View looking north from cliff over "The Black Cave," showing the Chalk nearly vertical; "The Gobbins" in the distance.—G. V. Du N

Memoirs of the Geological Survey.

EXPLANATORY MEMOIR

TO ACCOMPANY

SHEETS 21, 28, AND 29 OF THE MAPS

OF THE

GEOLOGICAL SURVEY OF IRELAND,

INCLUDING THE

COUNTRY AROUND ANTRIM, LARNE, AND CARRICKFERGUS.

BY

EDWARD HULL, M.A., F.R.S., &c.,
(DIRECTOR),

WITH

PALÆONTOLOGICAL NOTES BY W. H. BAILY, F.G.S.,
(ACTING PALÆONTOLOGIST.)

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PREFACE.

THE southern portions of the district here described, and parts of the neighbourhood of Antrim, were surveyed by the late Mr. Du Noyer during the years 1867–8, but, owing to his lamented death, were left unfinished. In 1872, however, the survey of the Antrim district was resumed by Mr. Duffin, who completed the mapping of the Antrim sheet (No. 28), and would have drawn up the Explanatory Memoir, which it was intended should accompany it, but that he was appointed County Surveyor to the western division of Limerick, and was consequently unable to devote the necessary time to matters belonging to the Geological Survey. Under these circumstances, I found it necessary to undertake the preparation of the Memoir myself, which I have endeavoured to do, partly from my own knowledge of the district, and partly from the notes and memoranda left by Messrs. Du Noyer and Duffin.

Mr. Baily has supplied the palæontological portion, and I have availed myself, to some extent, of the recorded observations of geologists who have written upon this district.

Owing to the circumstances here stated, the Memoir is not as full and complete as it would have been if drawn up by the surveyors actually employed in the survey of the district; but it is hoped it will be found sufficient, when combined with the geological maps, to give a general idea of the structure of the country embraced within the limits of observation.

EDWARD HULL.

Geological Survey Office, Dublin,
20th January, 1876.

THE

GEOLOGICAL SURVEY OF THE UNITED KINGDOM

IS CONDUCTED UNDER THE POWERS OF THE

8TH & 9TH VICT., CHAP. 63.—31ST JULY, 1845.

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ALEX. M'HENRY; E. LEESON.

The observations made in the course of the Geological Survey, are entered, in the first instance, on the Maps of the Ordnance Townland Survey, which are on the scale of six inches to the mile. By means of marks, writing, and colours, the nature, extent, direction, and geological formation of all portions of rock visible at the surface are laid down on these maps, which are preserved as data maps and geological records in the office in Dublin.

The results of the Survey are published by means of coloured copies of the one-inch map of the Ordnance Survey, accompanied by printed explanations.

Longitudinal sections, on the scale of six inches to the mile, and vertical sections of coal-pits, &c., on the scale of forty feet to the inch, are also published, and in preparation.

Condensed memoirs on particular districts will also eventually appear.

The heights mentioned in these explanations are all taken from the Ordnance Maps.

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EXPLANATORY MEMOIR

TO ACCOMPANY

SHEETS 21, 28, AND 29

OF THE MAPS OF THE

GEOLOGICAL SURVEY OF IRELAND.

PART I.—GENERAL DESCRIPTION.

The area contained in this sheet lies wholly within the county Antrim, and contains the towns of Antrim and Ballyclare, and the villages of Legoniel, Whitehouse, Whiteabbey, Ballynure, Ballyeaston, Doagh, Templepatrick, and Randalstown. It is bounded on the west by Antrim Bay, forming a part of Lough Neagh, and the River Main; on the east by a portion of Belfast Lough, and by a range of hills, including Knockagh, Carnbilly, North Carn, and Ballyfore Hill, all under 1,000 feet high; at the S.E. corner of the sheet are the village of Legoniel and Wolf Hill; and on the north, just outside the sheet, are the villages of Connor and Kells, and a range of hills, including Elliott's Hill, Big and Wee Collin, and Tildarg Hill, the highest of which (Big Collin) is 1,159 feet above the Ordnance datum.

Form of the Ground.

The bold escarpment which runs parallel to the northern shore of Belfast Lough, and of the valley of the Lagan, and which forms the margin of the basaltic plateau of Antrim, enters the district from the north at Knockagh, and, after a sinuous course of several miles, leaves it at the village of Legoniel, where it enters the district to the south, contained in sheet 36, which has been described in a previous Memoir. This escarpment forms the flank of Wolf Hill, 1,210; Squire's Hill, 1,230; Cave Hill, 1,188; Collinward, 1,196; Carnmoney, 766; and Knockagh, 917 feet respectively; from its foot the ground slopes rapidly, forming a talus down to the sea level. The escarpment is one of the highest interest for the geologist, as well as forming one of the most striking features in the very beautiful scenery about here. The bold outlines of Cave Hill and other neighbouring elevations are due to it.

From these hills, and from the others on the eastern boundary, the ground falls rapidly towards Lough Neagh, with, however, numerous undulations, consisting, partly, of drift-deposits, partly, of rock; some of the latter showing the peculiar terraced outline characteristic of basaltic formations. The district is traversed in a S.W. direction by the valley of the Six-mile-water, remarkable

for its beauty and its fertility. Towards the northern boundary of the district the ground rises rapidly from the shores of the lough to a range of hills, amongst which are Drumadarragh, 929; Tardree, 798; Carnearney, 1,043 feet respectively; and other lower hills. All around the shores of the lough the ground is flat and covered with drift-deposits, forming low rolling ridges. In the N.W. corner of the district is a tract of low boggy country, with low drift hills, bordering on the River Main.

Drainage.—The district is divided into two catchment areas. In one, a narrow strip on the eastern side is drained into Belfast Lough. The other, comprising the remainder of the district, is drained by the streams called the Six-mile-water and the River Main, with their tributaries, into Lough Neagh. The watershed runs in the line of Wolf Hill, Squire's Hill, Collinward, Carnmoney Hill, where it takes a considerable bend to the westward, and again turns E. to Knockagh, thence to Carn Hill, Carnbilly, North Carn, and Ballyfore. The peculiarity of the district being drained for such a length from the sea, inland, is due to the great central depression at Lough Neagh, and the high elevation of the basaltic escarpment and its neighbouring hills, which are abruptly terminated towards the south and east. This escarpment, however, must have once extended over the waters of Belfast Lough, and attained a much higher elevation when in this position.

The catchment areas of the Six-mile-water and the Main are separated by a line of watershed running from Lough Neagh over Corby Knowe, Carnearney, and Tardree.

The general direction of the minor valleys, through which the tributaries of these rivers flow, is N.W. and S.E., corresponding with the direction of the drift hills, or Drumlins, and also that of the rock-formed hills, which themselves have been moulded by several agencies of denudation or erosion.* W. E. L'E. D.

Part II.

2. *Formations and Groups of Rocks entering into the Structure of the District.*

Aqueous and Volcanic Rocks.

Recent and Post Pliocene.

Name.	Colour on Map.
Alluvium, Bog, &c.	*Light brown.*
Raised beaches.	*Burnt sienna.*
Drift, boulder clay and gravel.	*Engraved dots.*

Miocene (*Volcanic*).

Tabular Basalt Series.	Upper Sheets.	*Burnt crimson lake (dark).*
	Bole, Lithomarge, &c.	*Light-reddish brown.*
	Lower Sheets, amygdaloids, &c.	*Burnt crimson lake (light.)*
	Volcanic Ash, agglomerate, &c.	*Do. with white dots.*

* For an account of the rainfall near Carrickfergus, see paper by Robert Manning, M. Inst. C.E., on "The Results of a Series of Observations on the Flow of Water off the ground in the Woodburn District," Proc. Inst. Civil Engineers, vol. xxv. In the year ending June, 1865, the rainfall was 35·867 inches.

Eocene (?) (*Volcanic*).

Name.	Colour on Map.
Trachyte porphyry, Pitchstone porphyry, &c.	*Chrome and carmine.*

Cretaceous.

Upper Chalk, with flints.	*Emerald green (light).*
Upper Greensand.	*Do. (darker).*

Liassic.

Lower Lias.	*Chalons brown.*
Rhætic or Penarth beds.	

Triassic.

Keuper marl, with gypsum.	*Venetian red (deep).*
Bunter sandstone.	*Do. (light).*

Igneous Rocks.

Basalt, intrusive as dykes, or necks of old volcanoes, of Miocene age.	*Burnt crimson lake (dark).*

Triassic Beds.—*Bunter Sandstone.*—This lower division of the Triassic formation is only represented at the south-eastern corner of the sheet along the margin of the estuary, and is a continuation of the wider area around Belfast, and along the valley of the Lagan (sheet 36). The beds consist of soft bright red and variegated sandstone, sometimes obliquely laminated, and containing partings of marl, or shale. These are especially numerous in the beds just below the Keuper marls, and it is exceedingly difficult in some places to determine to which division of the Triassic formation such beds ought to be referred—though in England the line of boundary between the two members represented in Britain (the Bunter and Keuper) is sufficiently marked.

Excellent sections in the Bunter sandstone are laid open along the Carrickfergus-road, north of Belfast, particularly that along the new road near Fort William, where the rock is seen to be penetrated by several basaltic dykes. It is also seen, during ebb-tide, along the shore for about a mile, between White House, Lower, and White Abbey. Here it consists of laminated red and gray sandstones with bands of shale, dipping generally towards the west, except at Macedon Point, where a synclinal axis is observable. Throughout this distance the beds are traversed by basaltic dykes, which range in a direction about N. 20 W. It is probable that the beds at White House, Lower, are in proximity to a fault.

The beds along the coast, just described, are again laid open along the banks of the stream which descends from the hills to the sea at White Abbey. They are traversed by numerous dykes of basalt.

Keuper or New Red Marl.—This division forms the flanks of the escarpment, from the base of the Cretaceous beds down nearly to the shore of Belfast Lough, forming very rich pasture land, but generally more or less overspread by Drift deposits, or concealed near the base of the escarpment by landslips.

It consists of a thick series of red and gray laminated marls,

with occasional bands of micaceous sandstone containing pseudomorphs of salt crystals. Bands of gypsum, more or less irregular in extent and thickness, are numerous, and are well shown in the railway cuttings between Carrickfergus and Larne, at Kilroot and Cloghan Point.

The Keuper marls attain a thickness of over 800 feet in this district, as proved by the boring in search of coal made by the late Marquis of Downshire near Carrickfergus, and which resulted in the discovery of several beds of rock-salt, some account of which I now proceed to give.

Rock Salt.—This mineral is found in England in beds of considerable thickness in Cheshire, Staffordshire, Worcestershire, and other places, and always associated with the New Red Marl; and from the discovery of the same mineral in the marls of this district, a remarkable analogy between the formations on both sides of the channel has been established. An account of this discovery is given by Mr. J. B. Doyle,* read before the Dublin Geological Society in 1853. It appears from this account that a boring was put down at Duncrue, about two miles from Carrickfergus, and near the banks of the Woodburn River, at an elevation of about 300 feet above the sea, which, after passing through a great depth of gypseous marls, entered beds of salt. The following is the general section of the borehole.

Section at Duncrue Salt-mine.†

	Feet.	Inches.
1. Drift ("Diluvium"),	50	0
2. Red marls, with thin bands of gypsum,	500	0
3. *Rock salt* (1st bed),	15	0
4. *Salt* and blue band,	6	8
5. *Rock salt* (pure) (2nd bed),	88	0
6. Blue and red band with some salt,	17	0
7. Mixed salt and blue and red band,	13	0
8. *Rock salt* (pure) (3rd bed),	39	0
9. Thin blue bands,	6	6
10. Dark-coloured rock,	4	0
11. Freestone,	10	1
12. Gray rock (not pierced through),	2	4
	751	7

From this it appears that there are three distinct beds of rock salt, included in, and forming about 150 feet of, saliferous strata; and from the occurrence of gray sandstone below, it would appear that the position of the beds of rock-salt is at the base of the red marls, or in fact towards the upper limit of the Lower Keuper sandstone.‡ A company has been formed for working the rock salt, which is mined and exported from Carrickfergus. It contains from 95 to 98 per cent. of pure salt of commerce, and in 1873 the quantity raised was 19,392 tons.§

Rock salt has also been reached at Ballybig, or Magheramorne, near Larne, as I am informed by Mr. Robert M'Calmont, and this

* "Notes on the Salt-mine at Duncrue." Journ. Geol. Soc., Dub., vol. V., p. 232.

† This section is a combination of two sections given by Mr. Doyle.

‡ The boring at Carrickfergus confirms the view at which I had arrived some years ago in reference to the position of the beds of rock salt in England.

§ "Mineral Statistics" for 1873, p. 176.

seems to have been the first occasion in which its presence was ascertained in this district. Some years before, and independently of the discovery of this mineral on the property of the late Lord Downshire, Mr. Irving when sinking (or boring) for coal at Ballybig, came upon rock-salt, but did not persevere in his investigations.

Lower Lias *and Rhætic Beds.*—Cropping out here and there from beneath the Cretaceous beds in the district between Carrickfergus and Larne, we find traces of the lowest beds of the Lias, consisting of blue and dark shales, calcareous sandstones and limestones with pseudo-oolitic structure, containing fossils (*Avicula contorta* and *Ammonites planorbis*), indicating the stage of the Rhætic beds and overlying Liassic strata. The finest exposure of these strata in this immediate district is to be seen at Waterloo House, on the beach, about a mile N. of the entrance to Larne Harbour, where a considerable thickness of successive strata from the Keuper marls to the Chalk will be found dipping about W. 10 N., at 15°–20°. These beds outcrop also at White House, on the west coast of Island Magee, where they consist of dark gray shales and thin layers of limestone, highly fossiliferous; on the west they are bounded by a dyke of basalt. They are also seen in the Valley at Glenoe, and on the bank above Cloghan Point, but are very obscurely situated. They are overlaid unconformably by Cretaceous beds.

The section at Larne is considered by Mr. Ralph Tate to be "the key to the reading of the Liassic strata in Ireland," and he divides the series into the following members in ascending order:—*

1. The zone of the *Avicula contorta*, representing the Rhætic series, here attaining a thickness of over 100 feet.
2. The zone of *Ammonites planorbis*, consisting of black indurated shales with flattened specimens of this fossil and a few other molluscs.
3. The zone of *Ammonites angulatus*, questionably separable from the second, consisting of dark limestones and blue marls about thirty-five feet in thickness.
4. The zone of *Ammonites Bucklandi*. Compact blue argillaceous limestones, weathering white, charged with *Cyphæa incurva*.
5. Zone of *Belemnites acutus*. Not well represented, and forming the highest member of the Irish Liassic series.

Section at White Head.—The strata here are to be only made out with difficulty, owing to the manner in which they have slipped. The section consists of argillaceous thin-bedded limestones and dark shales, and a thin band of sandstone in the lower part—the whole having a thickness of about twenty feet. They contain according to Mr. Tate,† *Avicula contorta, Axinus cloacinus, Cardium Rhæticum*—with fish remains occurring in a very thin

* "On the Rhætic and Lower Liassic Rocks of Belfast." Quart. Journ. Geol. Soc. vol. xxi., p. 15 (1864).

† "The Liassic Strata of Belfast."—Quarterly Journal Geological Society, vol. xx. p. 106.

band near the lower part of the section—amongst which the same author has identified, *Gyrolepis Albertii*, Agass., *Acrodus minimus*, Agass., and *Saurichthys apicalis*, Agass. The above beds represent the Rhætic series, and rest upon the red Keuper marls.

*Section at Cave Hill.**—Liassic and Rhætic strata occur at the base of the basaltic cliff on the south side of Cave Hill, near Belfast. They occur on both sides of a basalt dyke, and the section as given in descending order by Mr. Tate, is as follows :—

		Ft.	In.
Liassic,	1. Indurated shales,	10	4
	2. Indurated marls without fossils,	3	10
Rhætic,	1. Black shales with *Axinus cloacinus* and *Avicula contorta*,	12	2
	2. Argillaceous limestone,	0	1½
	3. Shales,	2	8
	4. Three bands of argillaceous limestone,	0	2½
	5. Black shales with *Avicula contorta* and fish,	0	10
		30	2

These strata rest on the Keuper marls and are traversed by a basaltic dyke.

The existence of these strata shows that the highest beds of the Keuper marls have been reached, and left undisturbed; but the Lias formation itself, has been subject to almost entire obliteration by denuding agencies previous to the overspread of the Cretaceous beds. Whether the Oolitic beds ever extended into this part of the British Isles—must remain an unsolved question.

Cretaceous Beds. — *Upper Greensand.* — The Cretaceous strata form a narrow band between the basaltic sheets and the Liassic shales, or (in their absence) the Keuper marls; and in this position they are generally to be found cropping out at the base of the escarpment of the Antrim Hills, and by their extreme whiteness offering a striking contrast to the black masses of basalt by which they are surmounted. These beds rest unconformably on all the strata below them, and thus we find them sometimes resting directly upon the Keuper marls, as at Carnmoney Hill, and at other times on the Lower Lias, as at Cave Hill, Glynn, and Larne, the whole of the Oolitic (or Jurassic) series being absent.

This discordance of stratification between the Lower and Upper Mesozoic strata is general over the British Isles; and in order to account for it, we may suppose that, at the close of the Oolitic (or Jurassic) period, the bed of the sea was elevated into dry land, and while in this condition vast quantities of Oolitic and Liassic strata were denuded from off its surface, after which, upon the re-submergence of the land, the Cretaceous beds were deposited over the truncated and eroded surfaces of the older formations.

In lithological character—the Greensand is frequently of a

*"The Liassic Strata of Belfast."—Quart. Journ. Geol. Soc., vol. xx., pp. 105 and 108.

deep sap green, as at Woodburn Glen and Cave Hill; or of a paler leek green, as at Carnmoney Hill, White Head, and Larne. Under the lens it is seen to consist of grains of a green mineral, which Professor Galloway has kindly determined for me to be ferrous silicate (silicate of protoxide of iron), sometimes mixed with others of quartz and hornstone. At Waterloo, near Larne, the upper beds have a reddish colour, due to the oxidation of the grains of silicate of iron, and under the lens, are seen to consist of rounded grains of quartz, and green chlorite, cemented partly by a red paste of ochre, and partly by white carbonate of lime. It effervesces strongly with acid. I have examined fine dust of the Greensand, from several localities, under the microscope with a magnifying power of twenty-four diameters. In this way, the grains of silicate of iron appear as small rounded pebbles of deep opaque green colours, with a coating of pale calcareous matter. The grains are not affected by the magnet. The dust from Cave Hill gave the clearest results, and appeared to show that the grains were distinctly waterworn.*

It may be here observed, that no representatives of the Lower Cretaceous beds are found in this part of Ireland, and the most recent writers all concur that the oldest member of the Cretaceous formation is the representative of the Upper Greensand of England.† In this view the officers of the Geological Survey concur, both on palæontological and petrological grounds—as there is no resemblance between the beds of Lower Greensand of the south and east of England and any of the strata below the Chalk in this part of Ireland. On the other hand, the Upper Greensand of Antrim frequently bears a strong resemblance to the beds of this formation in Oxfordshire and Wiltshire; this resemblance has been recognized by the late Rev. W. Conybeare.‡

The succession of the beds as given by Mr. Tate, and corresponding with that furnished by Dr. Bryce,§ is as follows, in descending order:—

1. White limestone (Chalk) with flints.	
2. Chloritic sandstone and marls,	Upper Greensand.
3. Yellow sandstone and marls,	
4. Glauconite sand,	

The upper beds (No. 2), locally called "Mulatto Stone," are often conglomeritic, containing small pebbles of chert, quartz, and hornstone; the lower are often unctuous and marly, and the whole attain a thickness, varying from 10 to 20 feet. The beds

*This is the same mineral which gives the green colour to this formation in the S. of England. Professor Ehrenberg, of Berlin, has recently shown that the grains of glauconite of this formation are internal casts of foraminifera, and therefore of organic origin (Abhand. der Acad. der Wissenschaft, 1855).

†This subject has been so fully discussed by Prof. Ralph Tate ("Cretaceous Rocks of Ireland," Quart. Journ. Geol. Soc., vol. xxi., p. 15), that it is unnecessary to reopen it here. Amongst the observers who consider the Lower Greensand to be present is Dr. Bryce, the author of the excellent paper "On the Geological Structure in the North-east of Ireland"—(Trans. Geol. Soc. 2 Ser., vol. v.), but D'Archiac disagrees with this view, "Histoire des Progres," vol. iv., p. 8.

‡"Descriptive Notes of a part of the Coasts of Antrim and Derry," Trans. Geol. Soc. Lond., vol. iii., pp. 129-131, 167-173.

§"Geological Structure of the Counties of Antrim and Down," Trans. Brit. Assoc., 1852, p. 42. Only a very slight sketch of this paper is given i the report, and I quote from Mr. Tate's quotation.

are fossiliferous, and are well exposed at Waterloo, near Larne, on the west coast of Island Magee, and at White Head and Woodburn, and have yielded a large number of species of fossils, amongst the most abundant of which are *Inoceramus, Crispi. Exogyra conica, Ostrea semiplana, Terebratula obesa, Rhynconella robusta, Spondylus spinosa, Pleurotomaria perspectiva, Cidaris vesiculosa*, &c.*

Upper Chalk.—This formation is a pure white limestone, containing bands and nodules of flint which lie in the planes of bedding. In general the Chalk is hard, splintery, and highly fossiliferous. Owing to its firm texture it admits of being cut into translucent slices for microscopic examination; and I have thus been enabled to examine specimens from several parts of the Antrim District, all of which concur in showing that the rock is highly organic in structure, being chiefly formed of the calcareous shells of foraminifera, the whole bound together by an opaque calcareous cement. The foraminiferal shells are generally formed of crystalline calcite, showing under polarised light a play of colours characteristic of that mineral; they are often imperfect, and in size range from 100th to 600th of an inch in diameter. My friend, Professor T. Rupert Jones, F.R.S., was kind enough to examine the slices, two of which were from Dunwater Quarry, near Larne, the others from the neighbourhoods of Belfast and Moira. In examining these specimens he had the assistance of Mr. W. K. Parker, F.R.S., and they were able to recognize various sections of perfect and fragmentary foraminifera of small size, as follows:—†

1. *Lituola?*
2. *Valvulina.*
3. *Dentalina communis*, d'Orb.
4. *Bulimina* (*Ataxophragmium*).
5. *Textilaria:* two varieties of the small *T. gibbosa*, common throughout the Chalk.
6. *Verneuilina pygmæa*, Egger.
7. *Globigerina Cretacea*, d'Orb.
8. *Planorbulina*, small varieties related to *P. ammonoides*, Reuss.
9. *Pulvinulina Menardii*, d'Orb.

The authors add—"Although no new forms of microzoa occur to us in these slices of chalk from the north of Ireland, yet, as Professor E. Hull has already pointed out in his notice of these interesting specimens at the meeting of the Royal Geological Society of Ireland (June 12, 1872), the fact of the hardened chalk having been made to yield its secrets has a fascination for the naturalist; and the addition of even already known Foraminifera to the list of fossils found in Ireland is not without its use to the Palæontologist."‡

Chemical composition.—In composition the Chalk is nearly pure carbonate of lime; it also contains small quantities of other minerals, such as silica, magnesia, phosphoric acid, and iron-

* Tate, "Cretaceous Rocks," *loc. cit.*, p. 22.

† Journ. Roy. Geol. Soc. of Ireland, vol. iii., pt. 3, p. 88 (1872–73).

‡ *Ibid.*, p. 91. Besides the minute and microscopic organisms entering into the structure of the Chalk, the strata enclose numerous large shells of molluscs, echinoderms, &c., of which an account is given by Mr. Baily (p. 41).

oxide; but, perhaps, the most remarkable ingredient is that of oxide of zinc, discovered by Mr. E. T. Hardman, F.C.S., in specimens from two localities in county Tyrone.*

The following is an analysis of specimen from Magheramorne, which may be considered as representative of the formation in this district:—†

Analysis of Chalk, Magheramorne.

	Per cent.
Carbonate of lime,	98·63
Carbonate of magnesia,	0·38
Phosphate of lime,	0·10
Oxide of lime and alumina,	0·08
Silica and insoluble clay,	0·45
	99·64

The upper surface of the Chalk generally presents a deeply eroded aspect, worn into irregularities, and overlaid by a mass of gravel, composed of chalk-flints, generally of a red colour, and often showing exceedingly beautiful dendritic markings. Bands of clay and impure iron-ore are also occasionally present, as in the quarries above Carrickfergus. It is evident that the formation has been subjected to extensive denudation before the overflow of the tabular basalt, in consequence of which the thickness of the formation is exceedingly variable, and is everywhere much less than it was when originally formed over the bed of the sea. As regards the cause of the red colouring of the chalk-flints, the reader is referred to the views of the late Professor Jukes.‡

Chalk-flints consist of nearly pure silica, and assume numerous quaint and irregular forms, sometimes those of sponges. They are frequently hollow, the interior being coated with a white calcareous lining, and enclosing a siliceous dust, which Mr. Joseph Wright, F.G.S., of Belfast, has shown to be composed of shells of *foraminifera, entomostraca*, and *sponge-spiculæ*. These have been obtained from numerous localities, and from different beds of the Chalk by members of the Belfast Naturalists' Field Club.§ That the mass of the flint itself is of organic origin is clear upon an examination of a translucent slice under the microscope, when foraminiferal and other structures will become apparent.‖ Professor Rupert Jones says, with reference to a specimen from Moira, examined under the microscope—"The slice of the flint presents the same appearances as those of the Chalk, but less clearly, that substance being, as is usual, in a pseudomorphous state (silica after carbonate of lime), with the organic details less distinct."

Sections.—The Chalk being largely quarried for economic uses, sections are numerous along the basaltic escarpment. Besides

* Journ. Roy. Geol. Soc., Ireland, vol. iii., p. 159.

† "Guide to Belfast," by members of the Naturalists' Field Club (1874), p. 48. See also analysis of Chalk from Cushendall, by Mr. W. J. Wonfor, made in the laboratory of the Royal College of Science (Museum of Irish Industry). Journ. Roy. Dub. Society, vol. iii., p. 77.

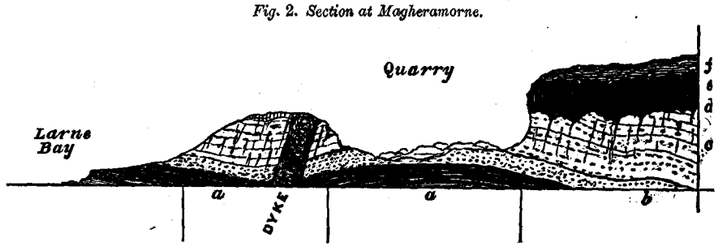
‡ Geological Magazine, vol. v.

§ See paper by Mr. J. Wright, on "Cretaceous Microzoa," Proc. Belfast Nat. Hist. and Phil. Soc. 1873, also "Guide to Belfast," by the Naturalists' Field Club, p. 50 (1874).

‖ I have examined slices from Moira, which seem to show that the silex is a pseudomorph replacing the original calcareous structure, which is decidedly organic.

being used for lime, it is used as a flux in the iron furnaces of Scotland and the north of England. At Glenarm it is manufactured into whiting, and the Glasgow chemical works consume large quantities.* The principal quarries and sections in our district are those at Cave Hill, where there is a section of 50 to 60 feet of chalk-rock penetrated by dykes; at White Head, near Carrickfergus; at Kilcoan, Ballydown, and Portmuck; on Island Magee, at Magheramorne, and Waterloo, near Larne; and at Templepatrick, in the centre of the basaltic district, where there is a section of 50 to 60 feet laid open (sheet 28). The occurrence of the Chalk in this position is undoubtedly due to the presence of a very large fault, which (as may be seen by reference to the map) ranges along the Valley of the Six-mile Water in a north-easterly direction, the strata on the north-west side of the fault being relatively elevated as regards those on the opposite side by several hundred feet. This is proved by the fact, that the iron ore at Ballypalady is nearly on the same level on one side of the fault with the chalk of Templepatrick on the other; while from numerous comparisons of sections in this district it is well known that these two deposits are separated by about 400 feet from one another. In many of these places, as at Magheramorne, basalt dykes are seen penetrating the Chalk; and at half a mile to the S.E. of the quarries at this place the tabular basalt passes right over the Chalk and Greensand, and for some distance rests directly upon the Keuper marl. The following section is shown at the quarries near Magheramorne:—

Fig. 2. Section at Magheramorne.



(*f*) *Drift clay*, &c., ... 10 feet thick.
(*e*) *Basalt*, massive, ... 45 „
(*d*) *Flint gravel*, of irregular thickness, filling hollows in the Chalk, ... 2 to 4 „
(*c*) *Chalk with flints*, slightly rolling, . . . 65 „
(*b*) Greensand (not seen) resting on (*a*) Lias.

Tertiary Volcanic Rocks.

The volcanic rocks occupy by far the larger portion of Sheet 28, and are referable to three distinct periods of eruption, ranging in all probability from the late Eocene down to the close of the Miocene stages of geologic time.† It would appear that at the close of the Cretaceous period the sea-bed of this district was elevated into dry land, and that extensive denudation of the Chalk and subordinate strata took place. The peculiar ochreous gravel which lies on the eroded surface of the Chalk, separating it from the overlying basalt, is a relic of this denudation; the hardly destructible flints having been left behind after the soft Chalk in which they were embedded had been removed.

* "Guide to Belfast," p. 48.
† Presidential address to the Geological Section of the British Association at the Belfast meeting. Report for 1874, p. 69.

Over this surface, and while the area was still land, the earliest product of volcanic action was locally poured out—namely, the trachitic rocks of Tardree Hill and surrounding district, which occupy the northern borders of the sheet near its centre, and again appear at Templepatrick. These rocks form a striking contrast, both in composition and appearance, to those which succeed them, which consist of basaltic beds of several varieties; so that I consider it probable that a considerable interval elapsed between the cessation of the trachitic and the commencement of the basaltic eruptions. Now, these latter, from the plant remains which they contain, are clearly referable to the Miocene stage; so that the earlier lava flows are probably referable to the Eocene, as already stated.

The whole volcanic series may, therefore, be arranged as follows, in descending order:—*

General Volcanic Series of the Antrim District.

			Maximum Thickness.
Miocene.	*Upper.*	(*c*) Beds of tabular basalt and dolerite, generally columnar, . (over)	400 feet.
	Lower.	(*b*) Beds of pisolitic iron ore, bole, volcanic ashes, and lignite, . .	50 „
		(*a*) Beds of tabular basalt and dolerite, generally amygdaloidal, and containing bands of bole, . . .	600 „ (unknown).
Eocene—*Upper.*		Trachyte porphyry, &c., . . .	

I shall now proceed to describe these formations in ascending order, by which means an approximate history of the volcanic operations will be unfolded.

Trachyte porphyry.—This remarkable rock occupies the high ground which lies to the N.E. of Lough Neagh, gradually sloping upwards from Antrim Bay till it attains an elevation of 943 feet in Carnearney Hill. It has been alluded to, or described by, several observers, incuding Portlock,† who calls it "porphyry of Sandy Brae," Berger,‡ and Bryce,§ but until the investigations of the geological surveyors had extended to this district, the true physical relations of this rock to the other volcanic products of this part of Ireland had not been clearly determined.

The area occupied by the trachyte will be best understood by referring to the map. It rises up as a dome, in the centre of which is Tardree Mountain, and in every direction sinks down below the beds of the lower basaltic series, which at Brown Dod,

* This is very nearly as stated in my address at Belfast. Rep. Brit. Association, 1874, p. 72.
† Journ. Geol. Soc. Dub., vol. i., p. 9.
‡ Trans. Geol. Soc. Lond., vol. iii., p. 129, 1st series.
§ Rep. Brit. Assoc., 1852, p. 42.

Scolboa, and Carnearney, have remained as isolated patches capping the trachytic rocks. The relations of the two groups of rocks can here be clearly determined, and it will be found that the latter pass underneath the former. The northern limits of the trachyte extend for a short distance into sheet 20, as the valley of the Glenwhirry River is in lower basalt.* It is probable that the vent through which the trachyte was erupted is situated under Tardree Hill.†

Lithological character, &c.—The rock consists of crystals of sanidine (glassy felspar), sub-angular blebs of smoke-quartz, and opaque white felspar, enclosed in a light gray felspathic paste. Occasionally minute flakes of black mica‡ (biotite) are observable, and a crystal of plagioclase (probably Labradorite) was detected in a slice I examined under the microscope, as were also minute crystalline grains of magnetite. The rock is slightly magnetic, and does not effervesce with acid. Sp. gravity, 2·433.

Microscopic structure.—I have examined two thin slices of the stone from Tardree quarry under the microscope. In one, a fine crystal of triclinic felspar was observed, and in both a few of black mica. The base is amorphous, of a light brownish mottled appearance, enclosing individual black crystals of magnetite, more or less numerous, and sometimes showing the octohedral form. The crystals of sanidine are structureless, clear, and fissured. They are generally well formed, and leave their impress indented on the felspathic paste. In the order of crystallization, it would seem that the magnetite was the first; then the sanidine, or the mica; then the silica; and lastly the paste in which these minerals are all enclosed.

Chemical composition.—An elaborate analysis of a specimen from Tardree has been published by Mr. E. T. Hardman, of the Geological Survey.§ The analysis was conducted at the Laboratory of the Royal College of Science, Dublin, by permission of Professor Galloway. The result is as follows:—

Silica,	76·960	per cent.
Alumina,	5·101	,,
Oxide of iron,	2·344	,,
Lime,	7·064	,,
Magnesia,	0·295	,,
Potash,	4·262	,,
Soda,	1·818	,,
Loss by ignition,	2·102	,,
Phosphoric acid (trace),	–	,,
	99·943	

The result of the analysis leads Mr. Hardman to conclude that the rock has been somewhat transformed since its solidification, owing to which the felspar, originally a normal orthoclase, is being

* This sheet is now being surveyed by Mr. Traill (1876).

† The form of this hill was probably that of an ordinary volcanic mountain—a cone with a cup; but it is probable that before the outburst of the augitic lavas, it had been considerably worn down by atmospheric abrasion.

‡ Mr. Hardman states that minute crystals of hornblende are present, but as biotite is observable under the microscope, I suspect that these have been mistaken for hornblende. A slice of the rock was also examined for me by Professor Geikie, F.R.S., with similar results to those stated above.

§ Journ. Roy. Geol. Soc., Ireland, vol. iii., p. 27.

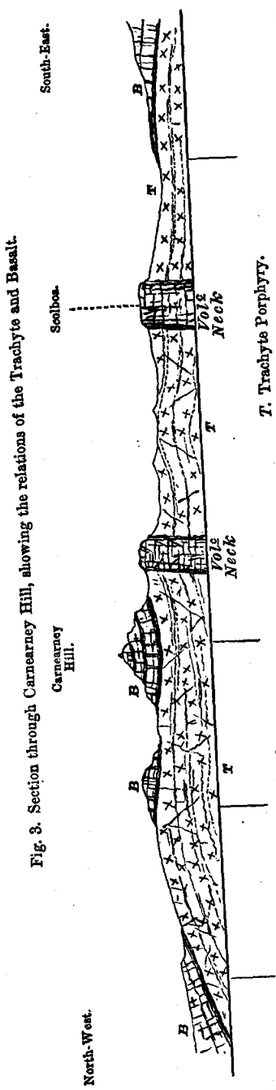


Fig. 3. Section through Carnearney Hill, showing the relations of the Trachyte and Basalt.

gradually transformed into a lime-felspar. It will be observed, however, that the analysis goes to confirm the determination of the presence of a plagioclastic felspar, which may, with much probability, be identified with Labradorite; and also of the magnetite, which is only visible by microscopic aid.

As compared with the chemical composition of granite, to which the trachyte is closely allied, there is a strong qualitative resemblance, but it differs quantitatively from all granites with which I am acquainted by the larger proportion of silica.*

Sections.—At Scolboa Hill the rock may be observed on the N.E. side, where it consists of gray compact enamel-like base with numerous well-formed crystals of sanidine, and little grains of silica. It has also a laminated structure, as was observed by Mr. Du Noyer, both here and elsewhere over this district, and on the south side of the hill the rock is in a decomposed state.

The relations of the basalt to the trachyte porphyry give evidence that the former protrudes through the latter in the form of old volcanic necks. The basalt rises to a higher level, while the laminated trachitic beds slope away from it towards the south. The basalt is rich in olivine.

Carnearney Hill.—The trachitic rocks are again well shown on the braes east of Carnearney Hill, which is formed of the tabular basalt, and under which the trachyte evidently passes. The lamination of the trachyte porphyry is here very distinct. The composition is similar to that of Scolboa, but the rock is more solid.

* Out of 13 cases of analyses of granites which I have collected, the highest contains only 75 per cent. of silica, viz.:—a specimen from the Mourne Mountains, analyzed by Rev. Dr. Haughton.—"Building and Ornamental Stones of Great Britain, &c.," p. 28 (1872).

Carnearney Cross Roads.—The rock here presents a more strikingly bedded appearance than elsewhere, soft and hard beds alternating, and of various colours, such as gray, yellow, and red, in distinct courses. It also contains much free silica, and is fast decomposing into sand. Near the plantation to the east of this quarry, a fine perennial spring bursts forth at the junction of the basalt and trachyte along a line of fault, which runs in a N.E. direction.

Fig. 4. Quarry of Trachyte porphyry and Rhyolite.

Tardree Hill.—West of the quarry there is a little cliff above the roadside where the trachyte assumes the columnar structure as shown in the sketch.

Fig. 5.

Quarry at Tardree Hill showing columnar structure of trachyte.

The columns, though ill-formed, are distinct, vertical, and of small size, and as the occurrence of this structure, though common in the basalt, is rare in this rock, it deserves to be noted.

There are two quarries, one on either side of Tardree Hill, that to the south being the more recently worked. It presents a vertical section of 50 feet of white trachyte porphyry, with a slightly bedded aspect, and traversed by vertical joints. It consists of a white felsitic paste, containing crystals of sanidine (glassy felspar), numerous grains of smokey quartz, and ill-formed crystals of decomposed white felspar; small pieces of obsidian are also present. The rock is quarried for post-stones, cornices, pavements, and building purposes, and is sent to Antrim, Belfast, Ballymena, and other places.

Templepatrick.—Trachytic rocks also occur at Templepatrick in proximity to the Chalk and basalt, but the relations are somewhat obscure.

Of this rock Mr. Duffin writes in his note book—

"On the upper side of the railway opposite the school-house, there is found a species of 'pearlstone.' It is almost all felspar of a compact texture, and of a pearl gray colour with a slight iron-staining and with a few dark specks through it. The same stone is found again round the church, and other places. Near the entrance to Upton Castle, a well was sunk in this rock to a depth of forty feet, and at the Police Barrack, within a few yards of the Chalk, another well was sunk in this rock to the same depth without entering the Chalk; and in the drain cutting being made up to a basalt quarry from the railway, various volcanic products (tuffs, &c.) were found."

From the verticality of the wall of the trachyte where near the Chalk, it may be inferred that the pitchstone of Templepatrick occupies the position of an old volcanic vent.

MIOCENE (*a*) *Lower Tabular trap series* (*augitic*).—As the trachytic rocks do not appear along the southern and eastern margins of the basaltic plateau, they have evidently been very partially distributed, or largely denuded before the outflow of the tabular basalts.

The lower series of tabular traps differ widely in mineral character from those I have just described. The beds are essentially augitic and basic—silica which attains so high a per-centage in the trachytic rocks (see page 18) being deficient in these, and only present to the extent of 42 to 57 per cent.* They consist of basalts when compact; dolerites when the crystalline structure and constituents are visible to the naked eye; amygdaloids when vesicular—the vesicles being filled by zeolites, carbonates, or other minerals; and bole, which is a reddish clay, resulting from the decomposition of the above under the atmosphere.

In structure these rocks are generally amorphous, or arranged in massive irregular beds, with a concretionary structure verging upon columnar. The essential constituents are Labradorite felspar, augite, and titano-ferrite (or titaniferous magnetite).

The beds frequently weather purple or red, owing to the oxidization of the iron which is present in considerable quantity. Besides the constituents above named, pseudomorphs after olivine are frequently present; but are seldom apparent except under the microscope. Zeolites, calc spar, and chlorite may often be observed filling the cavities of the cellular varieties, while the last named mineral often occurs in veins, or lining the joint-planes or fissures of the rock. Sometimes the rock is coarsely-crystalline; at other times it occurs as a dense compact homogeneous mass, requiring a high microscope power to bring the

* B. von Cotta, "Lithology" p. 124. A specimen of basalt (anamesite) from the Giant's Causeway, was found to contain 47·80 per cent. of silica. Streng, Poggend, Ann. xc. (1853), quoted in "Building and Ornamental Stones," p. 89.

component minerals into view. Nevertheless, the examination of several thin slices under the microscope shows that the constituents are essentially the same, and that the difference is due to the larger or smaller size of the individual crystals of augite or felspar. (See microscopic notes.)

Thin bands of red clay, or "bole," are seen sometimes to separate different beds of the trap, both of the lower and upper series. The most important is that which occurs at the top of the lower division of the Trap series, and which serves to separate it from the upper division; but other bands of less thickness are found at various stages, one about 12 inches, being very constant (according to the observations of Mr. Duffin), near Larne. Similar bands have been recognised in other volcanic districts, notably those of Ascension Island, by Sir C. Lyell, who considered they were due to the decomposition under the atmosphere of successive flows of lava. Chemical analysis confirms this view, as does also microscopical examination; for a thin slice taken from the neighbourhood of the Giant's Causeway, when examined under the microscope, showed that the structure resembled that of basalt, the felspar prisms retaining their form and substance unaltered, while the augite, and magnetite had been converted into an ochreous paste. The process of decomposition from the red clay into the solid trap may frequently be easily observed at the sections in Island Magee and about Larne.

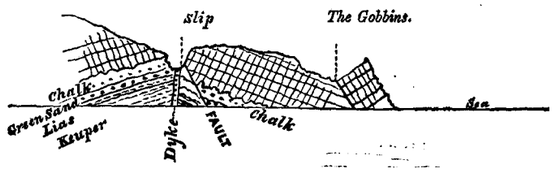
At Shane's Castle the rock is somewhat peculiar, and at The Rockery shows the following section, as noted by Mr. Duffin:—

(*d.*) Columnar basalt, compact, resting on—
(*c.*) Very thin lignite band.
(*b.*) Volcanic ash, or breccia, from 8 to 10 feet thick, of an ochreous colour, and containing rounded fragments of trap. This reposes on—
(*a.*) Compact basalt.

Fine sections in the Lower Basaltic series occur in the banks of the Six-mile Water opposite Muckamore Abbey, and on the hills north of Antrim; but owing to the great accumulations of Drift deposits, such as sand, gravel, and boulder clay, the rock is seldom exposed to view except upon the higher elevations. The thickness of the Lower series of basaltic sheets is, of course, variable, but Mr. Duffin has ascertained by two measurements that in some places it reaches nearly 700 feet.

Fig. 6.

Section at "The Gobbins," showing superposition of Basalt on Chalk, &c.



At "The Gobbins" the beds are seen to be thrown into a sharp anticlinal axis along the line of a fault, and vertical basaltic dyke. Above the chalk is the basalt; below it green sand, Lias and Keuper marls. The figure is from a drawing by Mr. Du Noyer.

(*b*). *Bole; volcanic ashes, with iron ore and lignite.*—This series, together with that overlying, has but a very limited range in Sheet 28, having been denuded off the whole area with the exception of a few outliers (isolated patches), all lying to the south of the great downthrow fault, which ranges along the valley of the Six-mile Water from Templepatrick northwards. It is solely owing to the presence of this fault that any of these beds are left in the district. I shall give some account of each of these outliers.

Ballypalidy Section.—This section is laid open along the cuttings of the railway about a mile E. of Templepatrick, and also in some pits, where the material is worked for fluxing with iron ore. The beds have been described by Mr. W. H. Baily,* and by Messrs. R. Tate and J. S. Holden,† and were originally examined for the Geological Survey by the late Mr. Du Noyer in 1868, who supplied the section of the beds given in Mr. Baily's paper on the plant remains therein enclosed.

There are two principal sections exposed, one in the quarry, where the strata are worked for fluxing,‡ the other in the cutting of the Northern Counties Railway, about 400 yards from the quarry. The sections are somewhat dissimilar, owing to the variable nature of the formation, but are on the same general geological horizon, and a small fault passes between the two, by the farm houses (see map). Their position in the general series is between the Upper and Lower series of Tabular basalts, both of which may be observed at Ballypalidy.

The following section was noted by myself on the occasion of my visit, in company with Mr. Duffin:—

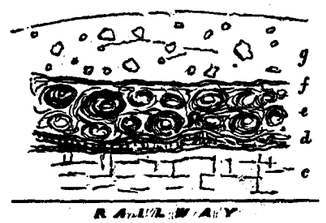
Section of Volcanic beds, in quarry, Ballypalidy.

(*g.*)	Drift, boulder clay.	
(*c.*)	Laminated shales of volcanic dust, in thin layers, and lying on an irregular surface of the next series (*b*) (worked for fluxing), from	5 to 8 feet thick.
(*b.*)	Volcanic agglomerate, of rounded and sub-angular pebbles of basalt and lava loosely accumulated (worked for fluxing), from	1 to 3 „ „
(*a.*)	Beds of brown and yellow fine grained mudstone evenly laminated, with occasional coarse bands of volcanic ash. In this numerous plant remains occur, more than . . .	12 „ „

The section in the railway cutting shows beds which are partly above, partly on the same horizon with those in the quarry, and is as follows:—

* Journ. Geol. Soc., Lond. vol. xxv., p. 357.
† Journ. Geol. Soc., Lond. vol. xxvi.
‡ By Dr. Ritchie of Belfast, who exports the material to be used as a flux in the iron furnaces.

Fig. 7. *Section in Railway, Ballypalidy.*



(*g.*) Boulder clay, and earth,	2 to 6 feet.
(*f.*) Band of lignite,	8 to 12 inches.
(*e.*) Spheroidal basalt,	4 to 5 feet.
(*d.*) Red and brownish bole and iron ore of irregular thickness, with plant impressions,	3 to 4 feet.
(*c.*) Bole, and volcanic ash (on the same level as the beds in the quarry),	5 to 6 feet.

An inspection of these beds cannot fail to lead to the conclusion that they have been stratified under water; and on a former occasion, I have expressed an opinion that they are of lacustrine origin, the materials having been originally blown into the air in the form of volcanic ashes, and afterwards deposited in the quiet waters of a lake.*

The plant remains, discovered in these beds by the late Mr. Du Noyer, and described by Mr. Baily, occur generally in the form of leaves, the impressions of which have been left on the bands of fine mud and bole, and agree with those previously obtained by the Duke of Argyle from the basalts of Mull; they determine the age of both to be Miocene. The following genera have been identified:—*Pinus, Sequoia, Cupressites, Platanus* (?) *Fagus* (?) *Andromeda* (?) *Quercus* (?) *Rhamnus* (?), together with which were found the elytra of small beetles.†

The railway section is traversed by three basaltic dykes, ranging in S. S. E. directions.

The following analysis of the plant layer in the quarry section has been made by Dr. J. Apjohn, F.R.S., of Dublin University, and is as follows:—‡

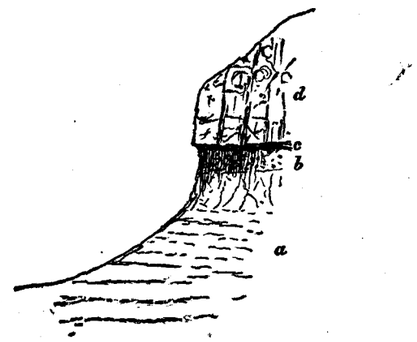
Water,	25·78
Silica with a little Alumina,	36·40
Peroxide of iron,	9·12
Alumina and other oxides,	28·70
Per-centage of metallic iron,	6·36

(2). *Lyle's Hill, near Templepatrick.*—This hill reaches an elevation of 747 feet, the higher portion being formed of the Upper Basalt, resting on pisolitic iron-ore and bole. These beds

* British Association Report (Belfast, 1874), Section C., p. 70.
† Baily, *Supra cit.*, p. 357, et seq. (with plate).
‡ Tate and Holden, *Sup. cit.*, p. 161.

are isolated, and crop out round the hill, except along the west where they are thrown down against the Lower Basalt along a fault ranging in a N.N.W. direction. At the time of our visit, in August, 1873, several small excavations had been made in the side of the hill for the purpose of testing the ore; at one of these the following sketch and section was taken:—

Fig. 8. *Section at Lyle's Hill, Templepatrick.*



(*d.*) Massive basalt, rudely columnar,	10 to 12 feet.
(*c.*) Band of clay,	4 inches.
(*b.*) (2) Pisolitic red iron-ore,	14 to 18 inches.
(1) Red aluminous ore (bole) of inferior quality,	4 feet.
(*a.*) Purple and reddish bole, lithomarge and clay passing downwards into amygdaloidal trap,	45 feet.

The ore here might be very easily worked by adits, and conveyed by a tramway laid down to join the Northern Counties Railway at Templepatrick.

(3). *Knowehead Section.*—At the farm of this name about 2 miles E. of Ballypalidy, occurs another outlier of the ash-beds somewhat similar to that at the latter place, but the section and actual area of the ground occupied is not very clearly defined. The columnar basalt seen in the quarry at the farm overlies the ash-beds; and Mr. Du Noyer states, that "Iron-ore was raised here by Dr. Ritchie. The bed consists of bole, and reddish mottled lithomarge."* This material has also been observed in small streams both to the north and south of Knowehead farm.

(4). *Ballymore District.*—This tract is by much the largest in the district, and passes into the sheet to the north (No. 20). It lies on the downthrow side of the great fault, which coincides with the valley of the Six-mile Water in the neighbourhood of Ballyclare. The out-crop has been traced by Mr. Duffin, either by surface indications or actual openings, from Lismenary to Baxterstown, where it is concealed under drift and bog, as shown on the map. The clearest out-croppings occur near M'Dowells-

* Written on Field Map.

town, and along the eastern slope of Ballymore Fair Hill, where the following section has been noted by Mr. Duffin:—

(*d.*) Upper Basalt.
(*c.*) Pisolitic iron-ore (about) 3 feet thick.
(*b.*) Red and ashy bole, mottled with white.
(*a.*) Deep purple lithomarge.

The dip is here W. 25 N. at 5°.

Irish Hill and Straid Hill.—This is another detached outlier of the iron-ore, and overlying lower basalt, extending from the southern flank of Irish Hill on the south, to the northern slope of Straid Hill, a distance of about a mile, with a diameter of about half that distance. The out-crop of the pisolitic ore, together with the underlying bole and lithomarge (of a purple colour, mottled white), are noted by Mr. Duffin at Irish Hill, the whole having a thickness of about 40 feet, resting on the Lower Basalt shown in an old quarry near the cross-roads; but I have no details regarding the thickness or quality of the ore itself. This completes the number of districts in Sheet 28, where the iron-ore occurs; but the finest sections are in the district to the north at Broughshane, near Ballymena, Shane's Hill, &c.

Antiville, near Larne (Sheet 21).—A small opening has been made by the banks of the little stream which descends into Larne Water from the north, near Antiville Bridge. The beds dip W. 10 S. at about 10°, and the upper basalt is seen overlying pisolitic iron ore, which again rests on red and purple bole and lithomarge.

The outcrop of the ore has been traced by Mr. Duffin for about a mile northwards from Antiville Bridge, where the beds are cut out by a fault which ranges in a N.E. direction.

As regards its continuation southward, there is every reason to suppose that on, or before, reaching the valley of Larne Water the ore, with its associated beds, is again thrown out by a large fault which coincides in direction with the valley itself; the beds on the south bank being below the horizon of the iron ore.

Black Hill, Glynn (Sheets 21 and 29).—The pisolitic ore in this district extends from a fault which ranges along the southern slopes of Glynn Hill southward, by Black Hill, nearly to the road which runs to the north of Black Hill Plantation. Its position here is, however, quite conjectural, as it nowhere outcrops beyond two openings that have been made on the hill-side, about half a mile N. of this road, which I visited, in company with Mr. Egan, in 1875. Mr. Egan supplies the following account:—"The openings (at the eastern outcrop) were made in two places, about 100 yards apart, the more southerly one being driven for some distance in along the bed of ore, which is said to average about 3 feet in thickness, with a dip to the west, and is underlaid by a bed of bole. The ore here, at least in part, is a rich brownish-red, compact mass, abounding in pisolitic grains of hæmatite, up to about one-fifth of an inch in diameter, and occasionally more. The other excavation was not carried on so far, the material met with being chiefly a light yellowish brown ochreous rock." The western outcrop, as shown on the map, is (in the absence of sections) quite conjectural.

Glenoe.—Indications of the presence of pisolitic ore occur in three or four localities amongst the hills west of Glenoe, namely (1), in the brook called "Raloo Water," near Merryland Farm, where "a layer of bole, among beds of amygdaloid, contains particles of what appear to be decomposed pisolitic ore."* It is probable, however, that this is only an accidental band. (2) Ballyvallagh, or Drummond's Hill, and Slimero, which seem to be formed of upper basalt, and where, S. of the road which runs in the valley between them, bole and iron ore is said to exist. (3) At Toppin, which is similarly situated. Here, near Bryan O'Neill's Well, a deep red ochre, with particles of iron ore, were observed by Mr. Egan, but the section is not sufficiently distinct to admit of certainty.

The following localities in Sheet 29 may also be noticed as containing ore of an inferior quality, occurring in casual beds, among the lower basalt. They are described by Mr. Egan:—

In a quarry at the east side of Lower Duff's Hill (2½ miles N.N.E. of Carrickfergus), pisolitic iron ore rests on the Chalk below the basalt. It was worked to a small extent during the last few years, and a number of tons shipped to England for smelting; but it contains impurities, chiefly in the form of large and small angular siliceous particles, derived no doubt from the flints in the Chalk. Two excavations were carried in under the hill, and the ore is said to have varied in thickness, from a few inches to five feet. It is a dark brownish-red mass, containing grains of hæmatite, and easily breaking up into fragments, having some of their surfaces polished and striated like a slickenside.

An impure ore exactly resembling the above, and also lying between the Chalk and basalt, exists in a quarry to the south of the reservoir N.W. of Woodburn Glen; and traces of it were observed in a similar position where the Chalk and basalt come together at the mill-pond N.E. of St. Catharine's.

In a section which occurs in a lane running northward by the old church, north of Woodburn Bleach Works, there is a band of bole of a bright red colour, containing grains of the ore. It is among beds of basalt and amygdaloid, and has an approximate thickness of 2 feet 6 inches.

Bole containing a little decomposed pisolitic ore, was observed in a small quarry at the N.E. of Lough Mourne; and ore of a better quality is stated to have been met with close at hand. In the former case the bed is 3 feet 6 inches thick.

Four hundred yards N.N.W. of Windygap National school (S. of Ballycarry), and close to the east side of the road, iron ore exists just below the surface. Of two specimens procured with difficulty, one is a red heavy mass with somewhat numerous grains of hæmatite. The other is a very compact liver-coloured lithomarge.

Finally may be noticed two beds among basalt and amygdaloid

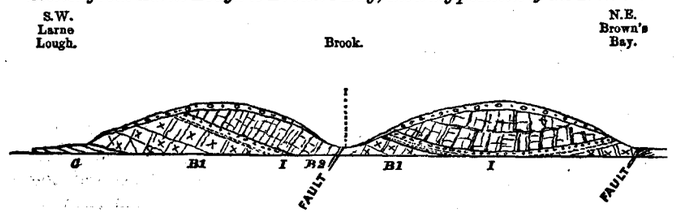
* Note by Mr. Egan on Map.

in the steep face of rock west of the railway tunnel at White Head. One of them, near the tunnel, is about one foot thick, and consits of a red mass varying in hardness, and in some parts containing many grains of iron ore. The other, higher up in the section, and a little farther to the west, is of a softer nature, of a bright red colour, and also contains many distinct grains of hæmatite.

*Ballylumford, Island Magee.**—The Upper Basalt iron-ore and its associated beds occupy two small areas at the northern extremity of Island Magee. The ore, bole, and lithomarge have for some years been worked in extensive excavations at Ballylumford Hill by Dr. Ritchie of Belfast, and exported to the English iron furnaces. The section here is well exposed at the pits, and consists of the following series—the whole dipping towards the N.E. at about 25°, in the direction of the fault which runs along the valley into Ferris Bay.

Fig. 9.

Section from Larne Lough to Brown's Bay, showing position of the Iron-ore.



B2. Upper basalt. I. Pisolitic iron-ore and bole. C. Cretaceous beds, &c. B1. Lower basalt.

Section at Ballylumford Pits.

	Thickness.
(*d.*) Decomposing concretionary basalt,	2 to 5 feet.
(*c.*) Pisolitic red iron ore,	2 ,,
(*b.*) Red bole (aluminous iron-ore), passing downwards into—	
(*a.*) Blue, purple and mottled lithomarge,	25 ,,

The following analyses of the bole and lithomarge at Ballylumford were supplied to Mr. Du Noyer by Dr. Ritchie:—

Analysis of Bole.

Silica,	8·92 per cent.
Titanic acid,	4·52 ,,
Peroxide of iron,	40·87 ,,
Alumina,	43·88 ,,
Magnesia,	0·53 ,,
Lime,	trace.

Analysis of Lithomarge, when calcined.

Silica, with titanic acid,	15·5 per cent.
Peroxide iron and alumina,	81·48 ,,
Magnesia,	3·06 ,,

Referring to this district generally, the authors of the "Guide to Belfast" state—that "on analysis of the pisolitic ores, they are

* The Geology of Island Magee is published on the Six-inch Map, Sheet 41 (co. Antrim), as well as on the One-inch Map, Sheet 21.

found to contain 30 to 65 per cent. of metallic iron, and a large per-centage of free alumina, without phosphorus or sulphur, and therefore of great value in the production of the higher qualities of iron and steel. The aluminous ore contains from 20 to 28 per cent. of metallic iron, and is extremely useful as a flux, and as a protection to the casing of the blast furnace"*

Ballycronan, Island Magee.—The other tract occupied by the ore and its associated beds in the Island is the higher portion of the ridge of Ballycronan, lying between the valleys which enter Ferris and Brown's Bays, but owing to the overspread of drift-clay and the absence of sections, the strata are seldom visible. The clearest evidence of the existence of these beds is obtained by the sections along the western slopes of Brown's Bay, where the Upper Basalt may be seen resting on pisolitic red clays, and underlying lithomarge beds of considerable thickness. Here indeed, those materials might be worked at less cost, and with greater facilities than at Ballylumford Hill, for they could be shipped directly from Port Narrow, within a few yards of the excavations.

From a consideration of the relations of the beds on the opposite side of Brown's Bay, it is clear that the valley coincides with the line of a large fault, along which the beds are thrown down on the west side. This fault brings the Chalk and Keuper Marls on the one side against the Lower Basalts on the other, and ranges in a S.S.E. direction, by Clover Vale, to Milltown, near which it enters the sea.†

A large basaltic dyke may be observed along the western shore of Brown's Bay, traversing the amygdaloidal basalt and lithomarge in a S.S.E. direction, and striking out to sea at Barr's Point.

Origin of the Iron-ores.—It is not my intention to enter upon a discussion regarding the origin of the pisolitic ores and their associated beds in this place, as I have already stated my own view of the subject in my address at the meeting of the British Association in Belfast.‡ I regard these beds as of lacustrine origin, and derived from basaltic uplands surrounding a series of shallow lakes. In the waters of these lakes was precipitated the iron, possibly by the agency of confervoid algæ, as in the case of the Swedish lakes of the present day, or by the escape of carbonic acid gas, owing to which the iron became oxidized and fell to the bottom.§

Upper Basaltic series.—Very little need be added to what has already been said regarding the tabular basalt which overlies the pisolitic ore in this district. The rock itself, except at Fair Hill (Sheet 28), near Ballynure, seldom attains any great thickness in the district here described, but it is found in all the spots described, overlying the iron-ore, bole, and lithomarge.

The mineral composition of the upper basalt varies but little

* *Supra cit.*, p. 60.
† See Six-inch Geological Map of Antrim, Sheet 41.
‡ Report of Section C., p. 70.
§ The views here stated closely agree with those of the authors of the "Guide to Belfast" (1874.)

from the lower. It is, however, more crystalline in general, and seldom occurs as an amygdaloid; in its massive state it, also, assumes the globular, or prismatic, structure. At Shane's Hill it may be seen forming the higher portion of the ridge, above the red band which marks the position of the iron-ores.

Volcanic "Necks."—The orifices through which the great beds of augitic trap have been extruded are but seldom visible, and when they do appear, generally occur in the form of a circular, or oval, boss of hard trap rising above the tabular sheets.

Fig. 10. *Carnmoney Hill.*

T. Lower basalt. L. Lower Lias.
C. Cretaceous beds. K. Keuper marls.

One of these old "necks," however, may be clearly made out at the southern edge of Carnmoney Hill, where it forms part of the escarpment, cutting through the basalt beds, the Chalk and the Keuper marls. It is about 400 yards across, and on its northern side is associated with volcanic ash, or agglomerate. The rock is a highly crystalline dolerite, the facets of the augite crystals being well developed and glistering; it also contains cavities filled with a curious pitchstone-like mineral of uncertain composition, and has consolidated with a radiate columnar structure. Mr. Du Noyer has recorded his opinion regarding the nature of this mass in the following note:—"I believe that this mass of columnar basalt represents one of the great pipes or feeders of the basaltic flows, and that the Chalk is absent here, but is present beneath the basalt on the flank of the hill in continuation of its observed outcrop."* It is in fact observable on the eastern flank of the hill, which is often dislocated by land-slips.

Two or more necks of basalt may be detected in the trachytic district north of Antrim; one of these, forming a small boss of columnar basalt, occurs in an isolated position at the southern foot of Carnearney Hill. Another still larger mass is the isolated boss of Scolboa Upper; but though the relation of the basalt to the trachyte indicates the existence of a "neck," the evidence is not quite conclusive.

Besides the old necks of Carnmoney and Scolboa, there is another at Ballygally Head, N. of Larne; but this is just outside the district, and will be described at another time. The peculiar round boss of basalt which rises above high-water, on the coast of Belfast Lough, known as Green Island, appears to be another of these old necks. Here it penetrates New Red Sandstone, and differs greatly in shape from the longitudinal dykes which

* This note bears date 1868, and is recorded on the Field Map.

occur in considerable numbers in that neighbourhood (see below). It is traversed by numerous cross joints, and is excessively firm. Other necks there may be in the district itself, which have not been identified; and whatever may have been the nature and magnitude of the volcanic cones which originally surmounted these "necks," we have no evidence regarding them, as the cones themselves have been completely obliterated by denudation.*

Basaltic Dykes.—These are exceedingly numerous in certain localities, traversing all the strata from the New Red Sandstone up into the bole, and iron-ore; but I am not acquainted with any case in the district here described where they traverse the upper sheets of tabular basalt, though such probably occur elsewhere.

These dykes are remarkably numerous along the shores of Belfast Lough, from Fort William to Carrickfergus, particularly from that part between White House and White Abbey, and in the banks of the stream descending to the sea at this latter place. In general they range in north-westerly directions, striking out to sea in long low walls of hard rock, traversing the softer sandstones of the Trias. On the six-inch map, Mr. Du Noyer has drawn these dykes with great skill, showing their varied forms and directions. Some are straight, but most of them have a slightly wavey outline, while others send off branches. There is one long dyke, below Copeland View and Ballynascreen House, which traverses the others in a N.E. direction parallel to the coast at this place. The boss of basalt, called Green Island, occurs in this district and, as already stated, has all the appearance of an old volcanic neck.

At Cave Hill quarries, numerous basalt dykes are seen penetrating the Chalk, and a few yards from the townland boundary one of these dykes traverses both the Chalk and the tabular basalt from which it differs in being of a more compact texture.

Perhaps the largest of the dykes in this district is the rock on which is built the massive walls of Carrickfergus Castle. At its seaward extremity it bifurcates, the branches extending out to sea. Northward it may be traced by the masses near the church, and on the north side of High-street; on the side next the harbour, it rises above the ground as a wall of rock. Mr. Du Noyer thus describes this dyke:—

"The coarsely crystalline basalt, on which the castle stands, is generally supposed to extend northward to the quarry at Rock View, a distance of three quarters of a mile; it is possible that the same dyke appears at Sulatober to the north.

"Along the shore at the extreme southern point of the castle the red and green marls, and thin sandy layers in contact with the dyke, are hardened and converted into a *gray grit* to a distance of two or three feet from the trap. Close to the base of the pier, the marls resemble gray ribboned slate where they touch the trap; in other places their bedding

* I have attempted a restoration of the physical features of the volcanic district of the N.E. of Ireland in my Presidential Address to the Royal Geological Society of Ireland, 1874. See Journ. Roy. Geol. Soc., vol. iv., part i. (New Ser.), p. 20.

is obliterated by the metamorphic action of the basalt. On analysis, the hardened shale, or 'gray grit,' was found to contain ten per cent. more silica than that which was not indurated, and which retains its red colour. The analysis was made by Mr. J. Hunter, of Queen's College, Belfast.*

Several other narrow dykes of basalt and dolerite occur west of the castle, and in the strand below Sea Park.

At Black Head, several dykes are to be seen penetrating the Chalk and overlying basalt, and at Bonnybefore, several narrow ones traverse the Keuper marls in S.S.E. directions out to sea. At Cloghan Point, near White Head, a massive dyke traverses the railway, and ranges out to sea, into which it may be traced by a series of basaltic blocks rising above the strand and called, "The Briggs or Pots of Kilroot." The dyke has a tendency to assume the horizontal columnar structure.

The coasts of Island Magee, at intervals show dykes of basalt traversing strata from the Keuper marls up to the lower basaltic sheets. One of those on the east coast in the townland of Balloo, is twenty-five feet wide, and inclined 30° from the vertical. It ranges nearly north out to sea, and is cut across by another dyke-like mass of dark basalt, which ranges E. and W. At Portmuck Bay, a dyke about twelve feet wide traverses the Chalk and overlying basalt, and at Port Narrow, in Brown's Bay, a dyke about fifteen feet wide may be traced to Barr's Point, cutting through the nearly horizontal sheets of amygdaloid.

Of the few dykes which can be observed traversing the tabular trap district of the interior, that of Donegore is the most remarkable. It forms at the surface a series of knolls, of which Donegore Moat is one, and may be distinguished from the sheets of trap which it traverses by its more crystalline structure; the latter being generally amygdaloidal. North of Loughermore House, it is supposed to bend round to the east so as to be connected with the crystalline basalt which appears in the knoll above Ballybentragh; but this is hypothetical.

Judging by the large number of these vertical, or highly inclined, dykes which are visible where sections are cut down into the older strata of this district, the actual number concealed from view by superficial accumulations, or which never reach the surface, must be very great. They are widely distributed all over the north of Ireland, the adjoining districts of Scotland, and the north of England, and are probably referable to the age of the later Miocene basalts, when some of the mass of molten matter, which was unable to escape through the volcanic necks of the period, was forced into the gaping fissures which were opened in the solid strata during this period of intense volcanic energy.

DRIFT DEPOSITS.

Lower Boulder Clay and Sand.—These superficial deposits overspread the greater portion of the district under description, and are represented on that map by engraved dots. They occupy all the low-lying country along the shores of Lough

* From Notes on Field Map by Mr. Du Noyer.

Neagh, with the exception of a few isolated spots, together with most of the sloping land stretching from the shore of Belfast Lough to the base of the basaltic escarpment. They are also thickly spread over Island Magee.

On ascending the higher elevations, such as Carnearney, Drumadaragh, Fair Hill, Carnbilly, Knockagh, Carnmoney, and the heights extending from Cave Hill southward, we find the solid rock reaching the surface. In such places, the Drift has been but sparingly (if at all) deposited, and has suffered more rapid denudation than in the less exposed situations. Along the bottoms of the hollows and river valleys these beds attain a thickness of perhaps 20 feet, or more. In the banks of Three-mile Water they have a thickness of 40 feet.

The Drift formation consists in this district of, at least, two members; the older being the Lower Boulder Clay; the newer, the stratified Sands and Gravels. In some districts, however, there is a third member, consisting of an Upper Boulder Clay; but I have no certain knowledge of its presence in that of Antrim, here described,* unless that in Masserene Park, of which the following, by Mr. Duffin, is a section:—

Drift Section, Masserene Park.

	Thickness.
a. (*Upper Boulder Clay?*)—Drift clay, containing small water-worn pebbles and sand,†	5 feet.
b. (*Interglacial Sands, &c.*)—Fine silt and sand, showing a stratified appearance, &c.,	6 „
c. (*Lower Boulder Clay.*)—Clay containing basalt blocks and other stones (bottom not seen),	3 „

The Lower Boulder Clay.—This is the lowest member of the Drift series, and generally consists of red or dark clay, very stiff and solid, without lines of stratification, and containing numerous pebbles and boulders of transported rock, such as basalt, schist, and chalk. It is generally allowed to be an ice-formed material, and when found directly resting upon solid rock, this latter is frequently found to present a surface more or less glaciated; and often showing grovings, or scorings, indicating the direction in which the ice has moved. The thickness of the boulder clay may be 20 to 30 feet; and in the valley of the brook which follows the northern base of Carnmoney Hill, the thickness may be even greater.

The Interglacial Sands and Gravels.—In the district around Antrim, these beds are not very largely distributed. The section in Dunnore River, Masserene Park, has already been noticed. These beds are truly stratified, and consist of water-worn sands, gravels, and occasionally laminated clay. Marine shells are sometimes found in them, of species and genera inhabiting existing seas. A section of these beds is shown in Lisnalin Burn, and in the railway cutting half a mile south of Antrim station.

* That this Upper Boulder Clay occurs in the adjoining counties of Tyrone, Armagh, and Derry, is shown by Mr. Hardman in his paper, "On some new localities for Upper Boulder Clay in Ireland."—Journ. Roy. Geol. Society of Ireland, vol. iv. (New Series), p. 73.

† Mr. Duffin adds, "evidently deposited by water."

The Upper Boulder Clay.—Clear sections in the valleys where the drift is thick would probably disclose this sub-formation. Though it resembles the Lower Boulder Clay in some respects, it is generally less stiff, and exhibits signs of bedding. It was the last of the truly glacial deposits of the Post Tertiary Period.

Raised Beach.

At intervals along the coasts of Antrim and Down, and as far south as Dublin Bay,* small terraces of shelly gravel occur, from 5 to 15 feet above the highest spring tides. The shells which they contain are blanched, and generally fragmentary, but of species living in the adjoining seas; and as the beds which contain them were evidently at one time formed in the waters of the sea, their existence now considerably beyond their reach proves that the coast has been recently raised.

Accompanying these terraces of gravel are also to be observed old sea-cliffs, penetrated by caves now never reached by the sea, and at Ballycastle, Red Bay, Glenariff, Island Magee (see fig. 11), and elsewhere, sea-stacks may be observed which cannot be referred for their formation to the action of the sea-waves when at their present position with regard to the land.

Fig. 11.

Old Sea-stack and Cliffs of raised Coast-line near Castle Robin, Island Magee.

On a former occasion† I have shown that this raised beach and coast corresponds with that which is so well known as "the 25-feet beach" of Scotland; and although it may be identified in other localities, it is nowhere more strikingly developed than in the district included in this memoir, the principal localities being the Curran at Larne, and Kilroot—where the shells have been examined and determined by the Rev. Dr. Grainger, amongst those from several other localities.‡

* Explanatory Memoir to accompany sheets 102 and 112 (2nd Edit.), p. 69.
† British Association Report, 1872 (Brighton), Trans. of Sections, p. 113.
‡ "Natural History Review," vol. vi.; also Brit. Assoc. Report for 1874, Trans. of Sections, p. 74. In this paper Dr. Grainger has included both shells from the raised beach, as well as those from the interglacial gravels at Howth, Ballybrack, &c., which belong to a different formation.

The most remarkable circumstance is the occurrence in both these places, but especially in the latter, of worked flint implements of "palæolithic" age, specimens of which are in the collection of the Geological Survey.*

The Curran, Larne.—The gravel of the raised beach forms here a terrace from 10 to 15 or 20 feet above high water, and has been laid open in the railway cutting as well as along the road from the town to the harbour. From this bed Dr. Grainger has collected the following†:—

Post Tertiary Shells from Larne.

Anomia ephippium.	T. cinerarius.
Ostrea edulis.	T. zizyphinus.
Pecten varius.	Litorina obtusata.
Cardium edule.	L. rudis.
Kellia suborbicularis.	L. litorea.
Lucina borealis.	Turritella terebra.
Tapes pullastra.	Cerithium reticulatum.
Tellina tenuis.	Purpura lapillus.
Corbula gibba.	Buccinum undatum.
Saxicava rugosa.	Nassa reticulata.
Solen pellucidus.	N. pygmœa.
Patella vulgata.	Cliona (borings).
Trochus magus.	

Kilroot Section.—The raised terrace here has been laid open in gravel pits near the railway station, and may also be observed along the coast, where the shelly gravels will be seen resting on stiff bluish estuarine clays of older date with oyster shells. These clays are very extensive in the estuary of Belfast Lough, and large numbers of shells have been determined by Mr. Stewart and Dr. Grainger, some of which have disappeared from the neighbouring seas. The shells of the raised beach are of more recent date, and are as follows:—*Anomia ephippium, Cardium edule, pecten maximus, Buccinum undatum, Cerithium reticulatum, Nassa reticulata, Patella vulgata, Litorina litorea, L. litoralis, Trochus umbilicatus.*

During the progress of the Geological Survey in this district in 1867, the late Mr. Du Noyer discovered numerous flint arrow-heads and other implements of palæolithic age in the gravels of Larne, Magheramurne, Kilroot, and Island Magee, an account of which he has given in the pages of the Journal of the Geological Society of London,‡ where he draws the conclusion that before the raising of the coast, this district was the seat of the manufactory of these implements, owing to its proximity to the Chalk formation from which the materials were derived. The specimens from Magheramurne are exceedingly rude and of small size, such as may have been used for arrow-heads or lances. Those of Kilroot are larger and more carefully worked, and

* In the galleries of the Royal College of Science, along with which are some shells from the beds partly collected by myself in 1871.
† Brit. Assoc. Rep. 1874, Trans. of Sections, p. 75. (Specimens of these shells are in the cabinet of Dr. Grainger.) From the estuarine clays a large number of species have been identified by Dr. Grainger and Mr. S. A. Stewart—"List of the Fossils from the Estuarine Clays of Down and Antrim, 1871."
‡ Vols. xxiv. and xxv.

were probably used as hammers or hatchets, or for clubs in warfare, while the smaller chips were used as arrow-heads.

Caves of the Palæolithic Period.—Along with other phenomena accompanying the raised coast, are the caves found penetrating the old sea-cliffs, and now beyond the influence of the surf or waves. At the entrance to Red Bay, on the north side, are very interesting examples of such caves hollowed out of red sandstone. Still further south, we have cases along the coast north of Larne, where the caves have been excavated in basalt, and others of a similar nature along the eastern coast of Island Magee. In similar caves at the Port of Ballintoy on the north coast, bones of the horse, ox, deer, sheep, goat (?), badger, otter, water-rat, &c., were discovered some years ago by Dr. James Bryce, F.G.S., and Dr. M'Donnell,* and it is not improbable that the exploration of those which remain may reward the explorer by further discoveries. It will probably be found that these caves have been hollowed out along some joint or fissure, which has given rise to a plane of weakness; while the waves have made use of the rolled pebbles and blocks of rock strewing the bottom as tools wherewith to carry out tunnelling operations.

Faults or Dislocations of the Strata.

The faults which traverse the rocks of this district belong to two systems—one, including the larger number, having a N.N.W. direction, the other a S.W. direction, nearly at right angles to the former. There is nothing to show that these two sets of fractures are not referable to the same geological period, viz., the interval between the Miocene and Pliocene. They are later than the Miocene basaltic sheets which they traverse, and they are earlier than the Pliocene clays of Lough Neagh.

Of the N.N.-Westerly system, the most important examples are—(1) The large fault which traverses Island Magee through nearly its whole length from the sea at Milltown to Brown's Bay, with a downthrow on the eastern side. (2) A fault crossing the neck of land between Isle of Muck and the coast, with a downthrow on the east side. (3) The fault which enters Ferris Bay from the south, with a downthrow on the western side by which the upper basaltic sheets are thrown down against the lower. (4) The channel between Larne Harbour and Island Magee also appears to be in the line of a fault, by which the basalt on the east side is thrown down against the Keuper Marls on the west. This fault is accompanied by a sharp anticlinal axis.

On the mainland there are several faults in the district between Larne and Belfast Lough, which are indicated by the relative position of the strata on either side. Of these the principal are—(1) The Copeland Water Valley fault, which, after crossing the watershed at Beltoy, enters the valley of the Glynn, which

* Trans. Brit. Association (1834), p. 658. Dr. Bryce considers that the caves were the abodes of man at the period when the bones were entombed, and that their presence is due to this agency.

it follows for some distance. This fault has a general downthrow to the east, as all the formations on the one side are on a newer horizon than those on the other. The map explains this sufficiently. (2) Another fault ranges along the western side of Lough Mourne, with a downthrow on the east, and another (3) strikes across the ridge above Carrickfergus, and ranges by Carneal Bridge northward.

The faults belonging to this system in Sheet 28 are not numerous as far as the evidence goes; but there may be more than those actually determined. Two small faults traverse the beds at Ballypalidy. These have the downthrow on the west side. A third traverses Lyle Hill, displacing the iron-ore and upper sheets of basalt. The downthrow is on the N.E. side.

South-Westerly System.—The great fault which follows the Valley of the Six-mile Water from Templepatrick northward belongs to this system; and at this point, where it brings the trachyte and Chalk on the one hand against beds only a little below the Ballypalidy series on the other, the downthrow on the south must be 400 to 500 feet. At the N.E. corner of the sheet, the upper basalt and subordinate bole and iron-ore beds, are cut off against the lower basalt by a fault, as shown by the map.

Another fault ranges along the Valley of Larne Water (sheet 21), having a downthrow on the N.W. by which the upper basalt together with the iron-ore and bole is thrown out on the south side of the valley. Another fault ranges through Ballyhampton, throwing out the same beds on the north side.

Palæontological Notes.

Localities from which Fossils were collected.

No. of Locality.	Quarter Sheet of 6-inch Map.	Townland.	Situation, Geological Formation, and Sheet of 1-inch Map.
		County of Antrim.	Sheet 21.
1	35/2	Ballygalley, . .	A little south of Ballygalley Head, three miles north of Larne; Chloritic sandstone; (Upper Chalk).
2	35/4	Black Cave, South,	Rocks on shore at Waterloo House, one mile north of Larne; Lower Lias.
3	35/4	Black Cave, South,	Road cutting near Waterloo House, a little west of preceding locality; Red Mulatto stone; (Upper Greensand).
4	35/4	Curran and Drumaliss.	Rocks on shore, a little east of Waterloo House; Lower Lias.
5	40/2	Glynn, . . .	On shore and in railway cutting about half a mile north of Glynn, and one and a quarter miles south of Larne; Lower Lias.
6	40/2	Curran and Drumaliss.	On shore three quarters of a mile north-east of Larne; Rhætic.
7	40/2	Inver, . . .	A little south of Larne; whitelimestone; Up. Chalk.
8	41/1	Ballydown, . .	West shore of Island Magee, three quarters of a mile north of Mill Bay; white limestone, and chloritic sandstone, (Upper Chalk); and glauconitic sands, Upper Greensand.
9	41/3	Kilcoanmore, . .	On shore at White House, west side of Island Magee; Lower Lias.

LOCALITIES from which FOSSILS were collected—*continued.*

No. of Locality.	Quarter Sheet of 6-inch Map.	Townland.	Situation, Geological formation, and Sheet of 1-inch Map.
10	41/3	Kilcoanmore, . .	Near Kilcoan school-house, quarter of a mile north-east of White House, Island Magee; chloritic sandstone; Upper Chalk.
11	41/3	Ballylig, . .	Large quarry at Magheramorne railway station, four miles south-east of Larne; white limestone; Upper Chalk, and Pleistocene on shore. Sheet 28.
12	51/1 and 51/3	Townlands of Ballyhartfield and Ballymartin.	On each side of Belfast and Northern Counties Railway, one mile and a quarter west of Ballypalidy station; Miocene.
13	56/4	Ballyaghagan, .	East end of Cave Hill quarry, south of Cave Hill, about two miles N.N.W. of Belfast; Rhætic beds.
14	56/4	Ballyaghagan, .	Rocks in stream west of Cave Hill; Lower Lias.
15	56/4	Ballyaghagan, .	Cave Hill quarry; glauconitic sands, chloritic sandstone, and white limestone; Upper Chalk.
16	56/4	Upper Ballysillan, .	One mile north-east of Ligoniel, chloritic chalk; Upper Chalk.
17	57/1	Roghfern, . .	East of Carnmoney Hill, quarter of a mile north-west of Rathfern; chloritic sandstone, and white Limestone; Upper Chalk.
18	57/3	Drumnadrough, .	White Well quarry, one mile north-west of Whitehouse; white limestone; Upper Chalk.
		SHEET 29.	
19	47/1	Redhall, . .	A little north-east of Ballycarry, about five miles north-east of Carrickfergus; chloritic sandstone; Upper Chalk.
20	47/4	Cloghfin, . .	Rocks on shore at Cloghfin Port, quarter of a mile north of Black Head; chloritic chalk; Upper Chalk
21	47/4	White Head, . .	At White Head quarry, about five miles north-east of Carrickfergus; chloritic sandstone and white limestone; White Chalk.
22	52/2	Middle Division, .	Rocks in Woodburn River, north of Bryantang Brae, two and a half miles north-west of Carrickfergus; Rhætic.
23	52/2	Middle Division, .	Rocks in Woodburn River, north of Bryantang Brae, two and a half miles north-west of Carrickfergus; glauconitic sands; Upper Greensand; chloritic sandstone and white limestone; Upper Chalk.
24	52/2	West Division, .	South of Bryantang, at south end of Belfast Waterworks Tunnel, three miles north-west of Carrickfergus; glauconitic sands; Upper Greensand; and chloritic sandstone; Upper Chalk.
25	53/1	Knocknagulliagh, .	North of Cloghan Point in railway cutting, half a mile south-west of White Head; Rhætic.
26	53/1	Knocknagulliagh, .	Cliff above railway cutting near preceding locality; chloritic sandstone; Upper Chalk.
27	53/1	Knocknagulliagh, .	At Cloghan Harbour, a little south of preceding locality; chloritic chalk; Upper Chalk.
28	53/1	Knocknagulliagh, .	In field south-west of Seamount, about four miles north-west of Carrickfergus; chloritic sandstone; Upper Chalk.
29	53/1	Kilroot, . .	A little south-east of Castle Dobbs, three miles north-east of Carrickfergus; chloritic sandstone.
30	53/1	Kilroot, . .	On shore near Kilroot Railway Station; Pleistocene.

LIST of the SPECIES of FOSSILS collected from the LOCALITIES mentioned in the preceding TABLE.

The numbers opposite each species refer to those attached to the localities.
The mark × placed before a number is intended to show the comparative abundance of the species at that locality.

RHÆTIC OR PENARTH BEDS.

ECHINODERMATA.—*Ophiuroidea.*

	Localities.
Ophiolepis Damesii (Wright), . . .	6.
MOLLUSCA.—*Conchifera.*	
Anomia irregularis, ...	13.
Avicula contorta, ...	6, ××× 22, ××× 25.
Axinopsis Ewaldi (Axinus cloacinus), . .	6, ××× 22, ××× 25.
Cardium Rhæticum, ...	6, ×××× 13, 15, 25.
Cucullæa Hettangiensis, ...	13.
Lima precursor, ...	6.
,, Valoniensis?	6.
Mytilus Hillanus, ...	13.
,, minutus, ...	13, 25.
Ostrea irregularis, var. Liassica, . . .	×××× 13.
Pecten Valoniensis, ...	×× 6, 15.
Placunopsis Alpina, ...	25.
Pleuromya crassa?	13.
Gasteropoda.	
Solarium Thomsoni, ...	×× 22.
PISCES.	
Gyrolepis Alberti, ...	×××× 22.
,, tenuistriatus, ...	22.

LOWER LIAS.

PLANTÆ.

Fossil wood with Extracrinus Briareus, . .	9.

ACTINOZOA.—*Corals.*

Montlivaltia Haimei, ...	9.*
,, mucronata, ...	9.*
,, papillata, ...	9.

ECHINODERMATA.

Cidaris Edwardsii (spines and plates), . .	9.
Extracrinus Briareus (joints and stems), .	×× 5, 9 *
Pentacrinus, sp. indet.	9.
Hemipedina Bechei (spines), . . .	×× 4, 5, 9.

ANNELIDA.

Serpula socialis, ...	9.
,, sp. indet.	9.

MOLLUSCA.—*Brachiopoda.*

Terebratula numismalis (Waldheimia), . .	9.
,, punctata, ...	9.
Conchifera.	
Anatina longissima (Panopæa elongata), .	9.*
Astarte Geuxii (A. tetragona, Portl.), . .	2, 9,* 14.
Avicula novemcostæ (A. inæquivalvis), . .	5.

* The asterisk placed after a number is intended to show that the species also forms part of the typical Portlock collection of Irish fossils at the Museum of Practical Geology, London, which I have examined.

	Localities.
Cardinia crassiuscula,	9.*
„ ovalis,	2, ××××9.*
„ „ var. hybrida,	2, 5.
„ „ var. Listeri,	9.*
Cardium Rhæticum (C. truncatum. Sow),	5.
Cucullæa Hettangiensis,	9.
Leda tenuistriata (Nucula rostralis, Goldf.),	9.
Lima gigantea (and L. punctata, young of do.),	× 2, ×××× 9, 14.
„ Hettangiensis (L. duplicata, in Portl.),	9.*
„ *pectiniformis* (*L. proboscidea*),	2, 9.*
„ pectinoides,	5, 9.*
Myacites, sp. indet.	4, 9.
Mytilus Hillanus (Modiola),	9.
„ minimus „	××× 9.
„ minutus „	9.
„ scalprum „	9.*
Perna (Avicula Pattersoni, Tate),	9.
Thracia, sp. indet.	9.
Ostrea arcuata (Gryphæa incurva),	×××× 2, 5, 9.*
„ arietes (Turquemia),	9.
„ irregularis,	5, ××× 9.
„ MacCullochi (Gryphæa bullata),	9.*
„ sp. indet.	2.
Pecten cingulatus,	2, 9.
„ dextilis (P. sublævis),	9.*
„ texturatus,	9.
Pholadomya ambigua,	9.
Placunopsis alpina,	2.
Unicardium cardioides,	2, 5, 9.
Gasteropoda.	
Cerithium constrictum,	9.
„ decoratum,	9.
„ tenuicostatum,	9.
„ sp. indet.	2, 5, 9.
Chemnitzia Henrici,	9.
„ sp. indet.	9.
Cylindrites ovalis,	9.
„ sp. indet.	9.
Dentalium Portlocki,	9.
Pleurotomaria similis (P. anglica),	9.
„ sp. indet.	2.
Cephalopoda.	
Ammonites angulatus,	9.*
„ Johnstoni,	2, ××× 9.*
„ planicostatus,	9.
„ planorbis,	×××× 4, 9, 14.
Nautilus, sp. indet.	9.

UPPER CRETACEOUS: UPPER GREENSAND.

"Mulatto Stone," "Glauconitic Sands."

ANNELIDA.

Serpula antiquata,	15.

ECHINODERMATA.

Ananchytes ovatus,	23.

MOLLUSCA: *Brachiopoda.*

Rhynchonella latissima,	23.
Conchifera.	
Avicula Rauliniana?	23.
Exogyra conica,	××× 8, ×××× 15, ××× 23, ××× 24.
„ harpa,	23.
Ostrea, sp. indet.	24.
Pecten orbicularis,	8, 15, × 23, 24.
„ quinquecostatus,	×× 15.
„ sp. indet.	24.

PISCES.

	Localities.
Fish scales, indet.	23.
Lamna, sp. indet. (tooth),	24.

UPPER CRETACEOUS: UPPER CHALK.

"Chloritic Sandstone"; "Chloritic Chalk;" "White Limestone."

PROTOZOA: *Spongida.*

Achilleum fungiforme (Goldf.),	19
„ sp. indet.	21, 23, 26, 28.
Cephalites alternans,	? 16, 21.
„ campanulatus,	? 16.
„ compressus,	21.
„ guttatus,	21.
„ longitudinalis,	21.
„ sp. indet.	15, 23.
Cliona cretacea, perforating Belemnitella mucronata,	7, 18, 21.
Coscinopora globularis,	19, 27.
„ infundibuliformis,	? 1, 8, 19.
Scyphia, sp. indet.,	15, 18, 21.
Siphonia terebrata,	20.
„ sp. indet.,	10, 19, 23, 24, 29.
Spongia, sp. indet.,	16.
Ventriculites alternans (bicomplicatus),	8.
„ decurrens,	8, 15, 16, 17, 19, 21, 26.
„ mammillaris,	10, 15, 16, 21, 23, 26, 29.
„ muricatus,	? 16.
„ radiatus,	11, 16, 18, 21, 26.
„ striatus,	? 20, 29.
„ tenuiplicatus,	18, 21.
„ tessellatus,	11, 15, 16.
„ sp. indet.,	16, 21.

CŒLENTERATA: *Actinozoa.*

Parasmilia centralis,	26, 27.

MOLLUSCA: *Polyzoa.*

Eschara, sp. indet.,	8.
Holostoma contingens,	11.
Brachiopoda.	
Terebratula carnea,	× 3, 8, 11, 15, 18, × 19, 21, 23, 26, 27, ×× 29.
„ semiglobosa,	× 3, 8, 10, 19, 21, 23, 27.
Rhynchonella plicatilis,	× 3, ×× 8, 11, 15, 18, 19, × 21, 23, 24, 26
„ limbata (? young of plicatilis),	7, 8, 10, 11, 15, 21, 27, 28.
Lamellibranchiata.	
Exogyra columba junr.,	19, 29.
Inoceramus Crispi ?	? 8, 10, 15, 16, 17, 18, 19, × 21, ×× 23, 26, 29.
Lima, sp. indet.,	15, 21, 27.
Lucina? „	29.
Ostrea semiplana,	15, 23.
„ vesicularis,	3, 18, 21, 23, 24, 26.
Pecten quinquecostatus,	1, 3, 8, 10, 21, 23.
„ sp. indet.,	3, 24
Periploma (D'Orb.), sp. indet.,	27.
Pholadomya decussata (Esmarckii),	11.
Spondylus spinosus,	1, 3, ×× 8, 10, 11, 15, 17, × 19, 21, ×× 23, 24, 26, 27, × 29.
Gasteropoda.	
Pleurotomaria perspectiva,	15.
„ sp. indet.,	8, 23, 26.
Cephalopoda.	
Ammonites Lewesiensis,	× 21.
„ Oldhami,	15.
„ Portlocki,	15.
„ sp. indet.,	29.

	Localities.
Baculites anceps,	15.
Belemnitella mucronata,	7, ×× 8, ×× 11, 15, ×× 16, ×× 17, ×× 18, × 21, ×× 22, 23, ×× 27.
,, plena,	? 21.
,, quadrata,	21.
Nautilus, sp. indet.,	15, 23.
Annulosa: *Echinodermata.*	
Ananchytes ovatus,	1, ×× 8, 10, 11, 15, × 16, × 19, 20, × 21, 23, 27, 29.
Cidaris clavigera,	26.
,, vesiculosa,	? 19.
,, sp. indet.,	11, 27.
Cyphosoma corollare,	15.
Galerites albo-galerus,	1, 8, 11, 15, 21, 26.
,, sub-rotundus,	? 15, 19, ? 29.
,, sp. indet.,	26.
Micraster cor-anguinum,	8, 17, 19, 24.
Annelida.	
Serpula avita,	? 26.
,, plexus,	10, 23, 28.
,, sp. indet.,	26.
Vertebrata: *Pisces* (Fishes).	
Gyrodus angustus (palatal tooth),	23.
Lamna acuminata (teeth),	19, 28.
Otodus appendiculatus (tooth),	23.
Oxyrhina Mantelli, ,,	21.
Ptychodus latissimus (palatal teeth),	15, 19.
***Reptilia* (Reptiles).**	
Sauroid bone ? Plesiosaurus,	23.

Remarks on the Fossils.

In the preparation of the foregoing list of species from the district included in Sheets 21, 28, and the northern part of Sheet 29, the valuable collection of fossils made by the Ordnance Survey, under the late General Portlock, has been consulted, including the typical specimens now in the Museum of Practical Geology, London, and part of the same series retained by the Geological Survey of Ireland. More recent and extensive collections have since been made by myself and assistant in the Palæontological department, Mr. A. M'Henry.

Much information has been also derived from the publications of Professor Ralph Tate, A.L.S., whose communication to the Geological Society of London on the Rhætic and Lower Liassic Rocks of the neighbourhood of Belfast, and on the cretaceous formations of the north-east of Ireland have been already cited.* Since then that gentleman has also published a list of Irish Liassic fossils, with notes on new and critical species.† I have also to acknowledge the assistance derived from a personal examination of the extensive collection of fossils from this district, made by the Rev. John Grainger, D.D., of Broughshane, who has always interested himself in Irish Palæontology.

* Expl. Sheet 36, Geol. Surv. of Ireland, p. 15.
† Belfast Naturalists' Field Club, September, 1870.

In the explanation to Sheet 36 (Palæontological remarks) fossils of identical species are enumerated from Rhætic and Cretaceous strata at Collin Glen near Belfast, and other places in the counties of Antrim and Down. What is now called "Rhætic," "Penarth," and "Avicula contorta" beds was formerly considered as constituting the base of the Lias, being included with that formation as the lowest division of the Jurassic or Oolitic series. In England it forms the lowest beds of the Lias at Aust Cliff, and Westbury-on-Severn, Gloucestershire, occurring also near Wells and Ilminster, Somersetshire, also in South Wales. It is the opinion of some geologists, in which I fully concur, that this series of deposits, like that of the Permian, is not of sufficient importance to constitute a separate formation, exhibiting merely a graduation of the Lias into the marls of the Upper New Red Sandstone formation. Several of these so termed Rhætic species are also common to the true Lower Lias.

A small well preserved Echinoderm belonging to the Ophiuroidea, from a marly deposit of these Rhætic beds at locality 6, I believe to be identical with *Ophiolepis Damesii*, described by my respected friend Dr. Thomas Wright, F.R.S., the eminent authority on this class of animals; the original specimen having been forwarded to him for description from North Germany.* He informs me that the same species was found at Garden Cliff, Westbury-on-Severn, and in the Avicula contorta beds near Nottingham. Rhætic species of fossils such as *Avicula contorta*, *Axinopsis Ewaldi*, *Pecten Valoniensis*, *Cardium Rhæticum*, *Solarium Thomsoni*, and fish remains, *Gyrolepis Alberti*, were abundant at localities 6, 13, 22, and 25.

From the Lower Lias clays of Island Magee (locality 9), three small, simple, discoidal, and depressed corals, two of them in the Portlock collection at the Museum of Practical Geology, London, viz., *Montlivaltia Haimei* and *mucronata*, the third, *M. papillata*, being in part of the same collection belonging to this branch of the Geological Survey.

Cardinia ovalis and its varieties, *hybrida* and *Listeri*, with *Astarte Geuxii* (*A. tetragona*, Portl.), are found in great abundance and most perfect condition, with both valves united, at the same locality, accompanied by *Lima gigantea* and other fossils; amongst them small univalve shells referred to *Cerithium*, *Chemnitzia*, and *Cylindrites*, also the characteristic and much larger species *Pleurotomaria similis* (*P. anglica*), with *Ammonites Johnstoni*, *planicostatus*, and *planorbis*, and a species of *Nautilus*.

The oldest strata of the Irish Cretaceous series is what is locally called "Mulatto Stone" or "Glauconitic Sands." The fossils of this deposit are identical with those of the Upper Greensand of England. In this district it occurs at Island Magee (locality 8), Cave Hill Quarry (15), Woodburn River (23), and south of Bryantang, near ditto, (24). The characteristic Ostreoid shell *Exogyra conica* is remarkably abundant at all these localities, with *Pectens orbicularis* and *quinquecostatus* at loc. 15. What is called "Chloritic Sandstone" and "Chloritic Chalk" appears to be merely a lithological peculiarity of the Upper Chalk, which is locally termed "White Limestone," being much harder and more compact than the Chalk of England. The fossils from each of these deposits are equally Upper Chalk species. Of the Spongida, *Cephalites*, and *Ventriculites* were frequent at localities 16 and 21.

The characteristic Upper Chalk simple turbinated coral *Parasmilia centralis*, was collected at localities 26 and 27. Of the Brachiopod shells characteristic of Upper Chalk strata, *Terebratula carnea* and *semiglobosa*

* Zeitschrift der Deutschen geologischen Gesellschaft; Jahrgang, 1874.

were abundant, the former occurring at eleven localities, the latter at seven, and *Rhynchonella plicatilis* at ten localities.

Of the Lamellibranchiata, fragments of *Inoceramus* doubtfully referred to *I. Crispi*, were found to be most frequent amongst the fossil bivalve shells, more especially of the Chloritic Sandstone; they occurred at eleven localities; *Ostrea vesicularis* and *Pecten quinquecostatus*, each at six localities, and the very characteristic Upper Chalk fossil *Spondylus spinosus* at as many as fourteen localities.

The most frequent fossils amongst the Cephalopoda were *Belemnites*, principally the common form *B. mucronatus* which occurred at eleven localities, being occasionally of large size, and in a good state of preservation. But few *Ammonites* were observed, the only species capable of identification being *A. Portlocki* and *A. Oldhami*, at locality 15, and *A. Levesiensis*. Of the latter species six examples were obtained at White Head Quarry (loc. 21), all of large size, one of them measuring two feet in diameter.

The well known Upper Chalk species of Echinidæ, *Ananchytes ovatus*, was collected from eleven localities, *Galerites albo-galerus* at six, and *Micraster cor-anguinum* from four localities.

The fish remains obtained from this district were few, consisting of characteristic Upper Chalk species; they include two remarkably fine examples of Cestraciont palatal teeth, *Ptychodus latissimus*, one of them obtained by the late Mr. Du Noyer, both from chloritic sandstone (locs. 15 and 19), also a few shark's teeth belonging to the genera *Lamna*, *Oxyrhina*, and *Otodus*, from locs. 19, 21, 23, and 28, and a tooth of a Pycnodont, *Gyrodus angustus*, from locality 23.

The only Reptilian remains observed was a fragment of bone, from loc. 23, which has been doubtfully referred to *Plesiosaurus*.

In the list of Fossil localities I have introduced that of the important deposits believed to be of Miocene age, occurring between the basalt, in connexion with iron-ore, at locality 12, townlands of Ballyhartfield and Ballymartin, on each side of the Belfast and Northern Counties Railway. The collection of fossils from this place, consisting of plants and a few insect remains, were described by me in the year 1869 in a paper read before the Geological Society of London.* This valuable bed of iron-ore between the basalt spreads over a great part of the county of Antrim, and will doubtless on further investigation yield additional plant remains to those I have enumerated in the paper quoted.

On the west shore of Larne Lough at Ballylig, four miles south-east of Larne, Sheet 21, loc. 11; and near Kilroot Railway station, Belfast Lough, Sheet 29, loc. 30, are Estuarine clay deposits, with numerous marine shells, mostly of existing species; lists of these have been published by the Rev. Dr. Grainger,† and S. A. Stewart, Esq.‡

WILLIAM HELLIER BAILY.

May 13th, 1876.

* Journal, Geological Society, vol. xxv., p. 357.
† British Association Report, 1852; and Natural History Review, 1859.
‡ Proc. Belfast Natural History Society, 1871.

PART IV.—MICROSCOPICAL NOTES.

Chalk from neighbourhood of Larne.—With 2-inch object-glass (25 diams.) the section shows a nearly opaque whitish structureless paste, enclosing great numbers of foraminiferal shells, some exceedingly minute. The shells are composed of clear calcite, and with polarized light, show a play of characteristic colours. Some of the shells were measured with the micrometer scale, and were found to range from 100th to 600th of an inch in diameter.

Under a high power nearly the whole mass exhibits a structural appearance. There are also a few specks, which I assume to be grains of magnetite or other metallic substance.

The species of foraminifera have been determined for me by Professor J. Rupert Jones, and are named in a former page (see p. 14).

Trachyte porphyry. Specimen No. 1, from Tardree Quarry.—With the 2-inch object-glass the slice shows a mottled felspathic base, in which are enclosed numerous grains of silica, a fine crystal of triclinic felspar enclosing quartz, a few large grains of magnetite, and a flake of mica. (This specimen did not happen to contain sanidine.) With a higher power numerous minute magnetite grains appear, which are accounted for by the chemical analysis (see page 18).

Specimen No. 2.—This slice was not successful, and the result of examination is similar to that of No. 1.

Lithomarge. Island Magee.—A piece was obtained showing a brecciated structure. Under the microscope, and with the 2-inch object-glass, it is seen to consist of a white structureless paste, enclosing numerous small grains of iron-ore, principally composed of magnetite grains and crystals, but some are of hæmatite. The former are strongly attracted by the magnet.

After grinding to powder in an agate mortar, and washing for some time, I succeeded in separating some of the iron grains from the earthy base, and by the aid of the achromatic condenser, I observed several opaque cubical crystals of magnetite (or titano-ferrite), together with a few of oxide of iron, which appear of a rich bronze colour.

The base, when seen under a high power, is structureless, translucent, and of various hues of light green and purple.

Basalts and Dolerites.—(1.) *Specimen from Shane's Castle.*—Very dense micro-crystalline rock; vesicular; no structure visible with the lens. With 1-inch and ¼-inch object-glasses structure is well shown, and is seen to consist of prisms of triclinic felspar (Labradorite?) in a light green augitic base, with abundance of minute opaque crystalline grains of titano-ferrite. There are several rounded grains of chlorite with convoluted structure observable. They are probably pseudomorphs after olivine.

(2.) *Specimen from Scolboa Hill.*—Finely crystalline granular dolerite with olivine grains in considerable quantity.

With the 1-inch object-glass it exhibits well-formed prisms, or plates, of tricilinic felspar in a base of light brown augite. There are also numerous groups and crystalline grains of chlorite which, as shown by the form, are certainly pseudomorphs after olivine. These grains are tinged with green round the edges, but are colourless in the centre. They are fissured with strong greenish scars, and with the polariscope afford only a very faint play of colours; whereas olivine when fresh and perfect presents under similar conditions very rich variations of colour, as in the case of the Vesuvian lavas.

Magnetite grains are comparatively scarce in this rock, possibly in con-

sequence of the original abundance of the olivine, which has taken up the iron of the primary molten mass.

(3.) *Amygdaloid from Magheramorne.*—Brownish-red highly vesicular rock, with numerous cells filled with zeolite and secondary minerals which do not effervesce with acid. It comes from the lower basaltic series.

Under the microscope, with the 1-inch object-glass, its crystalline structure is at once apparent. It consists of short prisms of slightly stained felspar imbedded in a paste of rich brown opaque material, together with grains and patches of iron oxide of a rich amber colour; of the minerals which fill the cells, some are zeolites, and show a stellate, or relticulated, structure. There are also a few grains of silica.

From the general appearance of the slice it appears evident that the whole rock has originally been a basalt which has undergone considerable transformation since its consolidation. The augite and magnetite appear to have become decomposed, and to have been converted into an earthy ochreous paste in which the felspar crystals are enclosed, these latter only having retained their original form. Water percolating through the mass has deposited the zeolites in the cells of the originally highl vesicular mass.

APPENDIX.

Appendix I.

Analysis of the white limestone of the county of Antrim, by William J. Wonfor, student in the laboratory of the Museum of Irish Industry; read before the Royal Dublin Society on Friday evening, May 25th, and reprinted from the Society's Journal for July, 1860.

The following is the per-centage composition of the limestone (chalk) :—

	I.	II.	Mean.
Silica,	0·644	0·539	0·591
Organic Matter,	0·069	0·024	0·046
Iron and Manganese,	0·438	0·454	0·446
Phosphoric Acid,	0·090	0·155	0·122
Lime,	54·969	54·969	54·969
Carbonic Acid,	43·120	43·218	43·169
Magnesia,	0·100	0·102	0·101
Potash,	0·261	0·260	0·260
Soda,	0·061	0·059	0·060
	99·752	99·780	99·764

Appendix II.

The following account of the origin and progress of iron mining in co. Antrim was read by Dr. John F. Hodges, F.C.S., before the Belfast Natural History and Philosophical Society in November, 1875, and may not be considered out of place as an Appendix to this Memoir :—

"The county in which we are assembled exhibits in its geological formations an assemblage of rocks of the highest scientific interest, and numerous papers descriptive of their characters are to be found in the transactions of this society; yet, if any one thirty years ago had predicted that the mountains of Antrim would be found to contain an inexhaustible store of rock salt, that in one year 100,000 tons of iron ore of the richest quality would be extracted from them, his statement would have been regarded as merely the wild imaginings of scientific enthusiasm. The wonderful development of the new industry, which in the course of a few years has been created in our neighbourhood, induces me to believe that a review of the history of iron mining in Antrim, and also of some remarkable industrial enterprises which preceded it in the same localities in which it is now so successfully carried on, will be found both interesting and instructive, and also serve as an introduction to other contributions, during the present session, on the industrial resources of the province. That the method of extracting iron from native ores was known in Ireland in the most remote times is shown by frequent references to it in our earliest records, and by the numerous names of localities formed from the Irish name for the metal, *iaran*, pronounced "eeran," which exist in different parts of the country. It is curious to find mentioned among the tributes due to the King of Connaught seven times fifty masses of iron, and Dr. Joyce, in his most interesting treatise on "Irish Names of Places," calls attention to the remarkable circumstance that the word for masses is *coera*, sheep, a sheep

of iron, corresponding to the term "pig of iron" used at the present day. Iron occurs as carbonate in the Basaltic rocks in a few localities in Antrim, and also in the forms of protoxide and peroxide in almost every part of the Basaltic area. Both the columnar and amorphous forms of basalt and the concretionary nodules termed onion stones contain from 15 to 18 per cent. of the metal, but the quantity is too small for profitable working. In some places, however, interstratified with the amorphous basalt, beds rich in metal have from early times been known to exist, though their great economic importance has only within a short period attracted attention. As many incorrect statements have been published with respect to the history of iron mining in Antrim, and as I have had an opportunity of observing the first attempts to utilise the ore, it may be instructive to give some account of the means by which this long neglected source of wealth has been successfully developed so as to become a most important addition to our natural industries. Thirty-two years ago, in 1843, I was requested by the late Mr. Crommelin, proprietor of Newtown Crommelin, a mountain village in the parish of Dunaghy, about ten miles from Ballymena, to examine some specimens of rock found near the village. It was a reddish coloured, somewhat soft rock, breaking with a conchoidal fracture. On analysis the specimens were found to yield from 18 to 25 per cent. of peroxide of iron, and 21 per cent. of moisture, which could be expelled by calcining the ore. Mr. Crommelin was most enthusiastic with respect to the possibility of smelting this ore on the spot by means of coke prepared from the rich carbonaceous turf of the district. A smelting furnace was erected at considerable expense, and repeated trials were made to smelt the ore, some metallic iron was obtained, specimens of which I have yet in my possession, but it was found impossible properly to separate the metal from the scoriæ, and the work was abandoned. The furnace was closed, and it seemed at the time that there was no prospect of obtaining any profitable results from the iron ores of Antrim. It was the general opinion that the iron stone of our northern mountains was too poor in metal to be employed in smelting. Yet in the same district in which this unsuccessful attempt was made, and at no great distance from the beds of poor ore, there existed those immense stores of rich metalliferous rock which remained for twenty-four years after Mr. Crommelin's experiments without their value being recognised. Pieces of heavy metallic looking rock had before this time been brought to the proprietor of the adjoining district, the late Mr. Edward Benn, whose name is well-known in connection with our local charitable institutions. At his request I made a number of analyses of these specimens, the result of which proved beyond all doubt that an iron ore of the most valuable description existed in the Glenravel Mountains. Some of these analyses attracted the attention of an enterprising English gentleman, the late Mr. James Fisher, who had an interview with Mr. Benn, who, to encourage him to investigate the extent of the mineral beds, gave him permission to open up the mountain sides, and to raise ore at the nominal rent of £10 per annum. Such was the beginning of iron mining in Antrim. It is true that carbonate of iron, which resembles the celebrated black-band of the Clyde iron field, had for many years been raised in small quantities at Ballycastle, and that a weak iron ore, known as the "Belfast Aluminous Ore," had for several years been worked with profit by Dr. Ritchie, at Ballypallidy and other places near the Northern Line of Railway, and exported to the North of England and Wales, not as a source of metal, but to serve as a flux in smelting rich ores; the large quantity of alumina, in some

samples amounting to more than half of the weight of the ore, rendering it of great value in the blast furnace, when siliceous red hæmatites are worked. It was not, however, until Mr. Fisher commenced his operations that our mountains were made to yield ores of the richest quality, equal in value to the best ores of Cumberland and North Lancashire. The locality in which Mr. Fisher made his first trials is about ten miles from Ballymena, and the same distance from Cushendall, where, on the property of Mr. Benn, the mountain named on the Ordnance maps Slieve na Neerin rises to the height of 1,800 feet above the sea. The ancient name of this basaltic elevation was "Slieve na Eerin," or the mountain of iron, a name which is still applied to it by the old inhabitants, and reports that surveyors working on it found the compass disturbed suggested, even before the discovery of its valuable ores, that in remote times its name may have been derived from the knowledge that it was rich in iron. The stratum of iron stone which Mr. Fisher opened up is situated about 900 feet above the sea-level. It was found to possess an average thickness of twenty inches, in some places expanding to three feet, and consists of an easily quarried mass of rich, red-coloured rock, in which are imbedded nodules of peroxide and magnetic oxide of iron. These nodules, which are characteristic of pisolitic iron ore, vary in size from a pin's head to that of a hazel nut; and, mixed with the red ore, are occasionally found large, brittle masses, of a brownish and sometimes almost black colour. Some of the black masses consist of loosely aggregated particles, having a bright metallic lustre. The dark-brown ore I found to be highly magnetic and parts of the black metallic-looking ore were also magnetic. For so far, the rich ore has been found only at a considerable elevation above the sea. The best qualities yield from 50 to 60 per cent. of metallic iron, while under the rich seam a poor ore is found in beds of from four to six feet in thickness, and yielding from 20 to 25 per cent. of iron. One of the first analyses of the rich ore, which was made by me in February, 1867, showed it to possess the following composition:—

100 parts consisted of—		
Peroxide of iron,	82·50	—capable of yielding 57 7-10 parts of metallic iron.
Alumina,	4·20	
Lime,	0·83	
Oxide of manganese,	1·67	
Silica,	8·90	
Moisture and water of combination,	1·90	
	100·00	

It also, I found, contained titanic acid and vanadic acid. The rare metal vanadium, before this analysis of our Antrim rocks, had not been known to exist in Ireland except in combination with lead, in a portion of ore from the South of Ireland, received many years ago by the late Professor Thos. Thompson, of Glasgow, from Pat Doran, the well-known veteran mineralogist, whose labours have contributed so much to the discovery of rare minerals in this country. For the first two or three years the ore was obtained by stripping the surface of the mountain, but at present it is raised by adits driven into the beds. At the time Mr. Fisher commenced work plenty of men could be got at 7*s.* a week. Now a labourer with three months' practice at mining can earn underground from 15*s.* to 20*s.*, while outside men earn from 13*s.* to 14*s.* weekly. Some idea of the extent of the operations at the Glenravel Mines may be formed from the statement which Mr. John Fisher, who has succeeded his father in working the mines, has kindly

furnished to me. In 1873 he informs me that he shipped 24,699 tons of ore, and altogether since the mines were opened 140,000 tons. The success which attended Mr. Fisher's operations led to the investigation of the quality of the ore in other localities, and since 1867 several mines have been successfully opened up in other districts, and a large amount of capital applied to the development of this new industry. At the present time the Antrim Mining Company, chiefly composed of gentlemen connected with the county, are working at Cargan, on the Glenravel property, and have also mines opened in numerous places over a great extent of country from Broughshane to Glenarm. The Parkmore Iron Ore Company and the Evishacrow Iron Ore Company are at work at the head of Glenravel. The lofty hills which bound the picturesque valley of Glenariff are resounding with the pickaxes of the Ballymena, Cushendall, and Red Bay Railway Company. Mr. Thomas Fisher and Mr. Postlethwaite are working profitably at Shane's Hill, near Larne; ore of good quality has also been raised at Coneen, at Knockboy, at Portrush, and in our own neighbourhood, near Carrickfergus. It is calculated that for the last two years more than 100,000 tons of iron have been shipped from the North of Ireland. In the Glenravel and Broughshane districts there are at present about 700 men employed in the mines, earning in wages about £1,000 weekly. At the commencement of the works considerable difficulty was experienced in obtaining competent workers, but it was found that a very short time was sufficient to convert the ordinary farm labourers of the district into excellent miners, able to pick from two to three tons of ore daily. A pleasant feature of mining in Antrim is the safety and facility with which the work is conducted. The ore is usually found cropping out in horizontal layers under a firm basaltic rock, which forms a safe roof to the adits, requiring but a small outlay for timber, which in English mining is a heavy item in the cost of working. A great obstacle to the progress of the work hitherto has been the difficulty of the transit to the shipping places; but mineral railways are now penetrating into the formerly secluded glens, and harbours are being constructed to afford accommodation for the increasing trade, and in a very short time it is expected there will be a greatly augmented export of ore. The North of Ireland is, therefore, likely to become a great mining district, and again, as in earlier times, furnaces for smelting ores may be erected in Antrim and Derry. It is a singular fact that, two centuries ago, iron ore was brought from Lancashire and smelted, by means of wood charcoal, within a few miles of Belfast, and the manufactured iron exported to England. Dr. Boate, in his Natural History of Ireland, speaks of the importance of our iron trade in the 17th century, and describes the various kinds of ore found in Ireland. He states that Sir Charles Coote alone, in his iron works, employed no less than 2,500 men. It seems that in Ulster the iron smelters, in ignorance of the rich ores lying around them, worked with English ores. Thus, he remarks, "there have been erected divers iron works in sundry parts of the sea coasts of Ulster by persons, who, having no mines upon or near their own lands, had the ore brought to them by sea out of England, which they found better and cheaper than if they had brought it from some of the mines within the land." Iron "bloomeries," as the smelting furnaces were called, existed in several places in this province 200 years ago. There were extensive iron works at Forge Bridge, near Draperstown; there were bloomeries at Randalstown; and in our own neighbourhood, at Old Forge, and New Forge, and at Whitehouse. And the great woods which then covered so much of the country afforded for a long period

abundant material for the manufacture of the charcoal required for smelting the ores. The destruction of the forests to prevent their serving as places of defence and refuge for the "wild wood kernes" served to diminish the supply of fuel, and after a time it was found necessary to abandon the manufacture of iron. An Act of the Parliament of Ireland in the reign of William III. shows how complete, from various causes, was the exhaustion of wood, as it states that, by the late rebellion in this kingdom, and the several iron works formerly here, the timber was utterly destroyed. It is curious how the failure of the supply of wood had at one time threatened the existence of the iron trade of England. Up to the beginning of the 17th century charcoal was the only fuel used in the English furnaces; and had not the art of making iron with pit coal been discovered, the trade could never have attained its present magnitude. For many years Dudley laboured in vain to induce the ironmasters to substitute coal for charcoal; and it was not until 1713 that Abraham Darby succeeded in convincing them that it could be successfully employed; and when it was rendered certain that coal coke could take the place of wood charcoal, a complete revolution was effected in the manufacture, and the coal districts of England became, and continue up to the present time, the chief localities of the iron trade. In that district in the County Antrim now so busy with the raising and transport of iron ore, some attempts were made a number of years ago to introduce other new industries calculated to give employment to the people, and to develop the resources of the country. These speculations were unsuccessful, but their history is full of interest."

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