Department of Agriculture and Technical Instruction for Ireland.

MEMOIRS OF THE GEOLOGICAL SURVEY OF IRELAND.

THE INTERBASALTIC ROCKS

(IRON ORES AND BAUXITES)

OF

NORTH-EAST IRELAND.

BY

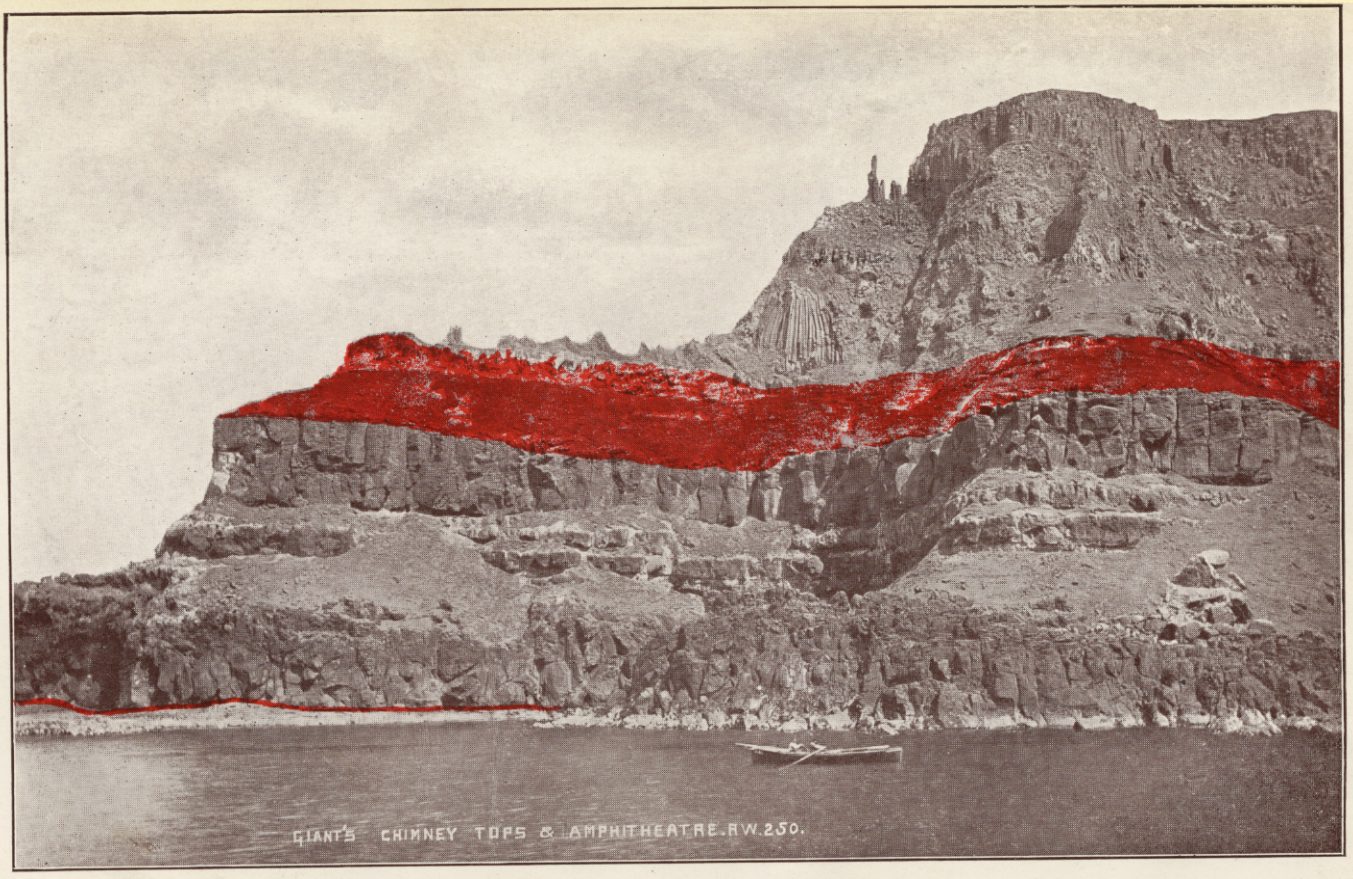
G. A. J. COLE, F.G.S.; S. B. WILKINSON; ALEXR. M'HENRY, M.R.I.A.; J. R. KILROE, A.R.C.Sc.I.; H. J. SEYMOUR, B.A., F.G.S.; C. E. MOSS, D.Sc.; AND W. D. HAIGH, A.R.C.Sc.I.

Published by Order of the Lords Commissioners of His Majesty's Treasury.

DUBLIN:
PRINTED FOR HIS MAJESTY'S STATIONERY OFFICE,
BY BROWNE & NOLAN, LTD., NASSAU STREET.

And to be purchased from
E. STANFORD, 12, 13 and 14 LONG ACRE, LONDON;
W. & A. K. JOHNSTON, LTD., 2 ST. ANDREW SQUARE, EDINBURGH;
HODGES, FIGGIS & CO., LTD., GRAFTON ST., DUBLIN.
From any Agent for the sale of Ordnance Survey Maps, or through any Bookseller from
T. FISHER UNWIN, 1 ADELPHI TERRACE, LONDON, W.C.,
who is the sole Wholesale Agent to the Trade outside the County of London.

1912.



Frontispiece.]

PLATE I.—CLIFF EAST OF THE GIANT'S CAUSEWAY, CO. ANTRIM.

The main Interbasaltic zone is coloured red, and a small similar zone in the Lower Basalts appears along the beach-level.
From a photograph by Mr. R. Welch.

PREFACE.

NUMEROUS references to the interbasaltic beds of northern Ireland occur in the previously published Memoirs of the Geological Survey. At the time, however, that these were written, the aluminium industry had not developed, and the analogy between many red laterites and the material known as bauxite had not been generally realised. The growing demand for iron ores has also made it desirable to reconsider those of northern Ireland, and the Geologists of the Survey, in 1907 and 1908, examined in detail the horizon where such ores are already worked, or where they may be expected to occur. The results are represented on the maps accompanying the present Memoir, which may be taken as replacing the hand-coloured geological maps of the same areas, so far as the interbasaltic beds are concerned.

The principles on which the revision of the interbasaltic series was undertaken will be best explained by the following extracts from a circular letter issued to the Geologists on 1st June, 1907 :—

"(i) The interbasaltic beds occur at various horizons, but mainly in a zone representing a presumably prolonged epoch of repose between two epochs of considerable volcanic activity.

(ii) The attention of the Geologists will mainly be given to this zone, marked by beds of iron ore, bauxite, and deep decomposition of the underlying basalt.

(iii) The recent and numerous observations on laterite in various countries show that many of the red beds hitherto classed as iron ores contain sufficient aluminium hydrate to render them, now or at some future date, of value as ores of aluminium.

(iv) The source of these beds may in some cases be found in the underlying basalts, in other cases in material brought from some distance and accumulated in lakes. The formation of laterite in tropical climates as a surface-crust, and possibly in connexion with alternating dry and rainy seasons, should not be lost sight of, even in cases where the lacustrine view has been put forward.

(v) In Co. Antrim local eruptions of rhyolite occurred in the comparatively quiet interval. Pebbles from these centres of activity may be found in interbasaltic beds, and are already known from the Glenarm area.

(vi) The mode of decomposition of these rhyolites makes it probable that the light-coloured bauxites were derived from similar lavas poor in iron.

(vii) Plant-beds are well-known in certain places. Remains of land-molluscs or other animals would be of great assistance, if discoverable. The interbasaltic beds are the only guides we possess in determining the geological age and duration of the eruptive period.

(viii) Local records of rumours of "coal" having been raised in this or that spot are common in the north of Ireland.

These should be investigated, as they may lead to the discovery of new beds of lignite; hence also of new laterite or bauxite layers.

(ix) The amount of exploration among the iron-ores and bauxites since the original geological maps and memoirs were prepared is already known to have thrown new light on the area occupied by these deposits; hence a revision of boundaries and the tracing of new ones may be necessary.

(x) But, on the whole, the present examination will be mainly concerned with the vertical series of deposits present at any point. The history and succession of the beds in the locality may then be traceable, as well as their horizon in the great basaltic series."

While no general revision of the volcanic region seemed necessary, the relations of the Upper to the Lower Basaltic Series naturally affect the question as to where the iron ore zone is likely to occur. Mr. J. R. Kilroe believes that the Upper Basalt may have a westerly extension, as was also suggested by Mr. Egan for the district of Benevenagh. Mr. Kilroe's views on this matter are stated in an appendix.

From the point of view of the geological history of Ireland, the main interbasaltic zone, with its plant-beds and contemporaneous eruptions of rhyolite, offers features of peculiar interest. The Survey has obtained from Dr. C. E. Moss, of the University of Cambridge, a review of the evidence afforded by the flora, so far as known. The cautious attitude adopted in this chapter will be appreciated even by those who are more hopeful than Dr. Moss of the results of studies among Cainozoic plant-remains. Thanks are due to the Council of the Belfast Natural History and Philosophical Society, and to Mr. William Swanston, F.G.S., for the loan of valuable specimens.

In Chapter VII. sixty-four analyses of materials from the interbasaltic zone have been brought together from widely-scattered sources. Other analyses probably exist, as is shown by the publication of some of these in the first instance in France and Germany. These analyses, though they vary in importance, will serve for comparison with those of similar materials worked in Europe, Asia, and America. This comparison has been facilitated by information as to the Indian ores, kindly given by Sir T. H. Holland, F.R.S., late Director of the Geological Survey of India, when on a visit to Ireland in 1906.

Mr. James Strachan, of Ballyclare, Analyst and Microscopist to the North of Ireland Paper Mill Company, has made detailed studies of the Antrim volcanic series, and has been so good as to furnish many useful suggestions, especially as to the part played by bacteria in the precipitation of iron ores from solution in natural waters.

Plates II.—VI. are from photographs by Prof. H. J. Seymour.

GRENVILLE A. J. COLE,
Director.

DUBLIN, *February*, 1912.

TABLE OF CONTENTS.

LIST OF ILLUSTRATIONS.

FIGURES IN TEXT.

THE INTERBASALTIC ROCKS
(IRON ORES AND BAUXITES)
OF
NORTH-EAST IRELAND.

CHAPTER I.

THE NATURE AND ORIGINS OF THE INTERBASALTIC BEDS OF NORTHERN IRELAND.

By Grenville A. J. Cole.

PROGRESS OF OBSERVATION ON THE INTERBASALTIC ZONE.

The occurrence of a zone of apparently stratified rock in the midst of the basaltic series of northern Ireland was fully apparent to the early visitors to the Giant's Causeway. The bright red colouring of the band half-way up the cliffs, in contrast with the brown and black joint-faces of the basaltic lavas, at once attracts interest and attention. In recent years the excavation of a path along the red zone has made it more accessible, and the separation of the basalts into an upper series of massive columnar lavas and a lower series of thinner flows is impressed upon everyone who walks eastward from the Causeway.

Though seams of red or ochreous clay occur at various levels in the Lower Basaltic series, it became gradually realised that these materials were mainly developed during a particular epoch, when the volcanic activity that gave rise to the basalts of northern Ireland died down for a time, and a broad surface of lavas became exposed to weathering. The beds of the red zone were known at an early date to include the argillaceous rock called "lithomarga"* or lithomarge, and the zone itself was traced over a wide area, from west of the Giant's Causeway to Glenarm and Island Magee.†

In 1843, attention was called by Mr. Crommelin, of Newtown Crommelin, to the iron ore of his district, and in 1861 Dr. Ritchie mined as an aluminous flux the fragmental iron ore of Ballypalady. In 1873 or 1874, through Mr. Walter Jameson,‡

* G. V. Sampson, "Memoir of the Chart and Survey of Londonderry" (1814), p. 103.

† An interesting account of the development of the iron-mining industry in Antrim is given by J. F. Hodges, Proc. Belfast Nat. Hist. and Phil. Soc., 1876, pp. 1-8, and Appendix to Geol. Surv. Mem. to sheets 21, 28, and 29, p. 47.

‡ See G. H. Kinahan, "Iron Ore Measures of Co. Antrim," Trans. Manch. Geol. Soc., vol. xxii. (1893), p. 458; and "Antrim Alumyte," *ibid.*, vol. xxiii. (1895), p. 165. See also Kinahan, "Additional Notes on Aluminium and its Ores," *ibid.*, p. 172.

certain pale grey or greyish brown deposits, found here and there above the iron ore, came into notice, as containing far more alumina and less silica than ordinary clays. These were compared aptly with the bauxites of Les Baux and other localities in the south of France, and were used, under the name of "alum-clay" or "alumite," for the production of alum. Still later, the development of the aluminium industry led to the use of some of these materials as aluminium ores; but so far it seems to be found more economical to prepare alumina from French bauxite in the works that were established at Larne for the exploitation of the Irish rock.

Lignites and plant-beds were observed on the same horizon as these interesting deposits, and have given rise to many stories of the discovery of coal in northern Ireland. A succession of observations has shown, moreover, that eruptions of rhyolite, long ago described by Richardson, J. F. Berger and others,* occurred during the epoch of comparative rest. The horizon of these rhyolites was correctly recognised by Sir R. Griffith † so far back as 1836, when he stated that the porphyry of Sandy Braes was formed "in the series of epochs between the lower and upper tabular traps."

It would accord with views prevalent among petrologists if it could be urged that the basalts and rhyolites of northern Ireland, and hence also the gabbro of Carlingford and the granite of the Mournes, originated by differentiation in a common cauldron. We must, however, be content to state, as Whitman Cross ‡ has done for a similar sequence in Hawaii, that there is as yet no evidence in favour of such a supposition.

The mode of origin of the interbasaltic beds of northern Ireland has been a matter of much discussion, and it has become necessary to revert in recent years to opinions held by observers at the opening of the nineteenth century. Faujas de Saint-Fond § was one of the first to note how basalt may pass by decomposition into red bole or grey clay. He found a clay, with all the structure of basalt, on "Mezinc" (Mézenc) Mountain, south of Fay-le-froid in the Cevennes; this clay adhered to the tongue and was easily sectile. Saint-Fond thus enables us to trace the connexion between lithomarge and basalt, the passage taking place *in situ* on the surface of the flow. He also refers to an observation by Sir William Hamilton in 1771 ‖ as to the production of a white earth from basalt, through the influence of the

* W. Richardson, "On the Alterations . . . in the Structure of Rocks," etc. Phil. Trans., 1808, p. 211; Berger and Conybeare, "Geological Features of N.E. Counties of Ireland," Trans. Geol. Soc. Lond., vol. iii. (1816), p. 109.

† Address, Journ. Geol. Soc. Dublin, vol. i., p. 158.

‡ Journ. of Geol., vol. xii. (1904), p. 520.

§ "Recherches sur les volcans éteints du Vivarais et du Velay" (1778), pp. 196-7.

‖ Phil. Trans., 1771, 5th May.

solfatara of Pozzuoli. The Rev. William Hamilton,* who courageously supported Desmarest's view of the volcanic origin of the Antrim basalts, wrote that "an extensive tribe of clays" arise from their decomposition; but he was attracted to the idea that the ochre beds had resulted from the igneous alteration of a ferruginous earth. His opponent, the Rev. W. Richardson, claimed to be not a Neptunian nor a Vulcanist nor a Plutonist;† but his views on basalt decidedly helped the Neptunian cause. He maintained, however, justly that the red strata had "been once pure basalt," stating this in an unpublished memoir read before the Royal Society of Edinburgh, and again in 1803.‡ Richardson became much interested in the interbasaltic beds,§ and in his "Letter on Zeolite and Ochre"‖ denies that the ochres are tuffs, and makes the important statement that "we find this ochreous substance in its natural situation, in every intermediate stage between sound blue basalt, and ochre red as minium; and we see that the passage from one extreme to the other is by shades perfectly insensible." On p. 15 he says, "we frequently find specimens composed of sound basalt and ochre mixed." But he does not like to assign the change to any specified cause, or to assert that it is still in progress.

Sir R. Griffith¶ made an important step in the discussion in 1836. At the Bull's Eye, Glenarm Park, he came upon "ochreous strata," which he referred to the alteration of quite another type of igneous rock than the basalts of the area. He observes that they "occasionally contain small crystals of quartz in double six-sided pyramids, and bear a strong resemblance to the decomposed clay porphyry of Sandy Brea." He held that "the ochre-beds probably originated in the projection of volcanic ashes from a submarine volcano, and the clay beds, sandstone, and wood coal were deposited among them at the bottom of the sea during the interval of the great eruptions of perfectly fused lava." Agreeing probably with Hamilton's suggestion that igneous alteration should be invoked, Griffith (p. 159) regarded the lithomarge beds of the Giant's Causeway area as fused or partially fused representatives of the Sandy Braes porphyry, which he rightly placed in the interbasaltic zone.

Here, then, a certain confusion was set up by the introduction of new and singularly acute ideas. J. E. Portlock** wisely disregarded, or remained unaware of, Griffith's suggestion of a rhyolitic origin for the red zone on the Causeway cliffs. He

* "Letters concerning the Northern Coast of the County of Antrim" (1790), Letter V.

† "Account of the Peninsula of Portrush"; Pamphlet, n.d.; Newry (?),1815 (?).

‡ "Inquiry into the consistency of Dr. Hutton's Theory," etc., Trans. R. Irish Acad., vol. ix. (1803), p. 458.

§ "On the Alterations . . . . in the Structure of Rocks," etc., Phil. Trans., 1808, pp. 195 and 200.

‖ In J. Dubourdieu, "Statistical Survey of the County of Antrim" (1812), Appendix I., p. 11.

¶ Address, Journ. G. S. Dublin, vol. i., p. 158.

** "Report on the Geol. of Londonderry," etc., Ordnance Survey, 1843.

regarded the bole in the east of Co. Londonderry (*op. cit.*, p. 145) as resulting from the induration of an alteration-product of the amygdaloids, and stated that "it is impossible not to see a passage in the one case, from the hard rock to the soft by decomposition, and in the other, from the soft to the hard by igneous induration; and thus to obtain a demonstration that not only the flows of basalt were successive and distinct, but also that a considerable time must have elapsed between each. It may be reasonably conjectured that some of the amygdaloidal beds were originally poured out rather in the state of volcanic mud than of lava; and that their induration and vesicular character were due to the action of the succeeding flow of basalt."

The jasperoid character of some of the layers seems to have influenced Portlock, and others in later times, towards the view that the bole beds had been baked by igneous action; and we must remember that little was known at that time as to the accumulation of silica at the surface in tropical climates by the evaporation of waters rising from below. Portlock (*op. cit.*, pp. 688-9) added the remarkable observation that a large amount of alumina might occur "in a free or soluble state" in soils derived from the Irish basalt. He does not state the acid that he employed, but he quotes a soil from the "tabular trap" of Tirnageeragh, in the parish of Maghera, as yielding 8·9 per cent. of "soluble" alumina.

About 1860, as previously remarked, attention was called to the interbasaltic zone by the development of iron mining in the County of Antrim. G. V. Du Noyer, of the Geological Survey, is said by Tate and Holden (see below, p. 155 of the work cited) to have maintained an aqueous and conglomeratic origin for the iron-ore of Island Magee before the Belfast Natural History and Philosophical Society in 1868. John Kelly,* however, in 1869, described the deposits as "volcanic ashes thrown up in the eruption, and disseminated in the water, making literally a red sea." He rediscovered Griffith's bipyramidal quartz crystals in the red zone near Glenarm (*op. cit.*, p. 303). In December of the same year, R. Tate and J. S. Holden† produced a concise but admirable account of the interbasaltic iron ores, which remains to this day the best contribution to an understanding of their mode of occurrence and petrology.

Tate and Holden distinguished an upper bed of pisolitic iron-ore from the massive ochre and lithomarge below. They traced the gradation of the lithomarge downward "into a basalt exhibiting concretionary structure, the outer coats not distinguishable from the lithomarge, while the kernel is a compact

* "On the Geology of the County of Antrim," etc., Proc. R. Irish Acad., vol. x. (1869), p. 307.

† "On the Iron-ores associated with the Basalts of the North-east of Ireland," Quart. Journ. Geol. Soc. London, vol. xxvi. (1870), p. 151.

basalt." On p. 155 they state that " the passage from basalt to lithomarge and bole can be traced in all cases ; not unfrequently large masses of basalt are to be seen in the midst of the lithomarge, the concentric layers presenting all the varieties of texture and colour between the hard and black basalt of the interior and the purple or yellowish argillaceous masses in which the basalt appears to be imbedded. Again, the boles often contain cavities filled with the ordinary zeolites of the amygdaloid basalts." The authors were probably in error in believing that some of the softer boles had been formed after the overlying flows had been erupted, while the harder ones and the pisolitic layer were due to contact-action from the later lavas (pp. 156 and 158). They urged that the decomposition of the lower basalts, giving rise to iron ores rich in alumina, took place under the waters of a lake, in which the associated plant-remains accumulated. Sir W. W. Smyth, in the discussion on this important paper, emphasised the aluminous character of the ores. None of the ores, however, quoted by the authors yielded more than 4·20 of alumina " soluble in acids " (p. 59); but it was pointed out that Percy had already shown that the Ballypalady ore contained some 30 per cent. of alumina, with less than 10 per cent. of silica (see analyses LIX. and LX. in the present Memoir).

The insistence on " metamorphic " action as a cause for the pisolitic ore probably obscured the remarkable merits of Tate and Holden's paper. Their views agreed, so far as the origin of the red beds was concerned, with those of the Neptunian Richardson in 1803, and as regards the induration of the deposits with those of William Hamilton in 1790. Portlock, on the other hand, had suggested mudflows to account for the appearances of stratification, while Kelly had styled the red beds " volcanic ashes." The officers of the Geological Survey reported on Ballypalady and Island Magee in 1876,* and a geological map of the Island Magee beds was published on the scale of six inches to one mile. In subsequent memoirs† the interbasaltic beds were generally regarded as of explosive origin, while the pisolitic ore was held to be derived from them in the waters of a lake. The round unaltered masses of basalt became unfortunately described as bombs, and earlier arguments on the subject appear to have been set aside.

E. Hull, who was probably the first to examine the interbasaltic rocks in sections under the microscope, adopted the fragmental and lacustrine view in 1874,‡ and his opinions, adverse to Tate and Holden, are naturally reflected in the publications of the Survey above referred to. The fact that

* Mem. to Sheets 21, 28, and 29 (1876), pp. 23 and 28.

† To Sheets 7 and 8 (1888), Causeway area ; to Sheet 14 (1886), Red Bay and Carnlough, pp. 20 and 22 ; and to Sheet 20 (1886), Ballymena and Glenarm area, p. 11.

‡ Address, Rep. Brit. Assoc., Belfast, 1874, Trans., p. 69.

the first iron ore worked successfully was that of Ballypalady, where the material is certainly of explosive origin, no doubt led to the reference of other ores to the same type of material. Pisolitic iron ore, moreover, is still forming in Lough Neagh,* and furnishes an interesting local example of lacustrine deposition.

William Gray's paper on Antrim bauxite, read before the Belfast Naturalists' Field Club in 1879,† does not appear to have been published.

Philip Argall‡ read an important paper in 1881 on the Glenariff ores, accepting them as allies of the Indian laterites, and expressing some hesitation as to the lacustrine theory of their origin. The history of the comparison with laterite is dealt with in the succeeding section of this chapter.

COMPARISON OF THE INTERBASALTIC ROCKS OF IRELAND WITH SIMILAR MATERIALS IN OTHER REGIONS.

In 1873 certain lateritic formations of India had been described in detail by R. B. Foote,§ and in 1878 G. H. Kinahan,‖ of the Irish Survey, remarked that some of the lithomarges of the County of Antrim were identical with laterites brought by A. B. Wynne from Kutch. F. R. Mallet¶ interestingly developed this comparison during a visit to the Antrim deposits. In opposition to Tate and Holden, he adopted the lacustrine view of their origin, and applied this to the explanation of the Indian laterites. He maintained that the acids from the decaying vegetation, as in so many accepted cases, had helped to accumulate the iron by leaching it out into pools from the surrounding rocks.

The interbasaltic ores of Ireland became still better known on the completion of G. H. Kinahan's "Economic Geology of Ireland."** On pp. 65-67 a general account is given, which is unfortunately in great need of proof-correction, as is also the analysis quoted from Argall on p. 122.

Kinahan also drew attention to the ores in 1884 and 1893, and a number of papers, including new analyses, followed.††

* G. C. Gough, Irish Naturalist, vol. xiii. (1904), p. 87.

† Proc. B. N. F. C., vol. i., p. 359.

‡ "Tertiary Iron Ore Measures, Glenariff Valley, County Antrim," Journ. R. Geol. Soc. Ireland, vol. vi. (1886), p. 98; and Sci. Proc. R. Dublin Soc., vol. iii. (1883), p. 151.

§ "Geol. of parts of the Madras and N. Arcot Districts," Mem. Geol. Surv. India, vol. x. (1873), pp. 27-58. The name laterite is derived from *later*, a brick. For a full description of Indian laterite, see "Geology of India," Geol. Surv. India, ed. 2 (1893), pp. 369-390.

‖ "Manual of Geol. of Ireland," p. 163.

¶ "On the Ferruginous Beds Associated with the Basaltic Rocks of North-eastern Ulster, in Relation to Indian Laterite," Rec. Geol. Surv. India, vol. xiv. (1881), p. 139.

** Journ. R. Geol. Soc. Ireland, vol. viii. (1885-9). Also in Sci. Proc. R. Dublin Soc., vol. iv. (1885), p. 310.

†† G. H. Kinahan, "Notes on Irish crystalline Iron Ores," Journ. R. Geol. Soc. Ireland, vol. vi. (1886), p. 306; and Trans. Manch. Geol. Soc., vol. xxii. (1892-4), p. 458. C. H. Williams, "Practical Notes on the Mining of Iron Ores, Bauxite,

Kinahan made the singular suggestion that the pisolitic iron ores occupy a shrinkage fissure, due to drying away of the lithomarge from the base of the lava-sheet above. He regarded the lithomarge as lacustrine.

Sir A. Geikie* in 1892 had recorded A. McHenry's discovery of rhyolite pebbles in the interbasaltic series of Glenarm, and this additional evidence of the age of the rhyolites was confirmed and extended by A. McHenry himself in 1895.† The Mourne granite was now correlated with the rhyolitic intrusions farther north, and has therefore considerable interest when we review the interbasaltic series.

The present writer‡ considered the relations between the rhyolites and the pale-coloured bauxites in 1895. He was not then aware of the remarkable generalisation made on this point by Griffith in 1836. He argued that the white bauxite of Glenarm (*op. cit.*, p. 106), with a specific gravity of 2·42, closely resembled the white ground of McHenry's conglomerate from the Libbert Mine, while it also resembled that of the decomposing rhyolite of Scolboa in the Tardree area. He suggested that acid vapours, during a solfataric stage of the eruptions, brought the alumina into solution by breaking up the silicates. Waters charged with alkaline carbonates would naturally arise at the same time in a rhyolitic area, and these would precipitate aluminium hydrate from the soluble aluminium salts, possibly through the intermediate unstable form of hydrous aluminium carbonate. The silica set free would pass off in such waters in solution.

C. W. Hayes§ made a similar suggestion in regard to the bauxite of Georgia and Alabama. Hayes held that sulphuric acid from decomposing pyrite had brought up the alumina in solution from certain shales, and that calcium carbonate had led to its precipitation. The formation of aluminium sulphate has been also put forward by later writers to explain the accumulation of the hydrate. It is unnecessary, however, to review the various theories that have been held, now that they have been so ably brought together by F. W. Clarke.‖ Clarke regards the suggestion of the intervention of sulphuric acid with some favour, owing to the presence of sulphates in association with bauxites and kaolins in certain cases.** E. C.

etc., of County Antrim," *ibid.*, p. 518. W. Peile, "Notes and Analyses of Iron Ores and Bauxite from the Crommelin Mines, Co. Antrim," *ibid.*, p. 522. G. G. Blackwell, "Notes on Bauxite of Co. Antrim and its Uses in the Manufacture," *ibid.*, p. 525.

* Ann. Address, Quart. Journ. Geol. Soc. London, vol. xlviii., Proc., p. 168.

† "On the Age of the Trachytic Rocks (Rhyolites) of Antrim," Geol. Mag., 1895, p. 260.

‡ G. A. J. Cole, "The Rhyolites of the County of Antrim; with a note on Bauxite," Sci. Trans. R. Dublin Soc., vol. vi. (1895), p. 77.

§ "Mineral Resources, Bauxite," 16th Ann. Rep. U. S. Geol. Surv. (1895), pp. 589 and 590.

‖ "The Data of Geochemistry," Bull. 330, U. S. Geol. Surv. (1908), pp. 417-424. See also G. C. Dubois, Tscherm. Mitt., Bd. xxii. (1903), p. 4.

** See, for example, Ransome on the derivation of alunite by the action of

Sullivan* notes that an acid solution, such as sulphuric acid, dissolves from orthoclase felspar a relatively large amount of aluminium, as compared with the more nearly neutral salt solutions, which remove chiefly the alkali metals. S. Passarge† has invoked the nitric acid of the atmosphere as an agent in the production of laterite (that is to say, ferruginous bauxite); while E. Kaiser‡ believes that carbonic acid may act on felspar so as to leave a hydrous aluminium silicate from which aluminium hydrate is deposited in alkaline waters.

H. Warth§ re-stated the problem when he showed how differently dolerite weathers in temperate climates and in the tropics.

M. Maclaren,‖ in a critical paper on Indian laterites, urges the potency of alternate wetting and drying of the parent rock, and of carbonic acid as an agent whereby the silicates are broken up. His view (p. 546) that hydration rather than dehydration goes on among the aluminous products may, however, be contested as a general proposition. J. R. Kilroe¶ furnishes a valuable review of the laterite question, and also accepts carbonic acid as a probable agent. He is influenced in his arguments by his belief that the German ores accumulated under temperate climatic conditions, which is by no means certain. F. P. Mennell,** commenting on Kilroe's paper, maintains the efficacy of tropical conditions of climate with alternating wet and dry seasons.

It is now, at any rate, unnecessary to discuss the efficiency of an acid emanation on a local scale in accounting for the production of laterite and bauxite. Despite the favour with which the idea of solfataric action has been received, the phenomena of laterisation are so widely spread as to demand a broader explanation.

Returning to the interbasaltic zone of Antrim, it is interesting to note that G. H. Kinahan,†† in 1895, when he sketched the history of the mining of aluminium ores in Ireland, predicted a great future, not only for the aluminous bole, but for the similar laterites of India and America.

The present writer, in various visits to the County of Antrim with classes from the Royal College of Science, became impressed

sulphuric acid on rhyolites and dacites, Prof. Paper 66, U. S. Geol. Surv. (1909), p. 176, etc. Also G. C. Dubois, Tscherm. Mitt., 1903, p. 4; and C. W. Hayes, on the Gila River alum deposits (Contrib. to Econ. Geol., U. S. Geol. Survey, 1906, p. 223). Hayes points out, in opposition to W. P. Blake, that the residual product from the action of the sulphuric acid on basalt is kaolin and not bauxite.

* "The interaction between minerals and water solutions," Bull. 312, U. S. Geol. Surv. (1907), p. 50.

† Compte Rendu, 6th Internat. Geol. Congress, London (1895), p. 671.

‡ "Ueber Bauxit-und Lateritartige Zersetzungsprodukte," Zeitsch. d. deutsch. geol. Gesell., Bd. lvi. (1904), Protokolle, p. 21.

§ "Weathered Dolerite of Rowley Regis compared with Laterite," Geol. Mag., 1905, p. 21.

‖ "On the Origin of certain Laterites," Geol. Mag., 1906, p. 536.

¶ "Laterite and Bauxite in the Vogelsberg," Geol. Mag., 1908, p. 534.

** "On Rhodesian Laterite," Geol. Mag., 1909, p. 350.

†† "Additional Notes on Aluminium and its Ores," Trans. Manch. Geol. Soc., vol. xxiii. (1895), p. 172.

with the evidence of deep decomposition of the basaltic rock *in situ*, and was led to adopt the views of Richardson, as against those who detected bombs and stratified ash-beds in the red zone of the Giant's Causeway. He was much strengthened in this conclusion by correspondence with Sir T. H. Holland, Director of the Geological Survey of India, who examined the Antrim series in 1906, and who at once compared the alleged volcanic bombs with the blocks of undecomposed rock found in the Indian laterites. At this time the literature of laterite was growing rapidly, and the position of laterite as a ferruginous bauxite became well established. F. R. Mallet* stated in 1883 that a pisolitic laterite in Jabalpur contained so large a proportion of alumina that it would serve well as a flux. Holland† records that H. Warth showed, in 1893, that a laterite of the Palni Hills, in the Madras Presidency, was a bauxite with 60 per cent. of alumina. This result was, however, not published at the time.‡ Holland (p. 62) associates the calcareous masses known as kunkar with the processes that give rise to bauxite or laterite.§ If running water were to carry off the calcium carbonate, the residue would be a laterite. Kunkar, in fact, occurs where running water is deficient, and laterite where it is available. There is a general tendency (p. 65) for dehydration to occur in laterite ; the high-level material in India, when newly formed, is a soft yellow limonite, which can be cut with a spade. On exposure it becomes hard and red-brown. The low-level laterite, washed down from it and re-cemented, is a dehydrated representative. The gibbsite ($Al_2 O_3 . 3 H_2O$) formed in the laterite similarly passes into diaspore ($Al_2 O . H_2O$), while göthite (p. 67) and even hæmatite at the same time crystallise in the mass.‖ Holland (p. 69) regards limonite and gibbsite as unstable at tropical temperatures, and ferric hydrate as a possible catalyser which helps the gibbsite to part with water.

The remarkable process, however, by which aluminium silicates pass, not into kaolin, but into aluminium hydrate during laterisation, with removal of silica in solution, presents to Holland an unsolved problem. He is unwilling to ascribe the change to tropical temperature and moisture, seeing that sufficiently similar conditions prevail in this respect (p. 63) in the Himalayan foothills, where laterite is not being formed, and in the Nilgiris, where it is abundant. He therefore suggests the presence of an organism, which might thrive in the slightly warmer climate of the Nilgiris, though unable to multiply farther

* Rec. Geol. Surv. India, vol. xvi., p. 113.

† "On the constitution, origin, and dehydration of laterite," Geol. Mag., 1903, p. 59.

‡ H. and F. J. Warth published this and a large series of analyses in a paper "On the Composition of Indian Laterite," Geol. Mag., 1903, p. 154. See also *ibid.*, 1905, p. 21.

§ On kunkar compare H. B. Muff, Rep. Geol. E. Africa Protectorate, Colonial Reps., Miscellaneous, No. 45 (1908), p. 23.

‖ On Indian gibbsite, etc., see Fermor, Rec. Geol. Surv. India, vol. xxxiv. (1906), p. 167.

north. This problematic organism requires silica, which it separates from aluminium silicates; and the silica is finally removed from the laterite by alkaline solutions. Under such action it would be reasonable to expect the more frequent occurrence of intermediate stages, in the form of silicified laterites, since it is impossible to believe that the silica-bearing organism would disappear simultaneously with its success in securing the silica that it desired. It may be remarked, however, that secondary silica accumulates in the laterites of West Australia,* while H. Stremme † has recently recorded flint-nodules in the laterite of the Vogelsberg.

The discussion of the origin of laterite in many lands has brought from J. Chautard and P. Lemoine ‡ the assertion that even the bauxites of southern France, which include lignitic sediments, probably originated as detrital laterites, from the decay of older felspathic rocks.§ They form a special horizon in the upper part of the Cenomanian stage, and, according to these authors, may represent an epoch of continental emergence under tropical climatic conditions. The present writer gave a general account of the red zone of the county of Antrim, in the light of recent researches, in 1908,‖ and urged that it had been produced by subaerial action. It was pointed out that not even the pisolitic ore could be taken as evidence of lacustrine conditions. This paper brought him a valuable letter from Mr. H. B. Maufe (formerly Muff), who had observed the actual formation of pisolitic iron-ore in Uganda.¶ The following quotations from this letter, dated 9th August, 1908, bear upon the interbasaltic zone of Ireland:—

"Practically the 'red clay' of British East Africa is identical with the 'bole' of Antrim, and chemically they are closely related. . . . Pisolitic iron ore is formed naturally on *sloping land surface*, provided that the forest growing on the red clay be removed (either by fire or by man). Alternate soaking by rain and solar evaporation, causing a complete change in soil conditions, is an important factor. In the 'Geology of India' the pisolitic iron ore (maram or muram) is described as formed on *exposed* surfaces of laterite. In Africa it always forms at or near the base of the red clay after destruction of the forest, and is brought to the surface by the denudation of the red clay.**

* A. Gibb Maitland, Bull. 26, Geol. Surv. W. Australia (1907), p. 62.

† "Überreste tertiärer Verwitterungsrinder in Deutschland," Geol. Rundschau, Bd. i. (1910), p. 343.

‡ "La Latérisation," Bull. Soc. Industrie Min., t. ix. (1908), p. 31.

§ Compare Geyer, "Die Gosaubildungen des unteren Ennstales," Verhandl. k. k. geol. Reichs., 1907, p. 57. This author regards bauxite in Austrian limestones as a residual *terra rossa* derived from solution of the limestone.

‖ "The Red Zone in the Basaltic Series of the County of Antrim," Geol. Mag., 1908, p. 341.

¶ H. B. Muff, "Rep. Relating to the Geology of the East Africa Protectorate," Colonial Reports, Miscellaneous, No. 45 (1908), p. 52.

** See Muff, *op. cit.*, p. 52.

"The red clay of East Africa is characteristic of the upland evergreen forest-zone. It is *always covered by forest*, and always lies on a sloping surface, so that there is a good natural subsoil drainage and the alkalies, etc., are carried off in the subsoil waters. The same conditions seem to obtain in other red clay countries (India, Virginia, Alabama, Honduras). These forests are not proper tropical forests. There is very little humus, and the very roots of old trees disappear completely by decomposition.

"I think, then, there is good ground for believing that the Red Zone of Antrim indicates *forest conditions* of the upland evergreen type of the tropical belt, but to say that tropical conditions are required is apt to be misleading. Red clay is forming in the bamboo zone at heights of 9,000 feet above sea level beneath the equator, but it freezes there any cloudless night, and the air temperature during the day is probably seldom above 80° F. Forty inches of rain per annum (at any rate if divided between two rainy seasons) is sufficient rainfall.

"That the lateritic decay of rhyolite has given rise to the pale bauxites of Antrim I do not doubt, but I think it must have occurred under *forest conditions*. Hence I find it difficult to follow you in your description of the formation of the 'sandy deposits *blown from crumbling* rhyolitic surfaces.' Might not this deposit be produced by the washing of a laterite by the gentle but heavy drip from the forest trees during the rainy season, the lighter clayey particles being removed? . . . . . The leaf-beds and lignites are not difficult to understand in view of forest conditions. All the same, their preservation is remarkable and requires special conditions, because the pools and streams (in the East African forest at least) are so alkaline that vegetable matter is macerated and all structure destroyed."

H. B. Maufe's important comments do not, however, dispose of the conception that a tropical climate is necessary for the production of highly aluminous laterites or true bauxites, such as occur in the county of Antrim. The red clay studied by him in East Africa is regarded* as a kaolin with ferric oxide or possibly turgite, and can be compared only with the bole and lithomarge of Antrim (see Chapter VII.). Unlike H. Warth, Maufe uses the term laterite for a true clay as distinct from bauxite. J. B. Scrivenor † defends a wide use of "laterite" to cover iron ores of tropical origin, whether aluminous or not; but T. Crook ‡ points out that F. Buchanan originally invented the word in 1807 for the ferruginous materials that are now shown to be rich in aluminium hydrate. From this point of view, which seems a just one, it is easy to decide as to what rocks may be styled laterites in Ireland. The matter is further discussed by L. L. Fermor § and by Meigen.‖

* *Op. cit.*, pp. 51 and 52. † Geol. Mag., 1909, p. 431. ‡ *Ibid.*, p. 524.
§ "What is Laterite?" Geol. Mag., 1911, p. 454, etc.
‖ "Laterit," Geol. Rundschau, Bd. ii. (1911), p. 205.

P. Vageler* has recently urged that a covering of vegetation prevents laterisation by promoting acidity of the soil, while tropical soils, being relatively poor in organic substances, have a neutral or even basic reaction. Under such conditions, the colloidal aluminium and iron hydroxides, $Al(OH)_3$ and $Fe(OH)_3$, which are held to be formed during the decomposition of the silicates, are precipitated almost as soon as they arise. From this point of view, kaolinisation is typical of acid soils and laterisation of those with an alkaline reaction. Maufe's reference to the alkaline nature of forest pools in Africa seems to account for the formation of laterite even where vegetation is abundant. As Vageler says, laterite may arise beneath a steppe or a primæval forest, so long as no acid reaction interferes.

We may conclude, then, that the pisolitic iron ore and the materials rich in alumina of northern Ireland originated in Eocene or Oligocene times under hot but not arid climatic conditions. There remains the question of how far algal or bacterial action has assisted in the deposition of the iron ores. The published discussion on Tate and Holden's paper in 1869 shows that Gallionella and similar organisms were present to the minds of certain speakers; but their agency was rejected by the authors, together with the lacustrine theory, except in the case of Ballypalady. Mr. James Strachan, however, of Ballyclare, who has supplied many interesting suggestions during the preparation of the present memoir, has made a special study of the bacteria that secrete iron oxide. In a letter dated 27th June, 1911, he writes of the Antrim beds:— "These deposits (iron ore, bauxite, lithomarge, etc.) represent a slow transition from a moist land-surface to true lacustrine conditions, and during the latter period iron-bacteria probably played an important part in the formation of the sediments." Mr. Strachan also pointed out, in a letter in 1908, how, "after a heavy shower of rain, it seems pretty certain that swarms of these organisms (Cladothrix, etc.) must be washed down from the surface into the cracks of the basalt, thus producing the familiar rotten appearance along divisional planes. . . . . With lacustrine conditions and a warm climate the action would of course be intensified." Mr. Strachan further writes that he is led to favour the lacustrine view, since he believes that ferrous carbonate, which would be in solution in the waters, plays an important catalytic part in the decomposition of silicates. So far, his studies on the Antrim iron ores have not been published for general consideration.

Enough, however, has probably been said to show that the ferruginous materials, whether pisolitic or not, mainly originated on a land-surface, and not on a lake-floor. Yet, even on land, as Mr. Strachan points out, in rock saturated from time to time with

* "Physikalische und chemische Vorgänge bei der Bodenbildung in den Tropen." Fühlings Landwirtschaftliche Zeitung, 1910, p. 873.

tropical moisture, it is possible that iron-bacteria have played a part. In reference to this, Mr. J. B. Scrivenor, of the Geological Department of the Federated Malay States, has kindly communicated the following extracts from a paper by Mr. H. N. Ridley.* Dealing with a form of Crenothrix, abundant in the Malay States, Ridley writes :—" The orange colour of this plant is due to hydrated oxide of iron deposited in the gelatinous sheaths of the filaments and the zoogloœa, and there can be little doubt that it plays an important part in the precipitation of iron oxide in clay and on gravel, etc., so as to form the rock commonly known here as laterite, if indeed it is not the origin of the whole of the rock. In clay it seems to grow on exposed surfaces and in cracks, through which a small quantity of water runs or settles, and I have detected this organism in red lumps of clay in a cutting, in abundance, in the stage of cocci dividing." The author goes on to say that Crenothrix is also found on roots over which water trickles, and that it here promotes a cylindrical deposit of iron oxide.† We cannot, however, at present attribute the removal of silica and the accumulation of residual alumina in laterite and bauxite to the presence of iron-bacteria. Hence evidence of their activity does not meet the real difficulty as to the formation of these materials.

Finally, whatever explains the brilliant colouring of soils in tropical regions, and the formation of laterite on a wide variety of rocks, will explain the physical and chemical features of the interbasaltic zone of north-eastern Ireland. The rich black film formed on the stones of rivers in Egypt,‡ the dehydrated ferruginous layer, often quite superficial, on the soils of the warm zones of the United States,§ and the bright colouring matter on rocks exposed to prolonged sunlight in various tropical lands,‖ all present phenomena of the same fundamental nature. Maufe's observations, already quoted, on the formation of red clay in Uganda within the forest zone, do not negative the belief that bright superficial colouring is in general to be associated with clear air and unimpeded solar rays. Stuchlik¶ thus indicates a lateritic origin for the " bunte Molasse " of the Oligocene beds of South Bavaria; while H. Stremme** calls attention to the red earths and bauxites of Cainozoic age in Germany, including the pisolitic iron-ore on the surface of Jurassic limestone in

* " Action of Copper Sulphate on Aquatic Plants," Agric. Bull. of the Straits and Fed. Malay States, vol. v. (1906), p. 405.

† For recent work on the iron-bacteria, see Rullmann, " Handbuch der technischen Mykologie," Bd. iii.,1904-6, and references in the Centralblatt für Bakteriologie, from 1904 onwards.

‡ A. Lucas, " The Blackened Rocks of the Nile Cataracts and of the Egyptian Deserts," a paper issued by National Printing Department, Cairo, 1905. Also abstract in Nature, vol. lxxiv. (1906), p. 280.

§ G. P. Merrill, " Rocks, Rock-weathering, and Soils " (1906), p. 374, with references to Russell, Dana, and Crosby.

‖ S. Katzer, Neues Jahrb. für Min., etc., 1899, Bd. ii., p. 177.

¶ Jahrb. k. k. Reichsanstalt, 1906, p. 298.

** " Überreste tertiärer Verwitterungsrinder in Deutschland," Geol. Rundschau, Bd. i. (1910), p. 337, with numerous references.

Swabia and Franconia, as evidence that tropical and sub-tropical conditions formerly prevailed. J. Walther's views on these deposits bear, in some measure, on the state of the land-surface in Ireland, since he suggests* that volcanic ash drifted from the Scottish Cainozoic eruptions may have been responsible for the pisolitic ore of central Germany. In view of the frequent development of such ores in other places, and of the possibilities of *terra rossa*, which Walther also recognises, the origin suggested by him seems remote. Walther remarks that the carmine and tile-red laterites collected by him in India and Ceylon in 1889 have passed into a dark brown state, and have lost their tropical brilliance in twenty years. Hence some of the duller iron-earths of various geological horizons may have originated under bright climatic conditions.

GENERAL CONCLUSIONS IN REGARD TO THE INTERBASALTIC ZONE.

It is clear that the pisolitic iron ores, laterites, and bauxites of Ireland may have arisen from any rock exposed to conditions such as now prevail in tropical India or Africa, and that these conditions prevailed in Eocene or Oligocene times. F. P. Mennell† states how laterite arises in Rhodesia on sandstone, limestone, granite, basalt, and various schists. J. B. Jukes,‡ so far back as 1850, observed pisolitic ironstone developed on granite in Western Australia. G. C. Bauer,§ whose work on the Seychelles added so greatly to the interest of the question, also describes laterite derived from granite. It has even been suggested that a red- to cream-coloured bauxite in Wilkinson Co., Georgia, has arisen through the removal of silica from a bed of kaolin.‖ Lithomarge passing into laterite occurs on rhyolite or granite in Mysore.¶ H. B. Maufe** shows how the red clay of East Africa arises from trachytes, which sometimes contrast strikingly with the superficial product, while at other times they are rotted and soft to a depth of twenty feet. Even in this laterite, titanium dioxide has characteristically accumulated until it forms as much as 3·12 per cent. of the clay. In the pale bauxite of Ballintoy (analysis III.) it amounts to 5·20 per cent., and in that of Glenarm (analyses XIV. to XVII.) it runs from 2·56 to 9·40 per cent. The Glenarm bauxites are believed to have a rhyolitic origin, and the titanium may originally have been present in rutile.

* "Lehrbuch der Geologie von Deutschland" (1910), p. 104.

† Geol. Mag., 1909, p. 351.

‡ "Sketch of the Physical Structure of Australia," quoted in Bull. 26, Geol. Surv. W. Australia, p. 63.

§ Neues Jahrb. für Min., 1898, Bd. ii., p. 163.

‖ O. Veatch, "A New Discovery of Bauxite in Georgia," Eng. and Mining Journ., New York, vol. lxxxv. (1908), p. 688.

¶ Records, Mysore Geol. Depart., 1906-7, p. 44. W. F. Smeeth seems almost too critical on this matter in his remarks on p. 15.

** Rep. Geol. E. Africa Protectorate, Colonial Reps., Miscell., No. 45 (1908), p. 51.

The derivation of bauxite from basic igneous rocks has been abundantly proved, as in the Westerwald, the Vogelsberg, India, British Guiana,* and elsewhere. When a pale material has resulted in such cases, as at Tuftarney in the county of Antrim, it has been suggested that water from overlying plant-beds has leached away the iron.† The titanium dioxide is believed to have become concentrated in these basic cases from ilmenite in the parent rook. One analysis of the Tuftarney product (analysis XXXIV.) shows 11·06 per cent. The small percentage of iron in some of these examples suggests that the titanium dioxide, whatever its origin, is now present as rutile, a condition in which it occurs in many argillaceous rocks.

The typical downward succession in the county of Antrim is (3) *pisolitic iron ore;* (2) "*pavement*" (a material varying from a siliceous iron ore to a lithomarge, with a false appearance of stratification, due to coloured streaks connected with the decomposition of residual blocks of basalt); (1) *lithomarge* (decomposed basalt retaining the original joint-structure and often showing pseudomorphs after the felspars of the ground-mass‡). Lithomarge may consist largely of kaolin; but in Ireland it passes into ferruginous bauxite, and its silica percentage represents silicates not completely decomposed. This passes down into a basic lava of the Lower Basaltic series. Pisolitic grains have been formed by concretion within the rock-mass even on this low horizon, and in places where red bole and basalt are closely intermingled.

The *pale bauxites* derived from rhyolite, as at Glenarm and Straid, overlie the pisolitic iron ore when they occur. At Straid, rhyolitic flows may have decomposed, under laterising conditions, *in situ*. In other places the rhyolitic matter is clearly detrital, and has been washed down as mud over a lowland, or has been transported, as a fine dust mingled with quartz grains, by wind. The occurrence of rhyolitic tuffs at Sandy Braes shows that some of this material may have been fragmental at the outset. The laterites and lithomarges of north-eastern Ireland, that is, the main mass of the interbasaltic zone, cannot, however, be connected either with volcanic explosions or with accumulation in lakes, but must be regarded as typical examples of soils and subsoils formed under conditions now prevalent, in regions of seasonal rains, nearer the equator.

* A carefully examined instance of the formation of laterite from dolerite (diabase) is given by J. B. Harrison, Geol. Mag., 1911, p. 120.

† G. H. Kinahan, Trans. Manch. Geol. Soc., vol. xxii. (1894), p. 458.

‡ Prof. Hull examined this rock and indicated the felspars in a microscopic section as early as 1874 (Rep. Brit. Assoc., 1874, Transactions, p. 69).

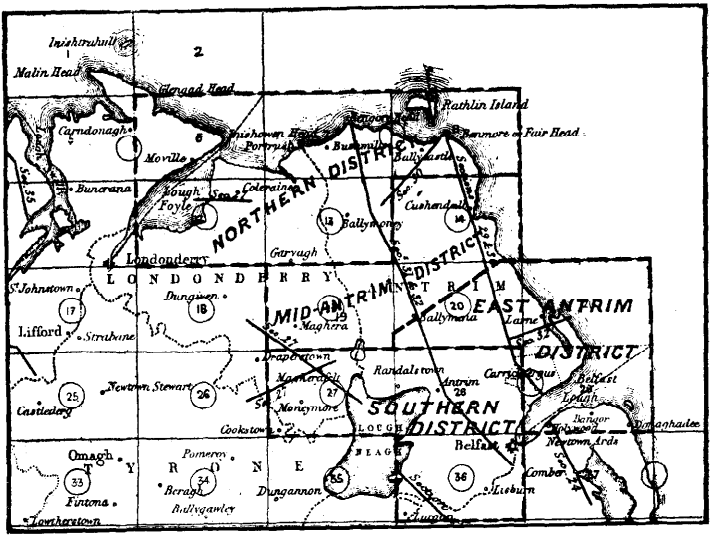


FIG. 1.—SKETCH-MAP SHOWING THE SHEETS OF THE MAP ON THE SCALE OF ONE INCH TO ONE MILE IN WHICH REVISION OF THE INTER-BASALTIC BEDS HAS BEEN CARRIED ON, AND THE DIVISION OF THE AREA INTO THE DISTRICTS DESCRIBED IN THE FOLLOWING CHAPTERS.

CHAPTER II.

THE NORTHERN DISTRICT.

BY S. B. WILKINSON.

INTRODUCTION.

The northern area of the interbasaltic zone occurs in parts of the counties of Antrim and Londonderry, and is clearly shown on the published maps on the scale of one inch to one mile, Sheets 7, 8, and 13.

There are four distinct localities where interbasaltic beds occur. The most important is the magnificent sea cliff of the Giant's Causeway, where the whole section is exposed to view. The second in point of importance is along a sinuous intermittent outcrop stretching from near Coleraine on the west to near Ballycastle on the east. The third occurrence is at Knocklayd Mountain, near Ballycastle, where an ore zone has been shown on the map; but in this instance the facts hardly warrant more than the indication of the boundary between the two basaltic series. The fourth locality where interbasaltic beds are met with lies to the south-east of Killagan Bridge, situated south-west of Ballycastle.

The outcrop of the interbasaltic zone in the two principal

areas is so correctly mapped as to need no alteration or revision, although at Craigahulliar, a townland about two miles south of Portrush, bauxite works have been opened since the original survey was made, and it is now seen that the zone drawn on the map is a few feet more to the east than the outcrop now proved. This is so insignificant as not to warrant an alteration of the engraved copper sheet. The officers who originally surveyed this area were the late Messrs. Symes and Egan, and Mr. McHenry, who has only recently retired from the service.

Although the geological lines drawn on the map are correct, the conclusion arrived at in the previous study of the interbasaltic zone must be considerably modified. At the time of the original survey of the district this zone was assigned to a deposit of volcanic ash, while the present investigation points to a condition of facts more in accordance with the deep decomposition of the basalt in place, as is stated in the previous chapter. With the exception of this point, there is little to be added to what has already appeared in the published Geological Survey Memoirs to accompany Sheets 7, 8, and 13 of this the northern area.

THE GIANT'S CAUSEWAY AND BENGORE HEAD.

The types of the interbasaltic formations of the northern district vary both in character and in their mode of occurrence, and, so far as one can ascertain, it does not appear that all the members that go to make up the interbasaltic zone are ever to be found present together.

By far the most important section is that of the Giant's Causeway and Bengore Head, on account both of the extent of rock laid bare and of its magnificent scenery. Referring to the Memoir to Sheets 7 and 8, p. 37, it will be seen that a "fault extending from White Park Bay on the east, to the mouth of the Bush river on the west, throws down on the north a great but unknown thickness of upper and lower basalt against the cretaceous beds on the south." The northern limit of this faulted area is the sea, from which the cliffs of basalt rise, often perpendicularly. The section here disclosed is particularly fine, and the interbasaltic zone is clearly defined (Plate I.). With regard to the scenery, the best view of this wonderful formation is probably from a boat, when the section can be seen as a whole.

On p. 24 of the Memoir to accompany Sheets 7 and 8 a reference is made to the iron ore deposits, which it will be advisable to quote, and which at once opens up the point of divergence caused by the more recent examination of these rocks :—*

"As before mentioned the division between the upper and lower basalt is marked by a considerable thickness of beds of

* For references to successive views, see Chapter I. of the present Memoir.

tuff or ash, together with bole, lithomarge, and pisolitic iron ore which always occurs below the upper basalt. This ore consists of small grains of hematite, from the size of a pea to ¼ of an inch in diameter, cemented together by a red or purple ochreous paste. Underneath the ore bed, which varies in thickness up to fourteen inches, are found red and variegated clays, and decomposing ash, called ' bole ' . . . .* Trials have been made all along the outcrop of the ochre-beds extending from Portrush to Bengore Head. . . . . The cliffs exhibit good sections of these deposits at different elevations, with an average thickness of about 40 feet, the workable bed not being more than a few inches thick."

It will be seen from this that when this Memoir was written in 1888 this great " ochreous " parting between the Upper and Lower Basalts was considered to be due to a deposit of tuff or ash. From later investigations, however, the ash theory must give place to one that has been in existence for some years in India,† namely, that this zone is due to a deep-seated decay of the upper surface of the lower sheet of basalt. The huge spheroidal masses, now rapidly weathering, that can be seen in the face of the cliff, particularly at the point on the pathway forming the western horn of the " amphitheatre," were originally supposed to have been " bombs " of basalt, discharged from a volcanic vent, and resting in an ashy matrix. They have a peculiar concentric structure, similar to the peeling of an onion. On a close study of these spheroidal masses, the flow-structure of the lava can be followed in some cases through the supposed matrix, and across the supposed " bomb," showing, in fact, that all is part of the same mass of basalt which has weathered " in place." The whole is traversed by innumerable strings of red and brown iron oxides (Plates II. and III.).

A thin section of the red altered amygdaloidal rock from this locality shows how the felspars may remain only partially altered, while the pyroxene and the ground have become mostly replaced by limonite. Crystals of chabazite occupy the steam-cavities. In more extreme cases, the basaltic structure disappears, and a ground of red anisotropic granules develops throughout the mass. These are too abundant to represent the product of alteration of any one original constituent.

G. A. J. C.

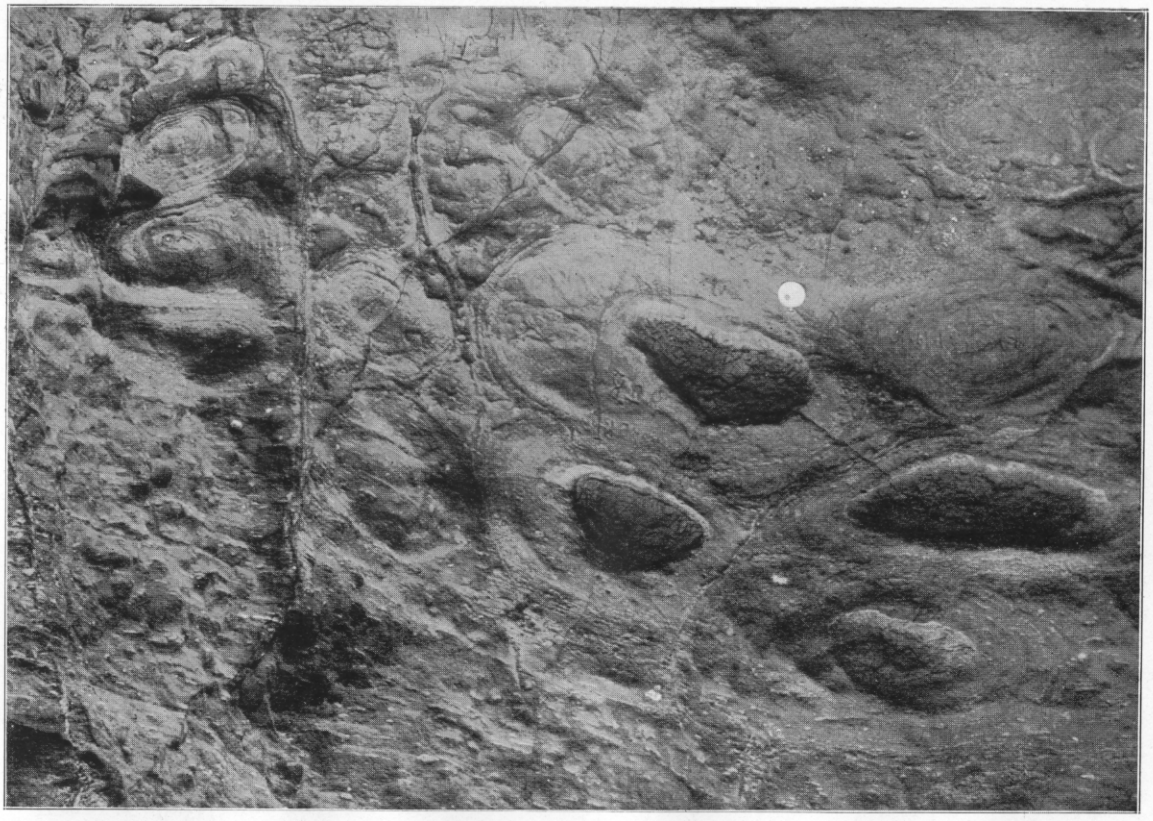
The occurrence of this great zone in the Causeway area shows that the interbasaltic epoch was of long duration, and this is supported by the evidence of thick beds of lignite, which are frequently found forming part of this zone. Owing to a footpath having been cut out of the face of the cliff, provided with an iron hand-rail, it is now easy to reach the lower portion of

* See analysis I. in the present Memoir.

† T. H. Holland, Records Geol. Surv. India, vol. xxxii., p. 175; and Geol. Mag., 1903, p. 59.

To face p. 18]

PLATE II.—Spheroidal Basalt decomposing into Bole and Lithomarge. Pathway to the Giant's Causeway from Bushmills.



To face p. 19]

PLATE III.—Lithomarge of the Interbasaltic Zone at the Giant's Causeway, showing residual cores of Basalt, and concentric banding, with fluidal structure, marked by amygdaloidal layers, in the lower part. The scale is shown by a penny placed on the rock.

the works informed me that below the Upper Basalt there were found, in downward succession :—

Thin deposit of lignite		1 inch thick.
Hæmatite	.. ..	4 inches to 12 inches thick.
Red clay	.. ..	2 feet.
Pavement	.. ..	20 feet.
Lithomarge	.. ..	6 feet, base not seen.

In examining this section, portions of fossil wood were found, probably from amongst the pavement. Although of a bright red colour and having a red metallic lustre, the fibrous structure of the wood is plainly discernible. Mention is made in the Memoir to accompany Sheets 7 and 8, p. 24, that " Bauxite was also worked in the mine at Killygreen, but the works are now abandoned." No information, however, was received confirming this statement, and no traces were observed amongst the heaps of ore, lithomarge, etc. At frequent intervals, old adits and openings are to be seen with their accompanying " tip-heaps," and although there are no means, either by examination of the works, or from mining records, of ascertaining the thickness of the different types, some idea can be formed as to what is to be found by examining these heaps.

We may now follow along this line of outcrop, and note wherever the zone is laid bare, or free from superficial deposits.

Following the feature made by the Upper Basalt sheet, with its columnar structure, northward from Killygreen, we note that two adits were opened in the townland of South Ballylagan, at the base of the basalt sheet. The material heaped up discloses a very bright red clay, with very little pisolitic structure.

Continuing along the feature a little north of the hamlet of Islandmore Upper, the interbasaltic zone is slightly disturbed by a fault, which throws it about two hundred yards to the west. It now follows approximately along the Portrush road, and at Cropreagh an old adit is seen on the roadside, with a small heap of the same very red clay as may be noticed in other localities. Still proceeding north to the townland of Corbally, the strongly marked feature of columnar basalt indicates the presence of the ore zone immediately below it. Here it will be seen by a glance at the published map that a fault has slightly dislocated the regularity of the line of outcrop, which has been thrown back south for about four hundred yards. The next point at which there has been any attempt made at working the ore is at Craigahulliar. Here there are two adits, some two hundred yards apart. The dump-heap of the southern one shows a considerable amount of good lignite, the other materials being red clay, pavement and lithomarge, all being much weathered and disintegrated, owing to the long period they have been exposed to the atmosphere. The northern adit is cut through a few feet of columnar basalt, which here dips north-west at

20°; immediately under the basalt is a bed of lignite some two feet thick, but rapidly dying out, the whole section being only ten feet in length. Under the lignite there is a deep red-coloured band of earthy hæmatite about one foot thick, and under this, as far as can be seen, red clay. There are no signs of pisolitic iron ore. The entrance to this adit is in better condition, but it is still unsafe to venture in, owing to the length of time that has elapsed since the ores were worked and the consequent rottenness of the pit timbers. From this point round to Urbalreagh, although very little is now seen, notes on the original field map state that "columnar basalt rests on poor ore, more like pavement; there is very little pisolitic structure and about thirty per cent. of iron." At Ballymagarry townland the regularity of the ore zone is disturbed by two slight faults; there are two or three adits, which have been long disused. The tip-heaps are made up of pavement and reddish brown mottled clay or lithomarge, all very much weathered and bleached. The roof of one of these adits is formed of the bases of the vertical columns of basalt, which are very clearly defined. From this point the interbasaltic zone is completely hidden by superficial deposits, but the contour of the ground and the columnar structure of the basalt enable the position of the ore zone to be made practically certain. A fault slightly disturbs the regular outcrop of the columnar basalt, throwing it south for about three hundred yards along the boundary between the townlands of Leeks and Glentask. Not quite half a mile south-south-west from Dunluce Castle, pisolitic iron ore occurs and has been worked at intervals. In the Memoir to Sheets 7 and 8, p. 24, we read: "Lately, however, rich deposits have been opened south of Dunluce Castle." This was in 1888; since that time the work at this mine was stopped, but quite recently it is said that it has recommenced (see analysis II.). During the period of the last examination in 1907 and 1908 the works were closed. The materials heaped up at the mouth of the adit were composed of a rich brown iron oxide, and the accompanying clay, "pavement," and lithomarge, very similar to the materials found in the heaps at Killygreen mine. Continuing northward, in the townlands of Glentask and Boneyclassagh there are several "try holes," showing that the ore zone is still present. At Ailsacraig these beds have been pierced by a later dyke or sill of exceedingly hard fine-grained basalt, columnar in structure and having a starch-like mode of jointing in its upper portions. The zone can still be traced sweeping round to the south-east, where the "try-holes" show that lithomarge is present. At Gortnacapple a fault, running approximately north and south, shifts the interbasaltic zone, throwing it towards the north. From this point to a considerable distance to the east of the village of Bushmills, across the valley of the Bush river, the line of division between the Upper and the Lower Basalt must be more or less hypothetical, owing to the amount of

superficial deposits. The surveyor is guided, however, by an occasional glimpse of the columnar formation of the basalt, and by a slight feature in the contour of the ground, which probably correctly indicates the line between the two basalts, but does not necessarily prove that the ore zone is present.

Following along this slight feature, it is not until the townland of Carnkirk is reached that any of the interbasaltic beds are exposed. Immediately south of the hamlet of Ballyallaght, pavement and lithomarge are slightly exposed, capped by the sheet of columnar basalt. Following still along the feature above referred to, in the townland of Lisnagunogue Lower, pavement and lithomarge are again slightly exposed to view, enough to indicate that the zone is present. From this point for a considerable distance east, in the neighbourhood of Drumnagessan House, the glacial deposits are very much deeper, and it is not till the townlands of Ballynastraid and Lemnaghmore are reached that the interbasaltic zone is again seen in several old workings. Here a change occurs in the nature of the material of the zone, and, as only the old workings and tip-heaps remain, it is better to quote from the Geological Survey Memoir, p. 24, since any information gathered when this was published, twenty years ago, is more likely to be correct than that which can be acquired at the present time :—

" To the S. of White Park Bay the pisolitic iron ore is replaced by a thick aluminous clay called 'bauxite,' which has been worked extensively by the Eglinton Chemical Company; an analysis of this bauxite is given in the explanatory Memoir to accompany Sheet 20."

An analysis published in 1889 is quoted in the present Memoir, Chapter VII., analysis III.; from this it is clear that the second of the three analyses in the Memoir to Sheet 20 represents the rock of Ballintoy.

Thin sections of the bauxite of Ballintoy show pale scoriaceous fragments of lava; but residual pieces of basalt occur, and the whole may have had a basic origin. The mass is commonly pisolitic.

G. A. J. C.

Continuing from the Memoir: " Bauxite was also worked in the mine of Killygreen, but the works are now abandoned.* The outcrop of the lithomarge and pisolitic iron ore deposits is very clearly traceable along the escarpment of the upper basalt from White Park Bay, and along by Ballintoy towards Ballycastle. The quality of the ore, however, was found so poor that it was never worked to any great extent. In the hill to the south of Ballintoy the ore bed has been replaced, over a considerable area, by a thick lignite deposit, about two feet in thickness, which was worked as coal some eighty years ago."

* See, however, p. 20 of the present Memoir.

Mr. William Thomson, the General Manager of the Eglinton Limestone Company, Limited, of Glenarm, Co. Antrim, and 212 West George Street, Glasgow, has kindly permitted the use of the following very interesting communication in regard to the Ballintoy area, in response to an enquiry from the present writer :—

"I was not with the Eglinton Co. when Ballintoy was being worked, so can give you no information at first hand. I have, however, talked the matter over with an old foreman who had charge of the workings, and, although he cannot give much information, still what he says may be of use to you.

"The bauxite bed worked by the Company extended over an area of some seven or eight acres. At the outcrop, and for a few yards in, the thickness was 6 feet or thereby. It then thinned for a few feet to less than 2 feet in thickness, thereafter rising to a fairly regular thickness of 2½ to 3 feet, until the bauxite disappeared and a pea-bed took its place. It was overlain in its whole area by the lignite, which ceased when the bauxite ceased. This lignite was separated from the bauxite by a bed of what I take to be bleas,* very dark in colour, and which disintegrated rapidly on exposure to the atmosphere. The lignite seems to have been of very inferior quality, only about 4 inches of its thickness being middling good coal and about two feet charred sticks, which in many parts was mixed with earth and stones. I have no analysis of this bauxite [bed], but it seems to have been of very fair quality, my information being that it was sometimes as high as 58 % in bauxite. . . ."

Mr. J. Starkie Gardner visited the Ballintoy section to examine the plant-remains, and gives an interesting account of the locality,† and this visit has been also recorded by Mr. William Swanston, of Belfast.‡

The interbasaltic zone must not be confused with the true beds of volcanic tuff and ash which occur in the neighbourhood of Ballintoy and Carrick-a-raide. At the latter place especially the fragmental nature of the deposit is clearly illustrated in the sea cliff. Great masses of basalt and chalk blown out of the volcanic neck now rest in a matrix of calcareous ash. In other sections which have been considered as having a fragmental volcanic origin, such as that of the Giant's Causeway, no masses of chalk or of any underlying strata have ever been detected. On comparing the two sections, it will be noticed that the flow-structure, indicated by innumerable zeolitic infillings of vesicles, which is so very remarkable in sections in the lithomarge at

* See Explanatory Memoir to accompany Sheet 35, p. 52, footnote ; "blaes" is a Scotch term for shales.

† "Lower Eocene Plant-beds of the Basaltic Formation of Ulster," Quart. Journ. Geol. Soc. London, vol. xli. (1885), p. 86.

‡ "The History and Origin of the Silicified Wood of Lough Neagh," 1885. Privately printed.

the Giant's Causeway, is quite absent from the true ash-bed in the vicinity of Ballintoy.

KNOCKLAYD.

The third locality where it is said that an interbasaltic zone occurs is at Knocklayd Mountain, near the town of Ballycastle. This hill forms a very prominent feature in the landscape. Reference is made to it on p. 7 in the previous Memoir as follows : "The only remarkable elevation in the district is Knocklayd, a hill about two miles S. of Ballycastle, rising 1,685 feet above Ordnance Datum. This dome-shaped mass consists of Upper and Lower Basalt, and Chalk, resting on a platform of mica-schist." There appears to be some discrepancy here with regard to the height, as the figure given on the six inch sheet is clearly 1,695 feet above O.D. On reference to one inch sheet 8, edition of 1887, it will be seen that the ore zone has been indicated by a dotted gold line on the E. side. In the revision of 1907, small exposures of bole and lithomarge were found on the west side, and in consequence the ore zone was carried round the whole mountain. The indication of an ore-zone appears misleading, as there is no evidence of any interbasaltic zone on the east side, and on the west side there are only one or two small exposures along the 1,250 feet contour line and immediately due south-west of the summit. The section disclosed is limited, and there is nothing to indicate that there is anything like the same development of clay beds, such as are to be found south of Kenbane or White Head. The thickness of the combined sheets, however, gives reason to suppose that the Upper Basalts are represented. On the east side of Knocklayd one can walk up a streamlet, which is the boundary between the townlands of Corrally and Essan, on basalt all the way, with no evidence of a break ; but the lower portion of the basaltic series is amygdaloidal and spheroidal, while the upper, although not columnar in structure, is exceedingly fine grained and compact.

KILLAGAN BRIDGE.

The fourth and last locality where there is any indication of the great interbasaltic zone is near Killagan Bridge. Here again it is very difficult to get a clear section. There is a certain thickness of red clay beds, but they are covered up and much overgrown. The following notes on the field maps may be quoted, the original survey having been made by the late Mr. Egan :—

"Bed of pisolitic iron ore worked here to a small extent, said to be at most about eighteen inches thick, a red earthy mass, abounding in irregular grains of black iron ore (magnetite), the latter being strongly acted on by the magnet. The works were stopped, it is said, upon reaching a dyke,

the fragments of which lie about, a hard, somewhat spheroidal basalt." The opening to which reference is made lies about two hundred yards north-east of Kill. To the south of Kill, immediately east of the road, the following notes appear on the field map :—" Iron ore : a thick mass cut into below boulder-clay, a red earthy mass generally softer and more earthy than that four hundred yards to the north-north-east, and not containing the hard grains. Partly consists also of a more compact reddish brown soft rock of the nature of lithomarge." If this zone is on the same geological horizon as the main zone, the Upper Basalt is not columnar, and does not form the same bold feature as along the outcrop between Coleraine and Ballycastle.

OCCURRENCE OF BOLE AT VARIOUS HORIZONS IN THE BASALT OF THE NORTHERN DISTRICT.

Unconnected with the main zone of interbasaltic material there are numerous localities where bole occurs. It is generally to be found of a very bright red colour, waxy and unctuous to the touch, and appears very compact. In writing of the Upper and Lower Basalts, it must be remembered that these two series were erupted as a succession of flows, which, as noted in the previous Memoir, p. 25, may be, "though very rarely, separated by thin bands of red ochre or red ash." It is suggested that these red bands may mark a period of rest between the flows, giving time for the decomposition of the surface crust of the basalt.

Good examples of bole bands may be seen as the Causeway section is entered from the west, near to the path and running out to sea. On close examination, the basalt structure can occasionally be traced in the bole. Again, further to the east, at Port na Callian, a bed of bole is seen in the basalt, a little south of the Horse's Back, while a band lies immediately above and another below the round hole in the rock which has been sculptured by the action of the sea and is locally known as "the Eyeglass." In the coast-section both east and west of Portstewart, and on the roadside between Dunluce and Portrush, several instances of bole occur, and on close examination the basalt structure can be traced in the red material. Sometimes the change is gradual, at other times as sharp as if a coat of vermilion had been laid on the rock with a straight-edge. The greater number of instances occurring in this district are to be found in the Lower Basalt ; but a very typical example occurs at Craighmore, some four miles east of Bushmills, where there is an outcrop of bole at Knockshanny. It is bright red, and from five to ten feet thick ; it has the usual waxy appearance and is overlain by a sheet of basalt. Immediately south of this outcrop another band occurs, which is not so thick and is composed of the closely-allied lithomarge and a little pavement ; this band is only about four feet thick, and is overlain by a sheet

of columnar basalt, exceedingly fine in texture, with socket joints and with a clearly-defined conchoidal fracture. These two beds of clay are probably on a much higher geological horizon than any of the zones before referred to, and are included in the Upper Basalt.

ADIT AT THE JUNCTION OF THE CHALK AND OVERLYING BASALT AT DOWNHILL, IN THE COUNTY OF LONDONDERRY.

Although not included in the interbasaltic zone, it is interesting to note that at a point a few hundred yards west of Downhill Railway Station a short adit has been driven inwards, on the top of the chalk, with the overlying sheet of Lower Basalt forming the roof. Below this, a soft clayey mass with the consistency of putty is charged with innumerable chalk flints. This soft rock has been stained a rich brown colour, probably by the percolation of the water from the overlying basalt. The flints can easily be picked out of the brown matrix with the sharp end of a hammer. The thickness of this soft material is here about six feet, and it appears as if it might extend inwards for some distance. On the surface of this clay there are numerous slickensides, indicating a considerable amount of pressure.

NOTE ON THE OCCURRENCES OF IRON ORE AT KEADY MOUNTAIN AND BOHILBREAGA.

By G. A. J. Cole.

Iron ore occurs near the junction of the basalt and the chalk at two or three points on the escarpment as it is followed southward from Downhill. Mr. J. R. Kilroe, during his geological mapping of the area on the scale of six inches to one mile in 1909, drew attention to the fine section on the face of Keady Mountain, due east of Limavady. The phenomena here were concisely described by Mr. Egan in 1885,* who noted the occurrence of "a three-inch layer of hard ferruginous matter, in the upper portion resembling the limonite below the basalt at Craignashoke [see later], but harder, and in the lower part becoming extremely hard and merging obscurely into the equally indurated mass of mixed flints and chalk." Portlock† speaks of seeing at Keady Mountain, between the basalt and the chalk, "the usual mixture of unctuous ochreous clay, broken pieces of chalk, and calcined flints." As at Downhill, the basalt seems to have flowed out over a land-surface on which clayey soils full of detrital flints had previously accumulated. The partial incorporation of this material in the lava is noticeable at both Keady Mountain and Downhill.‡ Mr. Kilroe has supplied the

* Mem. Sheet 12, p. 19.
† "Geol. Rep. Londonderry," etc. (1843), p. 110.
‡ Portlock, *op. cit.*, p. 102.

following more detailed account of the Keady section for the present Memoir :—

"A section of more than usual interest is to be seen in the western face of Keady Mountain, near the summit of the picturesque escarpment overlooking the valley of the Roe, about 3½ miles east of Limavady. Here a layer of bole of some 12 inches in thickness presents remarkable uniformity of appearance throughout about a third of a mile in length of a well-exposed face of rock. It is covered with rudely columnar dark green basalt, the bottom of which is very dark grey, nearly black, and laminated, forming a uniform layer some six to eight inches in thickness—probably the chilled portion of the lava resting upon the bole. Beneath the bole, the basalt upon which it directly rests, similar to that above the layer, and in parts strikingly columnar, has suffered decay similar to that which affected the upper portion of the Lower Basalt, beneath the iron ore of Antrim. The decay has resulted in the formation of lithomarge to depths of as much as 12 feet from the layer of bole. Reddening of the lithomarge has taken place here and there, adjoining the bole, and the substance known to the Antrim miners as "pavement" is then formed; the bole contains minute pisolitic grains. The lithomarge, and portions of the unaltered basalt adjoining it, contain large proportions of calcite and other forms of carbonate of lime. A white mineral which does not effervesce with acid, and a soft greenish white mineral, are also present in small quantity. At the east end of the section the lower layers of basalt are intercalated with and in places envelop layers and congeries of chalk fragments and flints—the latter being by far the most numerous. Small masses, up to 12 inches by 6 inches of highly crystallized carbonate of lime, and some of a soft black mineral, are also enclosed in the basalt at this (eastern) end of the section."

Lignite and "a layer of earthy brown hematite" were recorded by Portlock under the basalt of Craignashoke.* This locality is seven miles south-east of Dungiven, on the igneous scarp midway between Mullaghmore and Bohilbreaga. Portlock in his map correctly shows the lignite as occurring on the latter hill, to the east of Craignashoke proper. In 1872, G. H. Kinahan,† apparently unaware of Portlock's reference, stated that he had found limonite "in the hills called Bohilbreaga," and lignite, ten to twenty inches thick, in the townland of Dunmurry, *i.e.*, in the original locality. F. W. Egan surveyed the area a few years later, and reported‡ that an adit had been driven into the lignite bed; flints and fragments of chalk were brought out with the lignite.

* *Op. cit.*, p. 113.

† "Tertiary Iron Ore in the Co. Londonderry," Journ. R. Geol. Soc. Ireland, vol. iii. (1873), p. 83.

‡ Mem. Sheet 18 (1884), pp. 22 and 26.

On his MS. map, Egan describes the occurrence of the iron ore at Craignashoke as follows:—"Flints and chalk *in situ*, about 8 inches exposed (but said to be 2 to 3 feet thick), overlying whitish sandstone. Over it about 6 inches of brownish red pisolitic iron-ore (hæmatite). Then two inches of a softer form of earthy ore delicately streaked (laminated) light and dark brown (limonite), above which disintegrated basalt. Ore, however, said to reach a thickness of nearly 3 feet."

Egan* regarded this and similar occurrences round the basalt margin as deposits formed at the base of the Lower Basalt, since he held that the main iron ore zone was absent on the scarp east of Lough Foyle. At the same time, the thickness of the basalt on Benevenagh, some 850 feet, made him suggest that "part of this may possibly belong to the upper division of the series." Mr. Kilroe has pointed out to me in the field and on the maps the possibility of an overlap of the Upper Basalts across the lower series, and urges that the iron ores and lignites of the scarp in Co. Londonderry may prove to be on the same horizon as what is known as the main zone farther east (see Appendix, p. 120). The remarks of Prof. Seymour on the Coagh area (p. 101 of the present Memoir) should be read in this connexion.

CHAPTER III.

THE EAST ANTRIM DISTRICT.

By Alex. McHenry.

Introduction.

There are the two usual types of interbasaltic beds in this area, namely, the red and brown pisolitic iron ore and lithomarge on the one hand, and the grey bauxitic clays and associated rhyolitic gravelly and sandy beds on the other. These beds vary in thickness, as will be seen by the various sections and measurements where such were obtainable in past and present workings and excavations. It is an interesting fact that where the one variety exists the other is commonly wanting, as has been noticed by previous observers (see Memoir to Sheet 20, page 16).

GLENARM AREA.

(MAP 5, NORTHERN PORTION. ANALYSES IV.-XVII.)

Beginning in the northern portion of the district in the neighbourhood of Glenarm, rich pisolitic ore occurs to the west

* Mem. Sheet 12, p. 20, footnote. Compare A. McHenry, present Memoir, p. 39.

of the village. A mine is at the present time being worked by two adits at Glebe, two miles to the S.W. of Glenarm. This is the only mine that is now being worked for iron ore in the whole eastern district.

The top bed, No. 1 ore, is as usual the richer, and varies in colour from dark brown to bright red, and in thickness from six to nine inches. The second quality ore is never so rich; it is from a foot to 15 inches in thickness and red brown in colour. The "pavement," three to four feet thick, comes below the ore bed, and beneath the pavement is the lithomarge.

The total thickness of the lithomarge is uncertain, as it has not been excavated down to its junction with the unweathered Lower Basalt at this place. It will be seen, however, that it is known to extend beyond 27 feet.

SECTION AT GLORE (GLEBE) MINE, S.W. OF GLENARM, WITH PARTIAL ANALYSES OF THE MATERIAL, DRIED AT 100° C.

Basalt Roof	Feet	Metallic Iron	Alumina	Silica	Titanium Dioxide
Pisolitic Iron Ore ..	2	36·50%	26·31%	12·83%	4·67%
Pavement ..	2	27·00 ,,	29·89 ,,	13·92 ,,	5·31 ,,
Do. ..	2	24·94 ,,	30·13 ,,	10·61 ,,	5·42 ,,
Do. ..	2	21·68 ,,	34·01 ,,	8·91 ,,	5·39 ,,
Lithomarge ..	20	16·86 ,,	39·37 ,,	5·05 ,,	2·73 ,,

The above section and analyses were made in 1903, and were kindly contributed by Mr. A. McDonald, of the Antrim Estate Office, Glenarm, in a letter, 7th February, 1908. See also analyses VII. and VIII.

What is called first ore is about 12 inches thick, but of course it varies greatly, and gives about 36% of metallic iron. The second ore is about five feet thick, and gives about 18 to 20% of iron; this merges into lithomarge, from a red to a violet colour, which has been found to go to 27 feet in depth.

The section was furnished to Mr. McDonald by Captain Martin, Manager for the Antrim Iron Ore Co. It was carefully done to give the values at every two feet up to eight feet, and is very interesting as showing the gradually increasing percentage of alumina from the pisolitic iron ore downwards into the lower portions of the lithomarge.

From an economic point of view this is important as showing of what value the lithomarge may be in the future for the extraction of aluminium.

From the Glebe Mine the outcrop of the bed of pisolitic iron ore continues along the western side of the glen, and, rounding the head of the glen, is traceable northward along the east side for about three miles, till it is replaced by the grey bauxite

at Libbert Mine. In two stream cuttings in the escarpment, a little eastward of Corby Bridge, good sections of the ore bed and lithomarge are seen, with the Upper Basalt resting on the ore, and the lithomarge passing downwards into the Lower Basalt. The interbasaltic beds, which are very similar in both these sections, are between 30 and 40 feet thick, and in every respect resemble those at Glebe Mine on the opposite side of the glen.

At the top of the glen on the west bank of the river, 150 yards above Bull's Eye Waterfall, a good section of the pisolitic iron ore is seen in the cliff, the measurements again being very similar to those in the two sections above referred to a mile to the north. It is at this locality that Sir R. Griffith* and, later, John Kelly† noticed the occurrence of quartz grains in the clay band. Sir R. Griffith acutely observed that the ochreous strata here " bear a strong resemblance to the decomposed clay porphyry of Sandy Brae " (see Chapter I.).

At Libbert, a mile to the south of Glenarm, grey bauxite takes the place of the pisolitic iron ore. No evidence is now to be seen on the ground with regard to this deposit, from which the plant remains were obtained when the mine was being worked thirty years ago.

The adit entrance is now choked up with fallen rock from the overhead basalt, and the tip-heap is overgrown with thick scrub. Were this heap excavated with pick and shovel, additional specimens of plants might still be obtained in the unweathered blocks of shaly clay derived from rhyolitic matter. It was here that the present writer first found, many years ago, the rhyolitic gravel beds which proved that this portion of the zone, at least, was detrital in its origin, possibly accumulated in a shallow lake or swamp. This observation also helped to prove that the rhyolite in Antrim, from which this gravel was derived, was erupted between the lower and upper basaltic outflows.‡ Bosses of rhyolite similar in characters to the Tardree and Sandy Braes rock must have protruded through the lower basaltic sheets somewhere in the vicinity, and gave materials to form this gravel, sand, and clay prior to the outpouring of the upper basaltic sheets. The following section (Fig. 2) was laid open to view when the mine was being worked in 1879, and when, in company with the late W. H. Baily, the present writer made the collection of plants now in the Survey Gallery in the National Museum. The section was supplied by the Manager, Mr. Walter Jameson (see Report of W. H. Baily to the British Association in 1880, and the Memoir to Sheet 21, p. 16, and Geol. Mag., 1895,

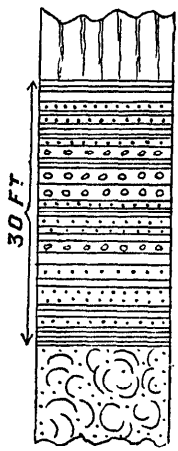
* Address to Geol. Soc. Dublin, 1836, Journ. G. S. Dublin, vol. i. (1838) p. 158.

† " On the Geology of the County of Antrim," Proc. R. Irish Acad., vol. x. (1869), p. 303.

‡ A. McHenry, " On the Age of the Trachytic Rocks of Antrim," Geol. Mag. 1895, p. 262.

p. 263). No lithomarge occurs between the rhyolitic clay beds and the Lower Basalt at this place.

FIG. 2.—SECTION AT LIBBERT BAUXITE MINE IN 1879.



Upper Basalt, black and compact.

Lignite.

Bauxite, grey.

Whitish, grey, and variegated laminated rhyolitic clay, shale, marl, sandy beds, and pebbly rhyolitic conglomerates.

Whitish and grey fine-grained laminated rhyolitic clay and shaly beds with plant remains.

Lower Basalt, amygdaloidal, about 300 feet thick, over the Chalk.

The locality of the plant bed was visited later by Mr. J. Starkie Gardner,* accompanied by Mr. William Swanston.

At Cullinane, two miles W. of Glenarm, bauxite was worked by the Eglinton Company about the same time as the Libbert Mine was in operation, the deposit being similar in character at both places, both in colour and texture. Great stools of carbonised trees were extracted from the deposit, but no leaf impressions are recorded from this locality. The bed from which the trees were obtained was two feet in thickness. As the area between Libbert and Cullinane contains pisolitic iron ore, and none of the grey rhyolitic beds, it would appear that the extent of these latter deposits was very local, and depended on the proximity of rhyolite to give the grey materials for deposition in shallow lakes and marshy places.

At the same time the few scattered grains of quartz in the pisolitic iron ore of the intermediate Glebe Mine indicate that some of the rhyolitic material may have been carried by wind and water agencies even into ground where the rhyolitic bosses did not appear at the surface.

The pisolitic iron ore is wanting both at Cullinane and Libbert.

The grey bauxite deposit again appears in the escarpment of Black Hill, two and a half miles S.S.E. of Glenarm. Rhyolitic sand and clay crop out under the Upper Basalt. This section shows some few feet of light grey quartzose sand and fine gravel at the top, then a blue grey and violet mottled lithomarge with irregular veins of red waxy bole. The depth of this bauxitic

* "L. Eocene Plant-beds of Ulster," Quart. Journ. Geol. Soc. London, vol. xli. (1885), p. 85.

clay and lithomarge is not very clear, but it is probably up to 20 feet or thereabouts.

No trace of the pisolitic iron ore was found here, so that the beds may be a continuation under the Upper Basalt of the Libbert tract of grey aluminous deposits to the N.W.

The outcrop from this point southward along the escarpment is obscured by the numerous landslips.

The next place where the zone appears is on the south slope of Ballygilbert Hill, where adits were driven on the ore bed. No section is visible now, but the spoil heap shows that the red pisolitic ore existed, also a very bright brick red bauxitic clay containing abundant grains of quartz, evidently derived from disintegrated rhyolite. The quartz grains were possibly carried into their position here by atmospheric agencies, such as sand-storms, or the matrix of the deposit may have been originally a grey rhyolitic paste subsequently stained red with iron oxide. It is evident, however, that the presence of the quartz grains indicates a transportation of material from its original location. It is a fact worth noting that in no instance in this district are such detrital quartz grains found in the clay deposits that occasionally occur between the Chalk and the Lower Basalt. This forms another point in favour of the mid-basaltic age of the rhyolites of eastern Antrim.*

The zone from this point appears to sweep round the south slope of Ballygilbert Hill to the stream. It then turns to the south and follows the boggy flat to near Linford Bridge whence it courses in a sinuous line, under heavy drift, towards Agnews Hill, where the grey-coloured rhyolitic bauxite again crops out.

The outcrop of the pisolitic iron-ore in the Upper Glenarm River valley that is shown on the previously published map proves merely to be a bed of red waxy bole between sheets of the Upper Basalt. It is slightly pisolitic, and merges gradually into the basalt. The head waters of the Glenarm River lie entirely in the Upper Basaltic area, and the boundary has been here revised (Map 5 of the present Memoir).

* Prof. Seymour, in his petrographic notes furnished on this area, describes the ground of the rock from the spoil-heap on Ballygilbert Hill (Specimens I 2270 and 2271) as having "a more or less fragmental or detrital structure. It is isotropic where translucent. In places the ground suggests an ash made up of basic material."

Prof. Seymour adduces the following arguments against the derivation of the quartz grains in this and similar rocks from rhyolite:—"(1) The granules are not wind polished to any obvious degree; (2) they are on the whole much smaller than the average quartz crystals occurring in the Antrim rhyolites as we now find them; (3) there is a complete absence of stratification of the quartz granules in the much less dense and finer grained matrix in which they are embedded." He urges that they may represent silica re-crystallised from that removed from the lithomarge during laterisation, and cites Australian quartzites, recorded by Gibb Maitland, which have resulted from the silica extracted from basalt and other rocks (see also p. 10). The crystalline form of the grains and their general characters, however, strongly support the explanation suggested by Griffith in 1836. Some of the quartz grains, moreover, contain the characteristic inclusions of glassy and stony matter that are common in the quartz crystals in the rhyolites.—G. A. J. C.

SHANES HILL AREA.

(MAP 5, CENTRAL PORTION.)

The deposit at Agnews Hill is quite similar to those at Libbert and Black Mountain, and no doubt is due to similar conditions and causes. It is of considerable thickness and extent, and may prove eventually to be of commercial value as an aluminous ore.

As already mentioned, the grey gravelly and sandy bauxitic clays crop out in many places along the north-east slope of Agnews Hill; in places they are seen in contact with the overlying Upper Basalt, and indurated by it. The thickness of the zone is over 30 feet. The pisolitic iron ore is absent in this area, as is usual when the grey bauxite is present. From this point southward along the escarpment the outcrop is obscured by slipped material, but its presence is well indicated by the grassy slope all the way, and by springs, till it crops out near the summit of Shanes Hill. Here numerous adits were driven in former times on the red pisolitic iron ore, which was found to be of good quality and quantity. On the south of the hill adits were also driven on the bed, and a great deal of the ore was extracted, which was sent down to Larne for shipment to England. Work was, however, abandoned about twenty years ago; but good samples of the ore, etc., can be seen in the old tip-heaps along the escarpment.

Along the N.E. side of the hill, in a stream cutting near an angle of the townland boundary, a section of the zone is seen showing 3 to 4 feet of pisolitic iron-ore over 8 feet of pavement, which overlies 30 to 40 feet of lithomarge, the bottom of the lithomarge not being visible. Two N.N.W. faults have lowered the zone in steps to the west, the eastern one for a distance of about 200 feet, the more western one for about the same extent or perhaps a little more.

The next point at which the zone appears is in a stream three-quarters of a mile S. of Shanes Hill Summit, where two to three feet of the ore zone overlie pavement and lithomarge cropping out in the river bank.

The zone is again seen in another small stream, half a mile farther to the S.S.W. From this point it follows along the escarpment in a westerly direction towards Moorfields, with occasional trends up the valleys of the tributary streams of the Glenwhirry River. Openings were made on the zone a little to the north of Ballyclare Junction, and the ore was found in good quality and quantity.

To the southward of Kilwaughter Castle a limited area of Upper Basalt is brought down against the chalk by a north-east fault, which has a downthrow on the south of 300 feet or more. The pisolitic iron ore bed was proved in an adit to the north of the Corn Mill, and in a trial boring near Hightown (see analysis XVIII.). The Upper Basalt is again brought down by another north-east fault in the neighbourhood of Taitstown. The throw

of this fault is also on the south side, and to the extent of about 100 feet.

SCAWT HILL.

(MAP 5, NORTH-EASTERN PORTION.)

A quarter of a mile S.E. of the volcanic neck of Scawt Hill a remarkable exposure of grey-coloured rhyolitic gravel, sand, and bauxitic clay, with traces of lignite, occurs. It looks as if this mass has been let down between two nearly parallel faults which run in a north-westerly direction from Carncastle to the foot of Scawt Hill. Mr. Traill's note on the original six-inch field map describes it as a "mass of yellowish white steatitic clay like along a fault." This explanation of Mr. Traill appears to me to be in a manner correct, *i.e.*, that a portion of the zone, with the Upper Basalt in its normal position resting on it, has been faulted down from its original horizon, which lay some 300 feet or more higher, and became tilted from the horizontal to the nearly vertical position it now occupies between the two faults while it was being displaced.

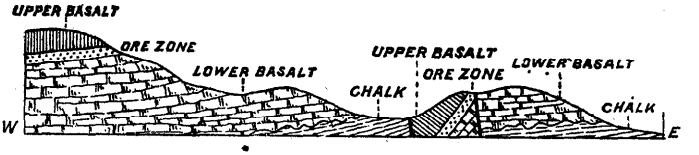


FIG. 3.—DIAGRAMMATIC SECTION ACROSS THE FAULTS S.E. OF SCAWT HILL.

This material was excavated some years ago and sent to Belfast for examination, when, it is said, it proved to be of good quality. The quantity is not likely to be sufficient to make it of economic value.

LARNE AND ISLAND MAGEE.

(MAP 4.)

A little to the west of Larne a small area of Upper Basalt is let down between two parallel N.E. and S.W. faults. Openings were made on the pisolitic iron ore zone on the east side, and to the north of Antiville Bridge. At one place, just under the new road, in a stream, a section of lithomarge in the bank shows over twelve feet in thickness. The ore was too poor to work.

Another small area occurs at Fair Green Hill. Here again the ore was too poor to work. No section is now visible.

Around the high ground of Glynn and Black Hills traces of the zone were observed at a few places, a feature along the escarpment marking the probable outcrop.

On Island Magee an important area of Upper Basalt is shown, with a rich zone of pisolitic iron ore and lithomarge between it and the Lower Basalt (Fig. 4). The old open pit section at

To face p. 34]

PLATE IV.—Spheroidal Basalt decomposing into Lithomarge.
Brown's Bay, Island Magee.

To face p. 35]

PLATE V.—Details of Spheroidal Basalt decomposing into Lithomarge.
Brown's Bay, Island Magee.

Ballylumford shows a thickness of over a hundred feet of the zone. This place was worked by Dr. Ritchie of Belfast over thirty years ago, the ore and lithomarge being exported to

S.W. Larne Lough. Brook. N.E. Brown's Bay.

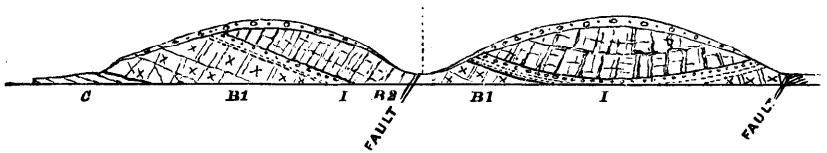


FIG. 4.—DIAGRAMMATIC SECTION FROM LARNE LOUGH TO BROWN'S BAY, SHOWING THE POSITION OF THE IRON ORE.

C. Cretaceous. *B1.* Lower Basalt. *I.* Pisolitic Iron Ore and Bole. *B2.* Upper Basalt.

England for use in the iron furnaces (see analysis XIX.). The following are the approximate measurements:—

Spheroidal, amygdaloidal and vesicular basalt	10 to 15 feet.
Dark brown pisolitic iron-ore (with quartz grains)	6 to 12 inches.
Red pisolitic iron ore (with quartz grains) ..	2 „ 3 feet
Red and brown ferruginous clay and bole ("Pavement")	4 „ 6 „
Red and purplish lithomarge	15 „ 20 „
Red and purplish and grey lithomarge ..	25 „ 30 „
Irregular sheet of weathering basalt	3 „ 5 „
Grey lithomarge	2 „ 3 „
Dark purplish and red lithomarge	6 „ 8 „
Reddish purplish and grey lithomarge with irregular lumps of rotting basalt ..	30 feet and more.

Total thickness of section about 100 feet. (See also section in Memoir to Sheet 21, p. 28.) The dip of the zone is 25° to the N.E.

The zone is also well seen along the southern shore of Brown's Bay, especially at low tide, and in the cliff above the road.

The lithomarge is over 80 feet in thickness, with a decomposing sheet of basalt in it near the bottom of the section, as in Ballylumford pit. The thickness of the lithomarge between the new road and the top of the cliff is about 60 feet. At the top of the section the junction of the pisolitic iron ore with the Upper Basalt is seen.

On the shore, just under the road and below high water mark, the spheroidal and onion-like weathering of the basalt sheet and its complete passage into lithomarge is very well shown, some of the cores of the rounded bomb-like blocks of basalt being still quite fresh (Plates IV. and V.). A quarry beside the cottage shows a portion of the unweathered sheet which occurs in the lithomarge, quite similar to the weathering

sheet in the pit at Ballylumford, the passage from the unaltered basalt into the lithomarge being fully apparent.

It is quite plain from these two sections on Island Magee, as well as those in other places on the mainland, that in all the cases lithomarge is entirely due to the decomposition of the basalt in place, and that the older view as to the origin of this zone from volcanic ashes cannot be maintained. The zone can be seen at low tide to curve round in a northerly direction against the fault.

A distinctly fragmental conglomeratic bed is noticeable on the shore below the pisolitic iron ore bed, the quartz grains being common to both. Irregular veins of bright red waxy bole are common in the lithomarge.

The supposed outcrop of the zone, as shown on the previously published map, does not seem to be justified by the field evidence or form of the ground, nor has it been proved at any place along the line. I believe the outcrop occurs as indicated on the revised map, and that the beds form a basin, with probably a slight break caused by the N.W. fault of Ferris Bay, as shown on the map.

Another fault of considerable extent, which runs from the Gobbins, in the S.E. of the island, to Brown's Bay on the north, brings down the Upper Basalt against the Triassic rocks, thus cutting out the Chalk and Lower Basalt. The throw of this fault must be about 400 feet.

BALLYNURE AND STRAID (IRISH HILL) AREA.

(MAP 5, SOUTHERN PORTION.)

To the north of Ballynure the spread of Upper Basalt continues north-eastward for some four miles. Several adits were driven on the ore bed in the vicinity of Fair Hill. From the nature of the stuff in the spoil heaps, the ore seems to have been of fairly good quality. The bauxitic clays below the ore bed seem also singularly good (see analysis XXI.). With the exception of very few quartz grains amongst the top layers, no other traces of rhyolitic deposits were noticed in connection with this area of Upper Basalt, so it may be assumed that rhyolite was not exposed to any large extent at the surface during the inter-basaltic epoch in this district.

A couple of miles to the south, an outlier of Upper Basalt occurs at Straid and Irish Hill. The grey rhyolitic and bauxitic beds exist here, and have been for some time worked for bauxite (see analyses XXII. to XXVI.). The total thickness of the zone is said to be about 80 feet. Fairly thick beds of lignite are found in connection with the grey bauxitic deposits. The sections, shown in Figs. 5 and 6, were supplied by Mr. John Furness, the manager of the mines.

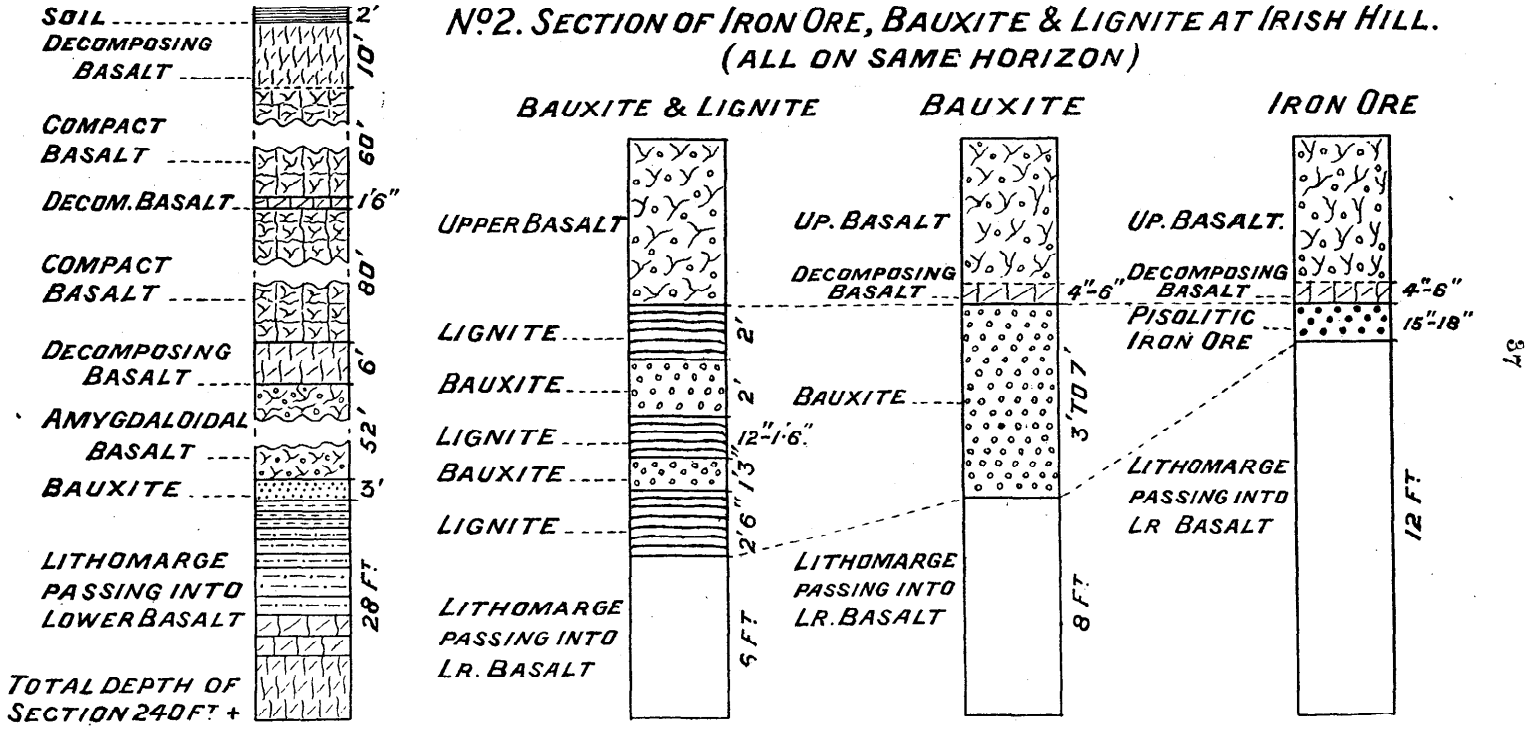

No 1. Section through Upper Basalt of Irish Hill.
Soil
Decomposing Basalt
Compact Basalt
Decom. Basalt
Compact Basalt
Decomposing Basalt
Amygdaloidal Basalt
Bauxite
Lithomarge passing into Lower Basalt
Total depth of Section 240 Ft +
2'
10'
60'
1'6"
80'
6'
52'
3'
28 Ft.
No 2. Section of Iron Ore, Bauxite & Lignite at Irish Hill.
(all on same horizon)
Bauxite & Lignite
Upper Basalt
Lignite
Bauxite
Lignite
Bauxite
Lignite
Lithomarge passing into Lr. Basalt
2'
2'
12"-1'6"
1'3"
2'6"
5 Ft.
Bauxite
Up. Basalt
Decomposing Basalt
Bauxite
Lithomarge passing into Lr. Basalt
4"-6"
3' to 7'
8 Ft.
Iron Ore
Up. Basalt.
Decomposing Basalt
Pisolitic Iron Ore
Lithomarge passing into Lr Basalt
4"-6"
15"-18"
12 Ft.

Fig. 5.

On the north side of this area, near Straid village, the grey bauxite gives place to the red pisolitic iron ore, but apparently only to a limited extent, as this ore soon thins out and becomes replaced by the grey bauxite.

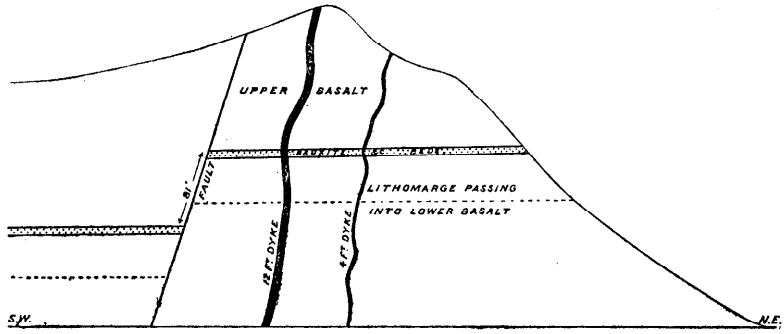


FIG. 6.—SECTION THROUGH IRISH HILL, STRAID.

This outlier of Upper Basalt is traversed by a N.N.W. fault which displaces the zone by 80 feet, with a downthrow to the west. The fault has been proved in the workings, and is marked on the revised map.

In some portions of the mine the rhyolite appears to have been decomposed almost *in situ*. In all instances the top layers of the bauxitic clay are charged with quartz grains out of the rhyolite. The bauxitic conglomerate and sandy beds are frequently interstratified with lignite beds up to two feet in thickness. One of the conglomerate beds seems to be largely composed of pebbles of an altered glassy rhyolite (obsidian). The evidence of sedimentation is very clearly shown in section No. 2, Fig. 5, where the three beds of lignite and two bands of bauxitic clay make a total thickness of over nine feet.

The rhyolitic gravel of Straid gives evidence of the exposure of the Chalk, or of explosion through this material, during its accumulation. A thin section from one block shows all the characters of the conglomeratic and glauconitic chalk that underlies the purer " white limestone " of Co. Antrim. The rounded quartz grains in this rock point to the need for caution when quartzose layers in the interbasaltic zone are being considered Some of the quartz grains may have been carried from Cretaceous horizons into this zone, and may have even become mingled with quartz that is clearly of rhyolitic origin.

G. A. J. C.

Below these beds are the pavement and lithomarge, which have been proved to a depth of over 28 feet. The lithomarge shows in places fine parallel colour-banding of grey, yellow and red, which simulates bedding in a remarkable manner; but the evidence on the ground shows that this is entirely due to weathering *in situ*, and that it has nothing whatever to do with ordinary sedimentation by deposition.

THE IRON ORE ZONE NEAR LOUGH MOURNE, NORTH OF CARRICKFERGUS.

(SHEET 29.)

With the exception of a prolongation of the Black Hill Upper Basalt outlier from Sheet 21 in the north, no other area of Upper Basalt appears to occur in Sheet 29. In this small tract north-west of Ballycarry trial adits were driven on the ore bed at a few places on the east side, and, from the nature of the material in the tip-heaps, the ore appears to have been of good quality. Quartz grains from rhyolite occur in the upper stratum of the zone, and again point to a mixture of rhyolitic material in the formation of the interbasaltic beds.

The two outlying patches of Upper Basalt shown in the previously published map, lying to the W. of Lough Mourne, have been relegated by the writer to the Lower Basalt. The division in the northern outlier, hitherto styled "bole" and "lithomarge," does not seem to represent the true zone between the Upper and Lower Basalts. At some places along this indicated line of boundary traces of rotten red amygdaloid occur which characterise some of the sheets of Lower Basalt in the district. This material was evidently regarded as the pisolitic iron ore zone during the original survey.

In like manner one or two indications of ordinary bole are said to occur on the north-western side of the southern area of Toppin Hill. But all the basalts on this hill have the characters of the Lower Basalt. The two areas of Upper Basalt should therefore, in the opinion of the writer, be omitted from Sheet 29 of the Geological Survey map.

PISOLITIC IRON ORE BELOW THE LOWER BASALT.

About three miles N.N.E. of Carrickfergus, on the S.E. slope of Lower Duff's Hill, an interesting deposit of pisolitic iron ore occurs between the Chalk and Lower Basalt. It consists of dark red-brown ferruginous clay with pisolitic iron, thin lignite patches, and rolled chalk flints. It occurs in irregular pockety deposits from a few inches to a few feet in thickness, and for a short time it was worked for iron. Similar deposits on the old eroded chalk surface occur in Woodburn Glen to the south-west, and to the west of Lough Mourne to the north.

It may be mentioned that deposits somewhat resembling the ordinary red pisolitic iron ore zone are found at many places resting on the eroded chalk surface and below the Lower Basalt. At a place to the N.W. of Lisburn, beds of lignite up to two feet thick are associated with this red pisolitic earth. (See also p. 26.)*

* A. Delesse ("Métamorphisme des Roches," Ann. des Mines, Sér. 5, t. xii. (1857), p. 419) gives the following analysis by Jas. Apjohn of a clay, described as "gris bleuâtre," from between the chalk and the red clay with flints. The

CHANGES IN GEOLOGICAL BOUNDARIES NECESSITATED BY THE REVISION.

It will be seen from the maps accompanying the present Memoir that some alterations have been made in the boundary line or zone between the Upper and Lower Basalts. Beginning in the northern part of the East Antrim area, it was necessary to shift the line on the west side of Glenarm valley, the field evidence being conclusive in this respect. Again, along the escarpment of Black Hill, abundant evidence exists for the alteration carried out. The line shown on the previous map as running up the head waters of Glenarm River required alteration, and a note on the original field map seems not to have been taken into account when the work was reduced from the six-inch to the one-inch scale. It must be admitted that the new line is in part problematical, but it is more nearly correct than that hitherto laid down. Some slight modifications were necessary along the escarpments of Agnews and Shanes Hills. In the latter area the boundary had to be prolonged from field evidence towards the south, and altered along the western valleys.

The boundary line of the area of Upper Basalt lying to the south of the Larne and Ballyclare fault had to be altered in conformity with the field evidence, thus increasing the extent of the Upper Basaltic outcrop.

The elongated outlier of Upper Basalt to the south of Glynn was extended on the north, traces of the red earthy zone having been found along the top slope of the hill, accompanied by a marked feature pointing to its probable existence. No evidence could be found for the E. and W. fault previously shown.

The patch of Upper Basalt immediately west of Larne has faults on its N., S., and W. sides, by which it has been let down some way from its original situation on the west. The zone-outcrop is seen in a stream on the east. A little west of the above area a small extent of Upper Basalt has been faulted down against the chalk, the downthrow being on the south side to the extent of about 500 feet. The ore bed has been proved along the southern outcrop at two places.

A small area of Upper Basalt occurs at Fair Green Hill, three miles S.S.W. of Larne, the ore having been excavated to a small extent on the east side.

Many outlying tracts of the Lower Basalt were examined

locality is Magheragall, which is about four miles W.N.W. of Lisburn, and is, no doubt, near the spot referred to above by Mr. McHenry :—

Silica	50·75
Alumina	20·87
Iron peroxide	15·90
Lime	0·72
Water	10·50
	98·74

G. A. J. C.

where it was supposed that outliers of Upper Basalt might be found to exist, such as to the west of Black Head, N. of White Head, to the south of Ballycarry, Sallagh Braes, and elsewhere, but none were met with.

CHAPTER IV.

THE MID-ANTRIM DISTRICT.

By J. R. Kilroe.

GENERAL DESCRIPTION.

The district to which reference is here made extends from the escarpment within the east coast of the county to that overlooking the Dungiven valley on the west, and forms a band some twelve miles in width, stretching from Cushendall Glen to the valley of the Braid River on the east; from Portglenone to Lough Beg in the middle; and from Garvagh to Maghera on the west. The area has already been described in some detail in the Memoirs accompanying the one-inch published Sheets 14, 18, 19 and 20, to which, therefore, reference will frequently be made. The revision here described has in view a more full and detailed account of the mineral deposits, which, as is well known, occur between the upper and lower series of basaltic sheets, and which, in the eastern parts of the district, have already yielded large quantities of iron ore and bauxite. The boundary between the Upper and Lower Basalts, as represented on the published maps, may be taken as fairly exact. The alterations which have been found necessary, in so far as they affect the area of the mineral deposits, are not in the aggregate of appreciable moment. The curtailment of the Upper Basaltic area is on the whole greater than the extension; but this remark applies to alterations in the boundaries shown on the one-inch maps, and not to the available supply of ore and bauxite remaining after many years of mining. It will be observed from future remarks that, judging from outcrop-indications, the most promising tracts are at present in the hands of leaseholding mining companies. Many of the numerous adits from which the various claims have been worked are now closed: indeed, many had been closed in 1886, when the original Survey maps and descriptions were issued. The utilizing of plant, rails, ore-slides, etc., attached to one or two centres of work, in each rented tract, as well as the advantage of concentrating labour, probably led to the retention of only one or two of the most favourably placed adits. Many, however, had to be abandoned on account of the unfavourable dip of the mineral seam, which occasioned flooding of the mines; in other instances the seam thinned out as it was followed.

In the course of this description, data will be presented to show striking changes of level in the mineral zone, some of which are possibly to be accounted for by original differences of level between the various surfaces on the Lower Basalt on which the deposits were formed. Some of the changes of level, however, are clearly of later date than the Upper Basalt, and are in certain cases due to faulting. The present north and south basins of the Main and Bann rivers are no doubt representatives of hollows originally existing on the uppermost sheets of the youngest basalts. Taking these considerations into account, it is not necessary to assume that the present surface of the Lower Basalt, at any point in the part of Antrim now under description, represents a horizon far below that of the Upper Basalt. As a matter of fact, it becomes doubtful in some cases whether we are justified in terminating the outlying areas (or, at one or two points, the main areas) of Upper Basalt where they disappear at a low level in obscure drift-covered ground. It can, on the contrary, be shown that the areas in some distances are more extensive and ill-defined than might be inferred from the previously published maps.

While this is the case, no additional outlying area of unquestionable Upper Basalt, from which a co-extensive deposit of iron ore or bauxite might be inferred, has been met with during the revision, distinct from the outliers already mapped; nor has any evidence or outlier of the mineral seam or its accompaniments, "pavement" and lithomarge, been discovered. It is difficult to imagine how these comparatively soft materials could have survived erosion, even under ordinary circumstances of denudation, if devoid of a protective covering of basalt. Much less is it likely they would have escaped the ice-planing which took place in the region during the Glacial epoch. It is improbable, therefore, that the mineral zone appears near the surface, concealed only by drifts, anywhere in Mid-Antrim, except as an outcrop under Upper Basalt.

Seams of bole, as already known, occur in the Lower Basalt; some have been noticed at points previously overlooked, as will be mentioned later; but the appearances at any of the points do not warrant the hope that remunerative operations could be undertaken upon any of those seams.

MINING AREAS.

There are in the district here described two main areas; one, the high ground lying to the north of the Ballymena and Cushendall Railway, which culminates in Slievenanee (1,782 feet) and Trostan (1,817); and another south-east of the same line, culminating in Carncormick (1,431) and Slievebane (1,326). They are separated by the valley of Glenravel Water and Cargan Water. A small portion of the extensive Glenarm area is also included in the district. It lies two and a half miles south of Carnlough.

Besides these areas, there are the outliers above referred to, nine in all, scattered over the surface of the Lower Basalt east of the Bann. The areas occupied by the mineral zone are practically equal in extent to those of the Upper Basalt; exceptions will be discussed later on. As will be seen from this description, all the best ore and bauxite prospects are already taken up by companies.

The first area which will be noticed is that lying to the west of Parkmore, culminating, as already mentioned, in Slievenanee and Trostan hills. In proportion to its extent, it is the most important in Mid-Antrim, and has the additional distinction of being the earliest, in this region, to yield iron-ore on a large commercial scale. Even before the present mines were started, attempts were made to smelt ore* in furnaces erected a short distance from the present railway-station at Cargan. The attempts seem to have been part of an ambitious and philanthropic scheme undertaken by Nicholas Delacherois Crommelin to improve and colonize a backward region. Another part of the scheme was to build the village of Newtown Crommelin, which stands upon the east slope of the hill crowned by Skerry Rock. The scheme was, unfortunately, not successful.

GLENRAVEL MINES.

(MAP 1, NORTH-WESTERN PORTION. ANALYSES XXVII. TO XXIX.)

Near the head of the valley north of Cargan, on its north side, is situated the tract which is focused in the mines to which the glen has given its name,† and where operations have been successfully carried on since they commenced in 1866. The opening of these mines was the practical inauguration of the important trade which has since been carried on, in this valley and other parts of Antrim, in the rich pisolitic and so-called "black" iron ores, which are shipped to England, where the smelting is done. The account of the commencement, for this reason, is interesting.

* Regarding the history of iron ore mining in Antrim, Mr. F. W. Hodges, J.P., of Glenravel House, has been good enough to inform the writer as follows: "The late Dr. Ritchie . . . worked the weak aluminous ore at a place near Antrim (town) shortly after the opening of the railway to Ballymena. Mr. Crommelin, of Newtown Crommelin, built a furnace and tried to smelt the same kind of ore that Dr. Ritchie was working, but of course failed. He did not know that there was rich ore in the Glenravel district. With these exceptions, no one had worked the iron ore, so far as I know, before Mr. Fisher." Mr. Hodges published a historical sketch of the mining about the year 1866 in the journal Iron. The antiquities of the region, as investigated by Mr. Edward Benn, former owner of Glenravel House, and relative of Mr. Hodges, are referred to by Rev. J. O'Laverty in his account of the Diocese of Down and Connor, vol. iii., p. 463, etc.

† See references in O'Laverty's "Diocese of Down and Connor," vol. iii., pp. 466-468; another name for the Rock is Skerry Ravel, *i.e.*, the rock overlooking the Ravel (River)—the Anglicised form of the Gaelic name *Freaghabhail* (Frawil). The river was the boundary between the ancient districts of Dalaradia and Dalariada, from Balsallagh to Glaryford (O'Laverty, p. 464).

Mr. James Fisher, of Barrow-in-Furness, Lancashire, who was identified, previous to 1866, with mining projects in Cumberland and Lancashire, and who was owner of some property at Cleggan, in the Braid Valley, became aware, through the Rev. Wm. John Macauley, P.P., of the existence of rich iron ore in Glenravel.* He at once took steps to localise it; and, finding its quality superior, proceeded to mine it. He rented the Glenravel tract from the late Mr. Edward Benn, as a tentative project, at the rate of £10 for the first year, and was able during the first half-year's tenancy to ship a large quantity of ore to England—18,000 tons, according to an account given from memory by Mr. F. W. Hodges—when the ore was worth 17s. to 20s. per ton.

The ore here, and generally throughout this region, is of the two kinds above mentioned, viz., "soft ore," which is an admixture of aluminous and ferruginous clay with a large percentage of embedded pisolitic concretions of limonite;† and "black ore," which is hard, compact and solid brown hæmatite or limonite, containing, in parts, a bluish black magnetic oxide. This is the case with a seam two feet in thickness which was being worked in 1907. An exceptionally rich deposit was found many years ago, not far from the present office of the mine, and about forty yards within the outcrop. It was as much as ten feet in thickness, measured twenty fathoms across, and yielded "60 per cent. of iron." Work was proceeding in 1908 on a seam twelve inches to eighteen inches in thickness. The outcrop to the west of the office in parts shows a seam not more than a few inches in thickness, so that the average of ten to twelve inches throughout, as reported, is probably correct. One ton of ore to the square yard is reckoned upon in the workings.‡

* Information kindly supplied by Mr. James Fisher, Junior.

† Mr. Fisher supplies the following information: "For many years after 1866 the aluminous or second grade ore was considered of no value; but for 15 or 20 years this poorer ore has been used as a flux along with the siliceous ores of Cumberland and Lancashire, with advantage, when its low price is taken into account. There is a wide difference of opinion amongst smelters with regard to it, however, some refusing to use it at any price, preferring to pay the higher price for the better quality, and buying it out of consideration for the metallic iron only. As this cannot be said to average, in the best qualities, over 40 per cent., its value is, and always has been, subsequent to the first 10 years' operation, very low, and it has never been valued so high in the minds of smelters as to cause them uneasiness if, and when, they could not get it at their own price. There is always a large quantity of limestone used in the furnaces with this and the Furness and Cumberland ores. . . . Glenravel ore has been smelted alone, but only experimentally, when it was found that the pig-iron was not only of an extremely dark colour, but that it contained many of the pellets which had passed through the furnace and run out into the pig-bed intact."

Replying to questions, Mr. Fisher wrote:—

"1st—It was not out of consideration of advantage as a flux that the mineral was (originally) raised, but for its value in metallic iron only.

"2nd—It has always been used in very small quantities compared with other ore going into the furnace at the same time.

"3rd—Limestone is used with it; but in smaller quantities with the low grade or aluminous ore than with the higher grade ore.

"4th—It is not considered advantageous to use more than the minimum quantity along with the better class of Spanish, African, and Grecian ores."

‡ At 11*d.* per hutch of 13½ cwt., miners can make from £1 to 22*s.* 6*d.* per week.

Mining is now carried on through an adit at Ballynahavla Bridge, about one mile W.S.W. of Parkmore station. This stands at the eastern extremity of a line of openings along the 1,050 feet contour (approximately.) These openings display the mineral series of the zone to full advantage, on an outcrop nearly a mile in length. Here, too, may be seen four or five abandoned adits through which operations were formerly carried on. The general section may thus be described :—

Upper Basalt, usually vesicular, in parts highly so.	
Capping of clay " brushings "* occasionally.....	2 inches
Pisolitic iron ore	3 to 20 inches
" Pavement," with patches, intercalated layers, and reticulated veins of grey lithomarge	8 to 12 feet
Lithomarge, varying from grey and mottled, above, to purple below	30 to 40 feet
Lower Basalt.	

The " pavement " floor of the iron ore is considerably uneven, and the seam is frequently disposed as in the accompanying sketch. In places it passes from pisolitic oxide into a bole,

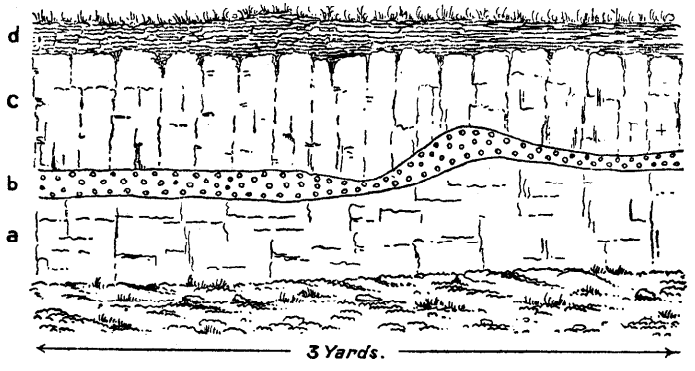


FIG. 7.—SECTION WEST OF THE OFFICE, GLENRAVEL MINES.

d. Peat.
c. Upper Basalt.
b. Pisolitic Iron Ore, 3 to 12 inches thick.
a. " Pavement."

which varies in thickness from twenty-two inches to two or three inches within a distance of thirty yards.

* " Brushings," of common occurrence throughout the mining tracts, may be red, brown, grey, " white " or blue, and consist of a thin seam, one or two inches thick, over the iron ore or bauxite, and under the Upper Basalt. Part of the latter—the lowermost much decayed portion—is also often included with the brushings. The clay, which is also termed " holing," because it fills hollows in the surface of the ore bed, seems to represent a sediment deposited from waters which lay upon the land surface prior to the outpouring of the Upper Basalt.

A cutting for a small railway siding is run through the "pavement" west of the office, exposing a depth of six feet, with two seams of bole, one of which seems rich in iron. Near the office a small stream cuts through the lithomarge and "pavement," exposing on one side a layer of basalt, and on the other globular exfoliating masses of basalt, contiguously embedded in lithomarge, obviously representing the layer of basalt on the opposite stream bank, and as obviously illustrating the origin of the lithomarge. In the "pavement" above the globular masses, moreover, are smaller roundish masses of lithomarge, evidently the ultimate stage of the peculiar weathering which affected the Lower Basalts during the interbasaltic period; and the exfoliating of these small masses reveals red ferruginous layers alternating with the grey, showing that the "pavement" is a lithomarge impregnated with iron oxide. When the appearance of stratification exists in the "pavement," it seems accounted for by some bands of the lithomarge having been especially susceptible to impregnation; just as the commonly occurring layers and veins of lithomarge in the "pavement" are suggestive of a greater resistance to impregnation in such cases. The quasi-stratification is to be well seen in the stream that bounds the Glenravel tract on the west—the mearing of the Legagrane townland, within which the tract is situated.

A good line of rails is laid from near the boundary just mentioned across the townland, parallel to the outcrop, and through Evishacrow and Parkmore to the present terminus of the Ballymena and Cushendall Railway. Until recently the ore was shipped from Red Bay, to which it was taken down from Parkmore in carts.*

CROMMELIN MINES, INCLUDING TUFTARNEY HILL.

(MAP 1, NORTH-WESTERN PORTION. ANALYSES XXX. TO XL.

The tract in which these mines are situate lies on each side of the wide valley of the Skerry Water. It includes the townlands of Tuftarney and Skerry East, and adjoins the Glenravel mining tract of Legagrane on the south-western slopes of Slievenanee. Mining was commenced here "about 37 years ago"† by the Crommelin Mining Company. Many of the adits along the outcrop on the east side of the narrow peninsular tract north of Newtown Crommelin had been closed for some years before the Memoir accompanying Sheet 14 was published. This was probably due to the ore failing, for no attempt has been made to reopen these mines. Bauxite occurs in one of the openings "three to four feet thick"‡ about a mile and a quarter north of the village; but, judging from the portion of the seam now

* The cartage, 1*s.* 9*d.* to 2*s.* per ton, has lately been considered insufficient, and the ore is now, in consequence, sent by rail.

† Information given by Mining-Captain Dryburgh in 1908.

‡ See Memoir to Sheet 14, p. 21.

exposed, it seems to be of an inferior quality. The section at a point one mile and a quarter north of Newtown-Crommelin is interesting, however, as illustrating the formation of this substance from interbasaltic rhyolite, through the peculiar decomposition which affected this and the basic igneous rocks during the period. Beneath the Upper Basalt occurs a layer, eight inches in thickness, of hard, black, very compact basalt, distinct from the main part of the Upper Basalt which overlies it, and which is a rapidly weathering coarse rock. The compact layer rests upon a thin dark grey mud or clay seam, which at one point inserts itself into the layer, as if this part of the rock, when flowing over the old surface, caught up part of the softer seam. It is otherwise difficult to explain its occurrence. The muddy seam clothes the uneven surface of whitish grey material—the bauxite, so called—portions of which are soft, and parts hard and stony. The latter portions, in fact, are decomposing lumps of rhyolite. They are contained in and dovetail with the softer material in a manner entirely suggestive of the derivation of the latter from the rhyolite. The soft grey material is margined near the basalt with a red ferruginous fringe. The accompanying sketch (Fig. 8) represents the relations above described.

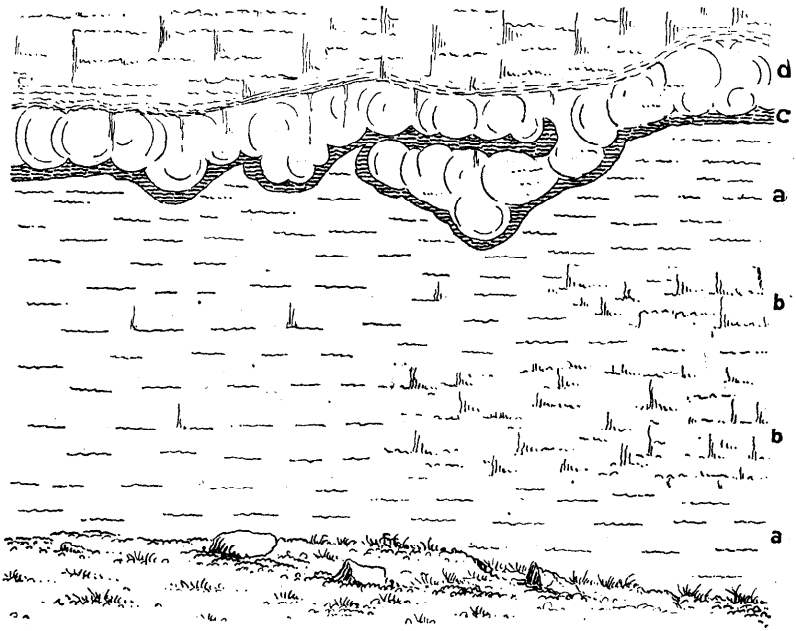


FIG. 8.—SECTION IN STREAM ABOVE NEWTOWN CROMMELIN. (Length about 8 feet.)

d. Upper Basalt.
c. "Brushings," dark-grey clay.
b. Undecomposed grey vitreous rhyolite.
a. Bauxite derived from the rhyolite, about 5 feet thick.

Skerry Rock, above Newtown Crommelin, which, upon close examination, seems to be separable as an outlier from the Skerry Hill tract of Upper Basalt, has been tried for ore, but without encouraging results. Indeed, it may be safely inferred that in the portion of the Crommelin mining tract now under description —extending from Skerry Hill southward to Skerry Rock—we have reached the north-western limit of remunerative mining, under present conditions, in this region; for in the Slieverush and Slievenahanaghan outliers, and that in Slieve-an-Orra still further north, as well as in the stream which flows south-westward from Skerry Hill, lithomarge and "pavement" only have been found, without iron ore or bauxite.

The line of outcrop on this the west side of Skerry Water valley terminates against a fault running north and south, with a downthrow eastward, as proved by trial borings.* There is

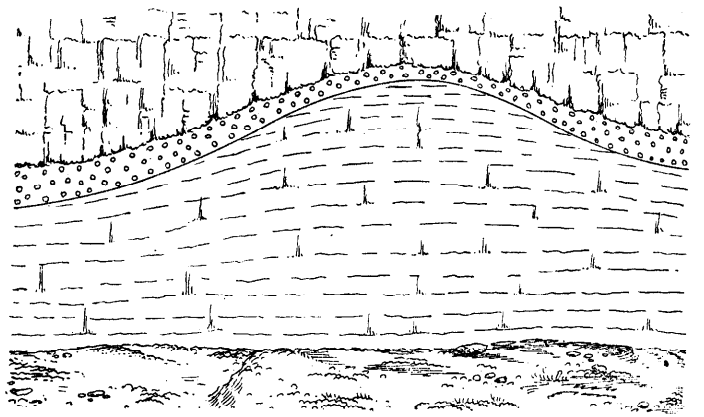


FIG. 9.—SECTION IN SOLOMON'S DRIFT MINE.

Pisolitic Iron Ore, 3 to 5 inches thick, between Upper Basalt above and "Pavement" below.

nothing at the surface to suggest such a break, for the geology of the ground at the valley head is much obscured by drift.

Passing to the east side of the upper part of the valley of the Skerry Water, some eight openings are to be seen along the outcrop to the mearing of the Glenravel mining tract, in all of which work had practically ceased when visited during the progress of revision, except in Heard's Drift, at the valley head, on the east side of the main stream. Much ore seems to have been removed from the adits along the outcrop; so far as information could be gathered, mining seems to have proceeded for upwards of a mile northward from the southern end of the outcrop in this tract, and about a quarter of a mile from its face inward. A line of rails has been laid along the slope near the outcrop from Cargan station to Heard's Drift, and some

* Mem. Sheet 14, p. 29.

twenty-five men were in employment, in mining and removing the ore from this mine, when the district was visited.

Some thirty tons of bauxite had then been recently removed from Solomon's Drift, an adit nearly half a mile south by east of Heard's Drift; and, though work had ceased, the writer was enabled, through the courtesy of the manager, Mining-Captain Dryburgh, to examine the mine and make the following observations. Between the outcrop and the bauxite is to be seen pisolitic iron-ore, varying from three to five inches in thickness, resting upon an uneven floor of "pavement," as in the section given on the preceding page (Fig. 9).

Further in, the iron ore ceases, and the "pavement" dovetails with grey bauxitic material, which is overlain *seriatim* upward by a thin clay seam styled "brushings," roof rock (very compact basalt) in a thin layer, and a thick layer of ordinary basalt, as in Fig. 10.

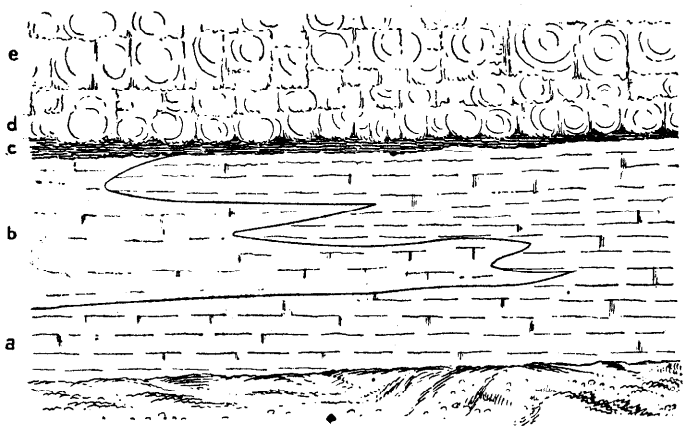


FIG. 10.—SECTION IN SIX-FEET LEVEL, SOLOMON'S DRIFT MINE.

e. Upper Basalt.
d. Compact basal layer of the flow.
c. "Brushings," a few inches in thickness.
b. "White Lithomarge," dovetailing with ordinary type, and derived from it by leaching away of iron.
a. "Pavement"; six feet seen.

Turning northward from the adit, which runs eastward, the point was reached where bauxite is to be seen. It varies from reddish and yellowish grey to nearly white, is granular and crumbly, and contains lumps and small masses of a white mineral segregated from the mass. It somewhat resembles felsitic ash, an opinion which might be held to be borne out by the inclusion of angular pieces of basalt, were it not that these have all the appearance of pieces remaining after the adjoining material had succumbed to thorough transformation, with scarcely anything of an intermediate variety intervening, to indicate progressive alteration. The bauxite rests upon layers varying in colour,

from light to dark brown ; and between two of the layers lies a corroded detached mass of basalt with an adjoining zone of material, less altered than the layers, and once evidently part of the enclosed basalt mass. Since we are elsewhere justified in supposing such considerable alterations of basalt in place to have occurred, the circumstances of the section are best to be accounted for by supposing that light grey bauxite has been here derived from basalt, the iron having been leached out, and segregation of white material having taken place sporadically through the mass. This white substance will be referred to below ; meantime the accompanying sketch is presented as showing the relations of the different layers, inclusions and overlying basalt (Fig. 11).

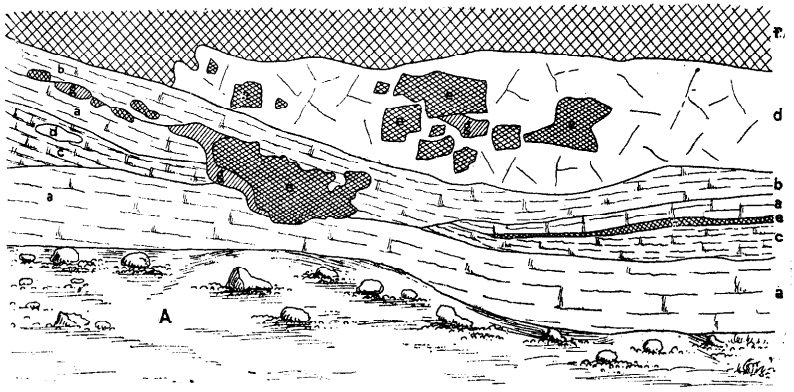


FIG. 11.—SECTION IN SOLOMON'S DRIFT MINE.

g. Partially decomposed Basalt.
f. Main Basalt.
e. Isolated masses of Basalt.
d. Light grey bauxitic clay.
c. Very dark brown bauxitic clay.
b. Dark brown bauxitic clay.
a. Light brown bauxitic clay.
A. Loose quarried material.

Tuftarney Hill, with its outlier of Upper Basalt and the mineral zone, has also been mined by the Crommelin Company wholly as it appears, for bauxite (see analyses XXXIII. to XL.). Three adits were tried prior to 1907 ; a fourth has recently been opened, and yielded a quantity of the substance from which specimens were taken by the writer for the analyses given below. The mass consists for the most part of dark and light bluish-grey material, which is of low specific gravity, and resembles lithomarge in touch, general appearance, and readiness to crumble on exposure. In parts it presents fair evidence of stratification, so much more distinctly than lithomarge or " pavement " that it may possibly result from the comminution of previously formed lithomarge during the interbasaltic period by wave-action, and its deposition as sediment from lake-waters ; the evidence, however, is not quite convincing.

While the white material exhibits a disposition to arrange itself along interlaminar spaces, it commonly crosses the laminæ zig-zag, and swells out here and there into fantastically shaped nodular lumps, which are obviously of segregative origin. What places this beyond question is that the white substance is fringed by an accumulation of the dark bluish mineral, which, scattered more sparsely through the matrix, gives it the colour above mentioned; this bluish mineral is also disseminated, more sparsely still, through the white substance. The accompanying sketch (Fig. 12) represents the manner in which the white substance occurs.

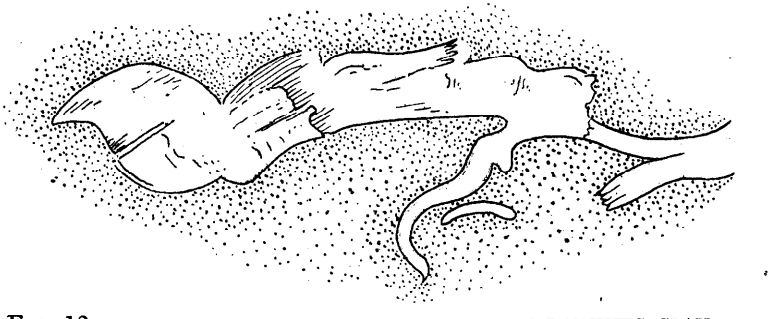


FIG. 12.—SEGREGATION OF WHITE MATERIAL IN BAUXITIC CLAY.
Tuftarney Hill Mine. Natural size.

The interesting material from Tuftarney Hill appears to be a lithomarge from which most of the iron oxide has been removed. The angular character of some of the white portions, and the small slickensides upon them, imply brecciation, and none of the structure of the original basalt remains. Far from being gibbsite, the white masses prove to be richer in silica than ordinary lithomarge. The blue-grey ground in which they lie differs from them mainly in the presence of the small dark granules. Mr. W. D. Haigh and myself have failed to separate these granules with dense liquids, owing to their minute size and the large surface they present. When the coloured parts of the rock are crushed and examined under the microscope, the dark granules are seen to be far less numerous than might be expected. Large examples measure 0·04 mm. in diameter. They are opaque, and are not attracted by a bar magnet. I have little doubt that they consist of the last residues of the pyroxene of the original basalt, as so often is the case in lithomarge, with a possible admixture of ilmenite, as is suggested by a comparison of the two following analyses :—

BAUXITIC DEPOSIT, TUFTARNEY HILL.

	I. White Portion. Analyst, D. S. Jordan.	II. Blue Grey Portion. Analyst, W. D. Haigh.
Moisture (free), lost at 110° C.	5·04	4·64
„ (combined)	13·78	17·72
Silica	42·54	27·93
Ferric oxide	0·60	2·03
Alumina	34·56	41·32
Titanium dioxide	3·75	5·46
Lime	trace	·60
Magnesia	0·00	·25
	100·27	99·95

The blue-grey portions are thus probably nearer in character to the original lithomarge, and the white portions were developed by segregation in the lithomarge, after the manner of the white streaks and irregular lumps in the altered zone of the Giant's Causeway. The appearance of stratification referred to by Mr. Kilroe would arise at this stage, and would be disturbed by the subsequent yielding and brecciation of the mass, which has caused the blue-grey portions to fill up cracks and interstices between angular fragments of the white material.

When considered as free from oxides of iron and titanium, and from water lost at 110°, the resemblance of the white substance to kaolin is somewhat striking. The constituents then appear as follows :—

	White Material, Tuftarney Hill.	Kaolinite ($H_4 Al_2 Si_2 O_9$)
Water	15·16	14·0
Silica	46·81	46·5
Alumina	38·03	39·5
	100·00	100·0

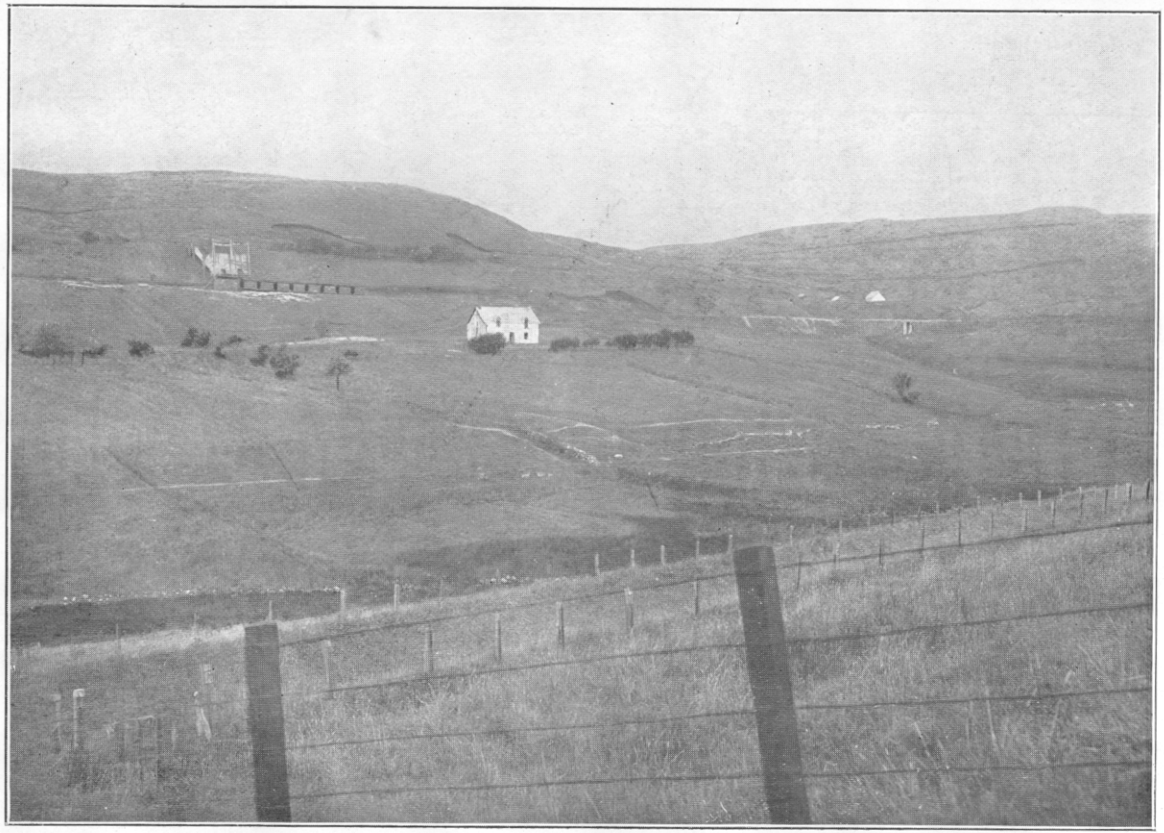
Except, then, for the leaching away of iron to some other spot, there is no sign in the white portions of the tropical processes of alteration, whereby aluminium hydroxides rather than kaolin are accumulated; yet the blue-grey material intermingled with the white has distinctly advanced towards a bauxitic stage, and the analyses of Tuftarney bauxitic clays given on p. 116 afford ample confirmation.

G. A. J. C.

EVISHACROW MINES.

(MAP 1, NORTH-WESTERN PORTION. ANALYSIS XLI.)

These mines, on the north side of the railway and of Cargan Water, between Cargan Station and Parkmore, were opened by Mr. Chambers forty-two years ago. After having been many years closed, they have recently been reopened and are now worked by the Crommelin Company, giving employment (in September, 1908) to 23 men, the iron ore and mining prospects being good. The tract adjoins that of the Glenravel mines on the north, along a stream which bounds Evishacrow. On the north shoulders of the hill, trial openings have been made, one of which, dug in 1907, revealed a faulted condition of the iron ore seam, from which it is inferred that a break runs north-eastward along the small valley of the Binvore Burn, to meet one running north by east near the working adits in Evishacrow. Enquiry concerning the latter fault elicited the doubtful information that it involves a downthrow to the east. This is improbable, because a boring was put down 38 years ago about a quarter of a mile south of Agan Bridge, and for about 160 feet, without finding ore. Rock rich in magnetite was here met with; probably Lower Basalt, for "pavement" and lithomarge appear in the banks of the Agan Burn between the point at which the trial boring was made and the bridge. The Upper Basalt then, with its underlying mineral seam, appears to form a thin cap, east of the N. by E. and S. by W. fault in Evishacrow. The ground is complex and difficult of reliable interpretation, without more



To face p. 53]

PLATE VI.—The Ore Zone (just above the mineral railway), Parkmore.

definitely established data. The faults are inserted on the map according to probability as to their directions, without certainty as to the sides on which the throws have taken place, or the approximate amounts of the throws.

A short railway siding carries the ore across a bridge over the Cargan Water to the Ballymena and Parkmore Line.

PARKMORE MINES.

(MAP 1, CENTRE OF NORTHERN PORTION. PLATE VI. ANALYSIS XLII.)

The tract on which these mines are situate, including the townlands of Parkmore and Barard, has been in the hands of the Antrim Iron Ore Company since 1879. It had previously been worked by the Parkmore Iron Company, which had its offices at Whitehaven, England. The outcrop of the seam runs from near the railway terminus northward along the east side of Trostan Hill, a terraced slope which overlooks the valley that opens on the sea at Cushendall. Many trials for ore have been made at intervals along the outcrop, and both iron ore and some bauxite were removed from several adits; but work is now centred at an adit near the railway station and entirely consists in iron ore mining. The following account of the mines is taken from the original Memoir to Sheet 14, p. 21 :—

"At the Parkmore Mines at the source of the Glenariff River, the ore is still worked by the Antrim Iron Company, and has proved remunerative; first quality (yielding 38 to 40 per cent.) being twelve inches thick; second quality, six inches to two feet; third quality, six to eight feet; fourth quality (lithomarge), up to forty feet. . . . Large crystals of calcite occur in the geodes in the basalt forming the roof of the mines. A downthrow fault of seventeen feet to the N.W. was encountered in the first workings of these mines, but the ore on the other side of the fault having been met with it was found that it increased in thickness away from the fault, the ore rising 1 in 22 to the west."

The richness of the ore at present given is 40 per cent. of iron, in a seam eight inches to twelve inches in thickness; 60 per cent. in picked samples. The seconds, which are a fairly rich "pavement," reach only 26 per cent. Together with the more important fault above mentioned, there are several small breaks of two feet and three feet in throw, and some dykes. The floor rises in steps from the outcrop inward, with inclinations of one in twenty to one in twenty-four; and there are "hollows" in which the "seconds" or "pavement" is sometimes thirty feet in thickness instead of six to eight feet, which is usual over the lithomarge. The manager,* moreover, informed the writer that, allowing for the slight rises inward just mentioned, the level is approximately the same throughout, though the old surface is

* Mr. Alexander Gillespie.

here and there cut up with hollows (perhaps original water-channels) 30 to 50 feet in depth.

Some seven or eight adits, northward of that now in operation near the railway station, seem to have yielded iron ore. Report has it that bauxite was found in some of the openings, but always near the outcrop, after which it gave place to iron ore. Bauxitic material now occurs in an adit on the northern side of the Essathohan Burn, a mile north of the railway station. An intelligent working miner* gave the writer the following information concerning the mode of occurrence of this mineral :—

The main layers occurred as lenticles 20 to 25 fathoms in width, and at most 2 feet to 2 feet 6 inches in thickness ; the roof falls and the " pavement " rises at each end. Between the lenticles there intervened from five to seven fathoms of poor ground, which had to be tunnelled at the miners' expense ; the profits obtained from the good material did not pay for such extra cost. There were in all three working levels, *i.e.*, adits, from which the " bauxite " was taken. No iron-ore was here met with, and the bauxite mining was abandoned because the material was too red (ferruginous). Several bore-holes were put down upon the zone, where the occurrence was most constant, near the outcrop at Trostan ; and sometimes bauxite was found near the outcrop, sometimes not. The levels were worked chiefly near the outcrop.

In this mining tract, and that of the Glenravel Mines on the west, it has been found that the further in the mining proceeds the harder the ore becomes, so that blasting is necessary to remove it. The pavement also becomes harder, even sooner than the ore ; though the lithomarge throughout may be removed with the pick. Columnar structure is not characteristic of the Upper Basalt in this region. It is frequently vesicular, and to ordinary vision it is not distinguishable from the Lower Basalt, except by relative position. The roof of the ore or bauxite seam is frequently a layer of almost glassy lava, as represented in the sketch on p. 49, with an intervening thinner layer of clay, more or less indurated, known as " brushings"; and geodes of calcite are commonly met with either in the clay or caught up in the layer of basalt below the massive layers of Upper Basalt.

The ore is sent by rail from Parkmore to Belfast, and the additional expense over that of somewhat similar ore shipped directly from Glenarm is counterbalanced by the average percentages of iron in the outputs at the two places, as shown in the following data, given here for comparison :—

Parkmore	No. 1 ore ..	.. 38 to 40 per cent. iron.
,,	No. 2 ore ..	.. 26 ,, ,,
Glenarm	No. 1 ore ..	.. 34 to 36 ,, ,,
,,	No. 2 ore ..	.. 15 to 20 ,, ,,

* Mr. Nicholas Birt.

The entire extent of the Slievenanee and Trostan area is 4,380 acres. If we omit 1,625 acres along the northern and north-western margin as probably barren, and estimate 1,213 acres as exhausted during the past 44 years' mining, 1,542 acres remain to be mined, which at one ton per square yard—the estimate given by the Glenravel mine-manager—represents 7,463,280 tons of iron ore. The outcrop of the interbasaltic zone is represented on the maps by a double line with dots when it contains, or has contained, minerals of commercial importance, whether iron ore, bauxite, lignite, or lithomarge; and by a single line when it is believed that these minerals are wanting or of trifling value.

A series of thin sections from the rocks of the Parkmore mines shows the most perfect gradations from ordinary ophitic olivine basalt to almost opaque "pavement" and iron ore. The ophitic pyroxene is the first mineral to be affected, and breaks up into opaque granules between the felspars, before the porphyritic crystals of olivine show more than marginal decay. Translucent red patches then appear in the olivine, eclipsing the green colour due to serpentinisation. The olivine ultimately passes, perhaps through an iddingsite stage, into the common red groundwork of the "pavement." In this "pavement" stage of the rock, almost all the felspar rods have become isotropic. The pisolitic ore no doubt represents a re-arrangement of the "pavement" material on the surface of the ground; but we have seen in other cases that pisolitic grains develop within bole *in situ*, and are thus a last stage of the alteration of a basalt.

G. A. J. C.

CARNCORMICK AND SLIEVEBANE AREA.

(MAP 1, NORTH-EASTERN PORTION.)

Turning to this, the second large area, and commencing our review at the extreme north-east angle, overlooking Red Bay, the outcrop of the mineral zone is well exposed along the escarpment which forms the precipitous southern side of Glenariff. Near Garron Point the escarpment is dislocated and traversed by numerous faults and landslips. These are availed of by the drainage of the plateau above, which sends its discharges down through many gullies and picturesque gorges. In consequence of the displacements, the zone has in places an exaggerated width of outcrop, even on the steeply sloping ground; while the usual order is easily traceable upwards from Lower Basalt through lithomarge and "pavement" to pisolitic iron ore—an unimportant deposit in this locality—and thence to Upper Basalt, which is here rudely columnar. The slopes above Galboly present miniature valleys between small fantastically pinnacled and castellated outliers of Upper Basalt on the one hand, and precipices of the same massively columnar rock on the other—the floor being formed of lithomarge, decked here and there with scattered blocks and talus from above. Where the section is

best seen, the thicknesses assumed by the members of the zone are as follows :—

	ft.	ins.
Upper Basalt	—	
Pisolitic Iron Ore.....	0	4
Pavement	12	0
Lithomarge.....	30	0
Lower Basalt .. .. from 70 ft. to	100	0
Bole bed	1	0
Lithomarge ?	2	6
Basalt ..... from 30 ft. to	35	0
Bole bed	1	0
Basalt	—	

The zone abuts against Lower Basalt half a mile west of Garron Point along a N.E. fault, and in the base of the precipice formed of tabular basalt one of the bole beds is to be seen, reaching a thickness of about four feet six inches before bifurcating ; after which one of the seams is from two feet to two feet six inches in thickness and the other less. These bole seams are remarkably persistent, being traceable along the escarpment face in the tabulated Lower Basalt, between its thick layers. Two only, those mentioned in the detailed section, are traceable throughout. One of them is sometimes seen overlying, and occasionally replaced by, a material resembling lithomarge, but devoid of the patches of white material that are so common in the latter. Bole is also to be seen in the railway cuttings south of Cargan, in the Lower Basalt. It will be mentioned in several other places, always in the Lower Basalt,* and at fairly uniform depths below the lithomarge zone ; which would seem to indicate prolonged exposure during cessations of basaltic outpourings at each of the horizons marked by the occurrence of the bole, and would also indicate that the cessations of basalt-flows throughout a wide area in this region were general at those horizons.

ARDCLINIS MINES.

(MAP 1, NORTH-EASTERN PORTION.)

Proceeding a mile and a quarter westward from Galboly, an adit is reached at Ardclinis, from which some ore has been taken. Lignite is also reported to occur here. As now seen at the adit, the ore seam has the appearance of a highly ferruginous ash, lending warrant to the statement in the original Memoir (Sheet 14, p. 20) that the ore, which is here non-pisolitic, is capped with ash. Such material, however, may be merely partially decomposed Upper Basalt (see below).

In descending the escarpment along the cart-track used for the mineral, lithomarge is to be seen in the Lower Basalt, and some 50 feet further down a bole bed occurs over a thin seam

* The bole mentioned by Mr. Wilkinson on p. 25, and to be seen near the high water level in the third bay at the Giant's Causeway (Plate I.), is probably on the same horizon, which is remarkable when the distance is considered.

of lithomarge, devoid of white material (see p. 56). In the next deep gully following that of Ardclinis, a quarter of a mile to the west, a section is exposed in Carrivemurphy, south of the waterfall, which shows the following series, viz. :—

Upper Basalt	—
Iron ore—very poor	1 to 2 feet
Pavement—yellow and grey interstratified	3 feet
Seam of carbonaceous and ferruginous clay	2 feet 3 ins.
Grey fragmental material, streaked with yellow	2 feet
Lithomarge	more than 10 feet
Lower Basalt	—

The samples collected by Mr. Kilroe from the beds hitherto described as ash at Carrivemurphy contain greenish grey fragments of basaltic lava, altering to clay, in a yellower or browner ground, in which pisolitic grains of iron ore have developed. The whole reminds one of the way in which pisolitic bole arises from compact lava at the Giant's Causeway ; but the truly fragmental nature of the lumps in the ferruginous ground at Carrivemurphy is attested by the occurrence with them of a few quartz grains, like those that we have elsewhere regarded as detrital. The fragmental layer, however, is probably merely the crumbled down surface of the underlying basalt. The upper part of the unbroken basalt is now represented by a characteristic lithomarge. The "ash" recorded from Ardclinis is still more like a decomposing lava-surface.

G. A. J. C.

The original Memoir (to Sheet 14, p. 20) has a reference to this section which runs thus :—"Ore was found above the waterfall. A fault occurs here, the ore being thrown down to the east. The fault-rock is composed of angular pieces of basalt cemented with a steatitic material. The section showed twenty-five feet of pavement and lithomarge, with but a trace of ore ; in the pavement were enormous bombs of rounded and exfoliating basalt." The " bombs " are, no doubt, as we have seen in other cases, residual unweathered cores. Mining does not seem to have been carried on here. Lower down are to be seen the persistent seams of bole in the Lower Basalt.

BAY MINES.

(MAP 1, NORTH-EASTERN PORTION.)

Some ore is reported to have been taken from the tract almost due south of Milltown R. C. Chapel in the townland of Drumnacur, known in the locality as " the Bay Mines." An adit is to be seen in the west face of a gully, along which runs a fault shifting the outcrop laterally about 200 feet. The description given in the Memoir (to Sheet 14, p. 20), for which data were obtained when the face of the outcrop was fresher than it is now, reads thus :—" Ore was proved in the brook coming from the mountain above Bay Lodge, Glenariff Valley, at 900 feet above the level of the sea, and was very thin and irregular, with a bed of

ash above and below it ; a small fault here throws down the ore on the west."

The section on the east of the fault shows a curiously reticulated ferruginous mass, twelve feet visible, having an appearance as if the reddish yellow substance had eaten its way upward, thus permeating the mass. The entire mass, as a consequence, presents numerous detached roundish lumps, and fantastically shaped pieces of basalt, in such relation to each other as to suggest a once molten magma fractured by rapid solidification and cooling, in which alteration proceeded along the main joints, rather than a volcanic agglomerate or ash.

Ore is reported to have been removed from an adit here, and carried down the escarpment to Milltown, at the cost of sixpence per ton. North of the adit, part of the way down the steep slope towards Milltown, a layer of basalt occurs, similarly cut up with reticulated veins ; but here the veins—in places up to six inches in width—are filled with red compact bole, which, in the veins, replaces the basalt. The layer of bole (and basalt) is about eighteen inches in thickness. Another seam of bole is here also to be seen, a little further down the slope, resting upon lithomarge devoid of white material.

Due south of the Glenariff National School a continuous section of the series of basalts, etc., is presented ; and here the mineral zone reaches a higher level than at any other point along the escarpment, being 1,000 feet above datum. This level is, however, not quite so high as at Parkmore, where the present working adit is about 1,030 feet, or at the Glenravel Mines, where the height reached by the zone is about 1,075 or 1,100 feet. The adjacent Crommelin iron ore mines range from 1,000 in the south to 1,100 and upwards in " Heard's Drift " in the north. The section at Milltown is as follows :—

Upper Basalt from 1,000 feet above the sea, upward.

Pisolitic iron ore	1	foot
Pavement	5	feet
Lithomarge (violet brown)	50	,,
Layer of basalt	6	,,
Lithomarge (blue and red)	12	,,
Lower Basalt (from about the 925 feet contour, downward)	172	,,
Bole at about 750 feet	3	,, 6 inches
Basalt	100	,,
Bole at 650 feet	1	foot
Basalt	75	feet
do. with bole seams (8, 2, and 3 inches)	80	,,
Basalt	25	,,

Chalk at 470 feet above sea.

Total thickness from chalk to top of iron ore ..... 530 feet, 6 inches.

In Greenaghan a trial boring was put down upon the seam, the outcrop of which here remains very perceptible, but information is wanting regarding definite results, though the indications show "pavement" and lithomarge at least. Ore ten inches in depth is reported at the escarpment brow in the stream which trenches the steep slope in this townland.

GLENARIFF MINES.

(MAP 1, NORTH-EASTERN PORTION. ANALYSES XLV. TO LI. SEE ALSO ANALYSES XLIII. AND XLIV.)

Continuing the traverse south-westward, the outcrop follows an almost straight course under precipitous cliffs which crown the escarpment, on the east side of Glenariff and the steep gorge of the Inver River, a tributary of the Glenariff River. Here a number of adits were opened, above a railway which was made to carry the ore along the valley side from Milltown south-westward, a distance of four miles. The original Memoir (to Sheet 14, p. 21) gives an account of the mines in this statement :—

> "The iron ore was worked extensively, and carried by rail to Red Bay for shipment ; for the most part these mines have been abandoned" [that is, in 1886]. "Eleven adits were driven, and the ore of first quality was found to be on an average eleven inches thick, and second quality nineteen inches, the level of the ore-bed being about 720 feet above the sea, with an inclination of about 1 in 30 to the S.E.
>
> "West of the Inver River the outcrop is well defined, and the ore is better and thicker than on the east side, there being two to four inches of red pisolitic, and eighteen inches of black pisolitic ore ; the inclination being to the W.S.W. at about 1 in 40."

These mines are now entirely abandoned. The track of the railway mentioned above is still to be seen running to a pier, now in ruins, about 400 yards east of Milltown on Red Bay. Provision had obviously been made for a large enterprise. Rumours were afloat in 1908 that work would be resumed ; but reopening would involve much initial expense. A dip of the mineral zone to the south-east, as mentioned above, would involve tunnelling at a lower level, as probably the least expensive means of relieving the adits of water. As regards prospects far within the outcrop, evidence along the Carnlough escarpment, especially in the Cranny Water valley, is not suggestive of a remunerative seam beneath the great peat-covered tract of the Upper Basalt around and to the north of Lough Cranny.

A section is exposed behind Glenariff Lodge, west of the Inver River, which shows only Upper Basalt, "pavement" and

lithomarge; and a trial boring was made about half a mile south-west of Parkmore House, apparently with no very promising results; so that the information given in the extract from the original Memoir (on p. 59) must have been obtained at points to the south of these.

This poverty in the tract margining Upper Glenariff—near the Lodge—is the more remarkable because of its intervening between the wealthy tract of Parkmore Mines and that of the Glenariff Mines on the east side of the Inver.

CARGAN MINES.

(MAP 1, NORTH-WESTERN PORTION. ANALYSES LII. AND LIII.)

The Cargan mining tract, east of Cargan village, is of exceptional interest, having been the first in which bauxite was discovered many years ago, by the present proprietor, J. F. W. Hodges, Esq., J.P. Regarding his discovery, Mr. Hodges writes as follows, February, 1909 :—"As to bauxite, none was mined anywhere in Ireland, before I found it about 40 years ago. . . . . close to Cargan hill, at Glenravel." The result of analyses made in Zürich by Mr. Hodges are given on p. 117 of the present Memoir. By these analyses Mr. Hodges proved the highly aluminous character of his specimens, since some persons to whom he had shown them had questioned their value and the application to them of the term bauxite. The results have been published in Prof. Lunge's "Handbuch der Sodaindustrie" (1896), vol. iii., p. 193, and English edition, vol iii., p. 212, together with those of two analyses of bauxite from Irish Hill, near Ballyclare, made by Spence (see p. 36).

According to information received,* the Cargan Mines were opened by the Antrim Ore Company, but now belong to the British Aluminium Company, and are worked by the Crommelin Company, who seem to have from time to time carried on a trade in bauxite, the chief trade being in iron ore. The original Memoir has the following note (to Sheet 14, p. 22) :—

> "The mines worked at Cargan, N.E. of Newtown Crommelin, by the Antrim Iron Ore Company, are rich; the following are the varieties produced :—
>
> †No. 1 ore, guaranteed to give 40 per cent.
> No. 2 ore, no guarantee, sometimes gave 25 per cent.
> No. 3 ore, no guarantee, sometimes gave 18 per cent.
>
> Numerous dykes were met with in these mines, which shifted the position of the ore bed; the general inclination of the bed was to the S.S.W. about 1 in 10."

* From Captain Dryburgh. According to other information, the mines were originally opened by the British Aluminium Company.

† "The estimated weight of the pisolitic iron ore, taking an average between very wet and very dry, is about 1 cwt. to the cubic foot" (Note in Mem. Sheet 14).

Three of the four adits seen were closed in 1907, and about a dozen men were employed. About that time, however, work was in progress to relieve the mine of water, with a view to re-opening one of the closed adits; and, judging from the vast quantity of water then issuing, there must have been a decided sag *inward*, that is, to the S.E., as well as an inclination S.S.W. as above mentioned—probably near the outcrop. Judging from the relation of the outcrop to the contour, there certainly is a considerable inclination of the zone southward. It falls from over 800 feet east of Cargan Railway Station, almost to 700 feet east by north of Glenravel House; that is to say, about 100 feet in less than one-third of a mile, or about 1 in 17.

According to information given by an intelligent miner, the following relations subsisted between the bauxite and iron ore as met with in this tract. The former occurs as lumps or masses and lenticular bands here and there, and was known in some cases as "white pavement." The bands sometimes are fifty or sixty fathoms across, measured horizontally, under poor pisolitic iron ore, and over "pavement." On each side of these layers is good pisolitic ore, six inches to eighteen inches in depth, averaging about twelve inches, always over red "pavement", containing 15 to 25 per cent. of iron. Good iron ore and "bauxite" do not exist here concurrently.

Black ore, as well as pisolitic ore, has been taken from the mines. In some cases it is of a rich bluish colour with metallic sheen. Highly crystallized calcite has been found here, as at Parkmore, and several other places, over the ore bed.

The minerals are transferred to Cargan Station by a small branch mineral line, and thence by rail to Belfast. The mineral line follows the outcrop around Cargan Hill to the mines next referred to.

DUNGONNELL MINES.

(MAP 1, CENTRAL PORTION.)

The mines of the Dungonnell tract lie in the angle formed by the outcrop of the mineral seam, where it follows the contours of the valley drained by the Ballsallagh Water. Four adits are to be seen on the north side of the stream, between the 700 feet and 800 feet contours. Working in these adits has long ceased.* The account in the original Memoir reads thus :—"At Dungonnell, in the Ballsallagh Water, the Antrim Iron Company are working rich ore from ten to fourteen inches thick. North of these workings in the high ground, a bore hole was driven down by the same company 205 feet through the Upper Basalt, and no ore was proved." (Mem. Sheet 14, p. 22.)

* The closing of these mines was not, as commonly reputed, in consequence of the ore ceasing or deteriorating in quality, but, as the writer is personally informed by Mr Hodges, through difficulties in agreeing with the requirements of the leaseholders.

The trial boring here mentioned was made a little to the west of the Sruhancrossagh burn, and at a level of about 825 to 850 feet. The fact that the ore was not reached at 205 feet from that level proves that the mineral zone must dip considerably to the northward at this point, which would occasion great difficulty in relieving the workings of water. To do this by tunnelling would necessitate the taking of the conduit to a point near Ballsallagh Bridge, about a mile downstream, where the level is 600 feet, to secure discharge; for the mineral seam, if continuous, as we assume, may be lower than 620 feet in Dungonnell, since it was not reached in the boring.

This fact, taken conjointly with the southerly dip of the mineral zone under Cargan Rocks—the hill rising up from Cargan Railway Station—furnishes evidence of a distinct syncline, the axis of which strikes westward. The outcrop of the zone must therefore lie in the drift-covered ground sloping south-westward towards Ballsallagh Bridge, dropping there much below the 700 feet contour—possibly to a level of 600 to 650 feet. This would have the effect of adding at least 40 acres to the mineral area, which would imply the existence of some 150,000 tons of ore. This estimate is arrived at by assuming twelve inches in depth of good ore, weighing about 15 cwt. per square yard*—unless faults intervene to truncate the synclinal trough, of which, however, there is no evidence.

Later on it will be seen that a dip to the south-eastward exists in the mineral zone passing under Carncormick Hill, on the south side of Glenravel Water. If this depression be continuous north-eastward, on the south side of the Ballsallagh Water, there must be an anticline along the valley of this stream near the outcrop of the zone on the north-west slope of Carncormick, as explained by the accompanying section (Fig. 13). The Dungonnell Mines were opened by the Antrim Iron Ore Company about twenty-six years ago.

A trial adit was run on the outcrop on the south side of the Ballsallagh Water, near the valley angle, about 150 yards from the stream; but it does not seem to have resulted in any profitable discovery. Southward, through the large townland of Ballsallagh, the slope is thickly covered with boulder-clay, and no report as to the character of the zone or its outcrop was obtainable.

* The weight is estimated at the Glenravel Mines at one ton per square yard (see p. 44). The estimate given by the original surveyors (Mem. Sheet 14, p. 22) could only apply to a very poor ore.

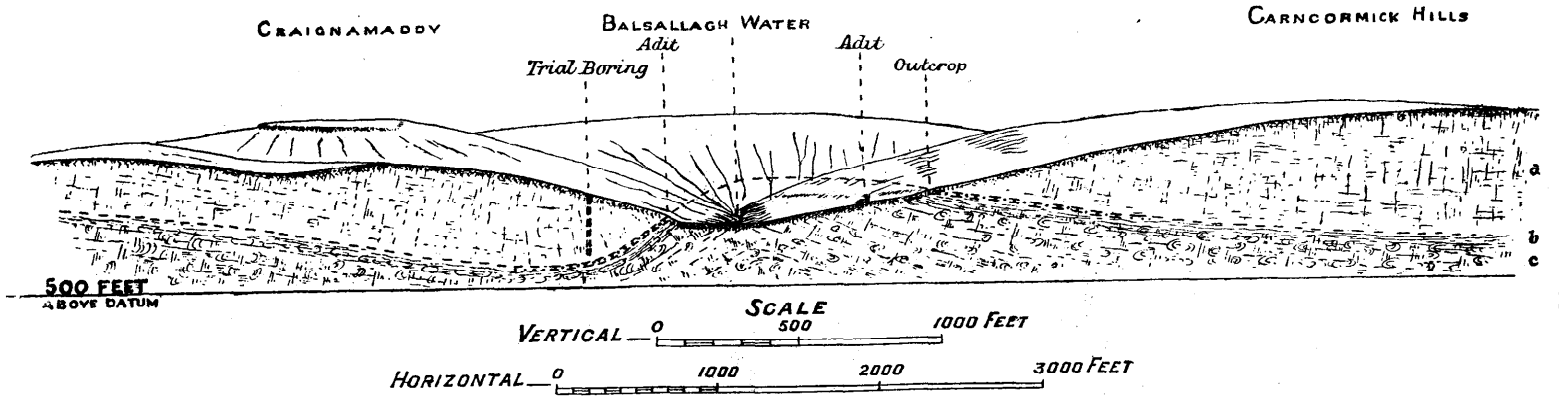
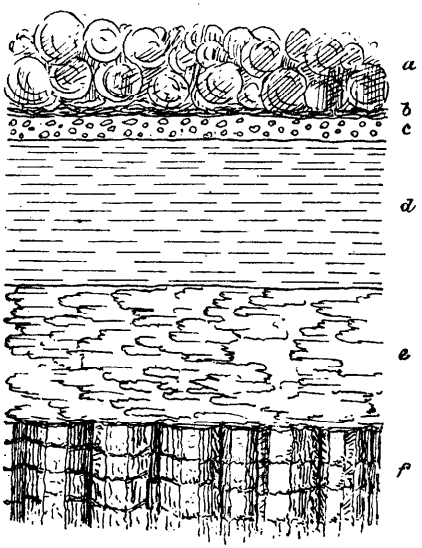


FIG. 13 —DIAGRAM OF THE DUNGONNELL MINING DISTRICT.

MOUNTCASHEL MINES.

(MAP 1, CENTRE OF WESTERN PORTION.)

These mines, situate in the townlands of Evishnablay, Crooknahaya, and Gortnageeragh, were opened about forty years ago by the Holloway family. Six adits were driven in the first two townlands, and one or two also in Gortnageeragh. Operations, including some crushing and washing of the iron ore, were centred at a point near where the outcrop crosses the mearing of the first two townlands, from which a branch mineral railway carried the ore from above the 800 feet contour to that of 450 feet, at Knockanully Station, on the Ballymena and Cushendall line.



a Upper Spheroidal Basalt.
b. Soft Clay (5 inches)
c. Pisolitic Iron Ore (1 to 1½ feet).
d. Pavement (8 to 10 feet).
e Lithomarge.
f Lower Basalt.

FIG. 14.—SECTION AT EVISHNABLAY MINE, IN 1886.

The succession of layers, inclusive of those forming the mineral zone, is thus described in the original Memoir (to Sheet 20, p. 12):—

> " Upper basalt (exfoliating) over five inches of clay; then pisolitic ore from one foot to one foot six inches thick, yielding 35 to 40 per cent. iron. This ore bed merges into the second quality called ' the pavement,' from eight to ten feet thick, which is worked according to the demand for the ore; yield said to be about 28 per cent. The third bed is violet lithomarge 20 to 30 feet thick and containing about 17 per cent. iron."*

* " Communicated by Captain Gillespie."

> " In the lithomarge are numerous remarkable rounded basaltic blocks of various consistencies and colours, some green and streaky. Numbers of the blocks are oval, reaching to six feet long, five feet broad, and two feet thick, well rounded ; and some are strongly magnetic."

This is followed by reference to the process by which, as was then supposed, these volcanic ejecta received their present shape ; and the description continues thus :—

> " In the iron ore bed of first quality there are numerous vertical basaltic dykes which have a general bearing in a N. 25 W. direction ; most of these are strongly magnetic."

The illustration (Fig. 14) is re-drawn from p. 13 of the Memoir mentioned.

The ore bed unfortunately dips eastward, and the matter of drainage in consequence presents a serious obstacle to profitable mining. Operations had been almost entirely abandoned for that reason in 1908, notwithstanding that a " level," or tunnel,

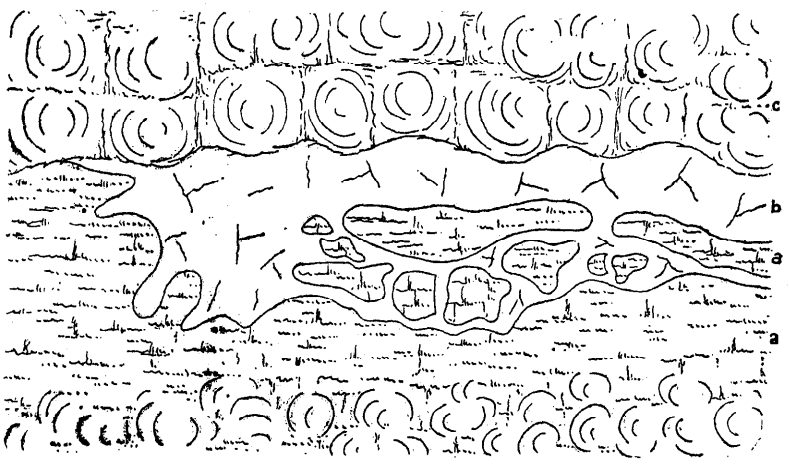


FIG. 15.—SECTION AT THE BUCK BURN.

a. Highly vesicular Basalt.
b. Bole pervading the Basalt.
c. Overlying spheroidal Basalt.

had been driven 900 feet through lithomarge to reach the ore, and in order to relieve the mine of water.

The lithomarge here was considered* to be about 100 feet in thickness, so that the inclination of the zone eastward might be roughly estimated as 1 in 9, that is, if the fall inward were uniform. If, however, the ore bed were level near the outcrop and afterwards fell eastward, which in certain parts of

* By Captain Dryburgh.

this tract seems to be the case, then the lithomarge need not be quite so thick as 100 feet, to allow of its being traversed by 900 feet of tunnel before reaching the ore. A thickness of 100 feet of lithomarge, and 10 feet of "pavement" is very exceptional.

Lignite, in small pieces, has been recorded* as occurring in these mines.

Following the outcrop still south-westward through Knockanully and Lisbreen, no indication of a profitable seam is apparent until the Buck Burn is crossed, where two trials have been made and pisolitic ore has been reported, but no mining has been attempted. Lithomarge is to be seen in the S. bank of the burn, without iron ore or much "pavement," abutting, as it seems, against basalt. This alone is visible higher up the slope, and must be thrown down against the zone along an east and west fault.

Some distance down the stream a seam of bole was noticed lying upon and permeating Lower Basalt in the manner represented in the accompanying sketch (Fig. 15).

Above, the bed terminates sharply against the overlying layer of basalt; and the depth of colouring in the bole, representing its increased richness in iron oxide, progresses from below upward. The writer believes that while the reticulating veins of bole are the obvious result of alteration of the basalt in place, the uppermost portion of the bed probably accumulated in a pool on the surface of the basalt before the succeeding layer of lava flowed over it. The deposit is commercially unimportant.

RATHKENNY MINES.

(MAP 1, SOUTH-WESTERN PORTION.)

From the Buck Burn westward the outcrop is concealed by glacial drift (boulder-clay) until Rathkenny is reached, where mining has been carried on for many years. The mines were opened in 1875 by the Antrim Iron Ore Company, according to information communicated by the present manager,† who writes:—"The first underground survey was made in April, 1876, and mining operations would be started six months previous to that." The company rents a tract comprising the townlands of Rathkenny and Carncoagh, and part of Killygore; and the ore is now brought to the surface through a shaft midway between the villages of Rathkenny Lower and Carncoagh Lower. The circumstances of the mine are thus stated in the original Memoir (to Sheet 20, p. 13):—

> "At Rathkenny Mine, about four miles north of Ballymena . . . . the outcrop of the ore-bed is

* Philip Argall, Journ. R. Geol. Soc. Ireland, vol. vi., p. 107.
† Mr. James Surgeoner.

under clay about five inches thick [" brushings "], as at Evishnablay. The ore-bed is traversed by numerous basalt dykes, two in particular, which are twelve feet wide and run in a N.N.W. direction; here the lithomarge is thirty feet thick. At the entrance to the mine there is a downthrow fault of twelve feet to the south, between the two adits. A little to the south-east of the adits, and near the hamlet of Carncoagh Upper, a bed of lignite replaces the ore-bed."

The pisolitic ore is visible at the surface at the entrance to No. 1 " level "—an adit beside the small stream which separates Rathkenny from Carncoagh. Small masses of " bauxite " (so called)—apparently a grey ashy-looking lithomarge—have been met with, but mining of this substance has not been undertaken here. The operations are limited to the getting of iron ore, which is of good average thickness, and is mostly pisolitic in

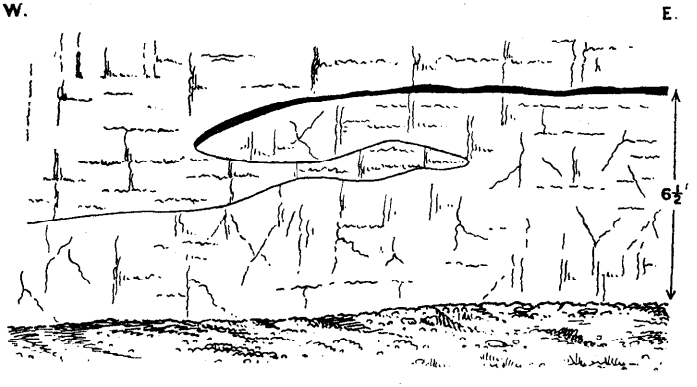


FIG. 16.—SECTION IN RATHKENNY NO. 1 ADIT.

A tongue of the Upper Basalt penetrates " Pavement " and Lithomarge; and a thin seam of Lignite intervenes in the upper part.

certain places, while it is " black ore " in others; a large quantity of both kinds has been taken from these mines. A fairly extensive bed of lignite with grey gritty bands and fossil wood has been tunnelled through under Carncoagh Hill and southward to Braeside.

Half a mile from the entrance to No. 1 adit, eastward, the lignite was observed to be 74 yards in width and from two feet to two feet six inches in thickness. It rests almost directly upon Lower Basalt, which only in certain places becomes lithomarge and white pavement. Beyond half a mile, the lignite drops suddenly to a depth which has not been ascertained, though a boring was put down 210 feet on the west slope of Carncoagh Hill, somewhere between the 600 and 650 feet contours. Between the thick layer of lignite and the adit-entrance, a section is to be seen showing the somewhat curious relations represented in Fig. 16. Lignite about three-quarters

of an inch in thickness rests upon pavement, and is covered with Upper Basalt. This latter, however, seems continuous with a tongue of vesicular basalt from which lithomarge and "pavement" have arisen by the peculiar weathering of the time; or which has been intruded into those substances after they, and probably the lignite, had been formed.

The outcrop of the seam at the point mentioned above, near the entrance to adit No. 1, is about 475 feet above datum. A boring was put down 150 feet on the iron ore at a point 520 feet above datum, midway between Carncoagh hamlet and Braeside, which proves the ore at that point to be 370 feet above datum. This gives a fall of about 100 feet from the outcrop where visible, that is, in about half a mile. In another boring the seam, with lignite, was reached at a depth of 95 feet from the surface at a point about 440 feet above datum, and about 300 yards south by west of the previous one, so that the level of the seam here is 345 feet above datum, showing a downward inclination to the south-westward, as well as to some extent south-eastward. An extension of the boundaries toward Cragywarren bog has accordingly been made on the revised map, which adds some 55 acres to the area shown on the original map. The drainage of this area of the seam would, however, be attended with difficulty.

Serious difficulties in this respect have been encountered in the portion of the Rathkenny tract now being worked. Tunnelling at considerable expense* became necessary, to relieve the mine of water, and this seems to have been the least expensive method of attaining that end. A tunnel was first run at a level of about 400 feet above datum; and another subsequently, 80 feet deeper, to discharge north-westward near the Maine River. The ore is extracted upward along the incline and backward toward Rathkenny; it is then railed down the slope toward the tunnel in hutches, and along the latter to the shaft, where it is taken to the surface and thence by a short branch railway to the main Ballymena and Cushendall Line at Rathkenny Station. Lignite was reached in the 95 feet boring; and beyond this point, that is, eastward of Braeside, the mineral seam occurs within 24 feet of the surface, showing that a fault intervenes.

In the tip-heap at the shaft head many pieces of light grey material resembling bauxite may be picked up. They are often studded with small roundish and angular eyes and scraps of white, sometimes red, material; and many angular pebble-like pieces of grey material occur in the red "pavement," suggestive in both cases of weathered volcanic ash. This grey material, however, seems to be merely patches of the "pavement" from which the iron oxide has been leached out—and this process probably occurred prior to the outflow of the Upper Basalt. This material corresponds to what is elsewhere known as "white marge." The

* About £1 per fathom.

red mottling in the grey, even when most suggestive of ash, is probably nothing more than spots where the oxide remained, or where perhaps it became concentrated by segregation.

The lithomarge in Rathkenny is frequently green, and sometimes contains reticulated veins of "pavement"-like material, similar in hand-specimens to those of bole which traverse the basalt in the bank of Buck Burn, as shown in Fig. 15. This mode of occurrence proves that the "pavement" is but a ferruginous lithomarge; an inference also reached from the mode of its occurrence in many other places, notably at Glenravel, as previously mentioned (see p. 46).

The ore at the Rathkenny mines is covered with a bluish clay ("brushings"), which in several places contains large geodes of calcite, as was noted also in the Parkmore and Cargan mines. Over the clay is often found superimposed a thin layer of tachylytic basalt, followed by the usual thick layers of the upper series.

CORREEN MINES.

(MAP 1, SOUTH-WESTERN PORTION. ANALYSIS LV.)

Adjoining the Rathkenny mining tract above described is one which stretches eastward along the south flank of the Carncormick Hills and comprises parts of the townlands of Eglish, Ballycloughan, Knockboy and Correen, leased and once worked by the Holloway family; but operations there had wholly ceased when the area was re-visited in 1908. Some bauxite has been taken from the Correen adit, which is still open, but is in a dilapidated state, and apparently flooded. Iron ore was also removed from this mine, and from that at Knockboy, which has been worked by three adits along the outcrop, here distinctly traceable for half a mile south-westward from the Correen adit.

A large quantity of ore seems to have been taken from Knockboy, but mining was stopped by the presence of a considerable fault, apparently with a downthrow to the west. Several trial borings were made west of the road running northward through this townland from Bushy Field without striking the ore. A boring was also put down north of Knockboy House, which was equally futile. No evidence could be found of ore, "pavement," or lithomarge in the tract stretching from the Knockboy outcrop across to Ballycloughan, where the outcrop is again visible; from which it is concluded that the basalt occupying this tract and extending southward to Knockboy House, possibly much beyond it, belongs to the upper series. The boundary shown on the original map is not sustained by the evidence; for iron ore occurs *in situ* south of that line, near the cottages, 300 yards north of Bushy Field House. Here, therefore, another considerable area must be added to that previously shown for the mineral zone—calculated to be at least 180 acres. This area, if the deposit of ore were uniform, and facilities for working and

drainage were available, would yield perhaps 655,000 tons of ore.

An attempt has recently been made* to reach the Correen bauxite by means of an adit run on the outcrop in Ballycloughan, eastward, through lithomarge. The operations were greatly hindered by mine water; and still more so, after proceeding a short distance inward, by a fault with a downthrow to the north-east. This effectually barred progress; the necessary steps for further operations were being considered when the owner died. The seam drops away toward the north-west, and when followed in this direction thin lignite was encountered, some of which is interlaminated and veined with calcite.

The fault referred to in the preceding paragraph, having a downthrow eastward—probably north-eastward at the point reached in the adit, as reported—forms the western limit of the barren tract which stretches southward through Knockboy, as already explained; and against it abuts the Ballycloughan outcrop trending south-eastward from the new adit. The form of the ground at Knockboy is suggestive of a continuation of the fault southward. The tract of Upper Basalt is thus let down between this line and the fault running southward from Correen by Bushy Field. The boring at Knockboy House, mentioned on a previous page, if continued deep enough, would probably strike the mineral seam eventually, unless put down on the west side of the line of fault; from which it would appear that the southern limits of the tract are concealed in the drifts covering the ground near the Braid River at Broughshane.

It may here be further mentioned that a boring was put down in a farmyard of the hamlet of Perrystown,† without result; another boring, reported "600 feet in depth" (though this is doubtful), was made "for coal" in a field near the road, on its east side, about 150 yards due east of the hamlet of Quarrytown in the townland of Ballycloughan. This boring, also, so far as could be ascertained, proved fruitless. It is said that the rhyolite was here mistaken for carboniferous sandstone.‡

To the north-east of Correen a mining tract was formerly worked by an adit nearly half a mile south by east of Elginny Upper; but mining has ceased there. The tract lies in the townland of Elginny, part of which is now in the hands of the Antrim Iron Ore Company, and is mined by "levels" driven westward from Clonetrace.

The Elginny tract is thus referred to in the Memoir (to Sheet 20, p. 13):—

> "Three miles S.E. of Rathkenny, in the townland of Elginny, a company formerly worked the ore, but the mine is now abandoned. Judging from the output as

* By Captain Dryburgh, acting for Mr. Holloway.

† The basalt at this point is curiously brecciated, having probably acquired a broken-up structure during fluxion.

‡ G. Cole, "Rhyolites of Co. Antrim," Sci. Trans. R. Dublin Soc., vol. vi., p. 110.

lying there, it looks a rich ore. The position of the bed can be traced for some distance, not only by the lithomarge, but also by the perennial springs, which are constantly found along the horizon of the lithomarge bed."

It is a striking circumstance that pisolitic globules are reported as of general occurrence scattered over the surface on Elginny Hill, a report which the writer was able abundantly to confirm. At first sight it seems natural to suppose that the mineral seam must somewhere crop out there. This, however, could scarcely be correct, for the rock here bears very little superficial covering by which it might be concealed. The occurrence is rather due to the ice of glacial times, which carried with it from the eastward the broken-up materials of the easily eroded seam. Independent evidence proves that such a flow proceeded westward from the Irish Sea,* in which case the glacier ploughing along the Braid Valley found abundance of iron ore, "pavement," and lithomarge cropping out along the flanks of Knockramer and the Clonetrace hills, immediately eastward of Elginny. The presence of pisolitic grains upon the almost driftless surface of Elginny Hill, in the absence of any source to the southward, or to the westward nearer than Rathkenny, seems good evidence of the former presence of a drift-bearing agent moving from the eastward. It may also be mentioned, as bearing out this conclusion, that numerous pieces of lithomarge, some quite large, "pavement," and chalk occur in the great sand and gravel pits of Knockan Hill, an important moraine mound about 70 feet higher than the river, near Knockan Bridge, west of Broughshane. The stratification of the sands has a westward dip, and the heap seems to have been laid down by water flowing southwestward from a melting glacier receding eastward.

CLONETRACE MINES.

(MAP 1, SOUTHERN PORTION, NORTH-EAST OF BROUGHSHANE. SEE ANALYSIS LIV.)

To the east of Elginny and north-east of White Hall extends a large tract leased by the Antrim Iron Ore Company. The ore is mined by two adits, one on the west side of the Quolie Water, which flows southward between the townlands of Clonetrace and Ballymena; another about a mile distant in the townland of Ballylig, at the farm-houses known as Ballylig Upper, where three closed adits are also to be seen. Mining was commenced in Ballylig in 1872, and in

* A record of striæ, given in the Memoir to Sheet 20, p. 22, shows evidences for a westward ice-flow in ten townlands, including five at least in the Braid Valley.

Clonetrace in the year following. In addition to the townlands of Clonetrace, Ballymena, and Ballylig, already named, the tract comprises parts of Elginny and Lough Loughan. The original Memoir (to Sheet 20, p. 14) contains the following reference to these mines, commencing with the description of a section near an opening on the outcrop which seems to be a disused adit east of the Quolie Water :—

> " At the mine worked by the Antrim Ore Company to the N.E. of Dogherty's Bridge, near Elginny, there is a remarkable section in the river on the east bank. Over the ore there are the ' brushings,' then columnar basalt. The ore varies in thickness up to about eighteen inches, and underneath the ore is the ' pavement ' of a buff colour, partly composed of volcanic ash ; a small kidney shaped lump of pure magnetic [oxide of] iron was found in this. No lithomarge was seen here, but it is probably present underneath. Following the section down the river, the ore has been removed from underneath the columnar basalt, probably by the action of the stream, and replaced by compact waterworn gravels. . . . . The ore of first quality, as worked here, has an average thickness of fourteen inches. No other ore is worked, as the cost of cartage to Ballymena* is so expensive. No. 1 ore is estimated to contain forty per cent. of metallic iron ; it is generally found in a loose gravelly state, and not in lumps as at other mines ; it is also much darker in colour."

In the course of working the Clonetrace mine the ore was found to range in thickness from three inches to as much as six feet in hollows. Considerable unevennesses were encountered, such as a drop of fourteen feet at the rate of a foot per fathom, on going westward ; and at about 300 yards to the north-west the floor rises again about seven feet.

The mine worked at Ballylig shows similar unevennesses, but the floor throughout, instead of being fairly level, as at Clonetrace, rises toward the north-west, in which direction the seam is worked. The thickness of the ore here varies from six inches to two feet six inches and averages about a foot. Reference to this mine seems to be made in the original Memoir (to Sheet 20, p. 16) thus :—

> " At Ballylig, N.E. of Broughshane, Mr. Traill notes ' a white fire-clay bauxite over pavement and twenty feet of lithomarge ' ; very close to this two adits have been driven into the ore-bed, which ranges from eight to

* Ballymena town, about six miles distant. The section described above is, curiously enough, in the *townland* of Ballymena. The price of cartage was 2*s*. 6*d*. per 20 to 25 cwt. The haulage is now done by light traction engines and waggons. Further reference to these mines is given on page 30 of the Memoir to Sheet 20.

eighteen inches in thickness, and with a slight dip to the north. These beds are traversed by numerous dykes."

As may be inferred from the previous quotation, the ore at the Clonetrace mine, described as "loose" and "gravelly," is chiefly of the pisolitic variety, very little "black ore" being met with. A large trunk of carbonised wood, lignite, was taken out of the mine in 1907. In this log of lignite the writer found large roundish crystalline lumps of pyrites.

The ground is much faulted and traversed by dykes of basalt. The faulting shown on the map, and the consequent displacement of the outcrop, have been established by trial borings made by the company at several points to the east, north, and west of the Clonetrace adit. Two important faults traverse the ground in a south-westerly direction between the hamlet of Elginny Upper and Elginny Hill, which seem to unite south-westward and form the Correen fault previously mentioned. The two branches in Elginny comprise, between them, a wedge of broken mining ground, let down to some considerable extent, more than thirty feet, so far as can be judged from information received. Other faults at Clonetrace manifest throws of sixteen feet, nine feet, and so on. East of Clonetrace, borings on each side of a presumed fault show a difference of level of some eighty-six feet in the ore, within a distance of 300 yards.

At Ballylig the outcrop is continued east of the leading road, and is not terminated against a S.W. and N.E. fault, as represented on the original map. Indeed, the principal adit—the one now being worked—is about 150 yards from the road on the side mentioned; and the mining has been carried on under the peninsular tract of Upper Basalt, shown south-eastward of Ballylig Upper.

The Upper Basalt in this region, at Clonetrace mine, as well as at Ballylig, is columnar, differing thus from the circumstances shown in Fig. 14, at the Mountcashel mines, on the north side of the mountain. Immediately below the columnar rock in the Ballylig tract is a thin layer of tachylytic basalt over clay "brushings," with calcite. Beneath the ore is pavement frequently showing quasi-stratification, and usually red and highly ferruginous, but sometimes light grey. This is often dotted with red angular scraps, occasionally of large size, so that it is extremely suggestive of volcanic ash. It has, however, probably an origin differing in no wise from that already attributed to the varieties of lithomarge and "pavement" at Rathkenny and elsewhere (p. 68, &c.). The red specks and patches often take a pisolitic form, and, in some instances, are obviously rich in oxide of iron. Good instances have been noticed in the tip-heaps from the Glenravel mines at Parkmore Railway Station, and at the Parkmore mine, which seem to indicate that, while the so-called

" white marge " is material from which ferruginous matter has largely disappeared, the included pieces of red and black oxide have become in various degrees highly concentrated by segregation.

It will be seen, therefore, from the foregoing account that distinct evidence is wanting in this mid-Antrim region for the existence of volcanic ash, except perhaps at Tuftarney Hill in the Glenravel Valley, and possibly in the north-east portion of the area.

Reference may here be made to the case of erosion mentioned in the original Memoir, quoted on p. 72 of this account. About 375 yards north-east of the Clonetrace adit the Quolie Water descends, at Blackrock waterfall, into a gorge now filled with shingle. The filling is fifty feet in depth, occupying a ravine cut out of the softer materials of the mineral zone ; and such a depth is suggestive of a greater hollowing out than can be attributed to post-glacial action of the stream. A diversion of the stream 300 yards higher up by a drift mound, and the resumption of its former almost north and south direct course, bear out the presumption that the old gorge was formed by a *preglacial* river, which, on being diverted, took its present directions, E. by S., S. by W., and S.W., in post-glacial times before re-entering its original one, S. by W. It was probably during this recent phase of its history that it was refilled with more or less washed drift material.

CLEGGAN TRACT.

(MAP 1, CENTRE OF SOUTHERN PORTION.)

Following the outcrop north-eastward from Ballylig, lithomarge is to be seen on the south-west slope of Knockcochran. Trial borings made on the east side of the hill did not reveal a workable iron seam. The outcrop is traceable chiefly by a feature in the ground, which is often slight ; but springs, which are more common on the outcrop than elsewhere, determine its position and direction with a fair degree of accuracy. When thus traced toward a point almost a mile north of Cleggan Lodge, the following interesting section is to be seen, though in a commercial sense it is of no importance, viz. :—

1.—Upper Basalt.
2.—Hæmatite and bole in balls and veins from a few inches to a foot in thickness.
3.—Basalt veined with bole.
4.—Lithomarge veined with bole.
5.—Lithomarge without bole.
6.—Lower Basalt.

The line of outcrop rises with fairly regular gradient from about 450 feet in Ballylig to 575 feet S. of Knockcochran, 600

feet on the south slope of Cleggan Mountain, 825 feet at the point of the section just referred to, and 780 feet half a mile to the north-eastward. A little more than a quarter of a mile to the north-east of where the above section is seen, a boring was put down on the steep slope descending to Cleggan River with no appreciable result; and the surface features are the only means obtainable for carrying the boundary line of the Upper and Lower Basalts further east, until Unshinagh is reached, south-west of Carnlough.

On the original map the boundary is made to cross the Cleggan River and encircle Neill's Top; but evidence for the line where shown could not be verified; nor could evidence be found for the outline of Upper Basalt represented as clothing the west slope of Ticloy Hill, south-west of Neill's Top. On the contrary, Ticloy Hill, being distinctly terraced, and the sheets of basalt forming it dipping at a very low angle to the westward, the Upper Basalt, if present, should be shown as symmetrically capping, in greater or less thickness, this prominent feature. The mapping seems to have been based upon the occurrence of a reddish brown much weathered vesicular basalt to be seen in a quarry at the foot of the hill on the west side, which was taken for the lithomarge of the main mineral zone. If it were this, it would necessitate a much greater extension of the Upper Basalt than appears at all justifiable. The rock resembles the variety of lithomarge which the writer has described on p. 56, and occurs in the river bank half a mile north by east, on approximately the same horizon as a deposit of bole seen in the bottom of a tributary stream a quarter of a mile to the north-west, near to where a basalt dyke is shown on Map 1. The bole and lithomarge occur at a level of about 650 to 675 feet above datum, while it was shown above that the main dividing zone of the Upper and Lower Basalts runs northward from Cleggan at a height of about 780 feet; that is, the lithomarge at Ticloy is probably 100 feet or more below the level of the Upper Basalt on the opposite side of the Cleggan River valley.

The steep slope of Cleggan Hill is continued in a direct line northward, forming a well-marked escarpment which stands back from the river on the west side at a distance of 200 to 600 yards for about two miles. At its extremity, the chief branch of the Cleggan River curves around it from the south-west, before turning southward, descending over two small waterfalls and rapids to the floor of a wide level valley. At one of the falls—the first after passing the rapids going upstream—the water has eroded a deep hollow or pool, strongly suggestive of much softer material than basalt—possibly lithomarge—below, under hard tabular lava. The banks are obscured by debris, and great pieces of thick layers which have dropped, or rather declined, from above; so that the most which can be said is that the line between the Upper and Lower Basalts probably crosses the Cleggan River here. The slope and foot of the escarpment, northward to

this point, are entirely obscured by drift and peat; and beyond the waterfall the mountain presents an almost unbroken expanse of peat, except along the second branch of the head waters of the Cleggan River, where no evidence of the mineral zone could be observed.

An important fault enters the obscure peat-covered ground from the south-east, as will presently be shown; and the boundary between the Upper and Lower Basalts, as above traced, seems to abut against this fault, leaving all the rock south-east of the river Lower Basalt.

CULLINANE MINE.

(MAP 1, SOUTH-EASTERN PORTION.)

This mine, in the townland of Aughareamlagh, near the hamlet of Cullinane, S.S.W. of Carnlough, was worked for bauxite in 1886, when the original Memoir was written. It is there referred to in the following terms (Memoir to Sheet 20, p. 16). After describing the "aluminous clay" (bauxite) of the Libbert mine in Glenarm Valley, the writer states:—"Similar clay separating the Upper and Lower Basalts occurs at Cullinane, two miles W. of Glenarm, where the bauxite is extensively worked by the Eglinton Chemical Company,* the clays being from six inches to two feet in thickness. Great stools of carbonised trees were extracted from these deposits." The operations there have long ceased, and the mine has been closed. In the tip-heaps of two or three adits, lithomarge, the usual accompaniment of the mineral seam, is to be seen, but there is little other evidence of the zone. Adits, also now closed, have been run upon the outcrop on the opposite side of the Doonan Water valley; and here the tip-heaps indicate an iron ore seam.

To the south-west of Cullinane, throughout the large townland of Aughareamlagh, the rock is well exposed in Curraghvohil Hill, but at no period has there been seen any indication of the bauxite and iron ore zone—neither these minerals nor lithomarge. This sudden disappearance, more perhaps than any other more obvious sign of faulting, between Curraghvohil Hill and Knock-stackan, justifies the insertion of the north and south fault-line which is shown on the original map and is adopted on the present one. The abrupt termination of the zone-outcrop southward through the adjoining townland of Unshinagh on the north, to be referred to presently, also necessitates the inference that a break occurs on the confines of Unshinagh and Aughareamlagh, while proof is wanting that Upper Basalt exists to the westward of the latter townland. This fault is believed to traverse the

* In an Appendix to the original Memoir (p. 28), notes are given, with results of analyses from which the quality of the Cullinane bauxite may be judged. See present Memoir, Analyses XIV. and XV.

townland known as Unshinagh Mountain (in contrast to Unshinagh), north-westward, into the great peaty tract previously referred to as that which conceals the boundary of the Upper and Lower Basalts, traced northward from Cleggan.

Again, the Chalk is to be observed in the Cullinane Burn just below the waterfall, and 600 yards above the Cullinane flax mill

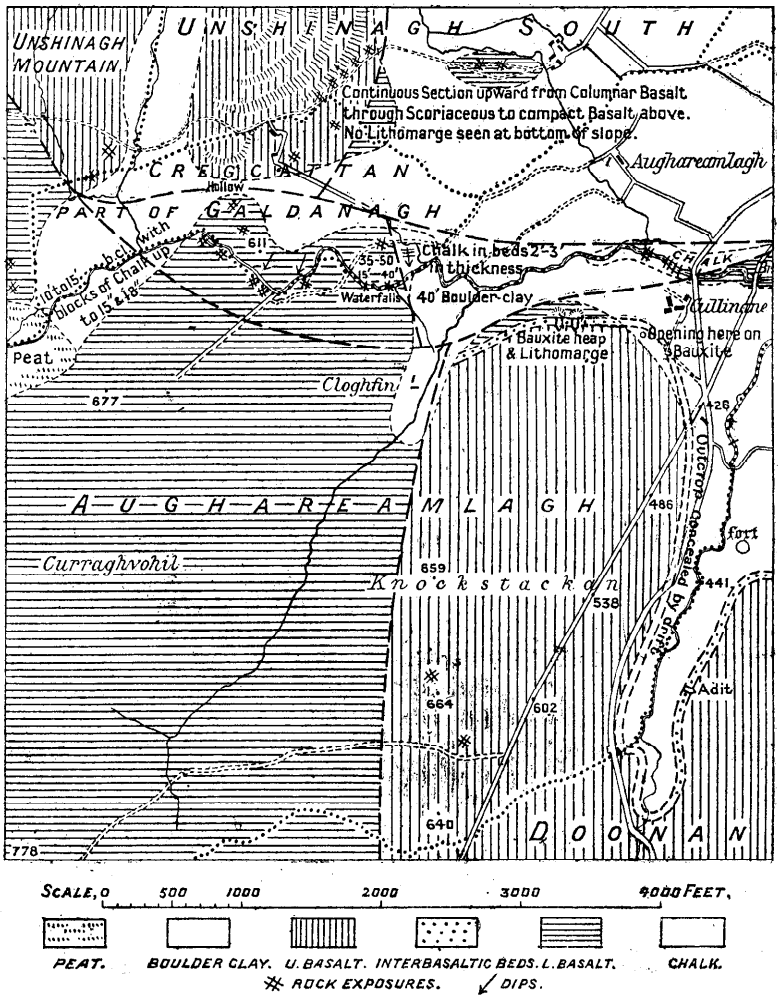


FIG 17.—GEOLOGICAL MAP OF THE CULLINANE MINING AREA.

and farm-houses, having a southerly dip; the bedding is truncated against tabular basalt. The truncation is along a north and south line, another break there intervening, which must be added to those already mentioned in the interpretation of this already intricate ground. A break also occurs between the chalk exposure in the stream and the Upper Basalt at the adits; for otherwise it would be impossible to account for the small

thickness of Lower Basalt, which usually is hundreds of feet; the level of the bauxite outcrop near Cullinane is about 450 feet and that of the white limestone in the burn below about 400 feet or more. The geology of this complex area, in so far as available facts and levels given on the six-inch Ordnance Sheet 29 admit of its interpretation, is shown on the accompanying map (Fig. 17).

CARNLOUGH MINES.

(MAP 1, CENTRE OF EASTERN PORTION.)

Along the range of the escarpment, northward, ore has to some extent been mined. In Unshinagh, adits were driven on a seam of pisolitic ore reported to be fifteen inches in thickness. Reference is made to this mine in the Memoir to Sheet 20 (p. 15) thus :—

> " At Unshinagh, three miles west of Glenarm, the iron-ore has been worked, and seven adits have been driven into the escarpment, about 750 feet above the sea. The southerly adit driven through the ore proved the grains of ore to be large, but the thickness of the bed was not seen; neither was the thickness proved in the second or third adit; but immediately north of this the ore was proved to be about fifteen inches, and the lithomarge to be forty feet thick. In No. 3 adit there was a thin band of lignite from one to five inches in thickness."

Mining has long since ceased in this townland, perhaps chiefly on account of the expense of transferring the ore to the main road; yet the prospect of profitable work here is greater than at any point further along the escarpment northward. Trial adits and borings have been made along the outcrop round into the Cranny Water valley, and, while the existence of the zone has been fully established, represented as usual by lithomarge, " pavement " and ore, at no point apparently has there been met with an ore bed of substantial thickness.

A change has been made in the mapping in the angle of the valley, toward the point at which the Cranny Water falls from the 760 feet contour, *from* the Upper Basalt, *over* the mineral seam almost to the 700 feet line. At the point where the outcrop forms the south-east bank, a good section is exposed, showing great round exfoliating masses of basalt, lying contiguously in two beds—seven masses up to four feet in diameter forming the top row, and eleven in a second row immediately beneath the former, up to three feet six inches in diameter, all embedded in lithomarge and " pavement." These are described as volcanic bombs on the original field map, but their origin is obviously different, and they resemble those previously noted as occurring at the Glenravel mines (p. 46).

The position of the roundish masses in this case, and their arrangement, which is anything but promiscuous, is sufficient to show that they are not volcanic ejecta. Several trial openings were made north-eastward along the outcrop from the point last mentioned to the townland of Gortin, north of the hamlet of this name, and, although pisolitic ore was obtained, its quantity did not warrant mining on a commercial scale.*

In tracing the outcrop northward, the Upper Basalt adjoins the Lower, appearing to rest directly upon it, from which it is inferred that a strike fault occurs here, probably the continuation of that traversing the high ground on each side of, and crossing, the Cranny Water valley. In the south bank of the burn which trenches the escarpment, between Scaryhill and Highlandtown, two thin beds of a variety of lithomarge (reddish weathering basalt) similar to that seen in Ticloy Hill and at several other points, are to be seen with some bole; they seem to correspond to the two bands about 100 feet below the mineral zone, traceable along the steep face and precipices of the Glenariff escarpment (see p. 56).

Northward of the point mentioned, in Highlandtown, the mineral zone reappears, as is to be well seen in the Black Burn, which bounds the townland of Drumnasole on the south. About 300 yards above the principal waterfall, where the burn has excavated a deep gorge in the Lower Basalt, occurs another waterfall, where the stream descends over a second low escarpment. Here also is a second gorge hollowed out of the Upper Basalt; and between the upper and lower escarpments stretches an expanse of comparatively level ground, which extends northward, and is almost wholly covered with drift and peat. In the burn, at the foot of the low escarpment, is to be seen a section, the details of which are here given, viz. :—

1. Rapidly decaying vesicular basalt.
2. Ashy-looking pisolitic iron ore ..... 9 inches
3. Brown grey ashy-looking pavement ?30 feet
4. Green and grey lithomarge.

The low escarpment formed, as above mentioned, of Upper Basalt is continued in an irregular course northward at distances of a quarter to half a mile from the summit of the main escarpment, and half a mile west by north of Garron Tower an old trial pit is to be seen where pisolitic iron ore and "pavement" have been proved to occur. No other evidence of the zone is to be met with until the point is reached with which the description of the zonal tract of this Carncormick-Slievebane area opened (p. 55).

* An industry in peat was commenced at the cost of considerable outlay, with the object of utilising the ammonia given off in burning, but work had been abandoned, it was said, temporarily, in 1908. A small industry has been started still more recently in Upper Basalt, north of Gortin, for road metal.

To summarise the prospects and circumstances of the area, it is apparent that the north-east limb offers little prospect, and that the best hope of remunerative mining lies in the south-western portion of the area. In fact, with the reservation of parts of the Glenariff area, and so far as present indications are to be relied on, the remunerative deposits are limited to the portion of the area lying to the west of a north and south line through Evish and Knockramer Hills.* Since it is impossible to say how far this area has been exhausted, an estimate of the available ore would be merely conjectural.

EVIDENCES OF FOSSIL VEGETATION IN THE MINING AREAS.

It is of interest to note that evidence of interbasaltic vegetation has been met with in Ardclinis, Mountcashel, Rathkenny, Ballycloughan, Clonetrace, and Cullinane mining tracts. Carbonised timber trunks were found in Clonetrace mine, without true beds of lignite; and stools of trees, carbonised, were reported from the bauxite of Cullinane mine.

OUTLYING TRACTS.

Reference in more or less detail has been made to a few of the outlying remnants of Upper Basalt; those, namely, at Slieveanorra, Slievenahanaghan, Slieve Rush, Newtown Crommelin, and Tuftarney, in Sheet 14. Those at Berk Hill (Sheet 20), south-west of Rathkenny, at Kinboe or Black Hill near Glaryford (Sheet 19), and two near Portglenone (also Sheet 19) will here be described.

BERK HILL OUTLIER.

(MAP 1, SOUTH-WEST CORNER.)

At Berk Hill an adit was driven for some distance on the outcrop in Clogher, east of the hill, at 420 feet above datum, with no satisfactory commercial results. Pisolitic iron ore was, however, found.

A quarter of a mile south of the adit, long since closed, a section was met with in a quarry worked in the Upper Basalt, showing successive layers as follows, viz.:—

1. Upper Basalt, vesicular
2. Tachylytic basalt ..... 3 ins. to 6 ins.
3. Grey clay ..... 2 ,, ,, 3 ,,
4. Lignite ..... 1 ,, ,, 2 ,,
5. Bole and " pavement " (over Lower Basalt).

The interesting members of this succession occur at 410 feet

* Until some economic process is discovered for dealing with the lithomarge as an aluminous ore. This substance occurs in large quantity and good average quality at the north-east corner of the tract.

above datum, sufficiently near the level of the iron ore of the Clogher adit to admit of the conclusion, pointed to by the nature of the thin layers, that here we have a greatly attenuated representative of the mineral zone. The gentle inclination of ten feet in a quarter of a mile, that is, from 420 feet at the adit to 410 feet above datum at the quarry, is also in keeping with an inclination south-westward noticeable in the line of outcrop when traced around the hill towards the west from Clogher.

On the east side of the road running northward from Clinty

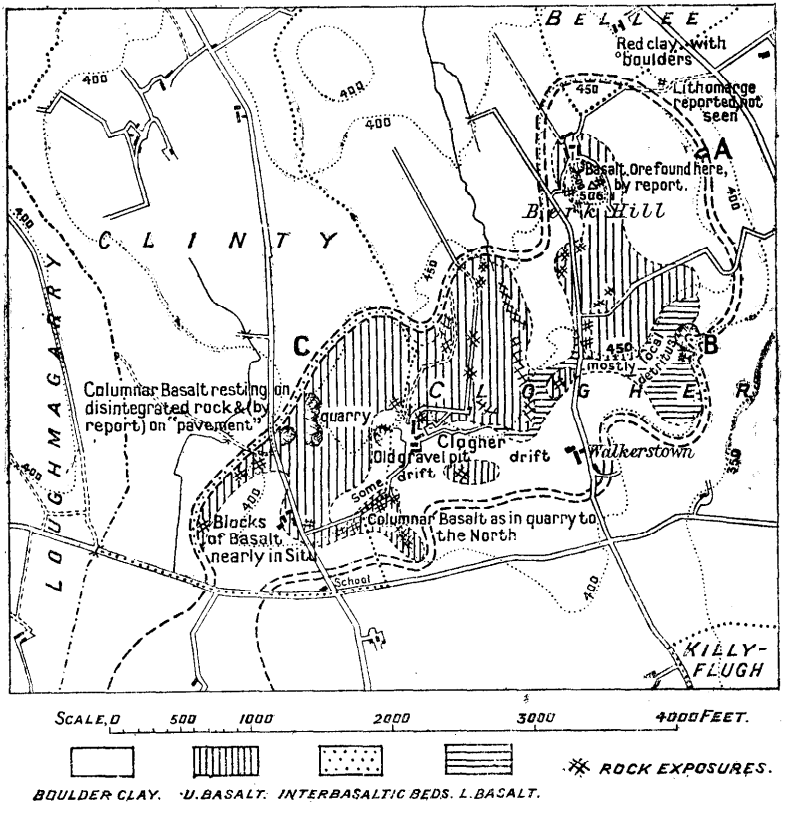


FIG. 18.—GEOLOGICAL MAP OF THE BERK HILL OUTLIER.

Schoolhouse is an opening in the Upper Basalt from which a great quantity of rock has been quarried; and the quarry-owner gave the information that red material is but just hidden in the floor, beneath massive layers of basalt which here are rudely columnar. About 150 yards to the north are to be seen "pavement" and lithomarge, also below the Upper Basalt, which is confirmatory of the report just mentioned. The level of the zone has here dropped below the 400 feet contour, in consequence of which the boundary crosses the Clinty road; and this fact, taken in conjunction with its inclination southward,

as proved on the east side of the hill, shows that the outcrop extends considerably beyond the line by which it is represented on the original map. A map on a larger scale (Fig. 18) representing the revised outcrop accompanies this description; by the contours on this it may be seen that the zone, with a thin covering of Upper Basalt, may occur even in the townland of Loughmagarry on the west, and southward beyond Clinty cross-roads, the ground here being all much obscured by drift.

BLACK HILL OUTLIER.

The most important of the smaller tracts in this district is that included in the townlands of Duneany and Glenbuck, about two miles from Glaryford Railway Station (Sheet 19). Both iron ore and lignite have been mined here, until the work ceased some twenty-six or twenty-seven years ago. The outcrop is traceable with a fair measure of precision along the foot of the hill, particularly on the west side. On the east side, and especially in the lower ground stretching away from the hill-base, the boundaries are obscured by drift. Some data have been procured in addition to those previously recorded, by which it would seem that the Upper Basalt, while very thin, spreads over a wider extent of ground than that represented on the original map. In Black Hill, however, this member of the basaltic group is about 150 feet in thickness. The account of the mineral zone given in the Memoir accompanying Sheet 19, p. 21, runs thus:—

> "In the north-east of the district [*i.e.*, Sheet 19] the iron ore has been traced along the plantation which skirts the hill west of the road; and where the bed is worked at the southern part of its outcrop the average section, as furnished on the ground, is as follows:—
>
> | | |
> |---|---|
> | "Red pisolitic ore, consisting of grains of hæmatite concreted by an ochreous paste ..... | 18 to 20 inches. |
> | "'Pavement,' a red and yellowish bole, or aluminous ore of inferior quality ..... | 7 to 10 feet. |
> | "Reddish and purple lithomarge, often finely mottled white ... | thickness unknown. |
>
> "The ore is cut off by the fault along the road, east of which it is covered by a considerable thickness of drift and basalt. The bed is said to be two feet six inches in thickness at Kinboe, where it was reached in a deep well. At Cullaleen, where it was worked to a small extent, it appears to have almost died out.
>
> "An adit was driven for about sixty fathoms in a north-westerly direction, near the stream under the road north of Cullaleen, through a bed which seems identical with

the 'pavement' described above, here ten to thirteen feet thick. Any of the richer ore that may have here occurred above it, has no doubt been removed by denudation.

"North of Pharis a bed of lignite occurs in the basalt, at some distance below the iron ore, and is said to be associated with a thick deposit of white clay, which in some places it overlies, but which, in others, forms a dyke that has to be passed through in order to reach the lignite. Several pits were sunk for this purpose, and a quantity [was] taken out for burning, but the work was not continued."

The adits are now in such a state of disrepair that it is impossible to reach any determinative sections. Information gleaned from an intelligent miner* who had worked in the mines here for twenty-two years, clears up some difficulties in the foregoing account, and agrees with what we know of the relations of lignite and iron ore elsewhere in the county.

First.—The writer has thus been assured that in moving along the lignite seam one passes to a seam of iron ore, on the same horizon, the boundary being fairly sharp along an E.N.E. and W.S.W. line through Pharis.

Secondly.—The "dyke" of white clay, also above mentioned, is not a dyke in the geological sense, but may have been material which had to be tunnelled in passing from one level where the lignite occurred to another where the same seam was faulted up. The term was used in a similar connection by miners who described the adit workings in the Glenravel region. A fault runs north by west here with a downthrow of about ten feet to the east, between Pharis and the roadside cottages, where two disused adits are to be seen.

Thirdly.—The white clay beneath the lignite is not a *second* deposit, similar in texture to "pavement," at a lower horizon in the basaltic series, but seems to be a representative, beneath the lignite, of "pavement" and lithomarge beneath the iron ore. The white clay is probably disintegrated Lower Basalt, like the lithomarge and "pavement" in an adjoining locality. But its light grey colour may be ascribed to the passage through it of the acids from the decaying vegetation above.

The lignite is said to thin out gradually towards the line where it is replaced by iron ore, as above mentioned, beyond which, southward, the former mineral does not reappear. Iron ore was mined extensively until twenty-five years ago, at a point on the outcrop west of the feature known as "the Glen," through which the main road runs northward, and about two-thirds of a mile south by east of Pharis. Iron ore was also

* Mr. John Shiel, whose account of the Pharis mine was amply corroborated by two other men who had also worked in the mines and who were interviewed before Shiel was seen.

mined on the south-west side of the hill a quarter of a mile due west of the Glen adit, and at a third point to the south-west of the Glen. These points lie within a circle of about a quarter of a mile radius, the summit of the hill being the centre; from which it will be seen that the deposit occupied a small area when mining commenced, and should be well-nigh exhausted, at least beneath

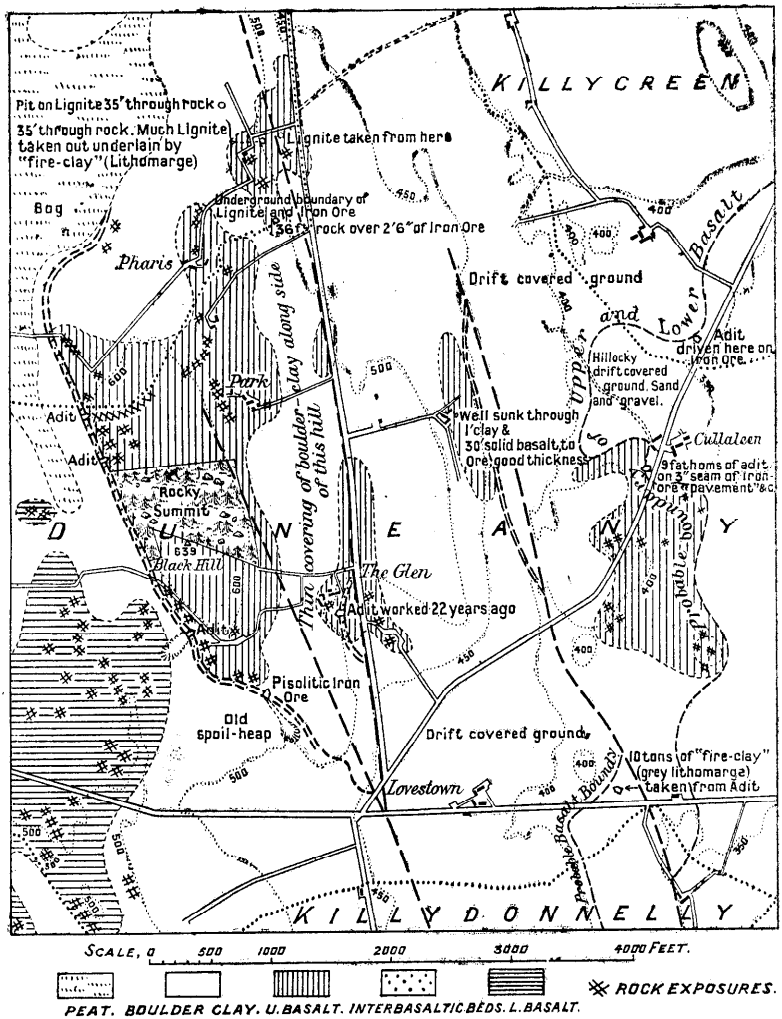


FIG. 19.—GEOLOGICAL MAP OF THE BLACK HILL AND CULLALEEN AREA.

the hill. It extends eastward, however, from the Pharis fault, which passes through the Glen; though, with the exception of a fair thickness of seam reported in a well-boring at Kinboe, there is no evidence of a profitable seam in the low ground. At Cullaleen, for example, about 500 yards east by south of Kinboe, the seam, which was followed for nine fathoms westward, is only about three inches in thickness, resting

upon "pavement." In Killycreen, about 400 yards north by east of Cullaleen, an adit was driven on iron ore, but with equally unfavourable prospects. These occurrences, however, are sufficient to establish the extension of the seam eastward, and, in the judgment of the writer, of Upper Basalt also, even where the series is now covered with drifts. The Upper Basalt is seen at Cullaleen forming a cap twelve feet and more in thickness over the iron ore. It is also to be seen nearly *in situ* south of Cullaleen at Duneany Fort; and the form of the ground suggests that the boundary may be continued northward into Killycreen and southward for some distance, perhaps beyond Lovestown, displaced probably by the faults shown on the accompanying large-scale map (Fig. 19).

Referring to these dislocations, the seam of ore drops from about 550 feet above datum, near the west foot of the hill, to about 450 feet at Kinboe and about 375 feet at Cullaleen. The drops seem due to a series of faults, shown on the map just mentioned, rather than to a gradual downward slope to the east, which would necessitate the inference that the seam extends through Killycreen far eastward under the valley of the Main River. There is a strong local impression that this is the case. If the mineral seam extended as far, say, as the middle of Killycreen, which is likely, it is probably represented north-eastward of Pharis by lignite rather than by iron ore.

At a point near the main road, on its north side, 400 yards east of Lovestown, several tons of "fire-clay," probably grey lithomarge, were taken from a small adit run into the hill, the "solid" geology of which is obscured by drift; the adit has long since been closed. It is assumed that this soft easily removed material was preserved during glaciation by a covering of Upper Basalt, and for this reason the boundary between the two basaltic series is inserted here.

TULLY HILL OUTLIER.

Two small outliers of Upper Basalt cap the Lower in the rugged tract south-east of Portglenone (Sheet 19), in neither of which the interposed mineral zone is of commercial importance. It is, however, of scientific interest, in that its existence here indicates the original extension, to this point at least, and possibly much further to the west, of the upper division of the basaltic series. Reference to the iron zone is made in the Memoir to Sheet 19, p. 16, in these terms, viz.:—"At Tully Hill, the ferriferous beds are, so far as is at present known, represented by lithomarge and an obscure bed of bole containing a few small grains of hæmatite, the richer ore having probably degenerated, or perhaps quite thinned out, as sometimes happens with the deposit in other localities."

The question which required determination during the revision was whether the mineral zone with its covering of Upper Basalt

really exists here, or whether the bole is not one of the thin seams which occur in the Lower Basalt. The evidence was closely re-examined, and although lithomarge, as well as bole, has been noted in a few places elsewhere in Lower Basalt, its thickness and persistence at Tully Hill shows that we are here dealing with the main interbasaltic zone. The existence of the zone, moreover, in this outlier is confirmed by the occurrence of a workable iron ore seam beneath the twin outlier of Carmagrim Hill, scarcely a mile to the south. This is shown as an outlier on the one-inch map of 1882, but it is just possible that the zone of ore may continue under the drift-covered country between the two outliers (Fig. 20).

CARMAGRIM OUTLIER.

The following brief reference to the ore beds beneath this outlier is made in the original Memoir (to Sheet 19, p. 16) :—

> " West of the rising ground south of Tully Hill, inferior ore has been met with, overlying lithomarge. Here the course of these beds can be traced northward as far as the bog lying to the east of the hill ; but their direction southwards is as yet to a great extent uncertain."

And again (p. 20) :—

> " The slight fault west of Prieststown brings down the ore-bearing beds on the west, its course lying through a small valley that traverses the upper basalt."

Some ore has been taken from a small adit south of Swanstown, west of the fault and small valley just mentioned. The operations, however, ceased after about three weeks' work, according to information received. The lithomarge underlying the iron ore seam is traceable a short distance further south along the flank of the hill formed of the downthrown portion of the outlier ; and it is also to be seen under the main portion of the outlier at three separate points along the outcrop of the seam a quarter of a mile north-west of Scullionstown.* The position and direction of the outcrop, as thus indicated, increase the area of the outlier given on the one-inch map, and, judging from the form of the ground, the ore bed is represented by a very thin seam of bole at the quarry about 300 yards south-west of Hillistown, and a similar one reported to have been met with in a drain in the townland of Kilcurry, two-thirds of a mile south by east of Hillistown.

The level of the bole bed on the north side of Tully Hill is 550 feet above datum, and it declines south-eastward so as to be about 410 feet, south by east of Hillistown in Casheltown, that is, a decline of about 50 feet per mile. If we suppose the

* Here, however, it more resembles the lithomarge mentioned on pp. 56, 57, &c., than the ordinary type.

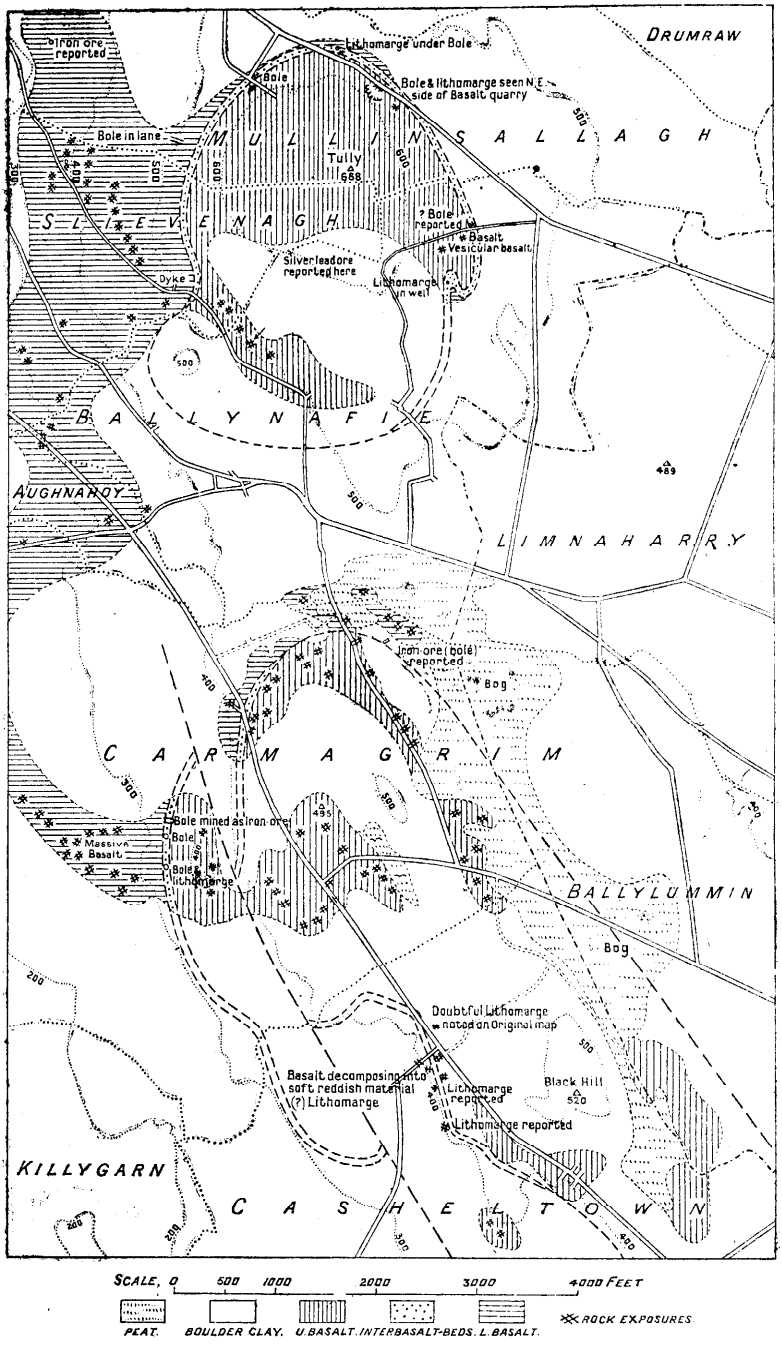


FIG. 20.—GEOLOGICAL MAP OF THE TULLY HILL AND CARMAGRIM OUTLIERS.

existence of the zone and outcrop to continue by Gillistown, towards Lough Neagh, with the rate of decline mentioned, the zone would be found to have declined 450 feet, that is, to about 60 feet below the level of the lake, if it were possible to trace it southward; and, in striking confirmation of this view, lithomarge and lignite have been found between the railway and the lake shore to the south-west of Randalstown. There seems little doubt, therefore, that the zone has a much wider extension in this part of Antrim than had been conjectured; and, if this be so, the Upper Basalt, previously shown as terminating on the south side of Carmagrim Hill, also extends much further south-east, even beyond Casheltown, and also eastward from the outcrop—how far eastward it is impossible to say.

The fault which skirts Carmagrim Hill on the south-west is probably continued north-westward by Finlaystown, where a bole bed occurs beneath a cap of basalt about a quarter of a mile south-east of that place. (See Fig. 20.)

ORIGINAL SURFACE OF LOWER BASALT IN MID-ANTRIM.

Throughout the foregoing account, frequent references were made to the changes of level to be observed in the mineral zone. They range from about 1,650 feet in the Slieveanorra outlier to about 500 feet above datum at Ballylig mine, and about 375 feet in the Black Hill outlier at Cullaleen. This drop toward the south of more than 1,100 feet in eleven miles—an average of 100 feet per mile—is fairly regular. There has, moreover, been a decline from 1,000 feet south of Red Bay to 400 feet, and possibly lower, in the Rathkenny mining tract. Undulations too have taken place, as in the Cargan mining tract, shown in section on p. 63; and the zone-level has been considerably disturbed by faulting, subsequent to the outpouring of the Upper Basalt. Some indefinite information has been given to the effect that the deposit in certain places is thicker on one side of certain faults than on the other side. In so far as such reports are to be relied on, they would show that faulting to some extent preceded the Upper Basalt, and this was probably the case. But fractures at that stage, however likely to occur, are not at all so numerous or important as those which occurred subsequently to the outpourings of the Upper Basalt. The differences of level now noticeable in the mineral zone, therefore, are for the most part due to this later faulting, as well as to buckling, and an unequal tilting of the series of a similar date. Such dislocations are here and there very pronounced.

It need scarcely be mentioned that the original floor of the lignite, iron ore, and bauxite deposits is not supposed to have been absolutely level—though in all probability it was approximately horizontal. A very remarkable uniformity prevails in the thickness of the iron ore deposit from Trostan Hill south-

ward to Clonetrace, a distance of nine miles; and from Dungonnell south-westward to Rathkenny, seven miles; this ore bed originally occupied a region of about 45 square miles, including, as we are entitled to assume, the denuded area of the Glenravel valley. The uniformity is rendered the more remarkable by the cessation of a profitable mining seam in the north-eastern promontory between Glenariff and Carnlough, its complete cessation at Newtown Crommelin and westward, and the vanishing of iron ore, "pavement," and good lithomarge north of Cleggan. The slight inequalities in the ore bed at Glenravel, Skerry East, Parkmore and elsewhere—for example, the thickening of the ore in hollows of the floor and thinning of it on the summits of minor elevations—are not sufficiently important to vitiate the broad fact of the uniformity of the deposit throughout the large area mentioned. The writer, therefore, suggests that the laterisation here took place in the floors of lakes, which were alternately filled and dried during wet and dry seasons.

CHAPTER V.

THE SOUTHERN DISTRICT.

By H. J. Seymour.

LYLES HILL.

(MAP 3, SOUTHERN PORTION. ANALYSES LVII. AND LVIII.)

The upper portion of this hill consists of Upper Basalt overlying a zone of lithomarge and bauxite (Fig. 21). Four adits have been run into the latter zone, exposing good sections, though the total thickness is not seen anywhere. Apparently, only the material excavated to form these adits was ever taken out, so that by far the greater part of the ore, which varies a good deal in quality from point to point, is still available. No workings have taken place here for some ten years.

North of the hill, and separated by a well defined fault running approximately N.W. and S.E., with a downthrow on the northern side, is another area of Upper Basalt, the scarp of which is very distinct on the south-east side, but gradually dies away towards the north-west. There is some evidence for the occurrence of the lithomarge zone here also, but it almost certainly thins out and dies away towards the N.W. end of the Upper Basalt outcrop, the boundary of the latter at this point being very obscure. The maximum thickness of the interbasaltic beds seen during my visit in any of the sections did not exceed six feet, and though they are certainly thicker, only the upper

five or six feet seem likely to be of commercial value. The whole of the material is of basaltic origin, and several residual "onions" of basalt still remain to attest this fact. The lithomarge at Lyles Hill is partly red and partly white in colour, the two kinds being intimately and irregularly mixed up together, so as to make it certain that the latter is merely a bleached variety of the former. Originally the whole of the decomposed basalt was probably red in colour, and ultimately the iron was leached out of certain parts in a very irregular fashion and concentrated in others. This supposition is confirmed by the fact that near the top of the zone the iron oxide is still more concentrated, occurring as pisolitic grains of hematite in a nearly white or yellowish white ground. This white material is seen in

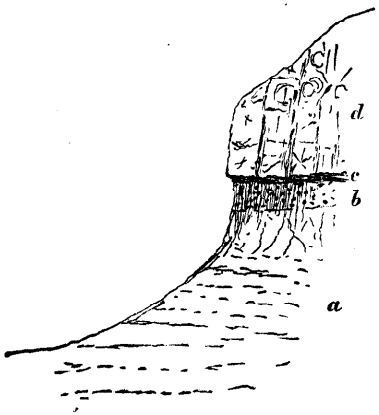


FIG. 21.—SECTION AT LYLES HILL, NEAR TEMPLEPATRICK. (August, 1873.)

(*d*) Basalt, 10 to 12 feet.
(*c*) Clay, 4 inches.
(*b*) Pisolitic iron ore, 14 to 18 inches, overlying red aluminous bole, 4 feet.
(*a*) Bole and lithomarge passing down into amygdaloidal basalt, 45 feet.

places forming narrow bands or layers, suggesting its formation along lines of water-circulation, though more generally it occurs in a patchy fashion in the red lithomarge, there being about an equal amount of both kinds present. Analysis LVII. distinctly shows the bauxitic nature of part of the material. The pisolitic layer is quite thin, measuring not more than a few inches, and the bulk of the material is matrix, the pisolitic grains not constituting more than 25 per cent. In a thin section of one of the boles, traces of the original basaltic structure remain, as is indeed apparent also to the unaided eye. The rods of felspar are replaced by an isotropic substance.

Between the lithomarge and the overlying basalt there occurs here, as elsewhere in the district, a thin clayey layer, usually

containing grains and crystals of quartz, the origin of the latter not being very obvious. Traces of lignite occur also in the same horizon, but only in very small quantity. North of the summit is a massive dyke of basalt, cutting through the ore zone, apparently along a line of fault which runs approximately parallel to the main fault line shown on the map.

KNOWEHEAD.

(MAP 3.)

According to the original Memoir published in 1876, "ash beds," like those at Ballypalady, occur here, and Du Noyer noted on the six-inch field maps of this area that "iron ore was raised here by Dr. Ritchie. The bed consists of bole and reddish mottled lithomarge." The Memoir further states that "this material has also been observed in small streams both to the north and south of Knowehead farm."

As the "ash beds" at Ballypalady are quite different in every way from the lithomarges of the district, there seem to be some discrepancies in the above quoted passages. In the course of the revision in this vicinity during 1908, no traces of "ash beds" or lithomarge were found *in situ*, nor could any satisfactory evidence for their occurrence be obtained from persons who had resided in the locality for thirty years or more. The columnar basalt close to and east of Knowehead farm may possibly be Upper Basalt, but there is no evidence of a satisfactory character available to determine this point.

Two well-sinkings of ten feet and eight feet respectively were noted in the neighbourhood, and both were sunk entirely through amygdaloidal basalt without reaching any lithomarge. With regard to the second outcrop of Upper Basalt noted on the published one-inch map (Sheet 28; date 1874) as occurring west of Knowehead, no traces of lithomarge occur, and not even a scarp serves to define the limits of the Upper Basalt. It would be well to consider this outcrop as doubtful.

BALLYPALADY (BALLYMARTIN).

(MAP 3.)

Iron ore was extensively worked here at one time (see Analyses LIX. and LX.).

There is little to add to the description already published of the plant-bearing beds of this locality, the sections being in fact much more obscure now than when examined by Du Noyer in 1868,* at which time quarrying operations were in progress.

* See W. H. Baily, "Notice of Plant-remains Interstratified with the Basalt in the County of Antrim," Quart. Journ. Geol. Soc. London, vol. xxv., 1869,

The principal section, about twenty feet high, exposed in the old quarry near the railway, shows alternating coarse and fine sediments in beds not usually exceeding a few feet in thickness. The material consists of basaltic debris in all states of crystallization. Four thin sections that have been examined show abundant fragments of basic glass, now in a palagonitic state. The finer sediments usually contain plant remains and casts of cones, the organic material now obtainable being in a quite fragmentary condition. The plants were first made known by Mr. Rowland Smeeth in 1862 (see pp. 105-6). The outcrop of these interbasaltic beds as shown on the one-inch published map (Sheet 28) needs no alteration, but some emendation has been effected in the colouring. Thus the railway cutting through the Upper Basalt on the east exposes the ash beds on the rail level for the greater portion of its length (Fig. 22), and again, the basalt

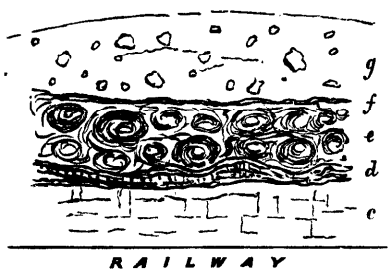


FIG. 22.—SECTION IN RAILWAY, BALLYPALADY.

(*g*) Soil and boulder-clay, 2 to 6 feet.
(*f*) Lignite, 8 to 12 inches.
(*e*) Spheroidal basalt, 4 to 5 feet.
(*d*) Bole and iron ore with impressions of plants, 3 to 4 feet.
(*c*) Bole and volcanic ash (on the same level as the beds in the quarry), 5 to 6 feet.

exposed in the stream between the two larger outcrops of Upper Basalt has now been coloured as Lower Basalt. As noted in the original Memoir, three basalt dykes traverse the Ballypalady beds in the cutting just referred to, though they are too small to be shown on the one-inch scale. Another larger dyke, omitted from the published map, traverses the large quarry, on both sides of the railway, in the Ballypalady beds further west. As the Lough Neagh clays containing lignites are not known to be traversed by Tertiary basalt dykes, it seems evident that the Ballypalady beds are part of a more ancient series. A large collection of plant-remains from the Ballypalady series has been examined by Dr. Moss, whose results are given in Chapter VI.

p. 357. R. Tate and J. S. Holden, "Iron-ores of N. E. Ireland," *ibid.*, vol. xxvi. (1870), p. 159. Also J. S. Gardner, "On the Lower Eocene Plant-beds of the Basaltic Formation of Ulster," *ibid.*, vol. xli. (1885), p. 85.

Dr. J. Apjohn made the following analysis of the plant-bed from the quarry* :—

Silica, with a little alumina.....	36·40
Alumina and other oxides, by difference.....	28·70
Iron peroxide.....	9·12
Water.....	25·78
	100·00
Percentage of Iron	6·36

NOTE ON THE BASALT DYKE AT DONEGORE.

In the vicinity of Carnearny, Scolboa and Browndod, as will be mentioned later, the occurrence of basalt *in situ* was noted well below the scarp which presumably delimited the extent of the Upper Basalt. The mode of occurrence in each case being similar, it was at first thought that the relatively low lying basalt represented intrusive material in the form of dykes. With a view to settling the matter, the large dyke at Donegore was specially examined to see how its mode of occurrence in the field compared with those of the previously mentioned basalt outcrops. In this case, however, the evidence goes to show that the mode of occurrence of the Donegore dyke is essentially different, forming, as it does, several steep knolls projecting well above the surrounding basalt. Incidentally it appears to the present writer that there is no satisfactory evidence for representing this dyke as being continued over half a mile eastward from the point where it crosses the road S. of Donegore. A reference to the original six-inch map does not explain the extension of the dyke on the one-inch map. It would seem to be best represented as a N.N.W.-S.S.E. dyke extending from Priest's Craig on the N. to just beyond the road on the south.

THE TARDREE AREA.

(MAP 2.)

Rocks belonging to this group occupy an extensive area of approximately twelve square miles in the vicinity of Tardree, north of Antrim town, while small outcrops occur at some six or seven isolated spots north-west and south-east of the main mass. These rocks have been dealt with in previous Memoirs of the Survey and in Sir A. Geikie's "Ancient Volcanoes of the British Isles." Professor A. von Lasaulx gave the first petrographical description of the Tardree type of rhyolite, and in 1895 Professor Cole† published a detailed account of the mode

* Tate and Holden, *op. cit.*, p. 161.

† "The Rhyolites of the County of Antrim," Trans. Roy. Dublin Soc., vol. vi., p. 77. Also "The Volcano of Tardree," G . Mag., 1895, p. 303.

of occurrence and the petrography of the various types. A year previously, Mr. A. McHenry, of the Geological Survey of Ireland, had demonstrated the interbasaltic age of the rhyolite in the case of an outcrop at Templepatrick in a section now entirely obscured by water.*

The present account has little to add to the previous literature on these rocks, except as regards certain boundaries and outcrops where modifications now seem desirable, owing to some new facts having come to light during the progress of the revision work done in this district.

Practically speaking, there are two types of rhyolite developed. The chief one is a white variety, porphyritic, and with a cryptocrystalline to crystalline base. The other and less conspicuously developed type is dark grey or black in colour and belongs to the pitchstones and obsidians. It is frequently porphyritic also. Some of the smaller outlying masses are non-porphyritic, cryptocrystalline, and generally beautifully fluidal, the flow structure being frequently almost vertical. Certain other structures common to rhyolites, such as perlitic structure, etc., are locally developed, and have been described by Professor Cole and Professor Watts.† As regards the relation of the two types, the field evidence indicates that the white or Tardree type is younger than the black glassy variety, which it overlies in several sections around Sandy Braes. In the low lying hollows in the vicinity, whence the white variety has presumably been denuded away, the pitchstone type is generally found. Near Sandy Braes, what appears to be an agglomerate-lava occurs between the two varieties, though it is a question as to whether the fragmental character may not be due to the disturbance of a loosely coherent material under the ice-sheet of the glacial period. Occasionally the pitchstone occurs in blocks or boulder-like masses surrounded by what appears to be the white variety in a disintegrated condition. About half a mile north of Browndod, for instance, is a small quarry section in a black pitchstone (an occurrence not previously noted), the upper portion of which consists of blocks of pitchstone in a whitish matrix. One of the black blocks is cracked across, and the two portions are shifted relatively along this line through a distance of four or five inches. This seems most probably attributable to differential movement under pressure of an ice-sheet, and the whitish matrix with the included blocks probably represents a rhyolitic boulder-clay. A good deal of the upper surface of the material in the Sandy Braes area is almost certainly boulder-clay, and contains several blocks up to one foot long of a compact grey felsitic rock (see reference further on), unlike anything known to occur *in situ* in the district. In the same district are some large masses of an agglomerate or volcanic ash, which however are certainly

* "On the Age of the Trachytic Rocks of Antrim," Geol. Mag., 1895, p. 260.

† W. W. Watts, "Note on the occurrence of perlitic cracks in quartz." Quart. Journ. Geol. Soc., vol. l. (1894), p. 367.

not *in situ* here, but are derived from the outcrop of a similar rock some 400 yards further north-west. This outcrop, which does not appear to have attracted the attention of any previous observer in the district, forms a well marked and fairly steep scarp facing south-east, about 20 feet high in the centre, and with a strike outcrop traceable for nearly one-third of a mile. The face of the outcrop is strewn with huge boulders of a coarse volcanic agglomerate, but the rock is also seen *in situ* close to and under the stone walls surrounding the vicinity. The matrix is fairly compact, but weathers into a porous ashy-looking material not unlike weathered mortar, and the contained blocks are mostly of the grey " felstone " type noted as occurring in the Sandy Braes boulder-clay. A thin section shows numerous fragments of grey lithoidal rhyolite, with angular quartz-grains. These grains lie both in the fragments of rhyolite and in the ashy ground. The field relations of this mass to the surrounding rhyolites are obscure, but the nature of the ground suggests that it is interbedded with them, the dip of the beds being towards the north, probably a little west of north, at a low angle. The included blocks are usually well rounded, but are occasionally markedly angular, as if brecciated by pressure, so that locally the rock might be termed a volcanic breccia.

In connection with these grey "felstone" inclusions, it may be mentioned that the porphyritic rhyolite occurring at the southern end of Ballygowan townland, and north-west of the group of houses at the cross roads, contains included xenoliths of a grey green felsite very like those occurring in the agglomerate. A second occurrence of a xenolithic rhyolite was noticed 300 yards due north of the same cross-roads, both localities being about one and a half miles southward from Sandy Braes.

The presence of these inclusions is noted on the original six-inch maps of the Survey in the case of the southern quarry, though no reference was made to them in the Memoir ; but the second occurrence has not been previously recorded.

It is very probable that the area represented on the one-inch maps as being occupied with rhyolite is too large, as this rock weathers very rapidly and the debris is carried far down the sloping ground and spread over the low-lying areas. In the absence, however, of definite evidence over most of the district, the boundary line has been allowed to stand except in some minor details.

The relation of the rhyolite to the Upper and Lower Basalts, on the supposition that the Upper Basalt does not occur in the district, can only be inferred, the evidence, such as it is, being confined to the vicinities of Carnearny, Browndod and Scolboa, three fairly prominent features in the topography of the district. In the two former localities, a considerable number of openings have been made, and pits have been recently dug through the rhyolite, generally close to its junction with the basalt outcrop-

ping at the surface, the object being to test the suitability of the altered rhyolite for the manufacture of china or pottery. A company styled "The Irish China Clay and Resources Co., Ltd." was founded for this purpose in 1907. The pits or openings, with a single exception, are sunk vertically for varying distances, up to perhaps thirty feet, and in only one case did the bottom of the pit go through into the underlying rock, basalt. One excavation was made in a horizontal direction on Carnearny, but unfortunately not sufficiently far in to show whether the basalt close by overlay the rhyolite or not.

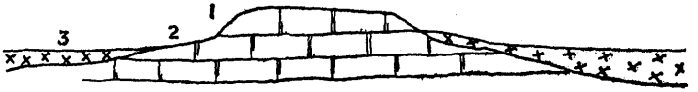
Commencing at Carnearny, the junction line of the rhyolite with the basalt south-east of the summit runs fairly horizontally till it nears the track crossing the southern slope of this hill. Here the boundary line rises up the slope for a height of some 40 or 50 feet, in such a manner, in fact, as to suggest that the rhyolite is banked up against the basalt, *i.e.*, that it occupies a basin-shaped depression in the Lower Basalt of this vicinity, from the rim of which it has been partially denuded. North-east of the hill, however, is a steep scarp rising up from the rhyolite, which here apparently underlies the basalt. The latter would thus belong to the Upper Basalt series, and a fairly distinct feature can be traced right round the hill delimiting its outcrop. On the south side no rhyolite is traceable below this feature, the country rock being basalt of a somewhat amygdaloidal character and presumably belonging to the lower series. At one point near the path south-west of the summit of Carnearny some red bole was seen, and this rather unsatisfactory evidence is all that can be offered for the occurrence of an interbasalitic zone in this district. Above this bole bed there rises up a more or less steep scarp of basalt which might be regarded as Upper Basalt.

A precisely similar feature also occurs both at Scolboa and Browndod, and hence it probably possesses some significance. On the south side of the track across the slopes of Carnearny is a small outcrop of columnar basalt forming a "neck" which cuts through the rhyolite, and which is therefore later and very probably of Upper Basalt age.

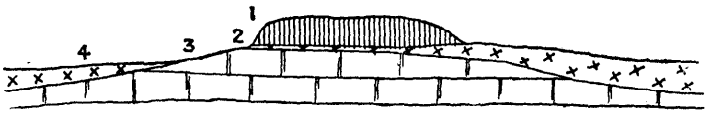
In the case of Scolboa, the outcrops of rhyolite are best seen on the north and east sides, this rock dipping towards and apparently under a well marked scarp of basalt. This scarp, as at Carnearny, is continued round on the south side, where it is seen to rise from a low level tract of basalt on the approximate level of the rhyolite of the north side of Scolboa. In and around Browndod an exactly similar state of things occurs, viz., an area of (presumably) Upper Basalt, apparently overlying rhyolite on the north and Lower Basalt on the south side.

As already mentioned, some twelve or more pits have been sunk through the decomposed rhyolite near its junction with the basalt, on the east and north sides of Browndod. These are all vertical, and unfortunately afford no direct information as to whether the rhyolite does or does not underlie the basalt close by.

One pit was sunk through the basalt on the higher slopes inside the junction, but was not sufficiently deep to reach the rhyolite, presuming that the latter underlies the basalt at this point. Within a distance, however, of about 150 yards another pit was sunk on the other side of the boundary through the decomposed rhyolite, and this reached the underlying amygdaloidal basalt at a depth of some ten feet. This depth, therefore, represents the total thickness of the rhyolite at this particular spot and rather tends to confirm the impression, already suggested at Carnearny, that the rhyolite simply fills up hollows in the Lower Basalt and thins out near its outer limits. The different rates at which rhyolite and basalt disintegrate would, if the former underlay the latter in these localities, show in some sections at least an undercutting of the base of the Upper Basalt.



1. Higher sheet of basalt, belonging to Lower series.
2. Underlying ,, ,, ,, ,,
3. Rhyolite at lower level on S.W. side of hill.



1. Upper Basalt.
2. Lithomarge or bole zone passing horizontally into Rhyolite towards the right, and regarded as interbedded between Upper and Lower Basalt.
3. Lower Basalt.
4. Rhyolite at lower level on S.W. side of hill.

FIG. 23.—IDEAL SECTIONS IN THE TARDREE AREA.

Not a single section was noticed showing such a feature. On the contrary, at every place where a scarp of presumed Upper Basalt occurred the rhyolite close to it had all the appearance of being banked up against the basalt.

In the absence of evidence from the mode of occurrence of the rhyolite, the evidence for the probable occurrence of Upper Basalt is as follows: Firstly, a small neck of columnar basalt outcropping through the rhyolite south of Carnearny, and, secondly, a somewhat larger and thick dyke in the vicinity of Tardree Cottage. Both these occurrences are clearly later than the rhyolite, but at the same time are very different in character from the basalt sheets forming the summits of Carnearny, Browndod, and Scolboa. While probably representing the connecting passages between the subterranean basalt reservoirs and the lava which formed the upper sheets, no direct connection can now be satisfactorily traced between these intrusive masses and the rock on the summits of the basalt hills close by.

Hence, in the absence of any definite evidence that the rhyolite does run under the basalt scarp of the areas under notice, these latter may be regarded as slightly more elevated tracts of Lower Basalt, portions, in fact, of sheets not completely removed by denudation. The only two alternative hypotheses are shown in the diagrams, representing idcal sections across Carnearny, Browndod, or Scolboa, in a direction approximately S.W. to N.E. (Fig. 23).

On the first hypothesis, as shown in the lower section, the bole bed on the S.W. of Carnearny is taken as indicating a division between the Upper and the Lower Basalt, and the rhyolite on the N.E. is regarded as underlying the basalt scarp. Further, the rhyolite is considered as having been partially denuded off the Lower Basalt, on which a bole bed was subsequently formed, the latter and the rhyolite being at a later date overlain by a sheet of Upper Basalt. The occurrence of a bole bed is not uncommon between the successive sheets of the Lower Basalts, as, for example at the fine Causeway sections (Plate I.), so that by itself it is not conclusive.

On the second hypothesis, as shown in the upper section, the Lower Basalt at Scolboa, Carnearny, and Browndod is considered as having a relatively higher elevation than the surrounding area, due either to (*a*) circumdenudation, or (*b*) because these were the actual sites of the fissures up which the basalt was erupted. In this latter connection it should be noted that the summits of Scolboa and Carnearny, as well as the site of the basalt neck near Carnearny, lie along a N.W. and S.W. line, parallel with the orientation of the Tertiary basalt dykes of Co. Antrim. Rhyolite then filled in the surrounding hollows in the Lower Basalt. On this hypothesis the whole of the basalt is Lower Basalt, the higher portion bounded by the scarp being merely a higher bed of the same series not removed by denudation. This also furnishes a reasonably satisfactory explanation for the shallowness of the rhyolite close to the basalt scarp N. of Browndod. Direct evidence, however, might be obtained (*a*) by continuing the horizontal adit on the N.E. side of Carnearny for a distance of about 60 yards, or (*b*) by deepening the pit sunk in the basalt (p. 97) on the N. side of Browndod some 20 feet, and, pending such definite information, it seems that no Upper Basalt occurs in this district other than the dykes just mentioned.

ESLERSTOWN.

(MAP 2.)

The evidence as to the mode of occurrence of the isolated patch of rhyolite at this locality is of a very unsatisfactory character. No solid material was observed *in situ*, and the outcrop could only be inferred from ill-defined features and the occurrence of lithomarge. As far as could be ascertained, there is a lenticular area of decomposed rhyolite bounded on the north

by a scarp of Upper Basalt and on the south by a narrow zone of lithomarge traceable only on the S.E. It is likely that the Upper Basalt formerly overlay the rhyolite, which is now partially exposed at Eslerstown, owing to the retreat of the scarp northwards, as a result of denudation. Sir A. Geikie has recorded a correction of the original mapping in this area, and agrees with Mr. McHenry that the rhyolite is intrusive in the Lower Basalts only.* About two-thirds of a mile to the west of this rhyolite area, in the Tully townland, is a round hill on the lower slopes of which lithomarge is stated to have been got in an old well sunk close to the farm-houses on the S.E. side of the hill. No further information was obtainable at the time of the revision work carried out during 1908.

BALLYCLOUGHAN, KIRKINRIOLA, AND CLOUGHWATER.

(MAP 1, SOUTH-WESTERN PORTION.)

Nothing need be added to the descriptions of the exposures of rhyolite furnished by previous writers. They lie in the mid-Antrim area, re-surveyed by Mr. J. R. Kilroe.

THE LOUGH NEAGH CLAYS AND ASSOCIATED LIGNITES.

These beds have been generally regarded as later than the Upper Basalts and probably Pliocene; but some authors have urged that they are interbasaltic.

Some years before the revision work in the Antrim district was carried out, a number of pits were sunk in various localities on the eastern side of Lough Neagh, through the Lough Neagh clays, with a view to exploiting the lignites associated with them. The work is stated to have been done by a Dutch company, which, however, ceased operations prior to 1907. The following information was obtained from residents in the vicinity of the pits, the sites of all of which were visited in 1908:—

(*a*) Coibally.—Some three miles S. by W. of Antrim, and close to shore of the lake, a pit some 44 feet was sunk. The first six feet was through typical boulder-clay, and the next 38 feet traversed a stiff blue clay, apparently the true Lough Neagh clay. At the depth of 44 feet a bed of lignite was struck, but the thickness is not known, as the bed was not cut through. It is stated to be over three feet thick. The lignite is of a brownish black colour and can be burnt fairly readily when dried. Incidentally it may be mentioned that this area is mapped as basalt, while the pit indicates a more northerly extension of the Lough Neagh clays than is shown upon the published map.

* "Ancient Volcanoes of Great Britain" (1897), vol. ii., p. 428. Compare the description and section in Memoir to Sheet 20 (1885), pp. 10 and 11.

(*b*) Bellbrook.—South of Lennymore Bay, Lough Neagh. A shallow pit was sunk through 18 feet of Lough Neagh clay, without reaching bottom or finding lignite.

(*c*) N. side of Sandy Bay (N. of Portmore Lough), E. of Rams Island.—Here, according to the statement of a resident, the company sank a pit close to the shore (at the foot of the lane leading from Darachrean to the lake), disclosing the following section :—

Lough Neagh clays.....	30 feet
Lignite	14 ,,
White Clay	6 ,,
Lignite.....14 feet, and bottom not reached.	

The lignite is stated to occur in a basin-shaped trough, and to outcrop on the shore north and south of the boring, but this statement was not verified on an inspection of the locality. No samples of the lignite could be obtained, the material left having been utilised locally as fuel.

(*d*) About half a mile due south of Sandy Bay Point, near locality (*c*), and on the left hand side of the small road going south, a 65 feet pit was sunk down to the basalt, and without any indication of lignite.

(*e*) Lady Bay.—About one mile S.W. of locality (*d*), and on the north side of the houses south of the church, a 27 feet pit was sunk in the Lough Neagh clays without reaching rock or lignite.

(*f*) Finally, at a place called Claremont, N.E. of Cranfield Bay on the north shore of Lough Neagh, and about five miles due west of Antrim town, two or three shallow openings were made, disclosing sections of considerable interest. The chief point is that here a grey lithomarge, clearly arising from the alteration of basalt *in situ*, occurs at the surface, thus indicating the presence of the interbasaltic zone, and hence the absence of the Upper Basalt (Analysis LXI.). In the second place, underlying the boulder clay, and between it and the lithomarge, was found a little lignite, which suggests the origin of, at any rate, some of the lignite beds in the Lough Neagh clays, viz., *that they are derived from the interbasaltic zone by denudation.*

This origin is indeed further indicated by the mode of occurrence of the Lough Neagh lignites, as revealed in the pits, details of which have just been given, for it is evident that they are only locally concentrated, and occur on many different horizons, as would naturally be the case were they brought to their position by rivers, and intermittently. The fact also that the Lough Neagh clays are not known to be penetrated by Tertiary dykes of Upper

Basaltic age is a further evidence of their more recent date, especially as the Ballypalady beds (p. 92), though exposed over a limited area, are seen to be thus penetrated.

Further, the grey lithomarge at Claremont is exactly the type of material the disintegration of which would result in the production of a clay similar to the Lough Neagh clays. It is therefore suggested that these clays are derived from the denudation of the interbasaltic lithomarges, which were exposed over a large portion of Antrim in Cainozoic times, and which perhaps never received a protective covering of Upper Basaltic flows. The sinking in of the earth's crust in this wide volcanic area apparently initiated the depression now occupied by Lough Neagh. This lake was once connected with the sea, but by a minor and subsequent uplift is now converted into a freshwater region. The Lough Neagh clays are so very thick in places, and the time during which they have presumably been accumulated is so short, that only an easily eroded rock, such as the altered basalt or lithomarge, could have furnished the material, and this inference appears to be further strengthened by the occurrence of "derived" lignites from the interbasaltic zone in the Lough Neagh clays.*

THE COAGH CONGLOMERATE.

This remarkable rock occurs over an area a few square miles in extent, occurring east and west and also some distance south of the village of Coagh. It has been described in the published Memoir as a volcanic conglomerate (Memoir to Sheet 27, pp. 29, 30), and would thus appear to have much interest in the geological history of the district. In the light, however, of our present knowledge of basalt and its mode of weathering, its fragmental origin does not appear to be satisfactorily established. Indeed, the original description† almost exactly tallies with the supposition that the so-called conglomerate is in reality a weathered spheroidal basalt. Unfortunately, some sections which would have thrown additional light on the matter, and which are referred to in the Memoir just mentioned, are no longer visible, having been obscured by vegetation or otherwise. However, sufficient evidence is still available to make it quite certain that the rock is merely a much weathered spheroidal basalt. For example, the river bank in the south of Ballygonny Beg townland exposes here and there beneath a dense coat of vegetation some satisfactory sections a few feet in thickness. These show the rock to consist of flattened "pebbles" or spheroids of basalt, the matrix, as noted in the earlier Memoir, being similar to these in composition, and really consisting of the more

* See Appendix II., and discussion and references in Sir A. Geikie, "Ancient Volcanoes of Great Britain" (1897), vol. ii., pp. 449-452, where observations by Mr. Clement Reid are recorded.

† Mem. Sheet 27 (1881), p. 29.

or less weathered concentric layers of adjacent spheroids. It is worthy of note that the so-called pebbles all lie with their longer axes horizontal, which would hardly be the case in a conglomerate of volcanic origin. It is also stated in the Memoir that the conglomerate rests on basalt. This cannot now be verified, but the observation probably indicates the occurrence of a spheroidal upper portion resting on the more compact lower portion of a lava flow.

About a mile north-west of Coagh, a section of basalt, resting near at hand on chalk, may be seen in a new road-cut. The rock here is markedly spheroidal, and resembles that mapped as conglomerate farther south. Convincing sections showing the rock to be a spheroidal basalt occur in the watercourse west of the small wood about one-third of a mile east by north of Coagh, and again in the river section 300 yards further east.

At the mouth of the miniature valley half-way between the two sections just mentioned, the spheroidal basalt rests on the chalk, in which are pockets filled with a decomposed flint breccia similar to that found in the basalt escarpment N.W. of Maghera.

Occasional flints and pieces of "felstone" or "quartz-porphyry" are noted in the Memoir as having been found in the "conglomerate," but these are of rare occurrence, and would appear to be confined essentially to the base or to where the "conglomerate" rests on the underlying chalk. A prolonged search in all the sections now available yielded only a few baked flints and a single pebble of rhyolite a few inches in diameter, the latter being probably the "quartz-porphyry" of the Memoir. This rhyolite is of similar composition to that occurring at Tardree, but is much finer in texture and has much smaller quartz phenocrysts.

Its occurrence is of considerable interest, since it implies either that the basalt in which it occurs is Upper Basalt (since the rhyolitic eruptions in Antrim are regarded as essentially interbasaltic), or that it was denuded off a mass of erupted or intrusive rhyolite older than the Lower Basalts; in that case fragments would have lain on the chalk along with the flints. The latter view appears to the present writer to be the most probable, having regard to the isolated nature of the occurrence. It may be remarked that in Skye,* where trachytic and rhyolitic rocks are mostly confined to a mid-basaltic horizon, there are also traces of rocks of these types among the earliest members of the Tertiary igneous series.

The occurrence, therefore, of foreign pebbles, on which the chief argument rested for the conglomeratic origin of the Coagh rock, does not seem to have great significance. All the phenomena observed in the sections now exposed are quite consistent with the view that the rock in question is a basalt in which spheroidal structure is rather highly developed. This lava

* A. Harker, "Igneous Rocks of Skye," Mem. Geol. Survey Scotland (1904), pp. 57 and 433.

was poured out over a denuded surface of chalk, on which rested flints and a few pebbles of rhyolite, and some of these naturally became incorporated in the lava, like the flints of Keady Mountain (p. 26), and were carried probably for a little distance in the flow. The rhyolite, and also the felstone previously recorded, must be regarded as older than the Lower Basalts, unless we are prepared to extend enormously the area over which the Upper Basalts spread in Co. Antrim. (See Appendix I.)

CHAPTER VI.

THE PLANT-REMAINS OF THE INTERBASALTIC ROCKS OF CO. ANTRIM.

By C. E. Moss, D.Sc.,

Curator of the University Herbarium, Cambridge.

(For references, see end of this chapter).

Of late years the study of Tertiary fossil-plants has, to a large extent, fallen into abeyance. The reasons for this comparative neglect are not far to seek. Tertiary fossil-plants are, on the whole, of a very fragmentary and unsatisfactory nature; and it is almost, if not quite impossible to determine, with any degree of exactitude, the systematic position of the majority of the specimens, especially those belonging to the class of flowering plants. Most of the available material consists of impressions of detached leaves or portions of leaves, less frequently of twigs, and still less frequently of fruits or seeds; and it is practically never the case that palæobotanists are able to reconstruct any Tertiary plant as a whole. Tertiary fossil-plants showing internal structure are rare; and even the few that are known rarely exhibit any structural features that are of absorbing interest to the botanical morphologist or systematist.

Contrasted with this, we find that the material of Palæozoic fossil plants is, in many cases, well preserved, that it has been found possible to reconstruct several such species of plants, and that the structure of many of them presents many important questions of affinity. It will thus be seen that the study of Palæozoic fossil-plants offers a far more promising field for research than that of fossil-plants from the various deposits of Tertiary age. Mesozoic fossils are intermediate not only in age, but also, as it happens, in the matter of preservation; though, from the standpoint of the morphologist, they are perhaps as interesting as the fossil-plants of Palæozoic age.

Much of the available material of Tertiary plant-remains in the various museums is undescribed and unnamed. Not only is it a matter of considerable difficulty to name precisely the majority of Tertiary plant-fossils, but much doubt remains as to the exact age of the various plant-bearing deposits. It is not surprising, therefore, that few botanists are at the present time devoting themselves to the elucidation of the problems connected with Tertiary plants.

Instances of the untrustworthiness of some of the older records of fossil Angiosperms have been supplied by Seward (1896); and this author also draws attention to the dangerous and misleading practice of assigning generic names, implying definite botanical affinity, to imperfect and indeterminable fragments. Gardner (1884, p. 283) even went so far as to stigmatise many of the determinations of the Antrim Tertiary fossils as "the merest guesses." Seward (1908) further pointed out that the enthusiasm of some of the earlier writers has been responsible for the publication of species founded on wholly inadequate data; and, in reference to a contribution by Coulter and Chamberlain (1904) on Fossil Angiosperms, he states that, while these authors admit the unsatisfactory nature of the material on which they formed their opinions, this unsatisfactoriness is even more pronounced than their treatment of it implies, since "the data . . . . . have in many cases been compiled by authors whose lack of botanical knowledge renders their records of doubtful value, if not positively misleading and pernicious." At the same time, Seward is of opinion that too much time has been spent in magnifying the unpromising features of the work instead of testing the capabilities of the available material.

The chapters on Fossil Angiosperms by Messrs. Coulter and Chamberlain (1904), if read in the light of the caution expressed by Professor Seward, give a useful and recent account of Tertiary fossil plants from the standpoint of modern botany; and Mr. Clement Reid also has an excellent and succinct account of the state of Tertiary palæobotany in the Encyclopædia Britannica (Reid, 1911), where he refers to the northern Irish deposits as "of doubtful age" (p. 553).

No complete monograph of the subject has ever been published, and the memoir by Ettingshausen and Gardner reached only as far as the Ferns and Gymnosperms (Ettingshausen and Gardner, 1879-1882). The literature of the subject is very scattered, and a great deal of it is hidden away in obscure periodicals in many languages.

With regard to the particular plant-remains found in the interbasaltic deposits of the county of Antrim, the material is, in some respects, more than usually unsatisfactory, as the venation of many of the leaf-impressions in the plant-beds, especially those of Ballypalady, is often very incompletely shown.

In County Antrim plant-remains have been found as "lignite,"

or "wood coal," or "fossil wood," or "silicified wood" from Lough Neagh; as a "leaf-bed" in an old cutting or quarry by the railway at Ballypalady near Templepatrick Railway Station (map 3); as a "leaf-bed" in the iron-ore and bauxite mine at Libbert, near Glenarm (map 5); and as a "leaf-bed" at Ballintoy, a little to the east of the Giant's Causeway. Lignites occur in many other places within the basaltic area, and occasionally in the escarpments at its borders. In a note by Forbes (Q. J. G. S., vol. vii., 1851, p. 103), it is suggested that the age of the plant-beds of the basalts of Mull is probably Miocene, as he thinks that the climatic aspect of the plant-remains is more mid-European than that of the floras in British beds of Eocene age. It must be remembered that the knowledge of Tertiary plants was then very vague and meagre, and that Forbes merely contended that the Mull deposits were "decidedly Tertiary" and "most probably Miocene." Still, Forbes' suggestion appears to have strongly influenced all the workers in the plant-remains of the interbasaltic rocks both of Ireland and of Scotland up to the time of Gardner. This last author contended later (1883-4) that no more could be said of the Mull plant-remains "than that they might belong to Taxites ?, Filicites ?, Rhamnites ?, Platanites ?, and Alnites ?;" and that "if the Mull beds were proved to be Miocene, it would not necessarily follow, from the evidence of the plants, that the Antrim beds were even approximately of the same age." Personally, I am not convinced that the Antrim plant-remains show, as Forbes contended, "mid-European" affinities so much as south-European.

According to Tate and Holden (Q. J. G. S., vol. xxvi., 1870), the first discovery of the plant-remains at Ballypalady was made by Dr. J. Bryce; but Bryce does not appear to have published any account of his discovery. Tate and Holden (*loc. cit.*) have supplied the following names for some of the fossils from Bryce's collection :—

Gymnosperms.
Sequoia Langsdorfii.

Angiosperms :—

Dicotyledons.—
Platanus aceroides.
Juglans.
Fagus.
Laurus.
Eucalyptus oceanica.
Hakea.
Celastrus.
Daphnogene Kanii.

Monocotyledons—
Graminites.

The first public notice of these plant-fossils appears to have been made by Mr. Rowland Smeeth in a course of geological lectures given at Belfast. Smeeth named some of the impressions *Pinus* and others *Cupressites*. The first published account is that by Baily (Q. J. G. S., vol. xxv., 1869, pp. 162, 163 and 357-362), in which the fossil-plants of the Ballypalady beds are stated to possess forms belonging to the following genera :— *Pinus, Sequoia, Taxites?*, and *Cupressites*. The presence of numerous dicotyledonous leaves is also noted, and forms are said to occur which resemble *Rhamnus, Olea, Andromeda, Fagus*, and *Quercus*. The occurrence of " parallel-ribbed stems " [? monocotyledonous leaves] is also mentioned, and these are doubtfully referred to sedges or grasses.

Baily regarded the Antrim remains as differing, as a group, from those of Mull, on the ground that *Platanites hebridensis* Forbes, which Lyell suggested was identical with the recent *Platanus aceroides*, had not been found in Antrim, whereas it was abundant in Mull (Forbes, 1851). However, this species was announced a year later by Tate and Holden (1870) as occurring in Antrim. Baily further supported his opinion by the absence of ferns from Antrim and their occurrence in Mull ; and here again the danger of laying undue stress on negative evidence was illustrated when fossil ferns were announced as occurring in Antrim by Gardner (1885, *c*). Again, as Gardner (1885, *b*) pointed out, the conclusion of Baily that the Mull plants differed as a group from the Antrim ones might be interpreted as opposing Baily's own view that both the Antrim and the Mull plants were of Miocene age. Baily's paper is a useful one ; but some of his conclusions were founded on insufficient evidence. There appears to have been some discussion after the reading of Baily's paper on the wisdom or otherwise of naming Tertiary fossils on very slender evidence ; and Baily, whilst admitting the force of this as a general contention, defended (*op. cit.*, p. 858) his naming of *Pinus, Sequoia*, and *Cupressites*.

Some account of the Tertiary plant-remains of Antrim is also to be found in the Reports to the British Association for 1879, 1880, 1881, and 1883. Brief descriptions of the plant-beds, with geological sections, are here given, as well as lists of the supposed names of the plants. The authors of these Reports regarded the plant-remains as of Miocene age, and as being most closely allied to the Tertiary fossil flora of Greenland. In the third Report (1881) Baily states that he regards the age of the Antrim deposits as Lower Miocene and contemporaneous with the Tertiary plant deposits of Mull and North Greenland ; but no definite reasons for this view are given. In the fourth and last Report (1883) Baily quotes Heer in support of the Miocene age of the Antrim deposits. He argues that as *Lastræa stiriaca* is regarded by Heer as a Miocene fern, and as this fern occurs in the Antrim leaf-beds, therefore the latter must be of Miocene age. It may, however, be very seriously

doubted (even if we admit the correctness of the naming of the plant in question) if the basis of this belief is sufficiently strong to veto any contrary opinion.

The Ballypalady fossils recorded in these Reports to the British Association are the following :—

Gymnosperms :—

Cupressites M'Henrici. Baily in Quart. Journ. Geol. Soc. Lond., xxv., pt. 15, 1869.
Sequoia Du-Noyeri. Baily, *op. cit.*, pt. 15, fig. 4.
Pinus Plutonii. Baily, *op. cit.*, pt. 15, fig. 1.
Pinus Graingeri. Baily, B. A. Rep., pt. 2, fig. 3, 1880.
Torellia rigida. Heer.
Taxodium sp.

Angiosperms :—

Dicotyledons—

Populus sp.
Alnus Kefersteinii (?). Goepp.
? *Fagus* sp.
Andromeda sp.
Viburnum Whymperi. Heer.
M'Clintockia trivervis. Heer.
Rhamnus sp.
Juglans acuminata (?). A. Br.
Salix sp.
Magnolia glauca (?). Heer.
Eucalyptus oceanica. Ung.
Hakea. sp.
Celastrus sp.
Daphnogene Kanii. Heer. (?).

Monocotyledons—

Phragmites œningensis. Ad. Brong.
Phragmites sp.
Poacites sp.
Iris latifolia (?). Heer.

Baily, as the acting palæontologist to the Geological Survey of Ireland, published notes on the Antrim fossils in various Survey Memoirs (Baily 1876, 1886, 1888) ; but he adds nothing of importance to his previously published communications. In one of the Reports (1886), he refers to Gardner's view of the Eocene age of the Antrim fossils, and says that this view, " in the face of such an authority as the late Dr. Heer and other eminent writers on the subject, must be considered of a purely speculative character." This, it will be seen, is a mere appeal to authority.

Gardner made a special study of the interbasaltic plant-remains of the county of Antrim and of Mull. In his first account

(Ettingshausen and Gardner, introduction to vol. i., p. 5, 1879-82), he associated himself with the theory of the Miocene age of the fossils; but shortly afterwards (introduction to vol. ii., p. 2, 1879-82) he altered his opinion. Still later, he argued with both skill and force against the view that the Antrim Tertiary plant-remains belonged to the Miocene, and asserted their alliance with the Heersian flora of Gelinden, "so low down in the Eocene that we have no representatives of it in England" (Q. J. G. S., vol. xli., p. 84, 1885).

Gardner (Annual Rep. and Proc. Belfast Nat. Field Club, 1883-84) also read a valuable paper on "The Age of the Basalts of the North-East Atlantic," in which he stated (p. 255) that "while a few years since we all felt positive that our Antrim fossil plants were of Miocene age, I can now show that we really know nothing for certain about them, except that they are newer than the chalk on which they in places rest." Gardner attributed what he terms "this fundamental error" (p. 256) of the Miocene age of the Antrim fossils to the influence of the great Swiss palæobotanist Dr. Heer, who, according to Gardner, laid too little stress on the stratigraphical evidence. The older view which Gardner criticised was that those Tertiary fossil floras comprising modern and temperate-looking genera, such as the plane,(*Platanus*), willow (*Salix*), beech (*Fagus*), alder (*Alnus*), hazel (*Corylus*), poplar (*Populus*), elm (*Ulmus*), pine (*Pinus*), *Liquidambar*, sassafras, redwood (*Sequoia*), and swamp cypress (*Taxodium*), must be Miocene, and that the floras consisting of Palmæ, Proteaceæ (*Hakea*, etc.), figs (*Ficus*), Aralias, Aroids, Podocarps, and Araucarias, are alone distinctive of the Eocene (p. 256). Gardner goes on to show that Eocene floras have been discovered which prove to be more varied than had been supposed, and that some floras about whose Eocene age there can be no doubt have as prevailing species the plane and perhaps willow and poplar. Moreover, Gardner urged (p. 262) that there is a total absence of any characters among the Antrim plants which would preclude their being referred to the Eocene. This conclusion may be stated in his own words:—"There is sufficient to show that attempts to fix the ages of [Tertiary plant] deposits by aid of dicotyledonous plants must for the present fail" (p. 257). There can be little, if any, doubt that Gardner's conclusions are, in the main, correct, though it is quite possible that he placed the Antrim deposits too low down in the Tertiary series.

Various views have, from time to time, been put forward with regard to the mode of origin of the Ballypalady plant-beds. Gardner (1885, p. 85) does not agree with the earlier writers in considering them lacustrine in origin; their coarseness and the brecciated nature of some of the layers, as well as their irregularity, indicate, in his opinion, the bed of a shifting river subject to variations in volume. If the beds are, as Gardner gives us reason to believe, fluviatile in origin, one must imagine that

they were laid down in a backwater : the numerous impressions of reed-like leaves lead us to conclude that there was here a Tertiary reed-swamp ; and the intercalated impressions of coniferous twigs and cones and of dicotyledonous leaves may be regarded as having been produced by the twigs and leaves which fell from the marginal and overhanging trees.

The reed-like impressions have received various names, e.g., *Iris latifolia ;* but it may be said at once that the impressions are of such a nature that any suggestion of a positive nature in untenable which states more than that they are probably the impressions of the leaves of some Monocotyledons. The late Duke of Argyll published an account, now widely known, of the Tertiary leaf-beds in the Isle of Mull, in which he suggested that the plant-remains had been laid down on " a marshy terrestrial surface " rather than the bottom of a lake, basing this opinion on the absence of shells (Argyll, 1851) ; but as molluscs are usually abundant on marshy terrestrial surfaces, as well as in lakes, some other reason must be found to account for the absence of shells, if this is in reality the case.

During the course of an investigation by the present writer, on behalf of the Geological Survey of Ireland, the leaf-bed at Ballypalady, in a railway cutting about a mile north of Templepatrick Railway Station (see p. 91), was visited, and it was found that the fossils at present exposed showed unmistakable signs of weathering. If fresh material is to be collected, digging should be resorted to in order to obtain more perfect specimens. The collections of the Antrim fossils in the geological division of the Royal College of Science, Dublin ; the National Museum, Dublin ; the Museum of the Field Club, Belfast ; and the British Museum (Natural History), South Kensington, have been examined, as well as a few specimens in some other geological museums, such as the Sedgwick Geological Museum, Cambridge. I wish especially to thank the Belfast Natural History Society and the museums at Dublin for the loan of their valuable collections. These collections show very few ferns, and a considerable number of gymnosperms (including an undoubted *Pinus*), of monocotyledons, and of dicotyledons. The latter exist, for the most part, as impressions of simple, entire or subentire leaves (including one which is with difficulty distinguished from a modern evergreen oak, such as *Quercus Suber* or *Q. Ilex*), and more rarely of partially lobed leaves, usually referred to the genus *Acer*. It is questionable wisdom to give names corresponding to modern genera to these fossils ; but their general character forcibly reminds one of leaves and twigs that might be expected to occur in the flora of some present-day sclerophyllous region with a warm temperate or sub-tropical climate, such as the Mediterranean region. It may therefore be stated, with some degree of certainty, that the plants whose remains are preserved in the Antrim leaf-beds were the product of a much warmer climate than now obtains in any portion of the

British Isles, and one that may be compared to that which at present characterises south Europe or north Africa. Whilst it is impossible at present to name satisfactorily the specimens in any collection of Tertiary plants, and particularly of Tertiary Angiosperms, it seems possible to judge, in a general way, the kind of climate which obtained when such plants were living, from a consideration of the general ecological type which the specimens represent.

It will be seen that the pessimistic attitude which modern botanists assume with regard to Tertiary plant-fossils is not wholly without justification. Before it is possible to assign particular Tertiary plant-deposits to any particular series, the whole of the botanical evidence must be re-examined and re-stated. At present it is not possible to state the age of any particular Tertiary series by an appeal to the nature of the plants preserved. It is more reasonable at present that the age of Tertiary deposits should be determined on geological grounds and the plants provisionally assigned to the series so determined than that the unsatisfactory botanical evidence should be used by geologists as assigning a particular deposit to a particular age.

As Seward (1903 *l.c.*) has maintained, the study of Tertiary fossil-plants "is well worthy of attention, and if undertaken by men who well recognise the limitations both of the capabilities of the material and of their own unaided power of identifying fragmentary fossils, it is a study that will yield results of the greatest importance." Seward recommends "an organised exploration of the later plant-bearing strata and of the wealth of material already collected, which should be taken in hand by experienced palæobotanists in conjunction with botanists who possess a wide and accurate knowledge of recent" plants. "It would not be difficult to obtain the assistance of experienced systematists to criticise determinations and to co-operate in the determination of species: a greater difficulty is to find workers who are willing to devote a considerable amount of time to a laborious task and to enlist the services of specialists in the determination of the material." It seems highly probable that unless some such co-operative plan of studying Tertiary fossil-plants is adopted, their study will continue to languish; for it can scarcely be contended that the promise of obtaining interesting and valuable results from a study of the available material is sufficiently great to attract the ordinary scientific worker.

In conclusion, a remark by Gardner (1885, *c*) is still applicable:—"I am sorry so little information can be given about the plants; but where nothing definite is known, it would be no service to science to add further to the guesses."

LIST OF REFERENCES.

ARGYLL, DUKE OF.—"On Tertiary Leaf-beds in the Isle of Mull." Quart. Journ. Geol. Soc. London, vol. vii., 1851.

BAILY, WM. HELLIER.—(*a*) "Notice of Plant-remains from the Beds interstratified with the Basalt of the County of Antrim." Quart. Journ. Geol. Soc., vol. xxv., 1869.

(*b*) Palæontological Notes in Mem. Geol. Surv. Ireland, to Sheets 21, 28, and 29 (1876), 20 (1886), and 7 and 8 (1888).

(*c*) "Reports on the Tertiary (Miocene) Flora of the Basalt of the North of Ireland." Reps. Brit. Assoc., 1879, 1880, 1881, and 1883.

CHAMBERLAIN.—See Coulter and Chamberlain.

COULTER, J. M., and CHAMBERLAIN, J. C.—Chapter on Fossil Angiosperms in "Morphology of Angiosperms"; London and New York, 1904.

ETTINGSHAUSEN, C. B., and GARDNER, J. STARKIE.—"A Monograph of the British Eocene Flora," Palæontographical Soc., 1879-1882. London.

FORBES, E.—"A Note on the Vegetable Remains from Ardtun Head" [Mull]. Quart. Journ. Geol. Soc., vol. vii., 1851.

GARDNER, J. STARKIE.—(*a*) "The Age of the Basalts of the North-east Atlantic." Rep. Belfast Nat. Field Club, 1884.

(*b*) "On the Lower Eocene Plant-beds of the Basaltic Formation of Ulster." Quart. Journ. Geol. Soc., vol. xli., 1885.

(*c*) "Eocene Ferns from the Basalts of Ireland and Scotland." Linn. Soc. Journ. (Bot.), vol. xxi., 1885.

See also Ettingshausen and Gardner.

HOLDEN.—See Tate and Holden.

REID, C.—Article on "Palæobotany (Tertiary)" in Encycl. Brit., 11th ed., vol. xx. 1911.

SCOULER, JOHN.—"Observations on the Lignites and Silicified Woods of Lough Neagh." Journ. Geol. Soc. Dublin, vol. i., 1838.

SEWARD, A. C.—(*a*) "Notes on the Geological History of Monocotyledons." Annals of Bot., 1896.

(*b*) "The Origin of the Angiosperms." New Phytologist, 1903.

(*c*) "A Contribution to a Neglected Branch of Botany" (review). New Phytologist, 1908.

TATE, R., and HOLDEN, J. S.—"On the Iron-ores associated with the Basalts of the North-east of Ireland." Quart. Journ. Geol. Soc., vol. xxvi., 1870.

CHAPTER VII.

ANALYSES OF MATERIALS FROM THE INTERBASALTIC BEDS OF IRELAND.

Arranged by G. A. J. Cole and W. D. Haigh.

The following analyses have been collected from a number of sources, and we owe several to the kindness of correspondents such as Dr. H. M. Atkinson, Prof. G. Lunge, of Zurich, and Mr. A. McDonald. Where the name assigned to the sample is placed between inverted commas, it is that given in the source from which the analysis has been derived. Some materials styled " bauxites " may thus seem better described as " bauxitic clays," the " alum clays " of older writers. Some of the " iron-ores," again, may in time prove valuable on account of their percentage of available alumina, and should be compared with the laterite ores of India. The analyses have been arranged in the order in which their localities have been dealt with in the present memoir. This method brings together the materials found in any one district. A list, however, has been given of the different types of material, showing the analyses that refer to each.

The " loss on ignition " in these analyses mainly represents combined water. Where " insoluble residue " was stated in the analyses supplied to us, this has been entered under silica. The percentage of silica stated in some of the analyses may include detrital quartz; but this is not likely to be the case when the materials are derived from the decay of underlying basalt.

It is obviously important to distinguish detrital silica, as quartz or chalcedony, from that occurring in combination; but the fine state of division of the materials in a clay or a commercial bauxite may render this impossible, even by the use of a dense liquid for separation.

Types of Material Represented in the Analyses.

Bole, Ochre, and Lithomarge.—I., XXXII., XLII., LVI., LVIII., LXI., LXIV.

Bauxite and Bauxitic Clay.—III., XIII. to XVII., XIX. to XXVI., XXXIII. to XLI., LII., LIII., LVII., LXII., LXIII.

Iron Ores.—II., IV. to XIII., XVIII., XIX., XXVII. to XXXI., XLIII. to LI., LIV., LV., LIX., LX., LXII.

The following analyses are, we believe, now published for the first time :—

I., IX.-XIII., XX., XXVII., XXXIII.-XLII., LII., LVII., LVIII., LXI.

	Altered basalt passing into Bole. Giant's Causeway (p. 18) Geol. Surv., 1910. Anal. D. Jardin.	"Iron Ore." Dunluce District (p. 21). "Mineral Discoveries in Ireland." The Times, London, 13th May, 1907. Financial Supplement.	Bauxitic Clay ("Alumite.") Ballintoy (p 22). J. R. Geol. Soc. I., 8 (1889), 66. Anal. J. Pattinson.	"Pisolitic Iron Ore." Tully, S. of Glenarm. Q. J. G. S. 26 (1870), 159. Anal. J. Cameron.
	I.	II.	III.	IV.
Silica	35·42	10·70	13·15	4·00
Titanium dioxide	4·80	5·90	5·20	2·00
Alumina	25·68	18·50	52·37	35·50
Iron peroxide	10·56	45·84	1·29	45·50
Manganese protoxide	—	Trace	—	Trace
Magnesia	—	6·68	Trace	—
Lime	1·96	1·40	·48	·35
Potash and Soda	—	0·97	·06	—
Loss on Ignition	9·59	9·90	27·13	12·65
Water driven off at 110°	11·23	—	—	—
Sulphur trioxide	—	0·11	·35	—
Phosphorus peroxide	—	Trace	Nil	—
	99·24	100·00	100·03	100·00
Percentage of Iron	—	32·09	—	31·85

	Iron Ore. Glenarm (p. 29). Geol. Surv. Mem. 20 (1886), p. 31. Anal. C. Riley.		*Ibid.* Antrim Iron Ore Co.	
	No. 1 Ore*	No. 2 Ore*	Glebe Mine. No. 1 Ore. Anal. J. W. Montgomery, 1874.	Glebe Mine. No. 2 Ore. Anal. J. Clarkson, 1899.
	V.	VI.	VII.	VIII.
Silica	12·93	7·81	11·31	9·36
Titanium dioxide	6·45	5·44	·63	5·21
Alumina	16·92	36·66	24·87	32·37
Iron peroxide	57·43	35·13	46·67	39·86
Iron protoxide	Trace	Trace	—	Trace
Manganese protoxide	Nil	Nil	·03	Nil
Magnesia	·88	Trace	—	·14
Calcium Carbonate	Trace	1·74	·22 (Lime)	1·45
Combined Water	5·7	13·06	16·42	11·34
Sulphur trioxide	·17	Trace	·02 (Sulphur)	·03
Phosphorus pentoxide	Nil	Nil	·03	Nil
	100·48	99·84	100·20	99·76
Percentage of Iron	40·20	24·59	32·67	27·90

* The No. 1 ore is the upper bed. No. 2 is immediately below, and contains less iron and more alumina ; it is extensively worked for use as a flux (Mem. Sheet 20, p. 30).

PARTIAL ANALYSES OF MATERIALS FROM THE GLEBE MINE (GLORE TOWNLAND), GLENARM (p. 29). COMMUNICATED BY MR. A. McDONALD.

	Pisolitic Iron Ore	Pavement. 1st two ft.	Pavement. 2nd two ft.	Pavement. 3rd two ft.	Lithomarge (ferruginous bauxite.)
	IX.	X.	XI.	XII.	XIII.
Silica	12·83	13·92	10·61	8·91	5·05
Titanium dioxide	4·67	5·31	5·42	5·39	2·73
Alumina	26·31	29·89	30·13	34·01	39·37
Iron peroxide (calculated from Metallic Iron)	52·14	38·57	35·62	30·97	24·08
Percentage of Iron	36·50	27·00	24·94	21·68	16·86

BAUXITIC CLAYS WORKED BY THE EGLINTON CHEMICAL CO. PROBABLY FROM GLENARM (p. 29).
XIV. and XV. from Geol. Surv. Mem., Sheet 20 (1886), p. 28. XVI. and XVII. from Thorpe, Dict. Applied Chem. 1 (1890), 75.

	XIV.	XV. (see XVI.)	Anal. Pattinson. XVI. (see XV.).	Anal. Fresenius XVII.
Silica	11·04	24·50	27·50	15·88
Titanium dioxide	2·56	9·40	9·40	5·02
Alumina	57·32	45·42	42·42	48·83
Iron peroxide	·24	1·54	1·54	2·24
Magnesia	·36	Trace	Trace	·17
Lime	·61	·46	·46	·62
Potash and Soda	·17	·04	·04	·14
Organic matter	Trace	Trace	Trace	—
Combined water	27·16	18·53	18·53	26·35
Sulphur trioxide	·30	·08	·08	·51
Phosphorus pentoxide	Trace	Trace	None	CO_2·28
	99·76	99·97	99·97	100·04

NOTE.—Analyses XV. and XVI. are clearly the same, with differences of 3 per cent. in the amounts of silica and alumina. Since it is uncertain which is correct, both statements are here quoted.

	"Pisolitic Iron Ore." Kilwaughter, W. of Larne (p. 33). Q.J.G.S. 26 (1870), 159. Anal. J. Cameron.	Iron Ore. (Ferriferous bauxite). Ballylumford, Island Magee (p. 34). Geol. Surv. Mem. 21 (1876), p. 28. Communicated by Dr. Ritchie.	"Bauxite." Near Larne (p. 34). Communicated by Dr. H. M. Atkinson. Anal. W. Crossley.	"Bauxite Clay." Ballynure (p. 36), Harker, "Igneous Rocks of Skye," Geol. Surv. 1904), p. 48. Anal. Antrim Iron Ore Co.
	XVIII.	XIX.	XX.	XXI.
Silica	36·44	8·92	20·84 (Insol.)	3·26
Titanium dioxide		4·52	6·10	4·53
Alumina		43·88	38·37	46·68
Iron peroxide	45·00	40·87	12·98	2·74
Manganese protoxide	Trace	—	—	—
Magnesia	2·44	·53	—	—
Lime	·56	Trace	—	—
Combined water	18·00	Not determined	22·43	25·13
Water driven off at 110°	—	—	—	17·00
	102·44	—	100·72	99·34
Percentage of Iron	31·50	—	—	—

"Bauxite." Irish Hill, east of Ballyclare (p. 36).

	Irish Hill Co. W. Peile, Trans. Manch. Geol. Soc., 22, 522. Also in Thorpe, Dict. Applied Chemistry, 1, 75. Anal. J. Pattinson.			G. Lunge, Handbuch der Sodaindustrie, 2nd ed., 3, 193 (English edition, 3, 212). Anal. Spence.	
	1st Quality. XXII.	2nd Quality. XXIII.	3rd Quality. XXIV.	XXV.	XXVI.
Silica	8·67	12·00	10·40	7·95	15·05
Titanium dioxide	5·80	6·20	4·20	—	—
Alumina	53·83	52·00	46·13	48·12	43·44
Iron peroxide	1·57	4·57	15·14	2·36	2·11
Magnesia	·13	·20	·26	—	—
Lime	·62	·79	·18	—	—
Potash	·01	·02	·04	—	—
Soda	—	·06	·24	—	—
Combined Water	29·27	24·00	23·39	40·33	35·70
Sulphur trioxide	·07	·07	·10	—	—
Phosphorus pentoxide	Trace	Trace	Trace	—	—
	99·97	99·91	100·08	98·76	96·30
Moisture lost on drying at 100°	7·50	·90	·85	—	—

	Iron Ore. Glenravel Mines (p. 43). Communicated by Mr. J. Fisher.	"Pisolitic Iron Ore." Glenravel Mines (p. 43). (S. slope of Slievenanee). Q. J. G. S., 26 (1870), 159.	
	XXVII.	Anal. J. Cameron. XXVIII.	Anal. Hodges. XXIX.*
Silica	8·15	9·00	8·50
Titanium dioxide	8·50	—	Trace
Alumina	7·76	—	4·20
Iron peroxide	68·01	71·00	81·50
Iron protoxide	·54	18·00	—
Iron disulphide	·05	—	—
Manganese protoxide	·23	Trace	2·57
Magnesia	1·10	—	—
Lime	2·53	—	·93
Carbon dioxide	2·16	—	—
Combined Water	·92	—	1·96
Sulphur trioxide	·03	—	—
Phosphorus pentoxide	·02	—	—
	100·00	98·00	99·66
Percentage of Iron	43·26	63·70	65·20

Materials from the Crommelin Mines (p.46).

Peile, Trans. Manchester Geol. Soc., 22, (1892-4), 522.

	"Pisolitic Ore." XXX.	"Pavement Ore." XXXI.	"Lithomarge." XXXII.
Silica	10·40	3·78	49·75
Alumina	2·80	41·13	29·88
Iron peroxide	59·40	33·34	6·61
Combined Water	8·40	15·55	5·48
Other constituents	19·00	6·20	8·28
	100·00	100·00	100·00
Percentage of Iron	41·58	23·34	4·62

* This seems to be the same analysis as that, adjusted to a total of 100·00, given by Hodges to the Belfast Nat. Hist. Soc. (See Mem. to Sheets 21, 28, and 29 (1876), p. 49).

"BAUXITE." TUFTARNEY (p. 50).

	"Bauxite." Anal. H. M. Atkinson. (Communicated by him.) XXXIII.	XXXIV.	Grey Material selected (see p. 51). Geol. Surv., 1911. Anal. W. D. Haigh. XXXV.	White Material selected (see p. 51). Geol. Surv., 1910. Anal. D. Jardin. XXXVI.
Silica	30·01	24·56	27·93	42·54
Titanium dioxide	6·10	11·06	5·46	3·75
Alumina	37·29	38·56	41·32	34·56
Iron peroxide	3·13	5·06	2·03	·60
Magnesia	—	—	·25	—
Lime	—	—	·60	Trace
Combined Water	20·76	18·73	17·72	13·78
Water driven off at 110°	—	—	4·64	5·04
	97·29	97·99	99·95	100·27
Lime and alkali metals (by diff.).	2·71	2·01	—	—

"BAUXITE," TUFTARNEY (p. 50).
Communicated by Dr. H. M. Atkinson.
Anal. W. Crossley.

	Lower Bed, light coloured. XXXVII.	Lower Bed, dark coloured. XXXVIII.	Average of "a large number of samples." XXXIX.	Average of seven other analyses supplied. XL.
Silica (insol.)	18·54	22·94	26·92	27·35
Titanium dioxide	1·61	1·61	7·94	7·06
Alumina	50·50	44·79	36·90	37·66
Iron peroxide	3·34	6·30	4·15	4·29
Combined Water	26·03	24·37	20·23	21·32
	100·02	100·01	96·14*	97·68*

	"Bauxite." Evishacrow (p. 52). Communicated by Dr. H. M. Atkinson. Anal. W. Crossley. XLI.	Lithomarge. Fisher's Mine, Parkmore (p. 53). Geol. Surv., 1910. Anal. D. Jardin. XLII.	"Pisolitic Iron Ore." "Red Bay" (possibly Glenariff). Q. J. G. S., 26 (1870), 159. Anal. Jas. Apjohn. XLIII.	Anal. J. Cameron. XLIV.
Silica	15·81 (insol.)	31·70	10·40	20·65
Titanium dioxide	4·69	4·68	2·80	Trace
Alumina	39·58	25·99		—
Iron peroxide	19·34	19·89	59·40	77·22
Magnesia	—	—	—	—
Lime	—	·67	—	—
Combined Water	19·31	12·70	8·40	2·13
Water driven off at 110°	—	4·18	—	—
	98·73†	99·81	—	100·00
Percentage of Iron.	—	—	41·58	54·05

* Dr. Atkinson informs us that the deficiency in analyses XXXIX., XL., XLI., and LII. is due to the fact that such constituents as lime and alkalies were not determined. These do not appear to have been present in the Lower Bed of Tuftarney.

† See foregoing footnote,

IRON ORES, GLENARIFF MINES (p. 59).

Ph. Argall, Journ. R. Geol. Soc. I., **6** (1886), 104.

	"Pisolitic Red Ore." Anal. A.B.Cowen.	"Pisolitic Black Ore," magnetic," Public Analyst, Wolverhampton.	"Pisolitic Black Ore, magnetic."	"Alumi-nous Ore."	"Alumi-nous Ore."	"Pave-ment."	"Pave-ment."
			Anal. E. W. T. Jones.				
	XLV.	XLVI.	XLVII.	XLVIII.	XLIX.	L.	LI.
Silica	8·40	5·05	10·93	15·40	12·20	15·90	38·70
Titanium dioxide	—	8·89	10·80	Nil	Nil	Trace	6·60
Alumina	10·19	4·25	1·75	34·70	36·50	38·14	4·40
Iron peroxide	62·43	71·64	67·54	28·83	35·93	28·44	27·96
Iron protoxide	4·75	1·88	Trace	2·5	Trace	Trace	Trace
Manganese protoxide	·28	·27	·17	Trace	·11	Trace	·18
Magnesia	·59	·61	Trace	1·51	1·41	1·10	Trace
Lime	2·80	·81	Nil	Nil	·53	Nil	Trace
Combined Water	1·88	—	2·26	9·00	10·23	12·25	11·36
Water driven off at 110°	8·48	6·40	5·61	7·80	2·76	4·60	14·78
Sulphur	Nil	Nil	Nil	Trace	Nil	Trace	Nil
Carbon dioxide	Trace	Trace	Nil	Nil	Nil	Trace	Nil
Phosphorus pentoxide	Nil	·20	Nil	·04	Nil	·08	·07
Loss	·20	—	·94	·22	·33	—	·95
	100·00	100·00	100·00	100·00	100·00	100·00	100·00

	"Bauxite." Cargan (p. 60). Communicated by Dr.H.M.Atkinson, Anal. W. Crossley. Average of a "large number of samples."	"Bauxite." Cargan Hill (p. 60). G. Lunge. Handbuch der Sodaindustrie, 2nd Ed., 3 (1896), 193. 2nd English Ed., 3, 212. Anal. Hodges	Iron Ore. "Broughshane. Geol. Surv. Mem. 20 (1866), p. 30. Anal. E. G. Tosh.	"Pisolitic Iron Ore." Knockboy (=Correen) (p. 69). 16th Ann. Rep. U. S. Geol. Surv. (1895), pt. 3, p. 81.
	LII.	LIII.	LIV.	LV.
Silica	14·75	6·01	7·08	6·30
Titanium dioxide	5·12	2·32	5·28	4·60
Alumina	42·72	61·89	12·54	12·75
Iron peroxide	19·74	1·96	65·42	63·70
Manganese protoxide	—	—	Trace	—
Magnesia	—	—	·08	·05
Lime	—	—	·20	·10
Combined Water	16·37	27·82	8·82	12·70
Water driven off at 110°	—	—	—	—
Sulphur	—	—	Trace	·02
Phosphorus pentoxide	—	—	·02	·06
	98·70*	100·00	99·44	100·28
Percentage of Iron	—	—	45·99	44·60

* See footnote to XL.

	"Ochre of the Basalt." Drumrankin, near Ballymena. N. of Tully Hill (p. 85), probably in L. Basalt. Journ. G. S. Dublin, 2, (1841), 140. Anal. Jas. Apjohn. LVI.	Ferruginous Bauxite. Lyles Hill (p. 89). Geol. Surv., 1910. Anal. D. Jardin. LVII.	Lithomarge. LVIII.
Silica	56·40	9·36	41·14
Titanium dioxide	—	7·20	4·80
Alumina	3·46	48·57	27·96
Iron peroxide	24·14	11·63	1·92
Magnesia	—	—	·77
Lime	·90	—	1·66
Potash and Soda	15·10	21·75	13·94
Combined Water			
Water driven off at 110°	—	1·56	8·26
	100·00	100·07	100·45

	"Brown Hæmatite," Antrim. Ballypalady (acc. to Tate and Holden, Q. J. G. S. 26, 162. Percy, "Metallurgy of Iron" (1864), p. 207. Anal. C. Tookey. LIX.	Anal. E. Riley. LX.	Lithomarge. Shore of L. Neagh (p. 100). Geol. Surv., 1910. Anal. D. Jardin. LXI.	"Bauxite." "Irish." Thorpe, Dict. App. Chem. 1 (1890), 72. Anal. Siemens. LXII.
Silica	9·75	9·87	39·17	3·50
Titanium dioxide	—	3·51	3·40	2·00
Alumina	27·95	34·57	28·41	35·00
Iron peroxide	35·91	27·93	2·67	38·00
Iron protoxide	6·57	5·08	—	—
Manganese protoxide	·05	Trace	—	—
Magnesia	·20	·62	·02	—
Lime	·60	·91	·70	—
Potash	·49	—	—	—
Combined Water	18·60	19·36	12·56	21·50
Water driven off at 110°			13·32	—
Phosphorus pentoxide	None	Trace	—	—
	100·12	101·85	100·25	100·00

	"Bauxite Clay." Antrim. Harker, "Igneous Rocks of Skye," Geol. Surv. (1904), p. 48. Anal. Antrim Iron Ore Co. LXIII.	"Ferruginous Clay," brick-red ("Plinthite"). Antrim. *Ibid.* from Thomson, "Outlines of Mineralogy" (1836). Anal. T. Thomson. LXIV.
Silica	14·50	30·88
Alumina	47·60	20·76
Iron peroxide	2·30	26·16
Lime	—	2·60
Combined Water	18·00	19·60
Water driven off at 110°	17·00	
	99·40	100·00

A few analyses of Bauxites are subjoined to show the general type of material utilised in the aluminium industry. Nos. LXIX. to LXXI. are quoted from R. L. Packard, "Mineral Resources of the United States for 1891," U. S. Geol. Surv. (1893), pp. 152-4. A series of 115 analyses will be found in Hintze, "Handbuch der Mineralogie," Bd. i. (1910), p. 1963.

	Revest, Toulon. Ann. Chim. Phys., 61 (1861), 321. Anal. H. S. Deville. LXV.	Allauch, Var. *Ibid.* LXVI.	Wochein, Carniola. Jahrb. Geol. Reichsanst., 16 (1865), 11. Anal. Lill: LXVII.	Vogelsberg. Zeitschr. für Kryst., 23,296. Anal. Liebrich. LXVIII.
Silica	2·8	4·8	6·29	1·10
Titanium dioxide	3·1	3·2	—	3·20
Alumina	57·6	55·4	64·24	50·92
Iron peroxide	25·3	24·8	2·40	15·70
Magnesia	—	—	·38	·16
Lime	—	—	·85	·80
Calcium carbonate	·4	·2	—	—
Combined Water	10·8	11·6	25·74	27·75
Water driven off at 110°	—	—	—	·85
Sulphur trioxide	—	—	·20	—
Phosphorus pentoxide	—	—	·46	—
	100·00	100·00	100·56	100·48

	Jacksonville, Calhoun County, Alabama. (Ref. see above.) Anal. W. F. Hillebrand. LXIX.	LXX.	Floyd Co., Georgia. Ref. see above.) Anal. Nichols. LXXI.	Armington Bank, Walker Co., Georgia. Ann. Rep. U. S. Geol. Surv. 1895. Part III. p. 587 LXXII.
Silica	10·25	21·08	2·80	2·66
Titanium dioxide	2·53	2·52	3·52	·96
Alumina	41·00	48·92	52·21	75·03
Iron peroxide	25·25	2·14	13·50	1·84
Combined Water	20·43	23·41	27·72	16·00
Water driven off at 110°	·65	·45	—	3·00
Phosphorus pentoxide	Trace	Trace	—	—
	100·11	98·62	99·75	99·49

	Nodular crust on Charnockite (practically Gibbsite). Kodaikanal, Palni Hills, India. Geol. Mag., 1903, p. 154. Anal. H. and F. J. Warth. LXXIII.	Ferruginous variety. Pulsa, India. *Ibid.* p. 155. Anal. H. and F. J. Warth. LXXIV.	"Brown pisolitic laterite." Katni, Jubbulpore *Ibid.* p. 179. Anal. T. R. Blyth. LXXV.
Silica	2·78	3·56	1·26
Titanium dioxide	·04	·13	7·51
Alumina	62·80	32·65	52·67
Iron peroxide	·44	47·27	7·04
Magnesia	·03	Trace	Trace
Lime	·20	·52	1·75
Combined Water	33·74	15·87	29·83
	100·03	100·00	100·06

APPENDIX I.

ON THE QUESTION OF THE WESTERLY EXTENSION OF THE UPPER BASALTS IN IRELAND.

By J. R. Kilroe.

The generally received view that the basaltic lavas west of the Bann River belong to the lower series of outpourings, as shown on the published one-inch maps, seems to me to involve a serious anomaly; and this was not entirely overlooked by the original surveyors. Mr. Egan, who estimated the thickness of the series at 850 feet in the vicinity of Benevenagh, recognized the possibility* that some of the lavas belong to the upper series. The succession of sheets, practically horizontal, which forms the series rises upward to about 930 feet in the ground immediately south of Downhill, and to more than 1,000 feet a little further to the south-west, while the base of the series descends below Datum level at Downhill; so that the thickness in the vicinity of this place is at least 950 feet.

A traverse of the country eastward from Carntogher to Upperlands—a railway station on the Derry Central Line, south of Garvagh—shows a corresponding if not a greater aggregate thickness of successive layers, presenting a series of low crags towards the west, while the ground falls gently towards the east; and no break or dislocation has been detected in the succession; nor has any dividing zone been observed, separating the sheets into an upper and a lower series.

The case therefore stands thus: On the west of the Bann occurs a great concrete series originally upwards of 950 feet in thickness; while to the east of the river the lower basalt nowhere attains any such dimensions. The thickness of this member, between the original chalk floor and the main interbasaltic zone of Antrim, can, with a fair degree of precision, be estimated in many places; and only at one point, to the writer's knowledge, does the Lower Basalt exceed half of the 950 feet.† Particulars render the anomaly still more striking.

Judging by the regular decline in thickness of the known Lower Basalt, it would be little more than about 150 feet in the vicinity of Coleraine (see thickness at Ballycraig in footnote);

* Explanation of Sheet 12, p. 24.

† The estimated thicknesses of Lower Basalt at several points are as follows, going respectively southward and north-westward:—

At Glenariff	about	550 ft.	At Trostan	about	450 feet
,, Garron Tower	,,	400 ,,	,, Slieveanona	,,	450 ,,
,, Drumnasole	,,	400 ,,	,, Knocklayd	,,	300 ,,
,, Carnlough	,,	350 ,,	,, Portmore (E. of Ballintoy)		300 ,,
,, Cullinane	,,	250 ,,			
,, Glenarm	,,		,, Boneyclassagh		250 ,,
,, N.E. of Carrickfergus		150 ,,	,, Ballycraig (1½ m. S.E. of Portrush).		200 ,,

this attenuated series has to represent more than 950 feet six miles off south-westward across the Bann. Prior to denudation, the thicknesses would have stood much nearer each other, while the character of the basalts is entirely against the assumption of great local thickenings of the series. The sheets from Benevenagh eastward present remarkable uniformity in thickness, and indicate regularity of accumulation. Consisting largely of amygdaloidal basalt, often assuming the "pipe" form,* the sheets must have been emitted in a very fluid state and spread themselves out widely in nearly horizontal sheets.†

The area has sagged considerably in the vicinity of the Bann, or been tilted correspondingly at Knocklayd and Benevenagh; and, if the basalt floor were restored to its probable original level between those hills, the anomaly of so great a thickness of Lower Basalt west of the Bann would be still more emphasised.

The conclusion that seems to me obvious is that the great series west of the Bann may be to a large extent Upper Basalt, with representatives of the usual iron ore zone at Keady Hill, and possibly in the red clay between the chalk and basalt at Downhill. A fault running north-westward along the low ground of the Bann valley, concealed by drifts, etc., with downthrow to the west, parallel to a known fault near Portglenone with similar downthrow, would bring the two basaltic series into juxtaposition; and the craggy slope east of the Bann near Portglenone, the prevailing easterly dip of the basalt sheets near Upperlands, and the interesting geographical conditions of Lough Neagh drainage, which cannot be entered on here, are facts which are all confirmatory of dislocation in the area after the Upper Basalt had been laid down.

APPENDIX II.

NOTE ON THE PROBLEM OF THE LOUGH NEAGH CLAYS.

By G. A. J. Cole.

As will be seen by Prof. Seymour's remarks on p. 100, the work of revision in the county of Antrim has, on the whole, strengthened the opinion that the great mass of clays south of Lough Neagh, in places 260 feet thick, and containing lignite and plant-remains included in ironstone nodules, is not to be regarded as part of the interbasaltic series. Mr. Wm. Swanston has estimated that the Lough Neagh clays cover 180 square miles, and it may seem remarkable that their geological age still remains a

* Fully discussed by Du Toit, Geol. Mag., 1907, p. 13.

† Dana gives an inclination of "one degree and less" for basalt flows in the Hawaiian Islands ("Characteristics of Volcanoes," 1890, p. 12).

problem. R. Griffith* classed them as Tertiary, and compared them with the "Miocene" clay of Bovey Tracy in Devonshire, now known to be of Oligocene age. Such observers, moreover, as Mr. J. Starkie Gardner and Mr. Swanston have felt that the plant-remains found in them resemble those from the interbasaltic beds of Ballypalady and from points on the lake shores, and yet cannot be regarded as derived materials washed into the clays. It seems quite possible that future investigation will reveal two series of plant-remains, those proper to the epoch of deposition of the clays, and those derived from the basaltic series on the shores of the depression. The absence of dykes penetrating the clays is, as Prof. Seymour points out, an important argument in favour of assigning to them a post-basaltic age. Yet whether that age is Oligocene, Miocene, or Pliocene, remains unknown. Mr. Swanston showed, as far back as 1879, that the molluscan shells supposed by Hardman† to come from the Lough Neagh clays were really associated with the post-Pliocene boulder-clays, and thus had no bearing on the earlier stratigraphy of the district. Mr. Clement Reid repeated this observation at a later date, when investigating the Pliocene deposits of the British Isles.‡

The well-known silicified wood of the Lough Neagh area has been claimed, on the one hand, as original to the Lough Neagh clays, and, on the other hand, as derived from the interbasaltic zone. The older tradition that modern timber becomes silicified in the waters of the lake was combated by J. Scouler in 1837, and has been long ago abandoned.§

The exceptional lowness of the water of Lough Neagh at the close of the dry summer of 1911 suggested to Mr. Wm. Swanston that a joint visit to the typical locality at Sandy Bay might produce new results. Mr. R. Clark and myself, in consequence, explored the shore opposite Ram's Island under his guidance. This is the district from which so much silicified or partly silicified wood has been obtained, and where it is piled up in rockeries in cottage-gardens. The celebrated mass weighing more than 700 lbs., as recorded by Richard Barton‖ in 1751, came from the gravel north of the River Camlin (Crumlin); but everyone who has dug considerable pits near Sandy Bay, from Barton's time down to the present day, agrees that silicified

* Second Report of the Railway Commissioners, Ireland, 1838, with Atlas and Griffith's first geological map. The beds are regarded as Miocene in the Geol. Survey Mem. to Sheet 47 (1873), p. 14.

† Geol. Mag., 1876, p. 556; and Mem. to Sheet 35 (1877), p. 89. The shells, at first described as Unio, were shown by Gwyn Jeffreys and Swanston to be the marine *Mytilus edulis* (W. Swanston, "On Supposed Fossiliferous Pliocene Clays overlying Basalt, near the Shore of Lough Neagh," Geol. Mag., 1879, p. 69).

‡ Sir A. Geikie, "Anc. Volcanoes of Great Britain" (1897), vol. ii., pp. 449-452.

§ For an analysis of the silicified wood, see J. F. Hodges, "On the Petrified Wood of Lough Neagh," Rep. Brit. Assoc., 1874, Trans. of Sections, p. 60.

‖ "Lectures in Natural Philosophy designed to be a foundation, for reasoning pertinently, upon the Petrifactions, Gems, Crystals, and sanative Quality of Lough Neagh in Ireland," Dublin (1751), p. 100.

timber occurs in the local clays, and not merely lying on their surface. As we shall see later, however, it is even now uncertain whether the silicified wood has been raised from below the boulder-clay.

Mr. Swanston and myself found the earlier pits on the site of Barton's "Ahaness" full of water, but with the help of a neighbouring farmer, Mr. Lowe, we had two fresh ones dug, to a depth of some five feet and three feet respectively, on the newly-exposed stretch of shore. Thin boulder-clay is at first passed through, and the stiff grey or white Lough Neagh clays are then entered. In the second and shallower pit, this clay was so churned up and mingled with the boulder-clay, probably by ice-movement during the glacial epoch, that it afforded no good evidence. The first pit, however, showed masses of black and brown lignite lying in very irregular positions, like material washed down by floods, rather than interbedded in quiet waters, with the clays. In this single visit we obtained no silicified specimen from the Lough Neagh clay; but Mr. Lowe has seen pieces taken from some level or other of the older pits.

On the shore and in the boulder-clay are the nodules of iron carbonate, from which leaves and stems have been collected in a far more perfect condition than those in the confused masses of lignite.* It is possible that these are the stones described by W. Buckland from Lough Neagh in 1845.† They are composed or almost pure or more earthy siderite, the pure varieties being pale grey. They weather on the surface to brown limonite. Mr. W. D. Haigh has made the following analysis for the Geological Survey from one of the purest masses, which measured about 30 cm. in diameter :—

PALE CONCRETION FROM SANDY BAY, LOUGH NEAGH.

Ferrous oxide, ...	57·10
Ferric oxide, ...	0·24
Alumina, ...	1·05
Manganese protoxide, ..	0·67
Lime, ...	0·70
Magnesia, ...	1·01
Carbon dioxide, ...	36·55
Insoluble residue and Silica	1·92
Water lost at 110° C., ..	0·85
	100·09

The insoluble residue amounted to only 1·6 per cent., and consists of clay with only a few quartz-grains. A more earthy and browner concretion yielded 11·75 per cent. of a similar material.

* See J. S. Gardner, "On the Lower Eocene Plant-Beds of the Basaltic Formation of Ulster," Quart. Journ. Geol. Soc. London, vol. xli. (1885), p. 91.

† "On the occurrence of Nodules (called Petrified Potatoes) found on the Shores of Lough Neagh in Ireland," *ibid.*, vol. ii. (1845), p. 103.

Mr. R. Clark, who spent an additional day along the lake shore near Glenavy, states that the ironstone nodules seem to be almost entirely confined to the spot opposite Ram's Island, the ancient Ahaness. During walks two miles on either side, they were found to die out completely. In one of the nodules, Mr. Clark found a cast of a gastropod shell among the leaves. Mr. R. Bullen Newton, of the British Museum (Natural History), has kindly examined this specimen, and regards it as probably the basal whorl of a Viviparus (Paludina). He draws attention to a somewhat similar specimen from the Lower Eocene (Woolwich Beds) of Dulwich, south-east of London, which is now in the British Museum, and which contains dicotyledonous leaves, together with remains of *Viviparus lentus*.

The shell from Sandy Bay is of interest as being, so far as I know, the only trace of a mollusc recorded from the basaltic series of Ireland and the Inner Hebrides. The only other animal remains are the elytra of beetles from Ballypalady,* and the scanty fish-bones found by Dr. Grainger in a boulder of marl (" resembling that of some of the deposits at Ballypalady "), in the drift of Cullybackey near Ballymena.†

Mr. J. Starkie Gardner ‡ describes the plants from the ironstone nodules as " most diversified, though usually small-leaved dicotyledons, which at first sight seem of very modern aspect. On closer examination, however, many are found to be characteristic of the English Middle Eocene, and others of the Lower Eocene. Others are common to Ballypalady, to Mull, and to Greenland. This mixture of types, so separated elsewhere, would be difficult of explanation, did the thickness of the deposit not warrant the belief that it may have been continuously forming throughout more than one period of the Eocene. . . . . The flora, however, is by far the most important link yet discovered between the Eocenes of England and those of high northern latitudes."

It will be seen that, in the foregoing passage, the nodules are regarded as being derived from the Lough Neagh Clays, and as having been formed in that deposit. This, however, is by no means certain. The very small residue of insoluble matter in one of the samples above referred to seems hardly compatible with concretion in the clay. The nodules can be dug out of the boulder-clay, from which, no doubt, they have been left as a residue on the shore. John Scouler,§ in his comprehensive paper, distinguishes an " alluvium," now recognised as boulder-clay, from the main clay below, and says that the nodules are " common in the alluvium." E. T. Hardman* remarks that it is

* Figured by W. H. Baily, Quart. Journ. Geol. Soc. London, vol. xxv. (1869), Plate XIV.

† Baily, " Fourth Report on Tertiary Flora of Ireland," Rep. Brit. Assoc. 1883, p. 210.

‡ *Op. cit.*, p. 91.

§ " Observations on the Lignites and Silicified Woods of Lough Neagh," Journ. Geol. Soc. Dublin, vol. i. (1837), p. 236.

difficult to say if the nodules at Sandy Bay come from the clay; but he records "clay-ironstones" in the potter's clay (Lough Neagh clays) of Creenagh, at the south-west end of the lake, and "hard siliceous clay-ironstone nodules" in the similar clay at Drumenagh. Wm. Swanston† in 1879 held, with Gardner, that the nodules at Sandy Bay came from the white clay, and mentions silicified wood as occurring in the nodules. F. W. Egan‡ records clay-ironstone nodules and silicified wood as occurring together on the west shore of the lake about one and a quarter miles north of the Ballinderry River.

The wood and the leaves so abundantly included in the ironstone nodules, and the composition of the nodules themselves, serve to connect them with the interbasaltic epoch. If, as seems likely, the Lough Neagh Clays are later than that epoch, the nodules found in them at certain places must be derived from the breaking up of the materials of some interbasaltic zone. G. Macloskie,§ who gave considerable attention to the microscopic structure of the silicified wood, refers it, following Kraus, to Cupressoxylon. Gardner states that all the wood from the Lough Neagh beds examined by him is Cupressineous, which, on Prof. Seymour's supposition (p. 100 of this Memoir), would not be surprising, the whole of the material being derivative,

Scouler‖ regards the silicified wood at Sandy Bay as local in origin, and yet as connected in some way with the basalts. G. Macloskie¶ recognises the similarity of the silicified wood to that found elsewhere in Antrim in the interbasaltic zone, but believes that it occurs at Sandy Bay only in the boulder-clay, and was first washed by Cainozoic rivers out of its proper horizon, and then transported to the Lough Neagh shores in glacial times. He quotes the important discovery by Wm. Gray** of a specimen of partly silicified lignite from between basaltic beds at Lawrencetown near Banbridge. Silicified wood, as Starkie Gardner shows, has been found on the surface from Dungannon to Glenavy, and thence northward to Coleraine, and was no doubt in all cases originally included in some interbasaltic zone. Gardner,†† however, believes that it is included in the Lough Neagh Clays, and not only in the overlying boulder-clay, and that it can be used in assigning an Eocene age to these important strata.

In spite of differences of view as to the age of the Lough Neagh Clays, we may then agree that the ironstones and the wood that

* "On the Age and Formation of the Lough Neagh Clays," Journ. Roy. Geol. Soc. I., vol. iv. (1875), pp. 174 (footnote), 179, 180. Also Mem. to Sheet 35 (1877), p. 72, etc.

† *Op. cit.*, Geol. Mag., 1879, p. 65.

‡ Mem. Geol. Surv. Ireland to Sheet 27 (1881), p. 34.

§ "On the Silicified Wood of Lough Neagh," Journ. R. Geol. Soc. I., vol. iii. (1873), p. 163, and Proc. Belfast Nat. Hist. and Phil. Soc., 1873, p. 51.

‖ *Op. cit.*, p. 239.

¶ *Op. cit.*, pp. 173 and 174.

** W. Gray, "Lignites of Antrim and their relation to true Coal," Proc. Belfast Nat. Field Club, 1873, p. 39.

†† *Op. cit.*, p. 90.

is now silicified once lay between sheets of basalt,* and accumulated on a land surface of early Cainozoic times. After what has been said about weathering under tropical conditions, we may compare the concretions of iron carbonate with the masses of calcium carbonate (kankar) that develop side by side with laterite in India (see p. 9).

H. B. Guppy † has interestingly described the association of silicified corals, flints, limonite, and concretions of iron carbonate, on the surface of the Kalikoso plains in Vanua Levu, Fiji Islands. These plains have been elevated in recent geological times above the sea, and their lagoons and freshwater swamps have now largely disappeared. Extensive silicification of the coral went on, as Dr. Guppy believes,‡ during the process of drying, and the iron carbonate was formed at the same time in the swamps. The " ironstone gravel," occurring in great quantity on the surface of the basaltic table-lands, seems to be the same thing as the pisolitic iron ore of Antrim. It " seems to have been formed during the disintegration of the rock on the moist surface of these densely-wooded plateaux; the process was not accomplished in ponds or swamps, but was carried out on ordinary damp ground " (compare the present Memoir, p. 10). Only one specimen of a silicified plant, the rhizome of a fern, came into Dr. Guppy's hands, and this was found in the centre of the island; but it is clear that in the Fijis we have limonite and concretionary iron carbonate produced, side by side with the silicification of organic remains. Guppy believes that the silica became substituted for the aragonite of the corals in the epoch between emergence above the sea and the complete drying of the calcareous muds of the lagoons. Since he does not find similar silicification in the neighbourhood of the hot volcanic springs, he regards the silica as derived from the sea water. In Antrim, however, the rhyolitic eruptions of the interbasaltic epoch may well have supplied the silica that altered the plant stems in certain places, while the iron carbonate was contemporaneously formed in swamps and the pisolitic ore upon the land-surface.

This view strongly favours the conclusion that the concretions and the silicified wood were derived simultaneously from some denuded area of the main interbasaltic zone. White clay with lignite actually occurs in this zone near Pharis (p. 88). The cutting up of the Upper Basalt into detached outliers north of Lough Neagh implies a great destruction of the iron ore and associated plant-beds. The pavement and lithomarge of so large an area may well, as Prof. Seymour suggests, have supplied the material of the Lough Neagh Clays, which we may continue to regard as of younger age than the interbasaltic epoch with which this Memoir is concerned.

* This was also W. H. Baily's opinion, as stated in his reports to the British Association, 1879-1883, where he describes several plants from the ironstone nodules of Sandy Bay.

† " Observations of a Naturalist in the Pacific," vol. i. (1903), pp. 351-360.

‡ *Op. cit.*, p. 359.

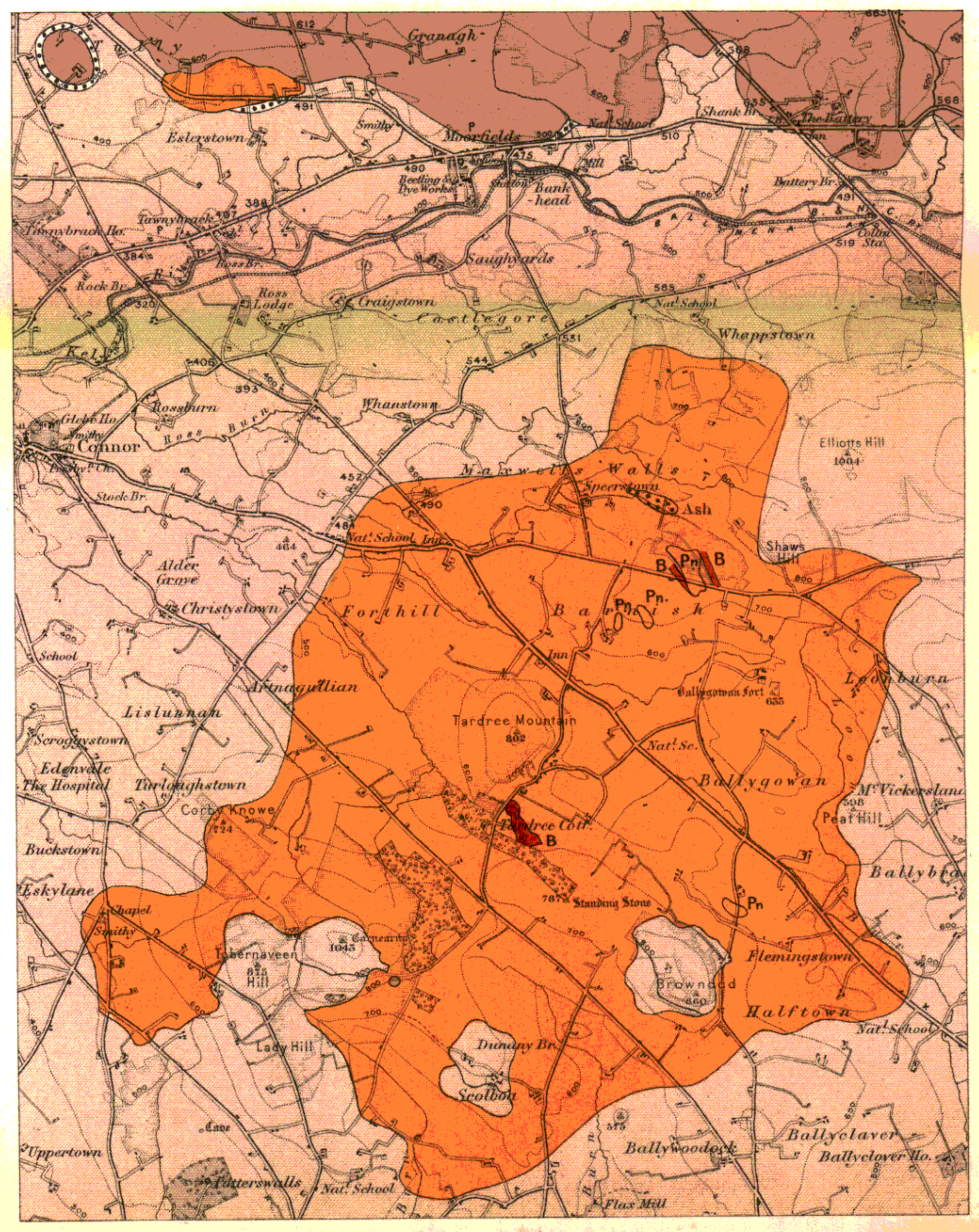
INDEX.

Wt. 2708.—S. 39. 600. 8/12. B. & N., Ltd.

GEOLOGICAL SURVEY OF IRELAND.

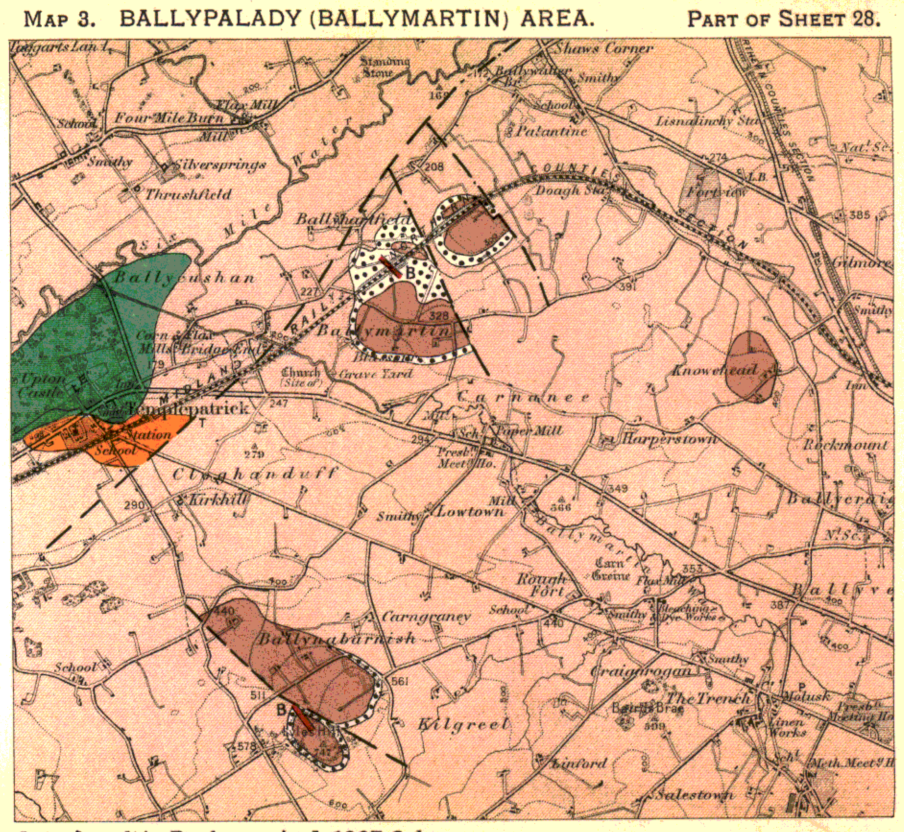
INTERBASALTIC BEDS OF NORTHERN IRELAND.

Map 2. TARDREE AREA. Parts of Sheets 20 and 28.



Interbasaltic Rocks revised 1907-8 by H. J. Seymour, B.A., F.G.S.

Map 3. BALLYPALADY (BALLYMARTIN) AREA. Part of Sheet 28.



Interbasaltic Rocks revised 1907-8 by H. J. Seymour, B.A., F.G.S.

INDEX.

Upper Basaltic Series.

Interbasaltic Beds (Bauxite, Pisolitic iron ore, Lithomarge, Volcanic ash, Lignite, &c.), where regarded as important.

Rhyolitic Series.
Pn Glassy types.

Lower Basaltic Series.

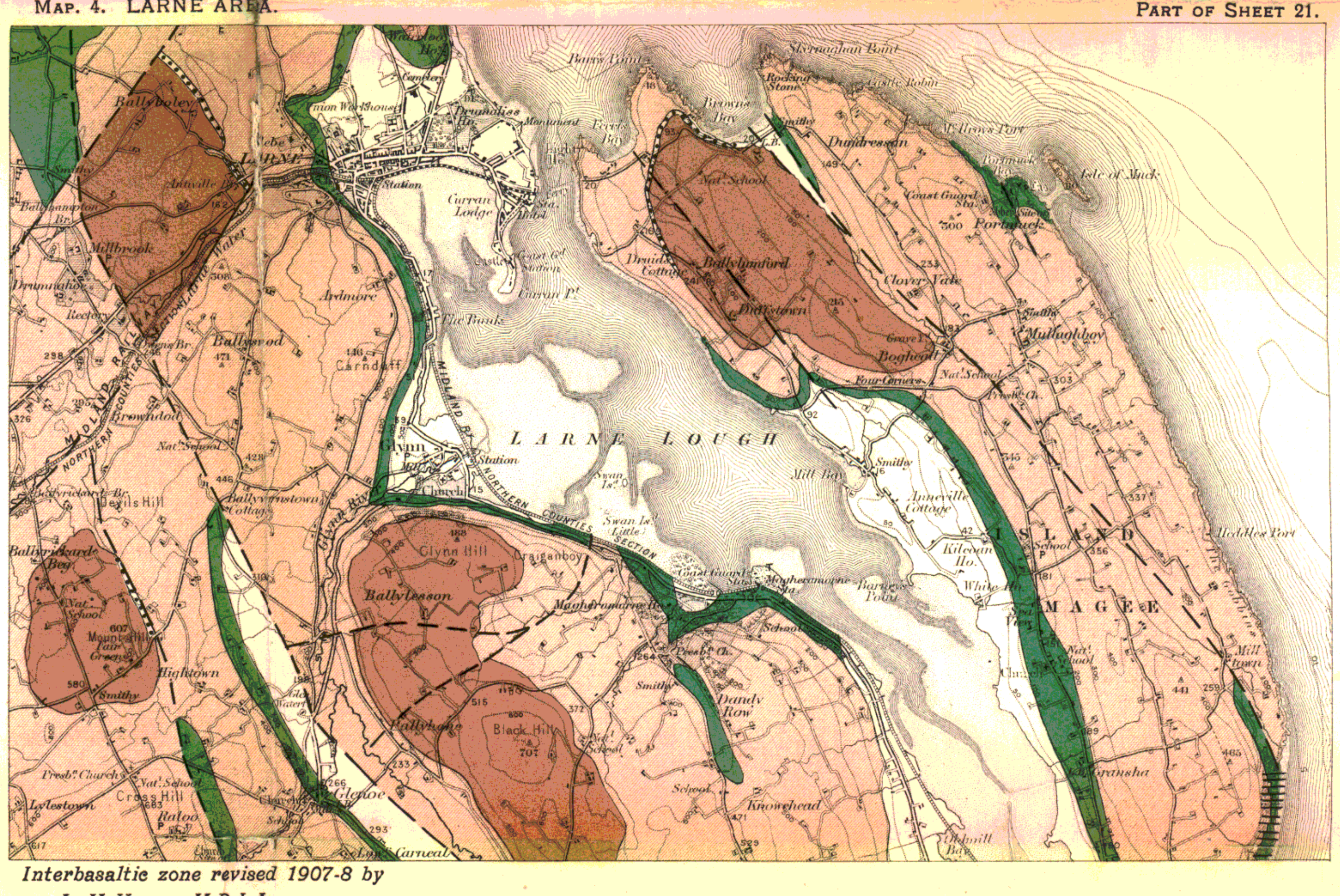
Intrusive Basalt & Dolerite.

Cretaceous.

Pre-Cretaceous Rocks.

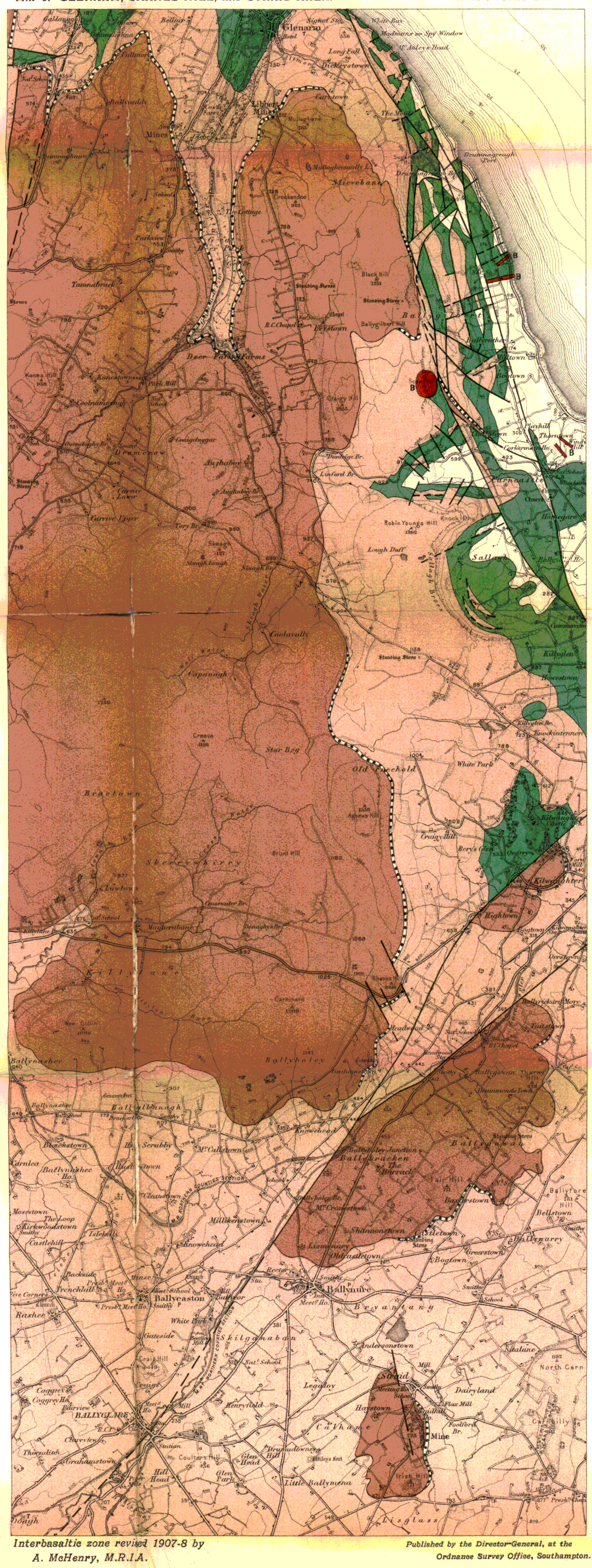
Faults are shown as black lines.

Map. 4. LARNE AREA. Part of Sheet 21.



Interbasaltic zone revised 1907-8 by A. McHenry, M.R.I.A.

Map 5. GLENARM, SHANE'S HILL, and STRAID AREA. Parts of Sheets 20 and 28.



Interbasaltic zone revised 1907-8 by A. McHenry, M.R.I.A.

Published by the Director-General, at the Ordnance Survey Office, Southampton. 1911.

Scale of One Inch to a Statute Mile

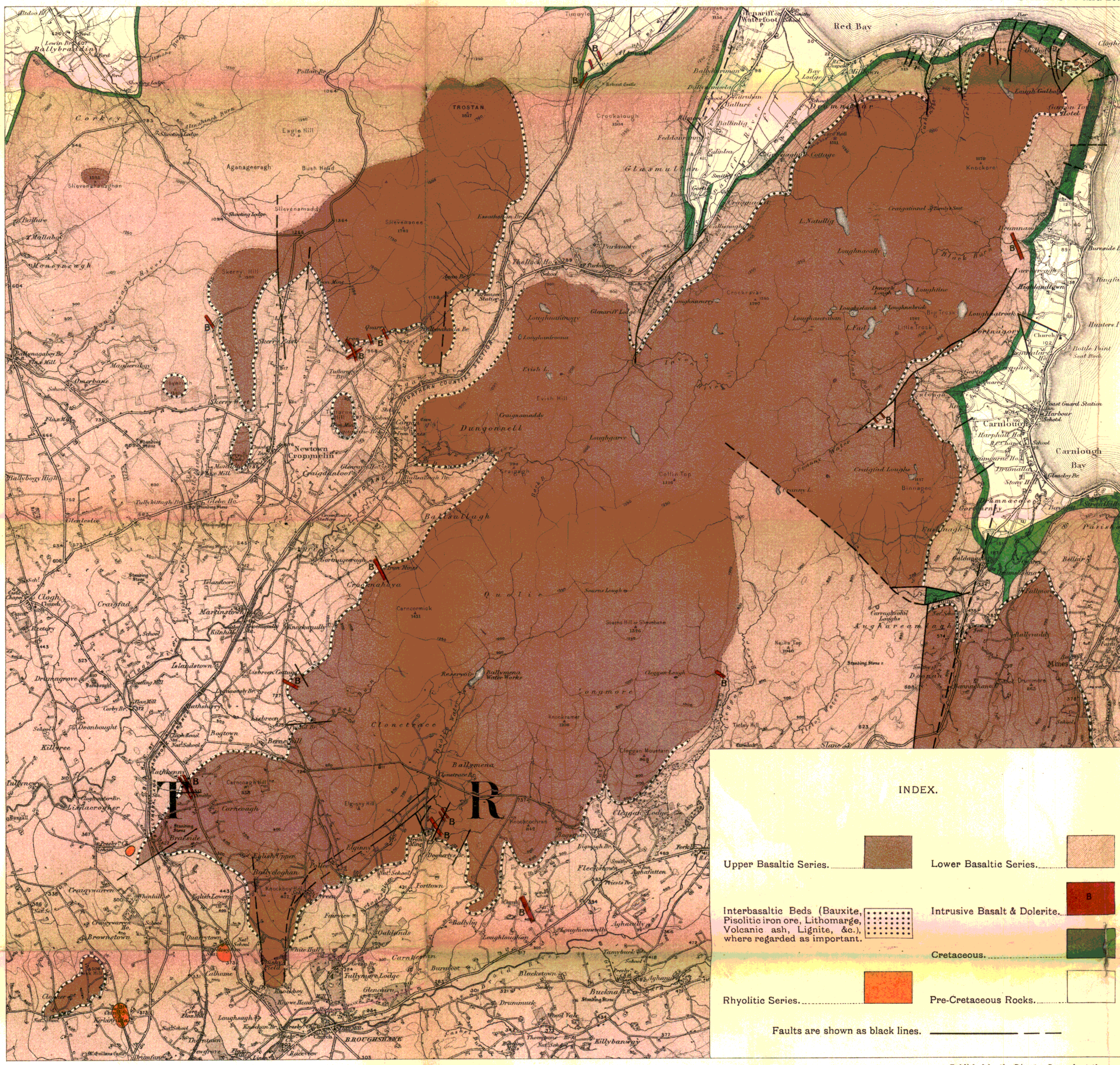
S. B. Wilkinson, Senior Geologist. G. A. J. Cole, F.G.S., Director.

GEOLOGICAL SURVEY OF IRELAND.

INTERBASALTIC BEDS OF NORTHERN IRELAND.

MAP 1. MID-ANTRIM DISTRICT.

PARTS OF SHEETS 14 and 20.



Interbasaltic zone revised 1907-8 by
J. R. Kilroe, A.R.C.Sc.I.
S. B. Wilkinson, Senior Geologist.
G. A. J. Cole, F.G.S., Director.

Published by the Director-General, at the Ordnance Survey Office, Southampton. 1911.