fell (F.).

Syntormon pallipes F. Common. June-Aug. Hesleden, Brancepeth (W.).

Xanthochlorus ornatus Hal. Not uncommon. Aug. Hesleden (W.).

Xiphandrium caliginosus Mg. Commoner in the South. May. Bishop Auckland (W.) most northerly record.

X. monotrichum Lw. More common in the North. July. Bedburn (W.).

LONCHOPTERIDÆ.

A small family of small slender flies with lance-shaped wings. Head oval, prominent eyes. Hind body and legs long. One genus, widely distributed. Larva in earth, under vegetable matter, detritus, etc. Metamorphosis peculiar with semi-pupa.

Lonchoptera lacustris Mg. Widespread as far north as Perth. Feb.-April. Gibside, Harperley, Bishop Auckland (W.). (=var. of *furcata* Fln.)

L. lutea Pz. Common. May. Low Fell (F.).

L. punctum Mg. Uncommon. March-May. Bishop Auckland, Harperley, Belburn (W.). (=*lutea* Pz.)

L. trilineata Ztt. Uncommon. March, April. Gibside, Bishop Auckland, Harperley (W.). (=var. of *lutea* Pz.)

L. tristis Mg. Common. Jan. Bishop Auckland (W.) apparently most northerly record. The species of *Lonchoptera* are very little understood. They may be varieties of one or two species.

PHORIDÆ.

A family of small flies, with relatively large wings with characteristic neuration. Some are apterous. Hind body short and tapering. Larvæ parasitic on snails and insects.

Aneurina (*Chaetoneurophora*) *curvinervis* Beck. Common. May, June. Harperley, Bishop Auckland (W.).

Beckerina umbrimargo Beck. Apparently common. June. Bedburn (W.).

Hypocera incrassata Mg. Widespread. Aug. Hesleden (W.).

Megaselia minor Ztt. Not common. May. Bishop Auckland (W.) most northerly record.

M. picta Lehm. Scarce. Aug. Hesleden (W.).

M. pulicaria Fln. Widely distributed. April. Bishop Auckland (W.).

M. ruficornis Mg. Widely distributed. May. Bishop Auckland (W.).

M. rufipes Mg. Common. Has been bred from wasp's nests, decaying vegetable matter and fungi. Common in Durham (W.).

Phora aterrima F. Common and widespread. May, June, Aug. Wearhead, Bishop Auckland (W.).

Pseudostenophora nudipalpis Beck. Common. May, June. Bishop Auckland, Brancepeth (W.).

Triphleba opaca Mg. Not uncommon. Bishop Auckland (W.).

PLATYPEZIDÆ.

A small family of little flies with often dilated hind tibiæ and tarsi. Males dark coloured. Females usually with silvery, orange or red markings. Males often hover or run on leaves of shrubs and low plants. Some species have been bred from fungi.

Callimyia amoena Mg. A not uncommon small beautiful fly. June, Aug., Sept. Bishop Auckland, Hesleden (W.).

C. speciosa Mg. Widely distributed. June. Bishop Auckland (W.).

Opetia nigra Mg. Widespread. Aug. Hesleden, Craster (W.).

Platycnema pulicaria Fln. A little known species. July. Bishop Auckland (W.) most northerly record. (More correctly placed in Empididæ.)

PIPUNCULIDÆ.

Small dark flies with enormous eyes. Wings long and iridescent. Of retiring habits, hovering in low herbage and hedgerows. A widely distributed family in both hemispheres. Larvæ parasitic on Homoptera.

Chalarus spurius Fln. Not uncommon but seldom abundant. Said to be parasitic on *Typhlocyba rosæ*. June-Sept. Low Fell, occasional (F.).

Pipunculus campestris Lat. (*ater* Mg.). Common as far north as Orkney. May-Sept. Hesleden, Bishop Auckland (W.). Low Fell, abundant (F.).

P. confusus Verr. Widely distributed. June. Harperley (W.).

P. extricatus Coll. M. S. Rare. June. Low Fell (F.).

P. furcatus Egg. Not uncommon in well wooded districts in the South. June. Barnard Castle (W.) most northerly record.

P. obtusinervis Ztt. Rare with few records. June. Low Fell (F.).

P. pratorum Fln. Not common. July, Aug. Hesleden (W.). Low Fell (F.)

P. terminalis Th. Widely distributed. July. Bedburn (W.).

Verrallia aucta Fln Fairly common. The males hover in small swarms. Durham (J. E. Collin, *E.M.M.*, 1931, 236).

V. pilosa Ztt. Widely distributed. June. Harperley (W.).

V. villosa v. Ros. Widely distributed. Edderacres and Shotton (J. E. Collin, *E.M.M.*, 1931, 235).

SYRPHIDÆ.

Usually medium or large showy flies with yellow or orange markings. Wings with "vena spuria." "Hover flies." Eyes bare or hairy. Antennæ three jointed with plumose or bare arista. Feed on pollen or honey. Larvæ aphidiphagous or in decaying vegetable matter, fungi, sap, or nests of ants and aculeates.

Arctophila mussitans F. Widespread. Mimics a *Bombus*. Aug., Sept. Hesleden, Shull. "With the exception of Shull, I have only seen this species on a few yards of waste ground at the corner of a wood at Hesleden, and there only during the last five days of August in two successive years. It was fairly common on the one spot, but I saw it nowhere else except at Shull, where I saw a pair of which I secured the male." (W.) Harnham, a few (C. Robson).

Baccha elongata F. Fairly common all over Britain. May-Aug. Hesleden, Bishop Auckland (W.). Gibside, Low Fell, not uncommon, flying furtively in and out of herbage, even among brambles (F.).

Brachyopa bicolor Fln. Widely distributed. Fond of sap and blossoms of hawthorn and Umbelliferæ. Resembles the Anthomyid *Phaonia scutellaris*. May. Bishop Auckland

(W.). (This is more probably *scutellaris* Dov.)

Chilosia albitarsis Mg. Common everywhere in spring on Caltha and Ranunculus. May-Aug. Belburn, Hesleden, Evenwood, Harperley, Bishop Auckland (W.). Low Fell, Prestwick Carr., Blanchland, Middleton-in-Teesdale (F.).

C. antiqua Mg. (*sparsa* Lw.). Widely distributed. May. Hesleden (W.).

C. fraterna Mg. Common. June. Gibbsnees (W.).

C. illustrata Harr. Not generally abundant. Mimics a Bombus. July-Aug. Hesleden (W.). Low Fell, common on Anthriscus (F.). Killingworth (C. Robson).

C. impressa Lw. Probably not uncommon. August. Hesleden (W.). Low Fell (F.).

C. intonsa Lw. August. Hesleden (W.).

C. maculata Fln. Uncommon. Attached to Allium ursinum. May, June, Belburn (W.). Low Fell, in fair numbers, males largely in the majority. Frequents the leaves of wild garlic and surrounding herbage, flying sluggishly and unobtrusively with short flights among the vegetation and not hovering. Generally accompanied by several species of anthomyids and muscids.

C. paganus Mg. (*pulchripes* Lw.). Rather common. April-Aug. Hesleden, Harperley, Wynyard (W.). Low Fell, not uncommon (F.).

C. proxima Ztt. Probably not uncommon. Aug. Hesleden (W.).

C. scutellata Fln. Rather common on Umbelliferæ. Aug. Low Fell (F.).

C. soror Ztt. Uncommon. June. Low Fell (F.), most northerly record.

C. variabilis Pz. Common on large-leaved herbage in sun, sitting with slightly outspread wings. Apl.-Aug. Harperley, Hesleden (W.). Low Fell, common, Prestwick Carr., Ravensworth (F.).

C. velutina Lw. A rare species. Aug. Low Fell (F.), most northerly record.

C. vernalis Fln. Common. Aug. Hesleden (W.).

Chrysogaster chalybeata Mg. Uncommon. The larva lives in the stem of the Sowthistle. July. Team Valley (F.).

C. hirtella Lw. Common in marshes on Ranunculus, etc. June-Aug. Harperley, Bedburn, Hesleden (W.). Blanchland (F.).

C. splendens Mg. Widely distributed. June, July. Low Fell, not uncommon. Team Valley (F.).

Chrysotoxum arcuatum L. Not common but commoner in the north. June-Aug. Hesleden (W.). Low Fell, Waldridge Fell (F.). Killingworth, Harnham (C. Robson).

C. bicinctum L. Not common but widely distributed. Aug. Hesleden (W.).

Cnemodon vitripennis Mg. Not very common. May-July. Low Fell (F.).

Criorrhina asilica Fln. Not uncommon on early hawthorn blossom in woods in spring. June. Low Fell (F.), most northerly record.

C. berberina F. Rather uncommon. Resembles a small humble bee. Essentially a May species. Low Fell. June, July, rather late dates (F.).

C. floccosa Mg. By no means common. May, June. Bishop Auckland (W.). Low Fell, on *Heracleum* and sycamore (F.), most northerly record.

C. oxyacanthæ Mg. Our commonest species. June, July. Low Fell (F.).

C. ranunculi Pz. By no means common in spring on early blossoming shrubs. Winlaton, one (C. Robson), most northerly record.

Epistrophe (Syrphus) annulata Ztt. Not common. June. Harperley (W.).

E. auricollis Mg. Not uncommon but never abundant. May-Aug. Bishop Auckland (W.). Gibside, Low Fell, not uncommon (F.).

E. auricollis var. *maculicornis* Ztt. Commoner than type. July-Aug. Hesleden (W.). Low Fell, not uncommon, one taken on 12-10-25, a late date (F.).

E. balteata DeG. One of the commonest species. Larva a great devourer of aphides. Common everywhere in Durham (W.). Low Fell, abundant, latest date Oct. 3rd (F.).

E. bifasciata F. Common, the male is a fine hoverer. June. Evenwood, Bishop Auckland (W.). Low Fell, Hamsterley (F.).

E. cinctella Ztt. Not uncommon. May-Sept. Gibside, Hesleden, Shipley, Shull (W.). Wingate's males differ peculiarly in the shape of the abdomen. Low Fell, common, Fallodon (F.).

E. cincta Fln. Not common but widespread. May-Sept. Bishop Auckland (W.). Low Fell, not uncommon. Gibside (F.).

E. compositarum Verr. Not uncommon. June-Aug. Hesleden (W.). Low Fell, frequent. Waldridge Fell, Team Valley (F.).

E. grossulariæ Mg. Not common. June-Aug. Hesleden, common in 1899. Gibside, Howick (W.). Low Fell, not infrequent. A strong and rapid flier (F.).

E. guttata Fln. Very rare in Britain. June-Aug. Low Fell, in considerable abundance. Very active. Spots on thorax variable in size and depth of colour, sometimes almost absent and sometimes fused (F.).

E. labiatarum Verr. Probably not uncommon. August. Hesleden (W.).

E. lasiophthalma Ztt. Not uncommon in early spring hovering in sun under trees in woods. April, May. Muggleswick, Harperley, Bishop Auckland (W.).

E. punctulata Verr. Widely distributed. May. Gibside, Low Fell (F.).

E. umbellatarum F. By no means common. June-Sept. Hesleden (W.). Low Fell, occasional, Waldridge Fell (F.).

E. vittiger Ztt. Not common in England, commoner in Scotland. August. Gibside, Shipley, Hesleden, Harperley, Wearhead (W.).

Eristalinus sepulchralis L. Not uncommon in the south of England, frequenting ponds about farmsteads. June. Croft Spa (F.).

Eristalis arbustorum L. Very common. May-Aug. Common everywhere in Durham (W.). Low Fell, abundant, Team Valley, Chester-le-Street, Forest of Teesdale (F.).

E. horticola DeG. Fairly common. June-Aug. Gibbsnees, Hesleden (W.). Low Fell (F.).

E. intricarius L. Not uncommon. The male is a magnificent hoverer. June-Sept. Hesleden (W.). Low Fell, Forest of Teesdale, Waldridge Fell (F.). Killingworth (C. Robson).

E. intricarius var. *furvus* Verr. Occurs with the type. Low Fell, Waldridge Fell, Forest of Teesdale, on *Caltha* (F.).

E. nemorum L. Widely distributed. August. Hesleden, Wearhead (W.).

E. pertinax Scop. Very common. April-August. Common everywhere in Durham (W.). Low Fell abundant, Forest of Teesdale, Waldridge Fell (F.).

E. rupium F. Montane, widespread in the north. June-August. Gibside, Gibbsnees, Hesleden, Wearhead (W.). Waldridge Fell, Blanchland (F.).

E. tenax L. Probably the most widely distributed Syrphid in the world. Larva "Rat-tailed maggot" lives in foul pools and ditches. Very common everywhere in Durham (W.). Low Fell, abundant (F.).

Eumerus strigatus Fln. "Small Narcissus fly." Not very common. Larva in bulbs of onions and narcissi. June. Low Fell (F.).

Ferdinandea (Chrysochlamys) cuprea Scop. Never common but widespread. Has been bred from larvæ in "Cossus sap." June-August. Hesleden, Brancepeth (W.).

Helophilus hybridus Lw. Widely distributed. Hovers over ditches in fens and fond of flowers of ragwort. July. Low Fell (F.).

H. pendulus L. Common all over Britain. Larva lives in stagnant water. June-August. Gibside, Hesleden, Wearhead (W.). Low Fell (F.). Killingworth (C. Robson).

Ischyrosyrphus glaucius L. Not common but in fair numbers in various places. July, August. Wearhead, Shipley, Hesleden, Gibside (abundant 12-8-96) (W.). Low Fell (F.).

I. laternarius Mull. Not common. July, August. Low Fell (F.).

Lathyrophthalmus (Eristalis) æneus Scop. Not uncommon on the coast. August, Hesleden (W.).

Leucozona lucorum L. Lot uncommon. Bred in Suffolk from larvæ in nest of *Bombus terrestris*. May-August. Gibbsnees, Bishop Auckland, Belburn, Hesleden (W.). Low Fell on stitchwort and Heracleum (F.). Killingworth (C. Robson).

Liogaster metallina F. Not uncommon on flowers of Ranunculus. June. Bollihope (W.).

Melangyna quadrimaculata Verr. Rather scarce. An early species feeding on sallow catkins. March, April. Bishop Auckland, Harperley, abundant (W.).

Melanostoma mellinum L. Very common. Larva aphidiphagous. May-July. Common everywhere in Durham (W.). Low Fell, Middleton-in-Teesdale, Gibside (F.).

M. scalare F. Almost as common as the last. May-July. Common everywhere in Durham (W.). Gibside, Low Fell, Middleton-in-Teesdale (F.).

Merodon equestris F. "Large Narcissus fly." Widespread. Variable in colouring, mimicking various species of *Bombus*. Larva harmful to tulip, lily and daffodil bulbs, also to wild hyacinths. June, July. Bishop Auckland (vars. *narcissi* F and *validus* Mg.) (W.).

Myiatropa florea L. Fairly common all over Britain. Apl.-Sept. Has been bred from pupa in decaying beech. Gibbsnees, Bishop Auckland, Hesleden. "There is a remarkable difference in the size of the female specimens. The two from Bishop Auckland were caught on the window of a greenhouse. The April specimen measures 14mm., the May specimen 16mm. The Gibbsnees August specimen only measures 9mm." (W.). Low Fell, not infrequent (F.). Killingworth, Harnham (C. Robson).

Neoascia floralis Mg. Not uncommon. July. Bedburn (W.). (This is probably *dispar* Mg. *nec* Ludbk.)

N. podagrica F. Common everywhere. One of the first syrphids to appear in spring and continuing till autumn frosts. Common everywhere in Durham (W.). Low Fell on dandelion. Forest of Teesdale, Prestwick Carr. (F.).

Pipiza austriaca Mg. A rare species resembling a black Crabronid. June, July. Low Fell, several (F.).

P. bimaculata Mg. A rare species. May, June. Low Fell, not uncommon (F.). Mr. J. E. Collin says of these specimens "I should call them the *bimaculata* of Verrall. On the other hand Lundbeck says that the female of *bimaculata* is distinguished by its clearer wings and your's and Verrall's have a distinct cloud."

P. fenestrata (Mg) Verr. Very rare. May. Gibside, with indistinct spots on 3rd abdominal segment (F.).

P. noctiluca L. Widely distributed. June-August. Belburn, Bishop Auckland (W.). Low Fell, several, Waldridge Fell (F.). Killingworth (C. Robson).

Pipizella heringi Brit. Coll. A very rare species. June. Low Fell (F.). Most northerly record.

P. virens F. Common. August. Hesleden (W.).

Platychirus albimanus F. Abundant. May-Sept. Common everywhere in Durham (W.). Low Fell, occasional melanoid females occur. Fallodon, High Force, Teesdale (F.).

P. angustatus Ztt. Not uncommon in marshy places. July. Bishop Auckland. Hesleden, common at rushes (W.). Ravensworth (F.).

P. clypeatus Mg. Abundant in low lying meadows. Common in Durham in meadows and marshes among rushes (W.).

P. immarginatus Ztt. Not common, mixed with its allies. July. Ravensworth (F.).

P. manicatus Mg. Very common. May-August. Common everywhere in Durham (W.). Low Fell, latest date Nov. 11th. Ebchester, Blackhall Rocks, Gateshead, Middleton-in-Teesdale, Ravensworth, Chopwell (F.).

P. peltatus Mg. Tolerably common everywhere. April-Oct. Wearhead, Belburn, Escomb (W.). Low Fell, common, Ravensworth, Team Valley, Chopwell (F.).

P. scambus Staeg. Widely distributed. June-August. Bedburn (W.). Low Fell, Team Valley, Ravensworth, Blanchland, Waldridge Fell (F.).

P. scutatus Mg. Common. The larva has been bred from rotten fungi. June-Sept. Common everywhere in Durham (W.). Low Fell, abundant, several males shewing suppression of one or two abdominal spots. Ebchester, Ravensworth.

P. sticticus Mg. Rare but widespread. June. Low Fell (F.).

Pyrophæna granditarsa Forst. Hardly common but not scarce. July, August. Hesleden (W.). Low Fell, several (F.).

P. rosarum F. Not common in marshy places. June. Harperley (W.).

Rhingia campestris Mg. Fairly common everywhere. May-August. Common in Durham. "It roams about among the stalks of the herbage below the leaves." (W.). Low Fell, abundant on *Allium* and *Heracleum* and among grass blades, low herbage and brambles. Flight short and leisured but quick if disturbed. Not noticed hovering. Usually sings when handled. Team Valley, Middleton-in-Teesdale, Gibside, Ravensworth, Prestwick Carr. (F.).

Scaeva (*Catabomba*) *pyrastri* L. Common everywhere. June-August. Larva feeds on aphides. Fairly common everywhere in Durham, Barnard Castle, Gibside, Hesleden (W.), Low Fell, Lambton Park (F.).

S. seleniticus Mg. Widely distributed. July, August. Wearhead, in fir plantation (W.). Low Fell, Lambton Park (F.).

Sericomyia borealis Fln. Not uncommon on open moors and in forests especially in the north. The male sings at rest. June-August. Gibside, Wearhead, males common among heather (W.). Low Fell, Waldridge Fell, Blanchland (F.). Killingworth or Harnham (C. Robson).

S. lappona L. Less common and earlier than the last, fond of bilberry. June. Waskerley (W.). Forest of Teesdale, not uncommon on *Trollius* (F.). Killingworth or Harnham (C. Robson).

Sphærophoria menthastri L. Common everywhere. May-August. Var. *menthastri* L. Hesleden, Wearhead, Wynyard (W.). Var *picta* Mg. Hesleden, common in August. Barnard Castle, Escomb, Bishop Auckland, Wearhead (W.). Var. *tæniata* Mg. Wearhead, Hesleden (W.).

S. scripta L. Generally distributed. August. Var. *scripta* L. Hesleden, common in August (W.). Var. *nigricoxa* Ztt.

Hesleden (W.).

Sphegina clunipes Fln. Hardly rare but by no means common. June-Sept. Shipley (W.). Low Fell, occasional. Fallodon (F.).

Syritta pipiens L. One of the commonest Syrphids in Britain. May-July. Common everywhere in Durham (W.). Low Fell, abundant on brambles, *Heracleum*, etc., Ravensworth (F.).

Syrphus. See also under *Epistrophe*.

S. albostriatus Fln. By no means uncommon. The larva feeds on aphides. June-August. Hesleden, Bishop Auckland, Gibside (W.). Low Fell, not uncommon (F.).

S. annulipes Ztt. Rare in England, commoner in Scotland. Fond of thistles and ragwort. June. Harperley (W.).

S. corollæ F. Common and variable. Preys on the aphid *Brevicoryne brassicæ*. May-August. Common everywhere in Durham (W.). Low Fell (F.).

S. latifasciatus Mcq. Uncommon and variable. May-August. Wearhead (W.). Low Fell (F.).

S. luniger Mg. Common all over Britain. May-August. Common everywhere in Durham (W.). Low Fell, Lambton Park, Hamsterley (F.).

S. lunulatus Mg. Not common in the south, commoner in Scotland. June-Sept. Hesleden (W.). Low Fell (F.).

S. nitidicollis Mg. Not common in woods. June, July. Low Fell (F.).

S. ribesii L. Very common everywhere, the larva feeding on aphides. May-Sept. Very common everywhere in Durham (W.). Low Fell, abundant, fond of honeydew on leaves of lime and sycamore and common on brambles, Middleton-in-Teesdale, Gibside, Lambton Park, Prestwick Carr (F.).

S. torvus O.S. Not uncommon. Larva feeds on aphides. Resembles *ribesii* but with hairy eyes. April-June. Low Fell, Gibside (F.).

S. tricinctus Fln. Not common in wooded places. May-August. Gibside, Hesleden, Harperley (W.). Low Fell (F.).

S. venustus Mg. Not uncommon in wooded districts in spring. Fond of flowers of wood spurge. April-July. Evenwood, Bishop Auckland, Belburn, Barnard Castle (W.). Low Fell, Chopwell (F.).

S. vitripennis Mg. Common. Closely allied to *ribesii*, but more of a garden species. May-October. Not as common as *ribesii* in Durham, Harperley, Hesleden, Wearhead (W.). Low Fell, Middleton-in-Teesdale, Waldridge Fell (F.).

Volucella bombylans L. Widespread to Orkneys. Larvæ scavengers in bee's nests. Body very hairy, humble bee like. Very variable. June-August.

var. *bombylans* L. mimics *Bombus lapidarius* and *derhamellus*. Witton, Bishop Auckland, Shull (W.). Low Fell (F.).

var. *plumata* DeG. mimics *Bombus terrestris*. Wearhead (W.). Blanchland (F.). Birtley, common, Killingworth, Harnham (W.).

var. *hæmorrhoidalis* Ztt. mimics *Bombus agrorum*. Wearhead (W.).

V. pellucens L. Rather common in wooded districts. The male is a fine hoverer. The female is fond of bramble and rose blooms. Larva acts as a scavenger in nests of *Vespa vulgaris* and *germanica*. June-August. Fairly common everywhere in Durham (W.). Low Fell, Waldridge Fell, Chopwell (F.).

Xylota abiens W. An uncommon species. August. Gibbsnees (W.). Most northerly record.

X. lenta Mg. Not common in the south and midlands, but found as far north as Ballater. June. Bishop Auckland (W.).

X. segnis L. Common in wooded districts on leaves of low shrubs. Mimics various *Tenthredinidæ*. June, July. Fairly common everywhere in Durham (W.). Low Fell, Ravensworth, Chopwell (F.).

X. sylvarum L. Common and widely distributed. July, August. Bishop Auckland, Harperley, Hesleden (W.). Low Fell (F.).

CONOPIDÆ.

A family, mainly consisting of brightly coloured wasp-like flies. Moderate size with large head. Antennæ long and projecting. Abdomen slender at base. Larvæ parasitic on Hymenoptera and Orthoptera.

Myopa buccata L. A widely distributed reddish fly found on flowers of dandelion, etc. May-June. Harperley, Bollihope (W.). Several other members of the family should occur.

ORTALIDÆ.

A family of flies somewhat resembling the Trypetidæ, often having maculated or spotted wings. Most of the species are black in colour and occur on herbage.

Herina afflicta Mg. Not common. August. Hesleden (W.). Most northerly record.

H. frondescentiæ L. Common and widespread. July, August. Hesleden, Waskerley (W.).

H. nigrina Mg. Not common. August. Hesleden, Craster (W.). Most northerly records.

ULIDIIDÆ.

Shining black flies, with or without markings, previously considered a sub-family of the Ortalidæ. Few British species, none found locally but *Seoptera vibrans* L. from its known distribution should occur.

TRYPETIDÆ.

A family of prettily marked flies whose larvæ live mainly in the inflorescence of flowers, frequently causing galls.

Acidia cognata Wd. Local but not uncommon. Larva mining leaves of coltsfoot. July, August. Bishop Auckland, Howick (W.), Gateshead, on window, Low Fell, not uncommon (F.).

A. heraclei L. The " Celery fly." Common and widespread. Larva blotching leaves of celery, *Heracleum*, *Angelica*, etc. April-August. Bishop Auckland, Bedburn (W.). Low Fell, abundant, Ravensworth (F.).

Carphotricha guttularis Mg. Not uncommon forming galls at the top of roots of yarrow. North Hylton, galls (B.). Most northerly record.

C. pupillata Fln. Not uncommon galling flower heads of

Hieracium spp. Birtley, Hylton, Wolsingham, Penshaw, Washington, Cox Green, Wylam (B. H.). Most northerly records.

Myopites blotii Breb. Not common, galling receptacle of *Inula* and *Pulicaria*. Greatham, Cowpen, Bewley, galls (H). Most northerly records.

Oxyna flavipennis Lw. Not common. Galls rootstock of *Achillea millefolium*. North and South Hylton, Ovingham, galls (B.). Most northerly records.

O. parietina L. Rare. Galls in stalk of mugwort. Birtley (H.). Most northerly record.

Paroxyna parvula Lw. (*absinthii* F. of List). Not common, bred from *Artemisia maritima*. July. Hesleden (W.). Most northerly record.

P. plantaginis Hal. Rare, deforming inflorescence of *Aster tripolium*. Greatham, galls (H.). Most northerly record.

Sphenella marginata Fln. Not abundant, by sweeping thistle and ragwort. August. Hesleden (W.). Birtley (H.).

Spilographa zoë Mg. Not uncommon. Larva mines leaves of *Senecio* spp. April-August. Bishop Auckland (W.). Low Fell, common. Ravensworth, bred from ragwort (F.).

Tephritis bardanæ Schr. Widespread in England. Larva deforming seed capsule of *Arctium lappa*. August. Hesleden (W.). Most northerly record.

T. formosa Lw. Rare causing hypertrophy of involucral bracts of *Sonchus oleraceus*. Biddick, Hylton (B.). Most northerly records.

T. hyoscyami L. Rare by sweeping *Cnicus lanceolatus*. Hibernates in furze. June. Evenwood (W.).

T. leontodontis DeG. Widespread, swelling the capitulum of *Leontodon autumnale*. Penshaw Hill, Allendale, galls (B. H.).

T. vespertina Lw. Common. Larva in heads of Compositæ. April, Sept. Harperley, Shull (W.).

Trypeta onotrophes Lw. Common and widespread. August. Hesleden (W.).

Urellia eluta Mg. Rare, swelling capitulum of *Centaurea nigra*. Greatham, Cox Green, Fatfield, Haydon Bridge (B. H.). Apparently most northerly records (galls).

Urophora cardui L. Not uncommon, forming large thick swellings on the stems of the thistle *Cnicus arvensis*. Wolsingham, Hylton, Penshaw, Gibside, Hedley, West Wylam (B.H.).

U. jaceana Hering. Not uncommon and widespread. Larvæ in flower heads of black knapweed. August. Hesleden (W.). Apparently generally distributed in Durham (H.).

U. macrura Lw. Not common. Thickens receptacle of flower of groundsel. August. Hesleden (W.). Birtley, galls on *Centaurea* (H.). Incorrectly identified?

Xyphosia (*Oxyphora*) *flava* Geoff. (*Tephritis miliaria* Schr.). Common and widespread on *Cnicus arvensis*. July, August. Hesleden (W.). Low Fell (F.).

Zonosema alternata Fln. Widespread. Larva breeds in rose hips which it deforms. Wolsingham (H.).

LONCHÆIDÆ.

Rather plump flies of shining blue-black colour and immaculate wings (*Lonchæa*), or yellow or grey flies with wing-markings (*Palloptera*).

Lonchæa chorea F. Common. Larva in manure. June-August. Bishop Auckland (W.). Low Fell (F.).

L. laticornis Mg. Uncommon. June, July. Bishop Auckland. "These seem to come nearer to *laticornis* Ztt. but for two of them *longicornis* would be a better name than *laticornis* and they may be two species." (W.).

L. vaginalis Fln. Common, This is probably *chorea* (F.). July-August. Bishop Auckland (W.).

Palloptera saltuum L. Common and widespread. June, July. Barnard Castle, Bishop Auckland (W.). Low Fell, common (F.).

P. trimacula Mg. Widespread. The larva has been bred from old rootstocks of *Angelica*. June, July. Bishop Auckland, Evenwood, Harperley (W.).

P. umbellatarum F. Common and widespread. June-August. Hesleden, Bishop Auckland (W.). Low Fell, common, fond of settling on bird droppings where it is protectively coloured (F.).

P. usta Mg. Widely distributed. July. Bishop Auckland (W.).

P. ustulata Fln. Common. July. Bishop Auckland (W.).

Toxoneura muliebris Harr. A rare prettily marked fly. Sept. Low Fell (F.). Most northerly record.

TANYPEZIDÆ.

The single species, *Tanypeza longimana* is a long legged fly allied to *Micropeza* but having the thorax more square in front. It appears to be rare in this country.

MICROPEZIDÆ.

A family of slender bodied flies with very long thin legs found on low lying herbage.

Calobata cibaria L. Uncommon. June, July. Bishop Auckland (W.).

C. petronella L. Common and widespread. June, July. Bishop Auckland (W.). Low Fell, not uncommon (F.).

Micropeza corrigiolata L. Not uncommon. June. Harperley (W.).

SEPSIDÆ.

Small shining black flies, often with constricted base to abdomen and a spot at tip of wing. Some occur on herbage, others swarm over mud round ponds and ditches.

Nemopoda cylindrica F. Common and widespread. May-August. Bishop Auckland, Hesleden, etc. (W.). Low Fell, Blanchland (F.).

Sepsis cynipsea L. Common and widespread, often in swarms. Larva in decaying vegetable matter. June, July. Common everywhere in Durham (W.). Low Fell (F.).

S. nigripes Mg. Not uncommon. April-Sept. Low Fell, Fallodon, Ravensworth, Hamsterley. (F.).

S. violacea Mg. Common. April-May. Bishop Auckland (W.).

Themira lucida Staeg. Rare. June. Low Fell (F.).

PIOPHILIDÆ.

A family of small flies which includes the well-known "Cheese fly." *Piophila casei* L.

Piophila casei L. A cosmopolitan fly whose larva lives in ripe cheese. May-July. Bishop Auckland (W.).

THYREOPHORIDÆ.

The only representative of this family in Britain is *Thyreophora furcata* F., which resembles a *Scatophaga* and has been found on dead horses. It has been taken in the Cambridge fens and at Porthcawl, but is apparently absent from the northern counties.

PSILIDÆ.

Shining black or yellow flies of rather elongate build with strongly retreating face.

Loxocera aristata Pz. Widespread but not common by beating whitethorn and other trees near water. August Hesleden (W.).

Psila atra Mg. Uncommon. June. Low Fell (F.).

P. fimetaria L. Common and widespread. May-July. South Durham. Deepdale (W.). Low Fell, abundant on leaves of elder, *Heracleum* and herbage generally. Ravensworth, Waldridge Fell (F.).

P. nigricornis Mg. Widely distributed. Feb.-May. Bishop Auckland, male in greenhouse (W.).

P. nigromaculata Strobl. Widespread but uncommon. July. Low Fell (F.).

P. pallida Fln. Not uncommon. June. Hesleden (W.).

P. rufa Mg. Widely distributed. June, July. Hesleden (W.). Low Fell common, (Fatfield (F.). (Probably *P. obscuritarsis* Lw.)

P. villosula Mg. Uncommon but probably overlooked. August. Hesleden (W.). Apparently most northerly record.

SCIOMYZIDÆ.

Yellow or grey flies with (in the *Tetanocerinæ*) characteristic porrect antennæ. They occur in low vegetation, the

Sciomyzinæ especially in water-meadows where snails, upon which many species are parasitic, abound.

Ditænia cinerella Fln. Common and widespread. June-August. Hesleden (W.).

D. schœnherri Fln. Local. August. Hesleden (W.).

Elgiva albiseta Scop. Widely distributed. July. Hesleden (W.). Ravensworth, not uncommon among rushes near R. Team (F.).

Hydromyia dorsalis F. Common and widespread. August. Hesleden (W.). Low Fell (F.).

Limnia fumigata Scop. (*rufifrons* F.). Widespread. July-August. Hesleden (W.).

Pherbina coryleti Scop. Common and widespread. August. Howick (W.).

Sciomyza albocostata Fln. Widely distributed. June. Hesleden (W.).

S. dorsata Ztt. Not common. July. Bedburn (W.). Apparently most northerly record.

S. scutellaris v. Ros. A rare species. June-July. Low Fell (F.).

S. ventralis Fln. Rare. Feb. Ravensworth, in dead tree stump (F.).

Tetanocera elata F. Common and widespread. July-August. Hesleden (W.). Low Fell, not uncommon. Blanchland (F.).

T. ferruginea Fln. Common and widely distributed. The larva is recorded by Brauer from under leaves of water weeds, *Lemna* and *Callitriche*. June-August. Hesleden (W). Waldridge Fell (F.).

T. lævifrons Lw. Common and widespread. Larva probably aquatic. June, July. Bedburn (W.). Waldridge Fell (F.).

T. sylvatica Mg. Not uncommon. June-August. Hesleden. Bedburn (W.).

T. unicolor Lw. Uncommon but widespread. August. Howick (W.). ? this species.

Trypetoptera punctulata Scop. Common and widespread. August. Hesleden (W.).

DRYOMYZIDÆ.

Dull yellow (or grey, *Actora*) flies easily mistaken for *Helomyzidæ*.

Dryomyza flaveola F. Common and widely distributed. Occurs in shady woods. May-Oct. Bishop Auckland. Harperley, Schull (W.). Low Fell, common, Chopwell, Ebchester (F.).

Helcomyza ustulata Curt. (*Actora æstuum* Mg.). Widespread on the sea shore. July. Hesleden shore (W.).

Neuroctena anilis Fln. Common frequenting moist meadows. June-October. Bishop Auckland, Hesleden (W.). Low Fell, common, Fallodon (F.).

NEOTTIOPHILIDÆ.

A small family containing the genera *Neottiophilum* and *Actenoptera*. The larva of the former lives in the nests of the thrush, blackbird, house sparrow and chaffinch. *Neottiophilum* occurs in Yorks and should occur in Durham.

SAPROMYZIDÆ (LAUXANIIDÆ).

A family of small yellow, grey or black flies found in shady or boggy places, often on grass and herbage in gardens or in woodlands.

Lauxania ænea Fln. Common. The larva is said by Winnertz to live in stems of *Viola*. June-Sept. Hesleden. Waskerley, Bishop Auckland (W.). Low Fell, common (F.). Birtley, on violet (H.).

Lycia affinis Ztt. Widespread. June-August. Low Fell (F.).

L. decempunctata Fln. Common. June-August. Bishop Auckland (W.). Low Fell (F.).

L. pallidiventris Fln. Widespread. July-Sept. Harperley (W.). Low Fell, not uncommon (F.).

L. rorida Fln. Common and widely distributed. June-August. Very common in Durham (W.). Low Fell, common (F.).

Minettia fasciata Fln. Not common. August. Hesleden (W.). Most northerly record.

M. inusta Mg. Widely distributed. June-August. Low Fell (F.).

M. lupulina F. Common. June. Bishop Auckland, Harperley (W.).

Peplomyza litura Mg. Widespread in England. June-Sept. Low Fell, not uncommon. Ravensworth (F.). Most northerly records.

Sapromyza apicalis Lw. Uncommon. July. Bishop Auckland (W.). Most northerly record.

S. obsoleta Fln. Not common. July. Bishop Auckland (W.). Most northerly record.

S. sordida Hal. Widespread in England. July. Low Fell (F.). Most northerly record.

Tricholauxania præusta Fln. Common and widespread. May. Low Fell (F.).

OCHTHIPHILIDÆ.

Grey flies with broad flat frons, and often rows of dark spots on abdomen.

Chamæmyia flavipalpis Hal. Widespread. August. Hesleden (W.).

C. polystigma Mg. Widely distributed. June. Bollihope (W.).

CŒLOPIDÆ.

A small family of maritime flies breeding in seaweed.

Cœlopa pilipes Hal. Uncommon. August. Craster, Howick (W.). Most northerly records. Hesleden shore (W.).

Fucomyia frigida. Fln. Uncommon but widespread. August. Craster (W.).

Orygma luctuosum Mg. Widely distributed. August

HELOMYZIDÆ.

A family of yellowish or brownish flies, some with spotted wings. They occur in shady places, many in the neighbourhood of fungi, while some species of *Leria* are commonly found on carrion.

Helomyza bicolor Ztt. Widely distributed. July-Sept.

Shipley (W.). Low Fell, in fungi (F.).

H. fuscicornis Ztt. Widespread, July. Shipley (W.)

H. hilaris Ztt. Not uncommon. June-Oct. Hesleden Shull (W.). Low Fell (F.).

H. lævifrons Lw. Not uncommon and widespread. April-Sept. Harperley, Shull (W.).

H. pallida Fln. Common and widely distributed. June-Sept. Bishop Auckland (W.). Low Fell, in fungi (F.).

H. similis Mg. Not uncommon. April-August. Wearhead, Harperley (W.).

H. ustulata Mg. Very rare. March-Oct. Bishop Auckland (W.). Low Fell, Ravensworth (F.).

H. variegata Lw. Common and widespread. March-Oct. Hesleden, Bishop Auckland (W.). Low Fell (F.).

Leria modesta Mg. A northern species. June. Low Fell (F.).

L. serrata L. Common and widely distributed, often on windows and in out-buildings. March-August. Bishop Auckland (W.). Low Fell, common (F.).

Morpholeria kerteszii Czerny. Rare. April-August. Hesleden, Harperley (W.). Most northerly records.

Scoliocentra cæsia Mg. Rare. June. Low Fell (F.). Most northerly record.

S. spectabilis Lw. Not common. April. Low Fell (F.). (Probably = *amplicornis* Cz.)

CHIROMYIDÆ.

Small yellow flies, two species of which are commonly found on windows.

Chiromyia flava L. Common. July-August. Bishop Auckland, Newcastle (W.).

CLUSIIDÆ.

Small flies with darkened clouds or patches on wings, to be found running about on rotting timber.

Clusiodes albimana Mg. Widely distributed. While larva and reddish pupa in rotten wood. February. Ravensworth, bred from pupæ under bark (F.).

ANTHOMYZIDÆ.

Small slender flies, found among grass and fen vegetation.

Paranthomyza nitida Mg. Not common. July. Low Fell, several (F.).

OPOMYZIDÆ.

A small family of yellowish flies, some with spotted wings, found on grasses and herbage.

Geomyza (*Balioptera*) *combinata* L. Common and widespread. Larvæ live in stems of herbaceous plants. July, August. Hesleden (W.). Low Fell, Ravensworth (F.).

G. tripunctata Fln. Common and widely distributed. Oct. Bishop Auckland (W.).

Opomyza florum F. Not uncommon by sweeping grasses. August. Hesleden (W.).

O. germinationis L. Common by sweeping herbage. June, July. Common everywhere in Durham (W.). Ravensworth, Low Fell (F.).

DROSOPHILIDÆ.

Small yellow, reddish or brown flies, of sluggish habit, often found on decaying fruit or fungi.

Diastata nebulosa Fln. Widely distributed. Sept. Shull (W.).

Drosophila confusa Staeg. Rare but widespread. June. Gibside. Bishop Auckland (W.).

D. fenestrarum Fln. Common, sometimes in swarms in houses. Larva on vegetable refuse, sawdust, etc. August-Oct. Low Fell, on windows. Gateshead (F.).

D. funebris F. Fairly common. Breeds in jam, wine, beer, decaying fruit, etc. April. Bishop Auckland (W.). Apparently most northerly record.

D. phalerata Mg. Widely distributed. Sept. Low Fell, in fungi (F.).

Scaptomyza tetrasticha Beck. Widespread. Has been bred at Oxford from pupæ in mole's nests. May. Low Fell (F.).

ASTIIDÆ.

Small slender flies with narrow wings, allied to the *Drosophilidæ*, often found on windows. No local species as yet recorded.

BORBORIDÆ.

A family of small and moderate sized flies associated with decaying organic matter, and scavengers in their early stages. Found all the year round, often in swarms, sometimes on windows.

Borborus equinus Fln. Very common. Larva in horse dung. May. Very common in Durham (W.). Middleton-in-Teesdale (F.).

B. geniculatus Mcq. Common, March-June. Hesleden, Bishop Auckland (W.).

B. nitidus Mg. Common. May, June, Oct. Barrasford, decayed fungi. Middleton-in-Teesdale, Low Fell (F.).

B. stercorarius Mg. Common. May. Bishop Auckland (W.).

B. vitripennis Mg. Common. May. Bishop Auckland (W.).

Leptocera fontinalis Fln. Common and widespread. Jan.-March. Bishop Auckland (W.).

L. humida Hal. Common. April. Hesleden (W.).

L. lutosa Stnh. Not uncommon on bare mud at pond edges. April. Gibside. Harperley (W.).

L. vitripennis Ztt. Common in winter and spring. May. Bishop Auckland (W.).

Sphærocera subsultans F. Common in horse dung. April. Harperley (W.).

TETHINIDÆ.

Small grey flies found by the sea coast, most of the species known previously under the generic name *Rhicnoëssa* Lw. No local species found as yet.

CANACEIDÆ.

Small brownish grey flies distinguished from the Ephydridæ by the presence of a cross-vein separating the second basal from the discal cell. Found on the sea coast. No local species found as yet.

EPHYDRIDÆ.

A large family of small and medium sized flies with aquatic larvæ, some said to resemble the rat-tailed larvæ of Syrphids.

Hydrellia griseola Fln. Very common. Larva probably lives in leaves of water plants. May-July. Low Fell, common. Middleton-in-Teesdale (F.).

Notiphila cinerea. Fln. Common and widespread. August. Hesleden (W.).

Parhydra aquila Fln. Widely distributed August. Hesleden (W.).

P. quadripunctata Mg. Widely distributed. July-August. Howick (W.). Ravensworth, common round marshy pond (F.).

CHLOROPIDÆ.

Small rather plump flies with bare arista, usually found in grassy places.

Cetema (*Centor*) *cereris* Fln. Widely distributed. July. Bishop Auckland, Bedburn (W.).

Chloropisca circumdata Mg. Not uncommon, often in swarms in houses in autumn. October. Bishop Auckland (W.). (April). Low Fell, swarming on windows (F.). Seaton Delaval Hall, swarming (K. B. Blackburn). Most northerly records.

Chlorops gracilis Mg. Rare. August. Hesleden (W.). Most northerly record.

C. læta Mg. Rare. August. Hesleden (W.). Most northerly record.

C. nasuta Sch. Rare. July. Bedburn (W.). Most northerly record.

C. puncticollis Staeg. Widely distributed. July. Bishop Auckland (W.).

C. scalaris Mg. Not common. August. Hesleden (W.). Most northerly record.

C. speciosa Mg. Widely distributed. June-August. Waskerley, Harperley (W.). Team Valley (F.).

C. pumilionis Bjert (*tæniopus* Mg.). The "Gout fly." Common and widely spread. Two generations in a year. Larvæ of first attack barley and less often wheat and rye. Second generation on couch grass. Hibernates as larva. August, Hesleden (W.). Vice counties 66, 67, 68, apparently common (H.) (Vasc. 11.29).

Elachyptera cornuta Fln. Common on broom. Has been bred from galls of *Lipara lucens*. April, May, Oct. Very common in Durham, Gibside, Bishop Auckland, Harperley, Belburn (W.).

Lipara lucens Mg. Not uncommon, forming galls on *Phragmites communis*. Norton, on reed, Birtley, larva from *Phalaris arundinacea*. ? this species (H.) Most northerly records.

Meromyza læta Mg. Widespread. July, August. Hesleden (W.).

M. pratorum Mg. Widely distributed. August. Hesleden (W.).

Oscinella frit L. The "Frit fly." Common. Three broods in the year. Winters as larvæ in wild grasses and winter wheat. Spring and summer broods on cereals, commonly on oats. June. Escomb (W.).

AGROMYZIDÆ.

Small flies which carry their wings in a characteristic ʌ-like attitude. Larvæ mainly leaf miners.

Agromyza meijerei Hend. Not common. The larva mines the leaves of laburnum. April. Low Fell, bred (F.).

Liriomyza flaveola Fln. Widespread. Larva on grasses. Aug. Bishop Auckland (W.).

L. lutea Mg. Not common. Ecology unknown. August. Hesleden (W.) Most northerly record.

L. pusilla Mg. Widely distributed. June. Larva mines leaves of *Hieracium* and *Sonchus*. Bishop Auckland (W.).

Napomyza elegans Mg. Widespread. June. Bedburn (var. *festiva* Mg.) (W.).

N. lateralis Fln. Common. Mines leaves of *Chrysanthemum*. Aug. Hesleden (W.).

Phytomyza flava Fln. Widely distributed. July. Bishop

Auckland (W.).

P. ilicis Curt. Common and widely distributed, mining leaves of holly. May. Low Fell, bred (F.).

P. notata Mg. Not common. May. Bishop Auckland (W.). Most northerly record.

P. pullula Ztt. Not common. May. Low Fell (F.).

ODINIIDÆ.

A single British genus with two species found about *Polyporus* and wounds on tree trunks. Considered by some authors a subfamily of the *Agromyzidæ*. No local species.

MILICHIIDÆ.

Species allied to *Meoneura,* etc., but with geniculate proboscis. Several species are found in association with ants. No local species as yet.

BRAULIDÆ.

A family with one species, *Braula cœca* Nitz, parasitic on the Hive bee. Not yet recorded for the North of England.

NYCTERIBIIDÆ.

A family of bat parasites with small head, flat tibiæ and five jointed tarsi. None of the species yet recorded from Northumberland and Durham though *Listropoda blasii* Kol. and *Nycteribia hermanni* Leach occur on Yorkshire and *N. latreillei* Leach in Scotland.

HIPPOBOSCIDÆ.

Flat flies with a small head and short legs with large claws. Wings strap-like or wanting. The " Forest fly," *Hippobosca equina* L. is well known in the New Forest.

Melophagus ovinus L. The " Sheep Ked," or " Spider fly." Common on sheep. Vice counties 66, 67, 68 (B.) (Vasculum, 1926, 80).

Ornithomyia avicularia L. Widespread on fowls, thrushes, blackbirds, owls, hawks, starlings, etc. Vice counties 66, 67 (B.).

O. fringillæ Curt. Possibly a form of the last. On robin, greenfinch and yellowhammer. Gibside, Fatfield (B.).

O. lagopodis Sharp. Widespread on the grouse. Vice counties 66, 67, 68. Blanchland (B.).

Oxypterum pallidum Leach. Scarce on the swift. Newcastle district (B.). Most northerly record.

Stenepteryx hirundinis L. Widespread on swallows and martins. Bishop Auckland, Darlington (W.), Dilston, Derwent Valley, Stocksfield (B.).

GASTROPHILIDÆ.

" Bot flies." Hairy bee-like flies with mouth parts usually atrophied. Larva stout and tough skinned. Parasitic on vertebrates in alimentary canal. *G. equi* Cl. and *G. hæmorrhoidalis* L. from their known distribution should occur.

CORDYLURIDÆ.

A family of small and medium sized flies, including the dung flies whose larvæ live in excrement. Many of the species are found in marshy places.

Amaurosoma tibiella Ztt. An uncommon small dark grey fly. May-August. Bishop Auckland (W.). Low Fell (F.).

Cordylura biseta Lw. Rare. May. Low Fell (F.). Most northerly record.

Leptopa filiformis Ztt. Rare. August. Waldridge Fell (F.). Most northerly record.

Norellisoma flavicauda Mg. Not common. May-July. Low Fell, several. Ravensworth (F.). Most northerly records.

N. spinimana Fln. Common and widespread. Larva said by Brauer to have been found in stems of *Rumex aquaticus.* May-August. Hesleden, Wearhead (W.). Gibside, Low Fell (F.).

N. striolata Mg. Not common. May, June. Low Fell, Middleton-in-Teesdale (F.). (The above three names probably represent only one species.)

Parallelomma albipes Fln. Not uncommon and widespread. June, July. Bedburn (W.). Waldridge Fell (F.).

Scatophaga inquinata Mg. Common. May-July. Bishop Auckland (W.).

S. lutaria F. Common and generaly distributed. May-July. Common everywhere in Durham (W.). Low Fell, preying on *Pseudomorellia albolineata* and *Pegohylemyia fugax* (F.).

S. maculipes Ztt. Widespread. May-October. Low Fell, preying on *Melanostoma scalare* (F.).

S. merdaria F. Common and widely distributed. Common in Durham (W.).

S. ordinata Beck. Widely distributed. June. Low Fell, preying on *Pegomyia bicolor* (F.).

S. squalida Mg. Common, especially in hilly districts. April-June. Bedburn, Bishop Auckland, Stanhope, Harperley, Gibside (W.). Low Fell, Middleton-in-Teesdale (F.).

S. stercoraria L. The "Dung fly" par excellence. Extremely abundant. Larva in cow dung. Adults frequent herbage to prey on other insects. March-November. Very common everywhere in Durham (W.). Low Fell (F.). Fallodon (H. B. Herbert).

S. suilla F. Not uncommon. June. Middleton-in-Teesdale (F.).

Spathiophora hydromyzina Fln. Widespread but uncommon. Aug. Hesleden (W.).

ŒSTRIDÆ.

A small family of parasitic flies, allied to the *Gastrophilidæ* with which they are frequently united. The larva of *Oestrus ovis* L. the "Sheep nostril fly" is parasitic in the respiratory passages of the sheep. It should occur in Northumberland and Durham. *Hypoderma bovis* L. and *H. lineatum* Vill. from their known distribution should also occur.

TACHINIDÆ.

An enormous family of parasitic flies, widespread over both hemispheres. Body usually stout, with strong bristles. Wings with first posterior cell nearly or quite closed. Squamæ large, covering the halteres. Arista bare. Larvæ mainly in lepidopterous larvæ, but also in insects of other orders; those of the Sarcophaginæ in decaying animal matter.

TACHININÆ.

Actia crassicornis Mg. Not rare and widespread. July-August. Bishop Auckland, Wearhead (W.).

Bucentes cristata F. Common and widespread. May-July. Belburn Wood, Bishop Auckland, Evenwood (W.). Low Fell (F.).

B. geniculata DeG. Common everywhere. Larva parasitises *Tipula maxima, oleracea* and *paludosa*. August-Sept. Marley Hill, Wearhead, Hesleden, Gibside (W.). Low Fell (F.).

Craspedothrix zonella Ztt (*vivipara* B. and B.). Rare. July. Bishop Auckland (W.). Most northerly record.

Digonochæta setipennis Fln. A northern species. The larva preys on the earwig. (Forficula auricularia). May-July. Bishop Auckland (W.).

Eriothrix rufomaculatus DeG. Common and widespread. July-August. Fond of ragwort. Hesleden (W.).

Ernestia consobrina Mg. Fairly common. August. Hesleden (W.).

E. nemorum Mg. Recorded by Wingate as *rudis* Fln. Fairly common. June-August. Shull, swarming on fir trees at one spot in July, 1902, but nearly all males. Hesleden (W.). Most northerly records.

E. rudis Fln. (*strenua* Mg. of Wingate's list). Our commonest species frequenting flower of *Euphorbia* in woods. June. Bishop Auckland, bred by Mr Greenwell (W.).

Eversmannia ruficauda Ztt. A rare northern species with few records. Ravensworth, bred from pupa in decayed bark (F.).

Exorista glauca Mg. Common and widespread. July, October. Bishop Auckland, Waskerley. Recorded by Wingate as *Parexorista fugax* Rnd. and *grossa.* B and B. (W.).

E. nemea Mg. Common and widely distributed. May-

August. Low Fell, not uncommon (F.).

E. vulgaris Fln. A common parasite of *Abraxas grossulariata* and numerous other lepidoptera. May-August. Bishop Auckland, Harperley (W.). Low Fell (F.).

Gymnochæta viridis Fln. Not uncommon. May. Escomb, Bishop Auckland (W.).

Lydella albisquama Ztt. Rare. Bishop Auckland, one male (Wingate), is the only one seen by Mr. C. J. Wainwright. (*Trans. Ent. Soc.*, 1928, 191.)

L. stabulans Mg. Common. June. Hamsterley (F.). Apparently most northerly record.

Lydina ænea Mg. Not uncommon and widespread. August. Hesleden (W.).

Lypha dubia Fln. Sometimes in great numbers in woods in spring. May. Bishop Auckland (W.).

Micropalpus hæmorrhoidalis Fln. A northern species. July. Shull (W.).

M. vulpinus Fln. Common over heather, etc. July. Hesleden (W.).

Pales pavida Mg. A common parasite of Noctuid moths. August. Bishop Auckland (W.).

Phyllomyia volvulus F. A fairly common species running over leaves with vibrating wings like a black fossorial Hymenopteron. July, August. Hesleden, Gibside (W.). Most northerly records.

Plesina maculata Fln. A species with habits like the last. Widespread, August. Hesleden (W.).

Ptychomyia selecta Mg. Comparatively common in the British Isles. Parasitic on sawflies and Lepidoptera. Bishop Auckland (W.). (Wainwright, *Trans. Ent. Soc.*, 1928, 193.)

Trichopareia seria Mg. A rare species. July. Bishop Auckland (W.).

SARCOPHAGINÆ.

Brachycoma devia Fln. A viviparous species said to devour the brood of species of Bombus. July, August. Hesleden (W.). Ravensworth, males (F.).

Sarcophaga carnaria L. The "Flesh fly." Very common.

August. By far the commonest of the genus in Durham (W.). Hesleden (W.) (*atropos* Mg). Low Fell, common (F.).

S. hæmorrhoidalis Mg. Common, normally breeding in excrement. August. Hesleden (W.).

S. incisilobata Pand. Not uncommon. July. Team Valley, several males (F.).

S. vicina Vill. Not uncommon. June. Low Fell (F.). (Several other species of Sarcophaga should occur).

CALLIPHORINÆ.

Acrophaga alpina Ztt. An uncommon northern species. May, June. Harperley (W.). Low Fell (F.).

Calliphora erythrocephala Mg. The "Blow fly." Common. April-Sept. Abundant everywhere in Durham (W.). Low Fell, abundant, Fatfield, Gateshead (F.).

C. vomitoria L. Ubiquitous. April-September. Not nearly so abundant as the preceding in Durham (W.). Low Fell, abundant, Ravensworth (F.).

Cynomyia mortuorum L. Commoner in the north. June, July. Harperley, Bishop Auckland (W.).

Lucilia cæsar L. The "Green bottle fly." Very common. The commonest of the bright metallic flies and varies much in colour. March-July. Abundant everywhere in Durham, Bishop Auckland (*ruficeps* Mg.) (W.). Low Fell abundant (F.).

L. illustris Mg. Equally common with *cæsar*. June. Low Fell (F.).

L. sericata Mg. The "Sheep maggot fly." Widespread. August. Hesleden (W.).

Melinda coerulea Mg. Common. August. Hesleden (W.).

Onesia aculeata Pand. Common. July. Ravensworth (F.).

O. agilis Mg. Common. May-August. Ravensworth, Low Fell (F.).

The records of *sepulchralis* L. given by Wingate are probably this species, Hesleden, Wearhead, Bishop Auckland.

Phormia grœnlandica Ztt. Common and sometimes abundant. March-October. "This fly was exceedingly common about Bishop Auckland while a small bone-manure factory was going at South Church. I have seen them clinging to the wall of the Clergy House and to the tombstones in the churchyard in solid masses of thousands. Since the factory was closed they have to a large extent disappeared.'' (W.). Low Fell and Gateshead, common, Barrasford (F.).

Pollenia rudis F. The '' Cluster fly.'' Usually abundant in houses, often clustering on windows and walls, frequently in swarms. Larva parasitic on earthworms. Jan.-October. Very common everywhere in Durham and one of the earliest flies to appear (W.). Low Fell, Barrasford, Otterburn, Ravensworth (F.).

P. vespillo F. Usually abundant. August. Wearhead (W.).

MUSCIDÆ.

A very large family of medium sized flies. Eyes of male frequently large and contiguous. Arista of antenna bare or feathery. Wings with 4th longitudinal vein usually straight to margin. Larvæ maggot-like breathing by a pair of tail spiracles, living in decaying animal and vegetable matter or plant tissues.

Acanthiptera inanis Fln. Rare but widespread. Larva in nests of *Vespa vulgaris* and *germanica*. July. Bishop Auckland (W.).

Allœostylus diaphanus Wd. Not uncommon. Males rarer than females. June-October. Bishop Auckland (W.). Low Fell, Ravensworth, on *Mercurialis perennis* (F.).

A. simplex Wd. Rather rare. August-September. Low Fell, on trunks of sycamore, etc. (F.).

Anthomyia pluvialis L. Very common in neighbourhood of water. Males perform aerial dances. Reared in France from the fungus *Hypholoma fascicularis*. Found occasionally in old bird's nests. June, July. Bishop Auckland, Hesleden (W.). Low Fell, common, Ravensworth (F.).

Azelia cilipes Hal. Not common but widespread. Found as far north as Shetland and Orkney. August. Hesleden (W.).

A. aterrima Mg. Not common. May. Bishop Auckland (W.). Most northerly record.

A. macquarti Staeg. Common on Umbelliferæ, sometimes on horse or cow dung. May-Sept. Bishop Auckland (W.). Low Fell, common. Middleton-in-Teesdale (F.).

A. triquetra Wd. Not common on flowers and leaves. May. Stanhope (W.).

A. zetterstedti Rnd. Not uncommon on flowers and foliage, umbellifers, etc. May-August. Hesleden, Bishop Auckland (W.). Low Fell (F.).

Botanophila (*Hylemyia*) *varicolor* Mg. Not common. May, June. Harperley (W.). Low Fell (F.).

Calliophrys riparia Fln. Not uncommon on stones in streams. Larva aquatic, carnivorous, feeding on small worms, larvæ and pupæ of *Pericoma* and watermites. August. Wearhead (W.).

Cœlomyia mollissima Hal. Not uncommon, chiefly in the north of England. Fond of flowers of *Caltha*. Larva in humus. May. Bedburn (W.). Low Fell, common, Middleton-in-Teesdale (F.).

Cœnosia lineatipes Ztt. Widespread. July. Low Fell (F.).

C. rufipalpis Mg. Widely distributed in woods. July. Bishop Auckland (W.).

C. sexnotata Mg. Widely distributed on oaks. June-August. Hesleden, Waskerley, Bishop Auckland (W.). Low Fell (F.).

C. tigrina F. Common, preys on various insects. September. Shull (W.).

C. tricolor Ztt. Not uncommon in marshes, etc. July-August. Bishop Auckland, Hesleden (W.).

Dasyphora cyanella Mg (*Pyrellia lasiophthalma* Mcq.). Common and widespread. April-August. Bishop Auckland, Harperley, Marley Hill (W.). Low Fell (F.).

Delia (Hylemyia) brassicæ Bouche. The '' Cabbage fly.'' Common. Larva attacks cabbage roots. April-June. Bishop Auckland (W.). Low Fell, abundant, on Allium ursinum and Haracleum (F.). Penshaw, in swollen root galls on rape (B.).

D. criniventris Ztt. Not common. Septr. Low Fell (F.).

Apparently most northerly record.

D. intersecta Mg. Not uncommon. May. Bishop Auckland (W.). Low Fell, common on sycamore leaves (F.).

D. trichodactyla Rnd. Common and widespread. Larva damages roots of beans. May. Bishop Auckland (W.).

Drymeia hamata Fln. Common on flowers. A sluggish fly. July, August. Hesleden (W.). Blanchland (F.).

Egle æstiva Mg. Common and widespread. May-July. Bedburn, Bishop Auckland (W.). Middleton-in-Teesdale (F.).

Enoplopteryx ciliatocosta Ztt. Rare on Calluna. April. Shull (W.).

Fannia aërea Ztt. Widespread. May-July. Wynyard (W.). Low Fell (F.).

F. canicularis L. The "Small House fly." Very common. Larva in manure and decaying vegetable matter. May-August. Very abundant in Durham (W.). Bishop Auckland, Evenwood, Hesleden (W.). Low Fell, Gateshead (F.).

F. coracina Lw. Common and widespread. May, Aug., Sept. Shull (W.). Low Fell (F.).

F. glaucescens Ztt. Not common. July. Low Fell (F.).

F. hamata Mcq. Not uncommon. Hovers like a *Syrphus* in shade of trees. May, June. Brancepeth (W.). Low Fell, Waldridge Fell (F.).

F. incisurata Ztt. Not uncommon. Larva in dung. May. Bishop Auckland (W.).

F. manicata Mg. Widespread. Autumn. April, May. Breeding abundantly in the museum macerating tub with *Scatopse notata* and another species of *Fannia* in the autumn of 1904. Bishop Auckland (W.).

F. pretiosa Schin. Rare. June. Low Fell (F.).

F. scalaris F. Common, frequently in or near houses. May-Oct. Bishop Auckland, common (W.).

F. serena Fln. A common outdoor species, occurring everywhere. Has been reared from a nest of *Vespa vulgaris*. May-August. Bishop Auckland (W.). Low Fell (F.).

Fucellia fucorum Fln. Common on sea coast. Larva said to feed on sand fleas. April-August. Hesleden, abundant on the shore about high water mark (W.).

F. maritima Hal. Less common than the last. June-August. Hesleden shore (W.).

Graphomyia maculata Scop. Common and widespread. Fond of Umbelliferæ. Larva carnivorous in vegetable refuse and dung. June-August. Hesleden (W.). Low Fell, common on Heracleum. Blanchland (F.).

Hæmatobia stimulans Mg. Not rare, often about cattle. Females bite. Males rest in the sun. June-August. Bishop Auckland (W.). Team Valley (F.).

Hebecnema nigricolor Fln. Rare but widespread. July August. Low Fell (F.).

H. umbratica Mg. Widespread on flowers and hedges. Larva in humus and dung. May, June. Bishop Auckland, Wearhead (W.). Low Fell (F.).

H. vespertina Fln. Not rare and widespread. May-August. Bishop Auckland (W.). Low Fell (F.).

Helina depuncta Fln. Not uncommon on Umbelliferæ and foliage. July, August. Low Fell (F.). Apparently most northerly record.

H. duplaris Ztt. (nec. Stein.). Not uncommon. August, Sept. Hesleden, Shull (W.).

H. duplicata Mg. Common and widespread. May-August. Hesleden, Wearhead, Shull, Shipley (W.).

H. impuncta Fln. Common. May-September. Bishop Auckland, common (W.). Low Fell, Blanchland (F.).

H. lasiophthalma Mcq. Not uncommon. May-August. Hesleden, Shipley (W.).

H. lucorum Fln. Common. March-September. Bishop Auckland, Escomb, Gibside, Stanhope, Hesleden (W.). Low Fell, Blanchland (F.).

H. marmorata Ztt. Widely distributed. May-August. Wearhead (W.). Low Fell, Blanchland (F.).

H. obscurata Mg. Widespread. Montane in Europe. May. Wynyard (W.).

H. separata Mg. Widespread. June, July. Harperley, Brancepeth, Shull (W.).

Hera longipes Ztt. A montane species not uncommon in Scotland and Northern England. May, June. Wynyard (W.). Forest of Teesdale, Low Fell (F.).

H. variabilis Fln. Also montane. Widespread. June. Harperley (W.). Hamsterley (F.).

Hydrophoria conica Wd. Common on flowers. June, July. Bishop Auckland (W.), Low Fell, Ravensworth (F.).

H. linogrisea Mg. Not common but widespread. April-August. Bishop Auckland (W.). Middleton-in-Teesdale, Low Fell (F.).

Hydrotæa ciliata F. Apparently common and widespread. June, July. Low Fell (F.).

H. dentipes F. Abundant. May-September. Very common in Durham (W.). Low Fell, abundant (F.).

H. irritans Fln. Abundant everywhere. One of the commonest British Diptera especially in warm damp weather. Annoying to horses and man. June-September. Very common in Durham, Waskerley, swarms (W.). Low Fell, abundant, Blanchland (F.).

H. militaris Mg. Tolerably common. August. Low Fell (F.).

H. occulta Mg. Common on flowers and leaves. Fond of flowers of Umbelliferæ. May-August. Bishop Auckland (W.).

H. similise Meade. Often passed over as *dentipes*. Most records from hilly districts. May-July. Low Fell, Blanchland (F.).

Hylemyia nigrimana Mg. Not common but generally distributed. May-August. Stanhope, Bishop Auckland (W.). Low Fell (F.).

H. strigosa F. Common and widely distributed. May-September. Common everywhere in Durham (W.). Middleton-in-Teesdale, Low Fell, Fallodon, Ravensworth, Blanchland (F.).

H. variata Fln. Abundant. A viviparous fly. May-September. Hesleden, Shull (W.). Middleton-in-Teesdale (F.).

Hylemyza lasciva Ztt. Not uncommon and widespread.

June. Low Fell (F.).

Lasiops semicinereus Wd. Common and widespread. June-Oct. Bedburn (W.). Low Fell, common, Ravensworth (F.).

Leptohylemyia coarctata Fln. The "Wheat bulb fly." Common. Larvæ destroy young wheat. August. Hesleden (W.).

Lispocephala alma Mg. Rare. Added to British list by Wingate on a male from Escomb, April 1898.

Lophosceles cristatus Ztt. (*pulcher* Meade). A northern species. Not common. July-August. Wearhead (W.).

Macrorchis intermedia Fln. Widely distributed. June, July. Bishop Auckland, Harperley, Shull, Bedburn (W.). Ravensworth, Low Fell, Blanchland (F.).

M. meditata Fln. Not common. Larva in humus. June-August. Wearhead. Bishop Auckland (W.).

Melinia pullula Ztt. Not common. August. Hesleden (W.). Apparently most northerly record.

Mesembrina meridiana L. Common. Fond of basking in the sun on stones and tree trunks. Larva in dung. May-October. "Common throughout the summer. It is often to be seen sitting on footpaths, flying off as one approaches, and alighting a few yards further on." Hesleden, Belburn, Marley Hill, Wearhead (W.). Middleton-in-Teesdale, Low Fell, common, Ravensworth, Team Valley (F.).

Morellia hortorum Fln. Common. Fond of Umbelliferæ. July-September. Hesleden, Wearhead (W.), Low Fell, Waldridge Fell (F.).

M. simplex Lw. Common and widespread. Common everywhere in Durham (W.).

Musca autumnalis DeG. Common. Often hibernating in houses in winter. Frequently recorded as the prey of Fossors, Asilids and *Scatophaga*. May. Darlington Park, males abundant on the seats near the pond (W.).

M. domestica L. The very abundant "House fly." Larva in manure, etc. July-October. Very common in houses in Durham, Bishop Auckland, Hesleden (W.). Low Fell, abundant (F.).