1, 2, 5, 6 and 11.

Memoirs of the Geological Survey.

EXPLANATORY MEMOIR

OF

INISHOWEN, COUNTY DONEGAL,

TO ACCOMPANY

SHEETS 1, 2, 5, 6, AND 11 (IN PART) OF THE MAPS

OF THE

GEOLOGICAL SURVEY OF IRELAND,

BY

EDWARD HULL, LL.D., F.R.S.; JOSEPH NOLAN, M.R.I.A.;
R. J. CRUISE, M.R.I.A.; AND ALEXANDER M'HENRY, M.R.I.A.,

WITH

PETROGRAPHICAL NOTES, BY J. S. HYLAND, M.A., PH.D.

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Fig. 1.—FRONTISPIECE.

Malin Head.—Cliffs of Quartzite rising from the Ocean.

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CALLAWAY, C., D.SC., F.G.S. . "On the Granitic and Schistose Rocks of Northern Donegal."
Quart. Jour. Geol. Soc., Vol. XLI.; 1885.
Considers the succession of rocks to rise from westwards—the highest beds being those of the L. Foyle series.

CLOSE, Rev. M. H., M.A., &c. . "Notes on the General Glaciation of Ireland."
Jour. Roy. Geol. Soc. Ireland, Vol. I.; 1866.
Describes the glacial phenomena of Inishowen; the directions of the chief systems of ice-striæ and drift ridges being given on the general map. Believes the ice to have moved from the interior to the coast.

GANLY, PATRICK, . . "On the probable existence of Fossils in the Limestone of Culdaff, co. Donegal."
Jour. Geol. Soc. Dublin, Vol. VII., 1856.
Believes that certain peculiar forms in the limestone of Culdaff may be due to organic remains in which the specific characters have been obliterated. They may be referable to some genus of zoophytes, as *Halysites catenulatus*, *Favosites Gothlandica*, &c.

HARKNESS, Prof. R., F.R.S., . "On the rocks of portions of the Highlands of Scotland south of the Caledonian Canal, and on their equivalents in the North of Ireland."
Quart. Jour. Geol. Soc., Vol. XVII.; 1861.
Considers the greater portion of Inishowen to consist of gneissose strata allied to the chloritic schists S.W. of the Grampians. Describes a flaggy gneiss at Malin Head as representative of the upper gneiss of Sutherland. Refers to the Culdaff limestone, and is of opinion that it has hitherto yielded no fossils. Gives a section from Malin Head to Inishowen Head.

HARTE, W., C.E., County Surveyor of Donegal. "On the occurrence of Kjökkenmöddings in the County of Donegal."
Jour. Roy. Geol. Soc. Ireland, Vol. I., Part 1.
Describes shell mounds at Inch Road Station and Inch Island. Gives list of species—also notes the occurrence of flint implements, &c. Believes that no alteration in the land took place since the period of the shell mounds.

" " "On the Post-Tertiary Geology of the County of Donegal, &c."
Jour. Roy. Geol. Soc. Ireland, Vol. II., Part 1.
Describes drift and glacial phenomena. Considers most of the latter to be due to local ice.

HAUGHTON, Rev. Prof., M.D., F.R.S. "Experimental researches on the Granites of Ireland."
Quart. Jour. Geol. Soc., Vol. XVIII., Part 3.
Describes and gives analyses of granites at Malin and Dunaff Head.

List of Papers referring to the Geology of Inishowen—*continued.*

Haughton, Rev. Prof., M.D., F.R.S.	"Experimental researches on the Granites of Ireland." Quart. Jour. Geol. Soc., Vol. XX., part 4. Gives analyses of granites from Ardmalin and Urrismenagh (Inishowen), with the mineralogical composition deduced therefrom. Compares the granite of Donegal with those of Scotland and Sweden. The latter has a stratified arrangement like that of Donegal.
Hull, Prof., LL.D., F.R.S., Director G. S. Ireland.	Physical Geology and Geography of Ireland. Stanford, London ; 1878. Raised beach at Inishowen described, p. 108.
Kelly, John, . . .	"On the Graywacke Rocks of Ireland as compared with those of England." Jour. Geol. Soc. Dublin, Vol. VIII. Slight notice of geology of Inishowen. Considers the quartz rock of Malin Head to be the lowest stratified rock in Ireland, p. 255.
,, . . .	"On the Geology of the County of Antrim, with parts of the adjacent counties." Proceedings Roy. Irish Academy, Vol. X., Part 3. Refers to geology of Inishowen. Considers the syenite of Malin Head with the quartzite over it to be the oldest rocks; the schists to be newer, and probably of Cambrian age.
Kilroe, J. R., Geological Survey.	"On directions of Ice-flow in the North of Ireland, &c." Quart. Jour. Geol. Soc., Vol. XLIV., 1888. The author believes that this district was glaciated by ice coming from Scotland. A map showing details of striæ is given.
Kinahan, G. H., M.R.I.A., Geological Survey.	Geology of Ireland. Kegan, Paul & Co., London ; 1878. List of mineral localities, including some in Inishowen p. 364.
,, ,,	Economic Geology of Ireland. Jour. Roy. Geol. Soc. Ireland, Vol. VIII. Gives list and brief history of mines, with economic applications of various rocks, including granite, limestone, slate, clay, sand, &c.
King (Archbishop), . .	*See* Portlock.
King, Prof. W., D.Sc., . .	"On the Age of the Crystalline Rocks of Donegal." Geol. Magazine, Vol. V. (new series), 1878, p. 465. Nature, 29th August, 1878 (Abstract of Paper read before Brit. Assoc., Dublin, 1878). The author obtained what he believed to be true fossils from the Inishowen (Culdaff) limestone, and thinks them to be identical with *Ptilodictya dicotoma* from Desertcreat, Tyrone (Portlock's Report, p. 339). Their occurrence proves the beds to be of Lower Silurian age.
M'Parlan, J., M.D., . .	Statistical Survey of the co. Donegal. Published by the Roy. Dub. Society, 1802. Gives lists of mineral localities, including Sir C. Giesecke's catalogue.

List of Papers referring to the Geology of Inishowen—*continued.*

Portlock, J. E. Genl., F.R.S., &c.	Geological Report on Londonderry, &c. Dublin; 1843. Abstract of Archbishop King's Paper (1702) on Shell Island, Lough Foyle, p. 22.
Scott, R. H., M.A.	"On the Granitic Rocks of Donegal, &c." Jour. Geol. Soc. Dublin, Vol. X. Dub. Quart. Jour. Science, Vol. III. Refers to the Culdaff limestone, certain structures in which resemble fossils; but does not believe them to be organic. Describes and gives a section of the hills called "The King and Queen of the Mintiaghs."
Scott, R. H.; Griffith, Sir R.; and Haughton, Rev. S.	On the Chemical and Mineralogical constitution of the Granites of Donegal and of the Rocks associated with them. Report by Committee. Brit. Assoc. Report for 1863. General Geology of Donegal described, with lists of mineral localities, analyses of granites, &c. The hornblendic igneous rocks of Inishowen are considered to be contemporaneous. The quartzose grit or conglomerate is described as "calcedonic conglomerate," and is believed to be similar to rocks in the Huronian series of Canada, the Tellemarken quartz-formation of Norway, and certain beds near Callander. The authors consider the coral-like structures in the Culdaff limestone to be concretions, and not of organic origin.
Wilkinson, G., Architect, M.R.I.A., &c.	Practical Geology and Ancient Architecture of Ireland. John Murray, London; 1845. Sketch of the geology of Donegal, with references to localities for building stones, &c., in Inishowen.

PREFACE.

THE Geological Survey of the promontory of Inishowen was carried out during portions of the years extending from 1883 to 1885; the southern part by Mr. Nolan, the northern and greater part by Mr. Cruise, and the district about Moville by Mr. M'Henry; each of whom has contributed the detailed description of his district to this Memoir. The general description, Chapters I., II., and III. has been written by myself.

The Inishowen promontory is not only interesting for its physical structure, but as yielding at Culdaff peculiar forms in limestone which many believe to be those of fossil corals of a type representative of the Lower Silurian period. These fomrs are described and illustrated in this Memoir.

Dr. Hyland has contributed a chapter on the petrographical characters of the rocks which enter into the structure of the promontory.

EDWARD HULL,
Director.

Geological Survey Office, Dublin,
October, 1889.

EXPLANATORY MEMOIR

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GEOLOGY OF INISHOWEN, NORTH DONEGAL,

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CHAPTER I.

Physical Geography.*

The district embraced within the limits of this memoir forms a remarkable promontory, bounded on either side by Lough Swilly and Lough Foyle, and jutting out far into the Atlantic Ocean, where it terminates in the Cliffs of Malin Head. Though not actually an island, as its name indicates, being connected with the mainland by a neck of alluvial soil, yet the name is not without significance, as pointing to the inference that within the historic, or at least traditionary, period it may have been really an island, at least during high tides. As we learn from Dr. Joyce, the peninsula between Loughs Swilly and Foyle received its name from *Eoghain* (now spelt *Owen*), ancestor of the great clan of the O'Neills, and this part of his extensive territory was called after him "Inishowen"—that is, Owen's Island.† As a physical fact, the narrow neck by which the promontory is united to the mainland, though about eight miles from shore to shore, is formed of an old sea-bed, which has been elevated into land, certainly in very recent times, and in all probability within the period during which Ireland was inhabited by Celtic tribes. It corresponds with the well recognised "25-feet raised beach" of our northern coast. This narrow strip, along which the railway from Londonderry to Buncrana is carried, has an average elevation of 20 or 25 feet above Ordnance datum, and only for a short distance near Pennyburn is the level materially exceeded, the ground rising to 50 or 54 feet above Ordnance datum, or 41 to 45 feet above mean level.‡

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* By Professor Hull.

† Joyce, "Irish Names of Places," 3rd edition, page 134. The period referred to was about the close of the fourth century, and gives us a clue to the limit of the epoch within which the promontory was an island.

‡ As the Ordnance datum is 8·094 feet below the mean level of the sea around the coast, an elevation of 25 feet would be only 11·188 feet above high water of ordinary tides. Owing to the bar at Magilligan Point, the rise and fall of spring tides in Lough Foyle is only 9 feet at the present time; formerly, when the shore was depressed, it must have been greater.

But the island of Inishowen, thus constituted, seems to have been itself a double island, owing to the existence of a second narrow strait by which it was crossed at the period above referred to. Between Culdaff Bay on the east and Trawbreaga Bay on the west there stretches a low neck of alluvial land, deeply covered with peat; and during the period of depression this was overflowed by tidal waters, as the old sea-bed, consisting of sand, silt, and gravel, well seen in the neighbourhood, underlies the peat which has grown over the surface since its elevation into land. The highest level of this alluvial tract is 50 feet above Ordnance datum, or 42 feet above high-water of ordinary tides, and of this probably 10 or 12 feet consists of peat. At its western end this strait communicated with the ocean both to the north and south of Doagh Isle, which is at present connected with the mainland by a bar and sand dunes forming the shore of Pollan Bay.

As regards Inch Island, a prominent rocky mass on the eastern shore of Lough Swilly, its insular character remained till, by artificial embankments, the alluvial flats by which it is separated from the mainland were reclaimed from the sea; previous, however, to the general elevation of the land this tract must have been covered by several feet of water at low tide. Thus, out of the existing promontory of Inishowen we may reconstruct a little group of four islands—namely, those of Malin, Doagh Island, Inishowen, and Inch Island—if we restore the relative position of land and sea as it appears to have been previous to the last important elevation of the land.*

The promontory of Inishowen, as now constituted, is exceedingly hilly, and consists largely of rocky ground, covered by heath and mountain bog. Its culminating point is Slieve Snaght,† a quartzite mountain which rises from the centre of the promontory to an altitude of 2,019 feet above Ordnance datum. There are several other elevations not falling much short of this; but the most prominent feature is the grand quartzite ridge of Raghtin More, which traverses the western portion of East Inishowen, between Dunree Head and Pollan Bay, and reaches an elevation of

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* Dr. Sigerson (Proc. Roy. Irish Academy, 2 Ser., Vol. 1, p. 212, *et seq.*) has adduced historical evidence in confirmation of the statement that Inishowen was an island, not only within the period of human habitation, but within that of history. In the Maps of the Escheated Counties of Ireland, 1609, of which fac-simile copies were taken at the Ordnance Office, Southampton, in 1861, a strip of water is shown connecting the Foyle and the Swilly Loughs across to the north of the "City of Derrie," just where the raised sea-bed occurs. Another strip of water is shown stretching from "the Lake of Loughfoile," near Saint Johnstown, to the inlet of the Swilly near Castle Hill. Derry itself stood on an island before the last elevation of the land, as a strip of water, recently a morass, bounded the hill on which the old city is built, on the west. Sigerson quotes passages from the Annals of the Four Masters, of the dates A.D. 1211 and 1010, in which the name *island* is applied to the present promontory; thus, in the latter case, the quotation runs—"A.D. 1010, Oenghus O'Lappan, lord of Cinel Enda, was slain by Cinel Eoghain, of the Island," *i.e.*, Inishowen. Thus historical evidence concurs with that derived from an inspection of the physical conditions, that Inishowen was actually an island up to within very recent times. The raised sea-bed referred to is in reality a representative of that of Kilroot and Larne, containing numerous worked flints, and of the 25–30 feet raised beach of Scotland, in which several canoes and other works of human art have been found. (See J. Geikie, "Great Ice Age," p. 311, etc.)

† *Anglice*, the Snow Mountain.

1,655 feet. Thus, although of no very great elevation, this mountain ridge, owing to its position as rising abruptly from the Atlantic and breaking off along its western slopes in a naked wall of quartzite, conveys to the mind an impression of massiveness which is not altogether dependent on its altitude. The ridge is traversed by the Gap of Mamore, which crosses the centre, and is coincident with a line of fault in the strata. The upper surface of the ridge is remarkably smoothed and rounded by glacial action.

Another peculiar feature is the pair of truncated, conical hills called the "King and Queen of the Mintiaghs" (Binmore on the map), formed of beds of trap capping quartzite. Though of no great height, the higher mass (or "King") being only 1,044 feet above the sea-level, their isolated position and peculiar form make them conspicuous objects from the deck of the steamer which plies between Fahan Pier and Rathmullen;* while in the distance, somewhat to the right, rises the massive framework of Slieve Snaght, the summit generally capped with snow in winter, and with cloud in summer. Other elevations are, Eskaheen, 1,377 feet; Glackmore, 1,293 feet; Crockglass, 1,309 feet; Glencaw, 1,123 feet; and Ashdevlin, 1,261 feet.

The coast line of Inishowen is generally rocky and precipitous except along the margin of Lough Foyle and the inlets through which the principal streams make their escape into the ocean. The northern coast is particularly bold, the cliffs often rising to heights of 500 or 600 feet, and at "The Pounds," north of Glengad Head, to a height of 802 feet above Ordnance datum. Malin Head (Fig. 1), although the most projecting point of the coast, is comparatively low (125 feet), but Dunaff Head, at the entrance to Lough Swilly, presents to the Atlantic waves a bold wall of granite and quartzite of over 600 feet in height. At Fanad Head, on the opposite side of the channel, here a little over four miles in width, a lighthouse points the mariner to the natural harbour of refuge which Lough Swilly affords, sufficiently wide and deep to allow of all the ships of the British Navy to ride safely at anchor. †

Watershed and Streams.—A line of watershed may be traced across the widest part of the promontory, throwing off the streams flowing south from those flowing in an opposite direction. Leaving the western seaboard at Dunree Head, the watershed ascends Aghaweel, and keeping to the south of Lough Doo, crosses the head of the Mintiaghs Lough, and ultimately ascends to the summit of Slieve Snaght. From this the line bends southwards, crossing the pass along which the Malin Road is carried at Cloghan, at an elevation of about 550 feet; thence passing over Crockanoy, it skirts the head of Lough Fad, and continues north-eastward by Crockbrack to the cross roads near Moglass, from which it runs along the summit of the ridge down to the coast at Inishowen Head.

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* The geological structure of these hills was described in 1862 by Mr. R. H. Scott, afterwards by Rev. Dr. Haughton.—*Journ. Geol. Soc., Dublin.* Vol. x., p. 14.

† The rise and fall of spring tides in Lough Swilly amounts to 18 feet, while in Lough Foyle it is only half this amount, owing to the bar.

Fig. 2.—The Tor Rocks—formed of Gneiss. The most northerly isles of Ireland.

Rivers.—Owing to the restricted limits of Inishowen, the streams are not large, although the annual rainfall amounts to about forty inches.* The principal streams flowing northwards are the Owenwerk, entering Lough Swilly; the Clonmany; the Straid and Donagh, which rise on the flanks of Slieve Snaght; and the Culdaff and Long Glen streams, all of which enter the Atlantic, and rise at or near the central watershed. South of this line, there are the Bredagh, Drung, and Maragh and Crana streams; the two former entering Lough Foyle—the latter, Lough Swilly. The Crana enters the Lough by a deep channel celebrated for its fish.

Chief amongst all the rivers in this part of Ireland is the Foyle, which enters the Lough of that name at Culmore Point, about four miles below the City of Londonderry. At this city it is a noble stream, over 300 yards across, and spanned by an iron girder bridge constructed to allow not only passengers and vehicles, but railway trains, to cross from side to side.† The channel which runs along the western coast of the Lough is sufficiently deep to allow ships of large size to come up to the harbour. The river is tidal as far up as Strabane and Lifford, and the rise and fall of spring tides in the Lough is nine feet. Occupying a large portion of the centre of the Lough is an extensive bank, but slightly covered at low water, called "The Shell Bank," consisting chiefly of shells, formerly dug up at low

* Dr. H. Lloyd; "Papers on Physical Science," p. 374. It is probable that on the west coast the rainfall averages about 42 inches, and on the east 40 inches; it often exceeds 41 inches at Moville, as will be seen on reference to Symons's "British Rainfall."

† A swivel-bridge in the centre allows vessels to pass through.

water and carried away by the country people for manuring the land, as described by Archbishop King at the beginning of the last century;* a practice, however, which appears not to have been continued to recent times. Between this bank and the north-western shore the channel continues till, opposite Magilligan Point, the bay opens out into the Atlantic waters.

Loughs.—Several little mountain loughs or tarns, such as Lough Inn and Lough Fad, occur amongst the Inishowen highlands, generally near the watershed, and just below some prominence. Four of these are found in the district of the Mintiaghs, and two others situated at the foot of Croaghmore and Tavash, along the line of the watershed. In all probability these little basins owe their origin to the former glaciation of this district, as is the case with the generality of such mountain tarns.

Islands.—Several islands rising from the Atlantic lie at some distance off the coast of Inishowen. The largest of these is Inishtrahull (Fig. 3), a rocky mass nearly a mile across from east to west, formed chiefly of gneiss; at a distance of about five miles from the north coast of the mainland, a lighthouse, showing revolving lights, serves to guide vessels on their course. Some dangerous rocks called "The Tor Rocks" (Fig. 2), rise above the surface a mile north of Inishtrahull.†

Fig. 3.—Inishtrahull.

Island of Gneiss in the Atlantic, as seen from the Coastguard Station, Malin Head.

The Garvan Isles form another group of rocky islets, three in number, rising about a mile from the coast of Malin Head, and formed of quartzite; while another small islet called Glashedy Island lies a mile off the coast in the bay between the prominences of Dunaff Head and Malin Head; this island is also formed of quartzite.

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* Dr. William King, Bishop of Derry, 1691; Archbishop of Dublin, 1702. The account above referred to is contained in a communication to the Royal Society in 1708, quoted by Portlock, "Geol. of Londonderry, etc.," p. 22.

† Inishtrahull means the Island of the Big Strand. The words are—*Inish*, island; *tra*, strand; and *h-ull*, an old and uncommon Celtic word for big or large. There is actually no very big strand at the present day, as I am informed by Mr. Cruise who geologically surveyed this island, but there is a raised beach—extending right across the western side of the island—now about 50 feet above Ordnance datum, or 30 feet above high water line—and it is not improbable that at the time the island received its name this may have been a big strand in the ordinary sense of the word.

CHAPTER II.

Rock Formations and Divisions.

Name.	Subdivisions.	Sign and Colour on Map.
Recent, . .	Blown Sand, ...	Red dots.
	Peat, Alluvium, ...	Chalons-brown and gamboge.
	Raised Beaches, ...	Burnt sienna.
Post-Pliocene,	Drift Clay and Gravel, . .	Engraved dots.
Carboniferous,	Upper Calciferous Sandstone, .	d^1 Prussian blue and Indian ink with yellow dots.
Metamorphic Rocks.	Micaceous and other Schists, .	μ Crimson lake.
	Do., when pebbly, . .	Do., with yellow dots.
	Quartzite, ...	9 Gamboge over lake.
	Gneiss, ...	ν Crimson lake.
	Crystalline Limestone, . .	λ Cobalt-blue over crimson lake.
Metamorphosed Igneous.	Hornblendic Sheets and Dykes (Diorite).	Δ Burnt carmine.
Tertiary Volcanic Rocks.	Basalt and Dolerite, . . .	B & Burnt carmine and carmine.
	Volcanic Ash, ...	Do. dotted.
Igneous Rocks (of uncertain age).	Basalt, ...	B. Burnt carmine and carmine.
	Diorite (Dykes), . . .	D. Do.
	Granite, ...	G. Carmine.

CHAPTER III.

General Geological Structure of Inishowen.

The geological structure of the promontory of Inishowen affords a key to that of north-western Donegal, and is remarkably well represented on Sir Richard Griffith's general Map of Ireland.* The general strike of all the rocks is from north-east to south-west, and they belong to that great series of metamorphic strata of which the north-west of Ireland is mainly formed. It would be premature to speak with confidence as to the true order of succession among these rocks. But if their apparent inclination is to be taken as an indication of their chronological sequence, then the lowest beds occupy the promontory of Malin Head and the Ridge of Raghtin More. These consist of massive quartzite invaded by granite at several points. To the west of Lough Swilly this quartzite forms the ridges of Knockalla and Knockalt.† The general dip of the Raghtin More quartzite is towards the south-west, beneath a variable series of micaceous, chloritic and other schists, with several bands of hornblendic trap, occupying a line of country from Glengad Head by Coolcross Hill, Bulbin, to the shores of Lough Swilly at Linsfort. This tract is generally depressed as compared with those bounding it to the north-west and south-east.

* "A General Map of Ireland to accompany the Report of the Railway Commissioners." Edit. 1885. The late Professor Harkness has drawn a comparison between the Geology of Inishowen and that of the Scottish Highlands, considering the one an exact counterpart of the other. He indicates the flexures and inversions of the strata, and illustrates the structure of the ground by a section drawn from Inishowen Head to Malin Head.—*Quart. Jour. Geol. Soc.*, Vol. xvii.. p. 268.

† Otherwise called Knocksalt.

The schistose series above described is succeeded in ascending order by a second quartzite series, forming a broken range of hills, in the centre of which is the culminating point of the peninsula, Slieve Snaght, and stretching from the coast north of Culdaff to Buncrana. The second quartzite series is not so solid as that of Raghtin More, as the quartzites are frequently interstratified with bands of quartzose schist and micaceous schist, and are diversified by sheets and bosses of hornblende rock and limestone, of which that of Culdaff is the most remarkable. On the western side of Lough Swilly this quartzite zone forms a range of hills rising to the north of Rathmullan, of which Crocknaglaggan is the highest point.

The general dip of the above series is southwards, and the beds pass below a second and more extensive series of schists, generally bluish gray and argillaceous (phyllites), but often dark and sericitic, and which, from the fact that the City of Londonderry is built upon them, may be called "the Londonderry schists." These beds occupy the wide tract extending from Buncrana and Fahan to Inishowen, and extend into both sides of the valley of the Foyle. They are probably subjected to considerable flexuring if not inversions, and in their extension southwards to the Saint Johnstown district have been worked for roofing slate.* A few bands of crystalline limestone occur, especially at Inch Island; but, as compared with the subordinate series, trap rocks are rare.

Occupying a range of high land, and stretching from the coast at Inishowen Head to that of Lough Swilly, south of Inch Island, we find a remarkable group of beds which, by their mineral characters, can be generally recognised, and differentiated from the other strata belonging to the great metamorphic series with which we are now concerned. These beds consist of fine conglomerate, or very coarse grit, generally greenish or purplish in colour, largely made up of felspathic materials, and reminding one of some of the coarser grits of the "Bala-Caradoc group" of North Wales. Amongst these grits are beds of sericitic slate, and the whole group appears to have almost escaped that metamorphic action to which the deeper seated strata have been more or less subjected.

These coarse felspathic grits are apparently amongst the highest, if not actually the highest, beds of the great metamorphic series of Donegal and Derry. In the mountainous tract of West Inishowen they occur among the higher elevations, forming a synclinal trough, which may be traced from Eskaheen mountain in a south-westerly direction by Ardevelin to Rockstown, on the borders of the marsh, and onwards by Finwell Hill to Roughin, on the shore of Lough Swilly. A fault, marked on the map, coincides with the general line of this axis. The grits are also found forming the tops of the range of hills rising above the western shore of Lough Foyle near Moville.

The geological age of the great series above described is still a question which remains for solution. The probabilities are in favour of the view that the beds of quartzite, crystalline schist,

* For description of these slates see Expl. Mem. to Sheet 17, p. 17.

and limestone are altered Lower Silurian beds; but until unquestionable fossil evidence be forthcoming, this view can only be regarded as problematical. The Culdaff limestone has yielded forms which have been hopefully regarded by several geologists,* the writer included, as likely to afford the much desired evidence. A collection of these peculiar forms has been made by the officers of the Survey, and specimens have been submitted to several palæontologists; but, owing to the absence of internal coralline structure, opinion regarding their organic origin has not been unanimous.† I am not yet without hopes that ultimately satisfactory evidence will be forthcoming; and as far as any value is to be attached to the presence of apparent annelid tubes in the quartzites of North Donegal, this amount of evidence must be admitted.

CHAPTER IV.

DETAILED DESCRIPTION:—METAMORPHIC ROCKS.

Londonderry District.‡

The country immediately west and north-west of Londonderry is hilly, though no great height is attained; the most remarkable elevation being the hill of Greenan, crowned by the ancient fort called the *Grianan na Aileach*, forming a prominent object for many miles around. Although only attaining a height of 803 feet, yet, owing to its position, an excellent idea of the physical geography of the district can be obtained from the summit. To the north and north-east are the Inishowen mountains; north-west is Lough Swilly, with the island of Inch, and the rocky country about Carowen and Finwell hill, occupying an insular position among the extensive alluvial plains that stretch along the south-eastern shores of the Lough from Burnfort to the Blanket Nook; while to the east, a narrower continuation of the same plain extends along the valley to Pennyburn, near Rosses Bay. South-eastward, an irregular line of low hills stretches towards the Foyle to the vicinity of the city of Londonderry, which stands on what was, till recently, an island in that river a little to the south-west of Rosses Bay.

Most of this district is composed of metamorphic rocks, except a strip of Carboniferous beds along the south-western and southern shores of Lough Foyle;—the margin of a basin, which must

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* Amongst these was the late Professor W. King, of Galway College, who regarded these forms as identical with the Caradoc Polyzoon, *Ptilodictya dichotoma* of Portlock.—*Nature*—Aug. 29, 1878. On the other hand, Mr. R. H. Scott, who noticed these forms in 1862, came to the conclusion that they were not organic. "On the Granitic Rocks of Donegal," *Journ. Geol. Soc. of Dublin*, Vol. x., p. 14.

† The specimens were taken over to London and shown to several Geologists, both British and Foreign, at the meeting of the International Geological Congress, 1888; and again in the Geological Section of the British Association at Newcastle-on-Tyne, September, 1889. The views of palæontologists will be found in Appendix B.

‡ By Mr. Nolan.

originally have extended over the whole area now occupied by the Lough, and to the erosion of which that inlet of the sea is probably due, as pointed out in the Memoir to accompany Sheet 12 (p. 6).

Mica Schist, Slates, Micacized Grits and Conglomerates.—These rocks, as already mentioned, occupy the largest area in this district. They consist chiefly of micaceous schists, in which the mica is probably one of the hydrous varieties. They are seldom highly metamorphosed, the rock in many places being merely a shining slate (sericitic phyllite). Associated with these are quartzose grits and conglomerates, the pebbles of which are enclosed in a micaceous paste presenting a schistose structure; but in many cases, particularly where interstratified with the slates, the beds are not micacized. In the vicinity of Moville we find, on the shore of Lough Foyle, green schists and grits, in which cleavage is by far the most conspicuous structure, inclining to the north-west at a high angle, while the beds dip to the south-east. Similar sections are seen along the shore for five miles to the south-west, near Vance's Point, where Carboniferous beds appear. At Black Point, in this locality, some beds of quartzite are interstratified with the schists. Rocks similar to those on the shore may be observed to the north of this, in the country about Pensylvania and Mullaghard, as also in the numerous streams that descend the hillsides; sections in rock also occur at Castle Cary, and in the stream to the west of that demesne. At about a mile to the north, on the mountain road to the east of this stream, is a steatitic schist locally known as "Camstone." Slabs of this rock are useful for lining ovens, and for other purposes requiring a fire-proof material. On the high ground to the north and north-west there is much peat, but rocks crop out abundantly on the hills called Puckan and Croaghmore, near Lough Inn. Like most of those already described they consist of green chloritic schists and grits, but they are here coarser and more massive. They are also greatly affected by cleavage, the direction of the planes of which varies from N. 20 E. to N. 20 W. with a high dip northwards. South-west of this there is a thick covering of Drift deposits and peat, but in the vicinity of the road leading from Derry to Carndonagh quartzose grits and schists come to the surface in many places. Close to the road at Cloghan (Sheet 5) is a rock of a very peculiar variety, occurring in several localities throughout this and adjoining districts. It is compact in texture, of a dark green colour, with irregular joints much stained by iron, and bears a considerable resemblance to a massive igneous rock; but in some parts its schistose structure is apparent, and on closer examination waterworn fragments of quartz and other rocks may be detected.* Thick beds of schistose conglomerate occur on the northern slope of Leamnacrossan hill, and are overlaid by similar beds of a green colour, and slightly calcareous. Southward of this the ground, even to the hill tops, is thickly covered with peat, but schists come to the surface

* See "Petrographical Notes," p. 52.

occasionally. At Glackmore hill they are little micacized, and at Meedanbane and Aughtbridge are slates very slightly altered. In the stream that flows eastward from Aughtbridge, and in those to the south at Ballyboe and Churchtown, good sections were observed. The rocks consist of micaceous and chloritic schists with fine grained grits. Many of these, too, appear to be little altered, particularly those near the boundary of the Carboniferous beds.

Quartzose grits and conglomerates, with schists and slates, crop out in several places on Crockanure and Eskaheen mountain. On the south slope of the latter, at the hamlet called "The Cut," the rock contains subangular pieces of felspar which impart to it a porphyritic appearance, resembling that described as "porphyroid."*

South-west from this is a rather large tract, comprising the greater part of the Scalp mountain and Asdevlin, composed of slates which, on the south-east, are separated from the quartzose grits and schists by a fault, while on the north-east they underlie similar strata. To the south-west these slates thin out, dovetailing among quartzose grits, schists, and conglomerates, till, at the road near the Junction Railway Station, they are represented by two or three narrow bands. To the north-east they are covered by an extensive peat bog, but apparently they thin out in that direction, as wedges of slate are met with on the opposite hills of Garranbane and Eskaheen. These consist of cleaved shining slates with, in some parts, subordinate beds of phyllite, and are often traversed by bands of colour indicative of the stratification. In the Carowen district, to the south-west, they appear under similar conditions, and in the southern, north-eastern, and northern parts of Inch Island are several beds of slate alternating with phyllites.

Quartzose grits and conglomerates occupy most part of the west and south-west of Scalp Mountain and Asdevlin, the greater portion of Cashel Hill, and the rugged district of Castlequarter on Inch Island. On the S.W. flanks of Asdevlin, near Crislaghsallagh, they attain their greatest development, and form massive crags. The ground-mass of this rock is for the most part a coarse phyllite, though in some places it seems to be little if at all micacized. At Rockstown, and on the roadside near the Letterkenny Junction Station, this rock has much of the pseudo-porphyritic character before noticed.

In the district north-west of the Inishowen range, and on Inch Island, several beds of limestone, or calcareous schist, occur. One of these, in which a small quarry was opened, is seen close to the road that traverses the extensive peat bog north of Scalp Mountain; and again at Monreagh and the hamlet of Asdevlin, blue limestone schists, contorted and bent into sharp synclinal curves, were noticed. South-westwards, near the Chapel of Crislaghmore, these beds reappear, and again on Inch Island, along the road leading from Carrickanee on the east to Mill Bay on the

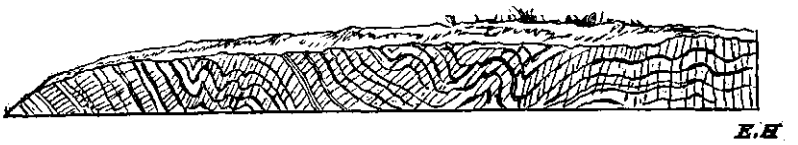
* Rutley's "Study of Rocks," p. 296.

west. At the quarry, a little north of Carnaghan Upper, the beds are for the most part highly contorted and inclined, while those at the top lie nearly flat; and being divided by joints into cuboidal portions, have much resemblance to a covering of trap rock. On the northern shore of Mill Bay these calcareous schists crop out, and are seen in section for nearly half a mile, the beds rolling at low angles. Similar rocks occur at the south-eastern end of the bay, where great blocks of calcareous sinter were observed. Near the top of Castlequarter Hill, over the conglomerates, limestones, probably representatives of these beds, are found; and again at the eastern side of the island, at the termination of the causeway leading to the railway station.

The most elevated part of the island called Inch Top is composed of slaty schists, cleaved and ribbon marked, but differing from the slates of Scalp Mountain in being distinctly micacized; and they are also seen to the south and south-west, often presenting a considerable surface of bare rock.

The north-western part of Inch Island is composed of massive quartzose grits and conglomerates, and similar rocks appear on the opposite shore above Fahan Railway Station. In the vicinity of the latter they form steep crags, and alternating with coarse schists, compose the ridge that extends N.N.E. towards Mouldy Hill, the summit of which is formed of a coarse, pebbly grit. Eastward of this there is much bare rock, chiefly coarse phyllites and schistose grits. Near Femellia some micacized flags were raised. The country about Fahan and Gollan Hill is mainly composed of slates of the same kind as those at Scalp Mountain before described. A good section may be seen on the shore, from the neighbourhood of Fahan Church northwards by the railway station. Opposite the church the lowest rocks met with are grey, slaty schists, succeeded by grey and blue, ribbon-marked, cleaved slates, which in many places, particularly near the railway station, are highly contorted. In the cutting at the station the

Fig. 4.—Section at Fahan Railway Station.



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Showing the relations of planes of cleavage and foliation to those of bedding in the strata.

slates are much indurated, some beds showing slight micacization. The relations between cleavage and bedding of the slates is represented in figure 4. Immediately under them is a well-marked bed of phyllite, then cleaved and contorted slates over another bed of phyllite, followed by coarse quartzose grits and contorted slates. On Gollan Hill these slates, with occasional beds of quartzose grit and phyllite, crop out in many places, but N.W. of the hill they are all well micacized. On the opposite shore of Inch Island, slates, probably continuous

with those at Fahan alternate with phyllites, but, as they are traced inland, become more micacized and schistose.

Returning to the Inishowen range, we find, south of the great fault that bounds the slates, much of the country composed of quartzose grits and conglomerates of two distinct types, the upper being a highly siliceous rock, similar to those just described, while the lower is a massive, green, pebbly rock, somewhat resembling that at Leamnacrossan Hill, already noticed, and like it, having externally the smooth, rounded, hummocky appearance so often observed in massive greenstones. This, too, is the prevailing character of the grits and conglomerates in the south of the Island of Inch, and the district of Carowen to the south-west, on the opposite side of the alluvial plain. Great masses of these grits also make up most part of the hill at, and south-west of, Burt House. Under them, at Speenoge, is a bed of the peculiar compact green rock already referred to at page 17. The upper portion of the hill is composed of phyllite and fine micacized grit in which cleavage is often the only visible structure, the dip being obscure in many places. At the summit, which is crowned by the remarkable fort of Greenan, the cleavage and dip have the same direction, though the latter is at a higher angle. Similar rocks make up the hills to the south-west. In some parts, particularly on Bogay Hill, the rock is traversed by a remarkable vein-like rib from one to two inches wide, across which the direction of the cleavage is altered. This structure, though somewhat irregular, and in parts separating into branches, appears to bear a relation to the bedding, as it coincides mainly with the direction of the coloured banding where such was observed.

On the east of the peat bog south of Castleforward a peculiar rock was observed which, in great part, bears a considerable resemblance to an igneous rock, consisting of felspar and hornblende, with serpentine and specks of black mica, yet its stratified character is apparent, and it appears to pass into green schists of the ordinary type.

South-south-west from this, and southward to Newtown Cunningham, little rock is visible; but on the north-west of the Glebe of Sharon quartzose conglomerates interstratified with schists are seen in a quarry, and similar beds are found a little to the north-west at Bogtown.

The ground eastward from this to Londonderry is composed of phyllite with fine grits, similar to those already described; but the coarse pebbly beds are rare, being only noted in a few localities, as may be seen by the map. Near the City of Londonderry rocks come to the surface at Killea, Minkey, and Creevagh Hills. In the latter there are micacized slates and flags, in which several quarries have been opened, though they have long since been abandoned. At Creggan, in the stream course a little west of the waterworks, are chloritic schists and grits with irregular veins of quartz and thin bands of limestone.

In the south-western part of the City of Londonderry is a large quarry in green shining phyllite, with thick beds of grit,

some of which are calcareous; stone from this quarry has been extensively used for building purposes. North of the city, on the roadside near Richmond, gritty phyllites appear, and at a mile and a-half to the N.W. at Shantallow, there are extensive quarries in similar rocks. Eastward from the latter locality rocks of like character are also seen in a quarry adjoining the main road from Derry to Moville, a little N.E. of Hampstead Hall. Some of the beds here, as remarked by Mr. Callaway, present undulating surfaces "such as might be mistaken for ripple marks."* Northward, about Steele's Town, and on the shore of the Foyle as far as Ballynagard, rocks of the same kind also occur.

North and East Inishowen.†

The metamorphic rocks and formations of East Inishowen are here considered in the supposed order of their formation, beginning with those in the islands off Malin, and the rocks of Malin Head, which are supposed to be the lowest in the series.

Gneiss.—On Torbeg, Tormore, and Inishtrahull—we find the rocks to consist of a well-defined hornblendic gneiss of a greenish colour, and quite dissimilar in character to any other rock of the district. Its general strike is E. 10 N., and the dip to the S.E. at high angles. As the relations of this gneiss to the other rocks of the district cannot be seen, it is impossible to assign to it any positive age; but it closely resembles the Archæan rocks of Canada, and of Sutherlandshire—hand specimens being in many cases undistinguishable. It is penetrated by numerous veins and masses of white quartz, and by basaltic dykes which will be afterwards described.

Between Inishtrahull and the main land, typical white quartzites, dipping to the S.E. at 40° to 50° form a group of rocky islets known as the Garvans.

First Quartzite series.—At Malin Coast Guard Station, and for some distance westwards, pink and white quartzites are much shattered and cleaved, the dip in many cases being uncertain. At the Watch Tower the rocks are felspathic, of a pink colour, and pass into gneiss; farther west there are beds of mica-schist associated with them. ‡

At Malin Head the pink quartzites predominate, but although highly altered, biotite being sometimes developed, yet the gneissose structure is not so apparent as in those referred to.

Along the southern shore of Malin Head to White Strand Bay flaggy quartzites dip steadily to the W. for a distance of

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* On the Granitic and Schistose Rocks of Northern Donegal, Quar. Jour. Geol. Soc., vol. xli., p. 231.

† By Mr. Cruise.

‡ For microscopic description of the quartzites, see "Petrographical Notes," pp. 51 and 52.

about half a mile, but gradually change their dip to the S.E., and are well seen along the shore, and at Cranny Hill near their boundary with the schists.

Eastwards from the New Pier at Malin the quartzites form bold cliffs; the section to their boundary with the schists, under which they pass, is 5¼ miles in length, and consists generally of massive quartzite, and thin flaggy quartzites with a few beds of quartz-schist, the beds being repeated by a series of synclinal and anticlinal folds; the prevailing dip, however, being to the S.E. These beds are broken through by numerous dykes of basalt. See p. 30.

The Garvan Isles are formed of these rocks. (See Fig. 5).

Similar rocks are frequently exposed inland; but as they are all of a similar character to those along the coast they need no further description, their outcrop and dip being shown on the map. A few bands of limestone and calcareous schist at Knockglass and Mossedge near the southern margin of Sheet 1, are associated with thin bands of black shales. On the northern shore of Doagh Island typical white quartzites dip at 40° to the S.E. under crumpled mica schists, the junction being well defined.

These beds are also exposed in the fine headland of Binion, on the shore to the S.W., where they are massive and even-bedded, with dips varying from 50° to 65° to the S.E. At Saul Point, the western extremity of Binion, a mass of fault rock occurs along the strike of the beds. A continuation of these beds forms the well-marked mountain ridge of Raghtin More and Croaghcarragh.

These rocks can be well studied in the fine section displayed through the "Gap of Mamore," a fissure formed in the ridge between Mamore and Croaghcarragh, along a line of fault at right angles to their strike. The dip is invariably to the S.E. at angles varying from 35° to 60°, and the strata here must be of very considerable thickness.

These quartzites are also well seen on the road from Clonmanny to Dunaff Head, and at the Head itself, where they are penetrated by irregular masses of granite and diorite, a mass of granite being brought up against their edges by a well defined line of fault.

First Schist series.—The lowest members of this series overlying the quartzites, form the cliff coast-line from their junction with the latter to Portnalong, 2½ miles north of Culdaff, in Sheet 6.

The section generally consists of micaceous, talcose and chloritic schists, generally highly crumpled, puckered and contorted, with beds of green and grey grit, the series being sometimes penetrated by veins and strings of quartz. The general dip is to the S. or S.E., but there are numerous folds, the beds in many cases rolling at low angles. At Glengad Head crumpled micaceous schists form a vertical cliff 200 feet high; sections in similar beds are also freely exposed along the coast line to their junction with the quartzites, and in the high ground to the west.

These beds extend in a general S.W. direction from the sea to the shores of Lough Swilly, a distance of about 18½ miles, and

occupy a tract of country about four miles wide, but on account of the numerous contortions and foldings their thickness is doubtful.

At Farragan Hill, in the N.E. corner of Sheet 5, beds of micaceous and chloritic schists are freely exposed, with a few bands of calcareous schists. North of Malin Village a narrow band of limestone occurs in them. On Doagh Island the beds consist principally of highly crumpled and puckered mica-schists rolling at low angles, with numerous strings and veins of quartz. Similar beds are freely exposed along the road between Carndonagh and Ballyliffen and in Croaghaughrim and Coolcross Hills to the S. of the road. On the road leading to Dunree Head a little S. of the Village of Clonmanny (marked Dunally on the map) large plates of mica can be obtained from the schists. A thin band of limestone occurs at Pincher's Corner along the same road.

Numerous sections in beds similar to those already described can be seen at Bulbin, 1,630 feet, and at Crockcore, 1,391 feet, all dipping to the S.E.

Between Mintiagh Lough and Lough Fad the schists are penetrated by numerous large veins and irregular masses of quartz, which closely resemble the gold-bearing quartz of Wales and Australia. Numerous beds of felspathic schist and quartz-schist are here associated with the general schists.

From Dunree Head to the southern margin of Sheet 5, talcose, micaceous, and chloritic schists, crumpled and puckered, full of flying quartz veins,

Fig. 5. The Garvan Islands—off Malin Head. Beds of Quartzite rising from the Atlantic.

are well seen along the low-lying coast. Beds of felspathic grits frequently occur in them. Their general dip is to the S.E. from 15° to 40°, but synclinal and anticlinal folds are frequent. At the southern margin of the map the dip, in black schistose beds, rises to 70°, where they pass under a bed of white limestone.

Second Quartzite series.—These beds extend from 2½ miles N. of Culdaff to the southern margin of Sheet 5, and are continuous to the shores of Lough Swilly at Buncrana, in Sheet 11 to the southwards.

In the southern part of Sheet 5 they form the well marked ridge whose summits are known as Crocknamaddy, Slieve Main, Slieve Snaght, and Slieve Snaght Beg.

In character this series of beds differs markedly from the quartzite of Raghtin More, being much more felspathic and having numerous beds of micaceous and felspathic schists and coarse grits associated with them.

From their junction with the schists near Culdaff, the following is the general section in ascending order :—

1. Flaggy quartzites.
2. Thick bedded quartz-rock.
3. Quartzites and quartz-schists, with thin bands of felspathic schist.
4. Flaggy and micaceous quartzites.
5. Quartzites and quartz-rock, with thin beds of talcose and micaceous schists.

These beds are penetrated by dykes of diorite, which will be afterwards described.

Similar beds to the above are frequently exposed in the high ground to the westward as far as Malin Village. To the S. of Culdaff and of the main mass of the limestones a well-marked anticlinal ridge of flaggy and massive quartzite may be observed. On the road a mile E. of Carndonagh, a mass of coarse grit was noted, associated with the quartzite. E. of Carndonagh the quartzites are shifted to the S., along a well-marked line of fault occupying the valley of the Loughinn River. South of the town these beds are generally concealed under a deep covering of drift. To the west of the town, however, they are frequently exposed, particularly at Crockerakilladner and in the river section a mile west of the hill, the beds being very much contorted and shattered at the latter place.

On the road to Derry, three miles S. of Carndonagh, a wedge-shaped mass of schistose rocks is brought in along a line of fault.

At the boundary between the underlying schists at Lough Naminn, on the road to Buncrana, typical quartzites undulate at low angles; Barnmore and Barnbeg (The King and Queen of the Mintiaghs), forming a conspicuous feature, see p. 31. East of these hills the quartzites are more flaggy, the ground rising rather sharply, forming Slieve Snaght Beg; the rock at the summit and western slopes being flaggy quartzite and quartz schist. South of the latter elevation, Slieve Snaght is composed of flaggy beds, dipping to the S.E. at 45°. Along this ridge the rocks are seldom exposed, unless at the summit, vast tracts of bog covering the mountains and low lands on either side. Flaggy quartzite and quartz-schist are, however, seen rising

through the bog at Slievemain,and at Crocknamaddy. The rocks on the latter hill are associated with micaceous, flaggy, and felspathic schists. A very sharp anticlinal fold in those beds was noted, the fold measuring only ten feet across at the bottom, and twelve feet high; the felspathic schists not being at all broken or crushed are quarried for flags, which shows that the flexuring movement probably took place slowly.

One other locality where the quartzites are exposed need only be referred to, namely, the Hill of Truskmore, 990 feet—two miles E. of Slieve Snaght. The beds consist principally of flaggy quartzites, with a few of more massive character. The axis of a well-marked synclinal ridge runs in a N.E. direction along the top of the hill.

Second Schist series.—The schists overlying the beds just described differ essentially from those under the quartzites. They are in many places but little altered, and contain numerous bands of coarse grit.

A mile E. of Culdaff slightly altered shaly beds occur, but at Warren Lodge a little further E., typical mica-schists are shifted to the N. along two lines of fault, bringing them against the limestones. At Dunmore Head the section, about 2,000 feet in length, consists of the following groups of rock :—

1. Mica-schist crumpled.
2. Talcose and micaceous schists.
3. Blue thin flags quarried for tombstones, &c.
4. Quartzose grits highly altered.
5. Micaceous schists.

Along the shore the beds alternate between chloritic schists, flags, flaggy felspathic grits, slaty grits, and massive bedded grits with grains of orthoclase, all more or less crumpled, puckered and rolling. In the valley at Redford reddish quartz-schists are seen.

Beds of schist and grit are exposed in many places to the S. of the latter, and the remainder of the beds in Sheet 6 are described by my colleagues, Messrs. Nolan and M'Henry.

A well-marked ridge running from Glenelly Bridge to the Carndonagh fault, the boundary between them and the limestone being also a line of fault, may be briefly noticed. This ridge consists of alternating beds of flaggy, micaceous, chloritic, and talcose schists dipping steadily to the S.E. at an average of 45°. These beds are in many cases highly cleaved.

In the S.E. corner of Sheet 5, near Mine-hill Bridge, a quarry was opened in flaggy talcose schist. South of the latter locality there are several exposures in coarse grit and felspathic grit.

Limestones.—These are found both in the series of schists and quartzites; their greatest development, however, is at Culdaff, in the middle quartzite series ; they will also be described in ascending order.

On the northern shore of Malin, quite close to the schistose boundary, a band of bluish-white calcareous schist occurs, but is of no commercial value. Near the northern margin of Sheet 5, at Mossedge, two bands of limestone are associated with some black schists. One of these beds is of a greyish-white colour, the

other being rather a calcareous schist. These three bands were all that were observed in the lower quartzites, while in the overlying schists there are only two very narrow bands seen in the stream N. of the village of Malin.

Several narrow bands of limestone occur in the upper quartzites at that village, the beds being either light blue or white in colour, crystalline, and always associated with igneous rocks.

At Culdaff the principal mass of the limestones of the district lies apparently in a synclinal trough formed in the upper beds of the quartzite. In some cases the beds at the village roll at low angles, while south of it they form a synclinal trough at the high angles of 70° and 80°; patches of dolomite are of frequent occurrence. The limestones, which vary in colour from grey to dark blue, are brought against the schists two N. and S. lines of fault. The peculiar forms found in these beds, which bear a strong resemblance to corals, are described in Appendix B.

One and a half miles S. of Culdaff wide bands, or series of beds, of pale blue limestone extend in a S.S.W. direction to Carndonagh, their boundary with the shales to the S. being a line of fault. It is probable that these are the Culdaff beds brought up against the schists.

All these limestones are quarried in the neighbourhood of Carndonagh and at Culdaff, as well as at intermediate places.

Beds of light blue limestone also occur S. of Carndonagh at Cashel Lower, Kellystown and Crockroosky, which are quarried in some cases extensively. These latter beds occur in the upper series of the schists. The few remaining exposures to be noticed are those near the southern margin of Sheet 5 at Turk, locally known as the Illies limestone, which is similar in character to that of Culdaff.

*Moville District.**

The district extending northward from Moville to Dunmore Head, and westward from Inishowen Head to Drumfadda Mountain, forms the eastern portion of the Inishowen peninsula north of Lough Foyle, and is included in Sheet 6.

This tract of country is as wild and rugged as almost any part of Co. Donegal, the coast line being bold and precipitous, except on the south-east along the shore of Lough Foyle. On the north the sea cliffs reach a height of four and five hundred feet, and are in but few places accessible except by boat.

An eastern branch of the Inishowen Mountains, ranging generally N.E. and S.W., extends into this district, the principal elevations being:—Crocknasmug, 1,076 feet; Crockaulin, 1,071; Crockavishane, 1,058; Craignamaddy, 1,054; Craigcannon, 996; Crockmore, 988; Tavish Hill, 937; Crocklummon, 927; Crocknabron, 906; Sheeg Hill, 900; and several others ranging down to 600 feet.

The district is entirely composed of metamorphic rocks, invariably covered by peat bog where the ground is high.

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* By Mr. M'Henry.

Numerous small streams rise in the hills and run short courses of a few miles to the sea. The principal river is the Gleneely, which has its source N. of Lough Fad Mountain, and flows northwards through the village of Culdaff, into Culdaff Bay. In the south the Bredagh River flows by the town of Moville into Lough Foyle.

Metamorphic rocks occupy the entire district of eastern Inishowen, outcrops being numerous all over the country; while the rock-bound coast lays open to view fine sections of highly-contorted strata, composed of various phyllites or argillaceous schists, grits, and conglomerates; even the last-named being affected by cleavage.

In the north, about Tremone Bay, massive, but fine conglomerate occurs interbedded with the slaty schists. These conglomerates are made up principally of white vein-quartz; they also contain pink and red felspar in slightly worn crystals and rolled pieces, all enclosed in a brown and grey sandy and micaceous base.

Brown, olive, and grey grits and flags are frequently met with which yield excellent building stone, notably at the Croagh Quarry, a mile south of Redford Glebe, and three miles S.E. of Culdaff.

The grey, olive, and greenish schists which predominate throughout, are micaceous and chloritic, and highly steatitic beds are occasionally to be met with, especially in the vicinity of Cross Roads and Meenickawillin. At the latter place the proportion of steatite may be sufficient to render them of some commercial value.

In the hilly country the schists contain a large proportion of lenticular beds of grit and fine conglomerate of the usual character belonging to the district. The strata are in all cases highly contorted, and dip at various angles, being in most places inclined towards the N.W. or S.E., and having a constant strike in a N.E. and S.W. direction.

Along the southern area, between Inishowen Head and Moville, the rocks are pretty equally made up of schists and grits, grey green, and sometimes brown and olive in colour, and often very chloritic in composition. Both the schists or slates and grits are so highly cleaved that it is sometimes difficult to determine the true bedding of the rocks. As in other parts of this peninsula, the beds are excessively contorted and crumpled, and dip at high angles on both sides of the prevalent N.E. and S.W. strike.

The rocks generally in the district are so slightly metamorphosed that they might be expected to yield fossils; but these, although diligently looked for, have not hitherto been observed.

Between Greencastle and Moville there are greenish grey grits well suited for building stone.

CHAPTER V.

Lower Carboniferous Rocks.

*Calciferous Sandstone Series.**—Strata referable to this series occupy a strip of country along the shores of Lough Foyle from

* By Mr. Nolan.

Craigboy to Culmore, having an average width of about half-a-mile, except at Muff where it is a mile wide, and is separated from the metamorphic rocks, for the most part, by a line of fault. The beds consist of red and flesh-coloured coarse sandstone, pebbly quartzose sandstone, and conglomerate. In the upper part sandy shales with yellowish sandstones occur, of similar character to those on the south and east of Lough Foyle; and like them, evidently belong to the same formation as the Dungiven beds (Upper Calciferous Sandstone) described in the Memoir to accompany Sheet 18. To the north-east these beds appear on the shore near Vance's Point, a little below the chapel, where they consist of greyish-white pebbly and generally calcareous sandstone; but, as the section is followed southwards, red conglomerates appear and ultimately predominate. At a mile south of Carrowkeel these beds are cut off by a transverse fault, which is visible on the shore at low water, where rusty-yellow quartzose schists of the metamorphic series are brought sharply against the Carboniferous sandstones. At Aughtbridge these latter reappear, though there are few openings on the shore southwards; but good sections may be observed in most of the stream courses. In the stream which enters Lough Foyle, near Ture House, reddish-brown sandstones and coarse flags are seen close to the road. Higher up are pebbly sandstones with red and purple sandy shales, which are bent over into an anticline and dip against the metamorphic rocks at a high angle. To the south-west yellow sandstones appear in a quarry close to the road at Mitchell's Town, and red and purple beds, apparently the south-west part of the anticline just described, are met with in the adjacent stream, close to the fault that bounds the metamorphic rock series. North-west of Muff coarse red pebbly sandstones, succeeded by others of a yellow colour, are met with in a stream, and close to the road which crosses it a little north of the village, these latter disintegrate into sand, which is dug out for scouring purposes. West of the village, reddish-purple pebbly sandstones appear in the stream near the church, and to the south-west, near Knowehead, rest unconformably on the metamorphic rocks. A little south-west of the village pebbly sandstones were observed in a watercourse on the east of the road leading to Ballyarnet, but no further sections are visible, though there can be no doubt that the rock extends under the adjacent raised beach.

CHAPTER VI.

Igneous Rocks.

*Londonderry District.**

Basalt dykes.—Igneous rocks are extremely rare in this part of the region, the only ones that occur being a few unimportant basalt dykes, probably of Tertiary age, seen on the shore of Lough Foyle. Why these dykes should be so rare here, and yet appear

* By Mr. Nolan.

in such large numbers farther west, in the granitic tract of Donegal, is a circumstance which it is difficult to account for.

Mr. M'Henry has made a similar observation concerning the absence of dykes from the tract of metamorphic rocks in the north-east of County Antrim, a district situated almost at the very centre of the Tertiary volcanic eruptions.*

Malin and Culdaff Districts.†

Diorite (Epi-diorite).—This rock occurs in dykes, sheets and irregular masses over the entire district, and varies but little in character.

At Malin Coast Guard Station diorite cuts through the lower quartzites in a very irregular manner, and, together with the quartzites broken through by the granite, makes a tangled mass. The rock here is of a rather finely crystalline character and dark blue colour.

Along the shore towards Malin Head several dykes are met with of more coarsely crystalline structure. At Pebble Strand, a large dyke occurs enclosing fragments of gneiss, and so highly altered as to pass in places into hornblende schist.‡

Diorite dykes traverse many parts of the Malin promontory; their position will be seen by reference to the map.

From the southern margin of Sheet 1 a large mass of diorite extends from the shore for a distance of over two miles inland in an irregular shape, widening out in places to nearly a mile in width. It is well exposed, and is evenly crystalline and greenish blue in colour. Some small dykes of the same character are seen on the shore N. of Lag Roman Catholic Chapel. In the schists near their junction S. of Lag a finely crystalline dark blue diorite dyke is seen, the outer edges of which exhibit a schistose structure.

On Doagh Island several of the typical diorites occur in irregular masses and along the lines of bedding of the schists.

From the village of Malin several well-marked greenish, evenly crystalline, dykes were traced in the upper quartzites for over a mile along the bedding. Massive irregular dykes or sheets more than a quarter of a mile wide occupy the ground from Drumaville to Templemoyle-bridge—the rock changing from greenish blue to blue in colour.

In the quartzites N. of Culdaff eight dykes are seen along the shore, some of them being traceable inland. They all have the appearance of being interbedded typical diorites. A short distance N. of the village of Culdaff a thick mass of diorite is seen, at its eastern termination being slightly faulted.

South of Culdaff other bands of diorite occur and were traced as far as Carndonagh.

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* The distribution of Tertiary volcanic dykes in the North of Ireland is represented in Plate I. of Dr. A. Geikie's "History of Volcanic Action in the Tertiary Period in the British Isles." Trans. Roy. Soc., Edinburgh, Vol. XXXV.

† By Mr. Cruise.

‡ See "Petrographical Notes," p. 51.

*Granite.**—This rock occurs in irregular tangled masses near Malin Coast Guard Station, cutting into the quartzites and diorites. In this locality the granite is of a reddish colour, and varies from finely-crystalline to largely-crystalline in texture.

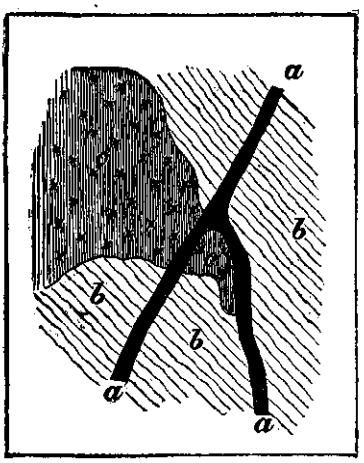
There are several irregular masses and patches on the hill at Ardmalin North, and Middletown. On the shore to the south at White Strand Bay the granite occurs comparatively in mass, and may be traced along the shore continuously for about half a mile, from whence it was observed occurring further along the coast in irregular bosses and small patches in the direction of Malin Head.

The granite is invariably red in colour, and evenly crystalline. It is in many cases cut through by dykes of basalt which also penetrate the quartzites, thus showing that the granite is older than the basalts which are probably of Tertiary age. In a cliff section a little south of Ineuran Bay there is a tangled mass of granite and dolerite, and my colleague, Dr. Hyland, is of opinion that the granite penetrates the dolerite.

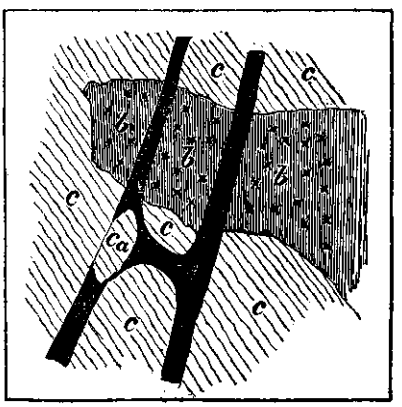
Basalt and Dolerite.—Numerous dykes from one to ten feet wide penetrate the gneissose rocks of Inishtrahull, particularly along its eastern shore. They are very finely crystalline, and of a dark blue or nearly black colour.

Along the shore on the mainland W. of Pebble Strand these dykes are very numerous, cutting through the gneissose and schistose rocks, but they are in general narrow. Others were also noted at Malin Head, and to the S. of Ineuran Bay, and along the shore to White Strand. Some fine examples showing how they penetrate both the granite and quartzites are represented in the following plans (Figs. 6 and 7.)

Figs. 6 and 7.—Dykes in North Inishowen.



(*a.*) Dykes of basalt.
(*b.*) Quartzite.
(*c.*) Granite.



(*a.*) Dykes of basalt
(*b.*) Granite.
(*c.*) Quartzite.

East of Malin Coast Guard Station, as far as Stookaruddan, these intrusive rocks become much more massive, and are usually

*See "Petrographical Notes," p. 42.

dark brown, and very compact in texture. They are well seen in the cliff sections, sometimes penetrating to the top of the cliff, while at others they send out angular offshoots not reaching the surface; in other cases the dykes change their inclination to the horizon. A fine example of this change occurs at Stookaruddan, the basalt penetrating the quartzites, and turning over to form the cap of the Stook. These dykes cannot be traced inland owing to the thick covering of drift and bog.

The only remaining basalt dyke is that seen on Doagh Island, on which the castle is built. It is of a dark colour, finely crystalline, and has pieces of quartzite caught up along its walls.

Carndonagh District, including Dunaff Head.

The town of Carndonagh itself is built on a mass of typical dolerite.* Between the town and Ballyliffen several dykes are also seen. At the latter village a narrow dyke crosses the road and in places is foliated.

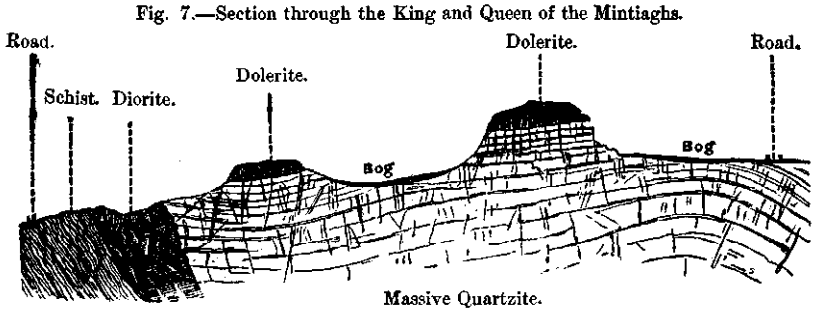
At Dunaff Head an irregular mass of evenly crystalline dark greenish grey dolerite forms part of the headland. A dyke similar in character is seen at the hamlet of Leenan.

Granite.†—This rock occupies a tract of country extending from Tullaghan Bay to the shores of Lough Swilly, one mile below Dunaff Bay. The eastern boundary is concealed by a raised beach; while on the west the granite is brought against the quartzites by a line of fault which runs in a N.E. direction through Dunaff Head. There are, however, some irregular intrusions of granite into the quartzites west of this fault.

The granite here, as well as at Malin Head, is intrusive, and is generally evenly crystalline, and mostly of a red colour. The rocks are well seen at Tullaghan, Rockstown, Ballynacarta, Dunaff, and along the line of fault. They are also exposed on the tidal shore to the S. as far as their boundary with the quartzites.

Basalt.—Two small dykes of basalt occur in this part of the district, one being narrow, dark-brown, penetrating the granite at Dunaff Bay, and the other running along the line of fault that passes through Mamore Gap.

Fig. 7.—Section through the King and Queen of the Mintiaghs.



North of the Mintiaghs Lough a wide evenly crystalline dyke of diorite extends from Lough Fad to Beam, a distance of about three

* See "Petrographical Notes," p. 45.
† See "Petrographical Notes," p. 39.

miles. Between Mintiaghs Lough and Lough Naminn there are several sheets and bosses of Pre-Tertiary dolerite all of the same character. The hills known locally as the King and Queen of the Mintiaghs are crowned by dolerite, and form a most conspicuous feature.

Large masses of dolerite are also exposed W. of the road leading to Buncrana at Rushfield, at Newtown, and near Keeloges Bridge. On the road leading to Dunree Head a large mass of dolerite has been for many years extensively quarried for road metal to supply Derry. The face of this quarry being wide, the rock can be studied with advantage. In general it is evenly crystalline, greenish in colour, resembling other rocks of the district. Its outer edges are not foliated, but at different places between the walls of the dyke there is distinct foliation, the rock in one place passing into a schist.* Copper pyrites was also noted in this dyke weathering into covelline.†

Another large dolerite dyke occurs at Laffin Hill, about two miles from the last. Here the rock is of a greenish colour, with white crystals of felspar weathering and standing out. In places this dyke is foliated. The remaining exposures of similar rock to be referred to are to be seen at Kinegad Hill, near the southern margin of Sheet 5, and at Truskmore.

Basalt Dykes.—Inishowen Head.‡—Only one basalt dyke was noticed in this portion of Inishowen. It occurs on the south slope of Crocknabron Hill, about two miles S.W. of Inishowen Head; breaking up in an irregular mass, having a S.E. and N.W. direction through grey and olive-brown slates. This dyke measures about ten feet across in its widest part, is finely crystalline in texture, and weathers spheroidally. Along its course the colour of the slates is altered from olive and grey to brown.

CHAPTER VII.

Drift Deposits, Raised Beaches, Peat Bogs, &c.§

West Inishowen.

Lower Boulder-Clay.—A considerable thickness of boulder-clay is spread over West Inishowen, and reaches a height of 1,000 feet on the flanks of the hills. The streams flowing from the uplands often cut deep sections through it, notably along the Cabry river and adjacent watercourses that enter Lough Foyle near Carrowkeel. This deposit consists for the most part of a stiff unstratified clay, though rude stratification was observed in a few places. Its pebbles and boulders have been chiefly derived from local sources.

No shells were noticed in the boulder-clay of this district although they occur in several localities in the country to the south and east of Lough Foyle, as mentioned in the Explanatory Memoirs to accompany Sheet 12, p. 25, and Sheet 18, p. 23.

Sand and Gravel.—These deposits are found along the greater

* See note by Dr. Hyland, p. 45–6. † See p. 47. ‡ By Mr. M'Henry.

§ By Messrs. Nolan, Cruise, and McHenry.

part of the shore of Lough Foyle, and in some places spread into extensive terraces, as at Kilderry, near Muff. For some three miles south-west of Moville, a line of gravel cliffs at an average height of about fifty feet borders Lough Foyle, and similar, though smaller, deposits may be observed on the shores of Lough Swilly. The components of these gravels consist chiefly of schist, quartzite and schistose grit, sandstone apparently derived from the local Carboniferous beds, together with chalk flints in some places.

Upper Boulder Clay.—In the cutting at Inch Road Railway Station the lower boulder drift, a stiff, grey clay, is overlaid by a reddish sandy clay, full of blocks, and in some parts passing into a coarse gravel. The distinction between this and the lower boulder clay is clear; and at the north end of the cutting this upper drift overlies beds of sand and gravel by which it is separated from the lower boulder clay.

The drift deposits covering a considerable portion of East Inishowen are supposed to belong to the lower boulder clay, and consist of clay with boulders and fragments generally of the rocks of the district. Flints, apparently from the Antrim chalk, however, were found in the high ground north of Culdaff, and as far west as Malin Head.

The upper limits of this deposit would seem to be about 850 feet, at which height it has been observed on the western flanks of Raghtin More. It is quite possible it may reach a much higher elevation on Slieve Snaght, as striæ were observed on the rocks at a height of 975 feet.

The lower boulder clay is but thinly distributed over this area except within the river valleys.

Along the Bredagh River, banks of it varying up to fifty feet in thickness are to be seen. These consist of stiff brown and grey clay, rudely stratified with irregular layers of gravel and sand, and containing large and small scratched boulders of schist and basalt. Chalk fragments and flints are also common. This deposit is of considerable depth in the vicinity of the rivers Glen, Glennagiveny, and Gleneely, where also it contains large striated boulders of schist and occasional basalt blocks as well as chalk flints, the presence of the latter indicating an ice-carriage from the eastward. No shells were noticed in any of the Drift deposits of this region.

Raised Beaches.—An extensive raised beach, probably the representative of the 25-feet beach of Scotland, borders the alluvial plain south-east of Inch Island, continuing to the south-west along the valley between Carowen and Burt, opening into the Blanket Nook, while to the east it occupies the valley that extends from Burnfoot, in a south-easterly direction to Pennyburn, the average height observed being 32 feet. At Farland Point, south of Inch Island, and along the coast of Lough Swilly south-westwards portions of a raised beach at the same elevation remain. This deposit mostly consists of fine bluish-grey muddy sand, often containing fragments of shells Small portions of a

raised beach are also seen on the southern and eastern shores of Inch Island, and a more extensive one stretches along the shore of Lough Swilly, from about a mile and a half north of Fahan to Buncrana, a large portion of which is thickly covered with blown sand.

On Inishtrahull a fine example of a 50-feet raised beach occurs in the centre of the island. The lightkeeper informed me that in the year previous to my visit—1885—during a gale from the N., this beach was covered with water for over two hours.

On the mainland, from Malin Coast Guard Station, a raised beach extends for two miles to the south, being sometimes one mile wide. This beach was at one time covered with bog, which is now nearly all cut away. At Malin Watch Tower there are fine examples of the 25, 50, and 75 feet raised beaches. Along the shore to Malin Head numerous patches of the 50-feet beach may be observed between the rocks.

The most important and extensive, however, of these raised beaches is that which stretches from Culdaff to Trawbreaga Bay. Its average height is about 50 feet, and most of its surface is covered with bog, which is being rapidly cut away. Another extensive raised beach stretches from Tullaghan Bay to Leenan Bay, the bog that formerly covered this beach being nearly entirely removed. As pointed out by Professor Hull, both these raised beaches are of a comparatively recent date. (See page 10.)

Along the south coast between Inishowen Head and Moville the 50-feet raised beach occurs in several places. It consists of sand and gravel, and is best seen between Greencastle and Inishowen Head. Shells of existing species are common throughout the deposit.

At Tremore, Kinnoge, and Glennagiveny Bays, the 25-feet beach is represented, and contains shells at each place.

Kitchen Middens.—Associated with the raised beach, mounds and accumulations of shells occasionally occur, which must be regarded as of human origin, inasmuch as flint flakes, fragments of bone and burnt wood are often found in them. They were observed on the shore north and north-west of Ballymoney, in the Carowen district, at Farland Point, at Inch Island, near the old castle to the south, and at Inch Road Railway Station. Of the shells, oysters seem to be in greatest abundance, but in the locality north-west of Carowen, whelks (*Buccinum undatum*) predominate. There were also found, in less quantity, limpets, mussels, pectens, &c. An interesting paper on this subject, by Mr. Harte, County Surveyor of Donegal, will be found in the Journal Roy. Geol. Society, Ireland, vol. I., part I., p. 154.

Peat Bogs.—The bogs may be divided into two classes, those on the comparatively low-lying ground and those on the mountain slopes and hills. The principal low-lying or flat bogs are almost entirely confined to those on the raised beaches, while the mountainous bogs cover large areas, both in the Malin district and to the S. and S.W. of Carndonagh, in some cases rising in complete sheets, covering both slopes of the Slieve Snaght range, and in many cases enveloping the top of this range. A

considerable area also of mountain bog lies to the E. of Dunree Head.

The high ground is almost invariably covered by peat bog of considerable thickness, while in the lowlands to the north-west about Cross Roads, Tirahork, and Cambry the same deposit is extensively developed. In these latter tracts, roots and trunks of forest trees (oak, fir, hazel, &c.) are abundant.

An immense covering of peat spreads over most of the country west and north-west of the Scalp range of mountains extending in some places over their summits. On the top of Crockglass, peat six feet thick is cut, but little of it is found on the southern slopes, except a tract east of Eskaheen mountain. Westward from Muff a flat bog, more than a mile in extent, occurs, southward of which little peat is seen till we reach the vicinity of Port Lough, where fuel of excellent quality is obtained.

Alluvial Flats.—These are comparatively small in extent, as there are no large rivers. The more considerable streams descend from their sources more or less rapidly, and do not give rise to alluvial flats.

The principal small alluvial flats are found along the Clonmany, Carndonagh, Culdaff, and Owenbeg rivers.

Blown Sand.—Considerable accumulations of drifted sand lie between Doagh Island and the mainland; in some cases forming sand dunes. Bones of the dog, pig, ox, and sheep have been found in them. Blown sand occupies a small tract S. of Leenan Bay.

Small accumulations of similar sand likewsie occur at Termon and Cornashamma Bays, and south of Inishowen Head, at White Bay.

Intakes.—The largest extent of intake, or reclaimed land, is that before referred to as lying south-east of Inch Island. Much of this ground is under cultivation, chiefly as pasture-land and cornfields. On the shore of Lough Foyle, south-east of Muff, a considerable intake has been made, but a few larger tracts to the north, adjoining the low flat shore of Kilderry, could also be reclaimed with advantage, not only in the gain of land, but also in the improved navigation of the lough.

Brick Clay.—In the plain of marine alluvium, west of Burnfoot, much plastic clay suitable for making bricks and tiles occurs, and extensive works for this manufacture are carried on here. Brick clay is also found on the opposite shore of the lough near Kilderry.

CHAPTER VIII.*

Principal Faults.

The largest and most important fault in this district is that which traverses the south-eastern part of the West Inishowen mountains, and reappears to the south-west at Carowen, on the opposite side of the marine alluvial plain. This fault, which has already been referred to at pages 15 and 18, separates the slate rocks from the metamorphosed grits and schists, and the evidence for its existence, as may be seen by the dip-arrows on the map, is of the clearest character. The downthrow appears to be to the south-east. Another great fault, which has also been previously mentioned on page 28, bounds the strip of Carboniferous rocks that extends along the shore of Lough Foyle and separates them from those of the metamorphic series. This is proved in some places as at Ture and Aught by the position of the Carboniferous beds which dip directly against the schists, and also at Craigboy where they lie at right angles to them. Even where the newer beds dip from the older, the angle of dip is unusually high; the rocks, too, show slickensided surfaces, and other marks of disruption, while springs of water abound along the line of junction. About the middle of its course this fault is shifted by a smaller one bearing nearly N. and S., the evidence for which, as before remarked, is apparent on the shore at low water.

Minerals.

Bog iron ore.—A little of this deposit is raised on the eastern slope of Glackmore Hill, N.W. of Aughtbridge. The ore is largely diffused over the entire district, of various qualities, in some places being abundant and in others scarce. It has been largely exported both as an iron ore and for the purification of gas; but of late years this industry has greatly fallen off.†

Mines.—On the W. side of road, S. of Carndonagh, leading to Derry, some shafts were sunk in former years on what, to judge from the fragments lying about, appears to be a very poor lode of galena (or lead ore). I could obtain no information on the subject.

Glaciation.

The prevailing direction of ice-striæ in this peninsula is northwards varying from N. and S. to N. 20° E., the ice in general appearing to have come from the south. There are also abundant evidences of a glaciation bearing E.N.E. and W.S.W., occasioned by ice coming from the north-east as some of the *Roches moutonnées* present their steep faces to the westward. Among the places deserving special notice as exhibiting glacial phenomena in a marked manner may be mentioned Inch Top on the island of that name, the hard quartzose rocks of which are extensively planed and scored showing every system of striation observed in the district.

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* By Messrs. Nolan, Cruise, and M'Henry.

† In 1883 the quantity exported from Londonderry was 3,155 tons; "Mineral Statistics, U K. for 1888."

Most of the phenomena observed here are probably due to the general land glaciation of the country. The boulders of granite and other rocks from the central parts of Donegal found near Londonderry have been regarded as evidence of transportation by floating ice during a period of submergence.*

The rocks of this region are very extensively ice-worn. In the high ground particularly the striation is beautifully seen in numerous places, and indicates a general movement northwards. A little N.E. of Moville, on the rising ground above the road to Greencastle, a few good examples of *Roches moutonnées* are to be seen showing a N.E. direction.

The following is a list of the striæ observed over this eastern portion of Inishowen:—

TABLE OF ICE STRIÆ, INISHOWEN, CO. DONEGAL.

Townland.	Locality.	Direction of Striæ.	Remarks.
Killea, . .	Top of Hill N.W. of Creevagh Hill.	E. 10 N.	—
Ballyargus, .	South part of Puckan Hill,	N. & S.	—
Clare, . .	Roadside E. of Condum Hill,	N. & S. N. 20 E. newer.	Two sets of striæ observed on the same rock surface. Those bearing N. 20 E. cut across the other.
Drung, . .	Near Magherard, . .	E. 10 N.	Grooves on glaciated rock surface.
Ballynakilly, Grange, .	Inch Island. North, west, and south of Inch Top.	N. 10 E. N. 20 E. N. 40 E.	This hill is well glaciated, particularly on the south, where there is a great extent of bare rock planed & ice-dressed.
Glack, . .	Inch Island—Half-a-mile S.S.E. of Inch Top.	N. 50 E.	—
Figary, . .	Cutting at Fahan railway station.	N. & S.	Top of the slates opposite station planed and striated.
Carrowmullin, .	South slope of Gollan Hill, Fahan.	N. 10 E.	Several localities above demesne wall.
Roosky, . .	Mouldy Hill N.E. of Fahan,	N. 20 E.	Top of hill shows striæ in several places.
Ballynahone, .	Femellia, 1 mile E. of Mouldy Hill.	N. 40 E.	Striæ on side of low cliff.
Grange, . .	N.E. coast of Inch Island, Lackan Point.	N. 10 E.	—
Carnashannagh, .	Bank of stream half mile N. of Burnfoot.	N. 20 E.	—
Birdstown, .	One mile N.E. of Birdstown House.	E. 25 N.	Grooves on rounded surface of green quartzose grit.
Garvary, . .	One mile E. of Birdstown House.	E. 20 N.	*Roches moutonnées* crags facing westwards. This is clear evidence that some of these groovings are due to ice coming from the north-east.
Gortcormacan, .	One mile and a-half S.E. of Scalp Mountain.	E. 25 N.	Striæ and grooves.

* "Physical Geology and Geography of Ireland," p. 210.

TABLE OF ICE STRIÆ, INISHOWEN, CO. DONEGAL—*continued.*

Townland.	Locality.	Direction of Striæ.	Remarks.
Moness, . .	Half-a-mile S.W. of Burt House.	E. 10 N.	Green quartzose grit rounded and ice-dressed.
Mulleny, . .	N.E. of Castle Hill near Blanket Nook.	E. 20 N.	—
Carrowreagh, .	South part of Greenan Hill,	N. & S.	Striæ on ice-worn hummocks.
Tirmacroragh, .	Half-a-mile S.E. of Radford Glebe.	{ N. 10 W. N. 10 E. }	Two sets.
Ballycharry, .	Close to Ballycharry Scotch,	N. 10 to 15 E.	—
Drumaville, .	Drumaglass Bridge, .	N. 10 to 15 E.	Several places.
Ballymagaraghy,	Croaghdoo Head, Crockadartan, and Crockbrack.	N.	Top of hills.
Drumasternan, .	A little N.E. of Millhead, .	N.	—
Leitrin, . .	Around Falmore, . .	N. 5 to 10 W.	Several places noticed.
Aghatrubrid, .	A little N. and N.E. of Sheeneen.	N. 10 W.	Two places.
Carrowblagh, .	W. of Cross Roads and Craigcannon Hill.	N. 10 W.	—
Drumlee, . .	A little N. of Greenock, .	N.	—
Gulladoo, . .	Craigcannon Mountain, .	N. 10 W.	Top of hill.
Ballynally, .	,, ,, .	N. 10 W.	,,
Monyglen, .	Crockduff Hill, . .	N.	,,
Drumaweer, .	Crockaulin Mountain, .	N.	,,
Carrowtrasna, .	Crocknasmug ,, .	N.	Top of hill, several places.
Balleegan, .	Barnes Hill, . . .	N.	,, ,,
Ballymacarthur,	Hills N.E. of Crockaulin Mountain.	N. 5 W. & N. 5 E.	Two sets.
,, .	,, ,, .	N.	Top of hill.
Stroove, . .	Top of Crocknasmug Mountain.	N.	—
Moneydarragh, .	Lough Nastackan, . .	N. 5 W.	Shore of lake.
Tullyalda, . .	A little W. of Rowantree Rock.	N.	—
Tiryrone, . .	Crockbrack Hill, . .	N. 10 & 15 W.	Several places.
Ballybaun, .	Sheeg Hill, . . .	N.	,,
Glencrow, . .	A little N.W. of Glencrow, Lower.	N. 5 E. & N. 20 W.	Two sets.
Bredagh Glen, .	Gulladoo Hill and Hill E. of Bredagh Glen.	N. 5 & 10 W.	Several places.
Gulladoo, . .	Brockagh, . . .	N. to N. 10 W.	,,
Carnagarve, .	Lugmore Hill, . . .	N.	—
,, .	A little N.E. of Moville, .	N. 15 W.	—
,,	,, ,, .	E. 15 & 20 N.	*Roches moutonnées* going S.W. -- in two places.
Ardmalin, . .	On southern slope of boss on which Malin Tower stands.	N. 45 W.	—
—	Quarter of a mile south of Watch Tower.	{ S. 10 W. E. & W. & W. 20 N. }	Three sets.
Drumcarbit, .	West of Malin village, on shore.	N. 45 W.	—
Raghany, . .	At Rosheeny, near road, .	N. 10 W.	—
Carndonagh, .	West of Strath's Bridge, .	N. 15 W.	—
,, .	South of Redford Glen, .	N. & S.	In this case blue flags are polished, the striation being deep and well preserved.
Lederg, . .	N. of Crummins Bay, on slope of Raghtin More.	N. 80 W.	—
Dunree, . .	One mile S.E. of latter locality.	N. 35 W.	—
Fegart, . .	Near village, . . .	N. 80 E.	Along shore.

APPENDIX A.

PETROGRAPHICAL NOTES ON INISHOWEN. By J. S. HYLAND, PH.D.

The rocks, which were collected from Sheets 1, 5, and 6, for microscopical examination, may be grouped and described under the following headings:—

(1) Granites.
(2) Pegmatites (Hauy).
(3) Quartz-diorites.
(4) Lamprophyres (Camptonites).
(5) Dolerites (Ger. Diabase).
(6) Epi-diorites.
(7) Basalts.
(8) Biotite-schists.
(9) Actinolite-schists.
(10) Hornblende-schists and Amphibolites.
(11) Quartzites.
(12) Grits with Phyllites.

(1) GRANITES.

As typical representatives of the granites of Inishowen, specimens were collected from Dunaff Head and from the district of Ardmalin and Malin Head. The differences between the rocks of these two localities are sufficiently striking to permit of their separate description. The predominating granite at Dunaff Head is a biotite amphibole-granite (amphibole-granitite). Biotite-granite or granitite also occurs; but appears to be less frequent than the other type. Only the latter facies was recognised at the other locality. Another very important difference between the rocks of the two districts is that, whilst the granites of Dunaff Head exhibit no traces of deformation, the granites of the Malin District show every evidence of having been affected by the metamorphism common to the region.

A distinctive feature of the granitite as compared with true granite is the excess of a lime-soda-felspar and a proportionate diminution in the quantity of quartz present.

(*a*) *Granitites of Dunaff Head.*—These rocks are medium-grained, and are either pink or grey, the latter being the usual colour. Their structure is generally non-porphyritic, and it is rare to find the orthoclase tending to produce a porphyritic character. The constituent minerals can be recognised by the naked eye.

Under the microscope the quartz is as usual irregular in form. Liquid inclusions are very common; but enclosures of rutile needles are not so frequent as is customary. At times the quartz is seen to be partially enclosed by the orthoclase, and it would thus seem that the formation of the quartz occurred whilst the building-up of the orthoclase was still proceeding.

The dominant felspar is orthoclase, and the form is generally well developed. Zonal structure is common and may even be recognised with the naked eye on hand specimens by a variation in the degree of lustre shown by each successive zone. The composition of this orthoclase is likely to be far from simple. Decomposition tends to facilitate

the observation of the zonal structure, although it obscures the delicate tracing of the various zones. In the little altered crystals the zone of extinction is seen upon rotation of the section to pass slowly and progressively outwards without any kind of break until it reaches the outer shell. In addition to orthoclase, there occurs a triclinic striated felspar, the optical behaviour of which points to its being a representative of the lime-soda-felspars. Microperthite is rare. The alteration of both felspars leads to the formation of kaolin and muscovite, two processes which are chemically allied to each other. The pink or reddish colour of the orthoclase is due to the hydration of small enclosures of iron ores. As frequent inclusions in the felspars little flakes of hematite may be mentioned, which lie along the direction of the striation, and are due to the oxydation of magnetite.

The biotite* which usually occurs in ragged patches, possesses the following pleochroism:

$$\mathfrak{a} = \text{brownish yellow};$$
$$\mathfrak{b} \text{ and } \mathfrak{c} = \text{dark brown.}$$

In one and the same crystal lamellæ are to be seen, which are parallel to the direction of the best cleavage and which are different from the other portion of the crystal in their pleochroism. The change of colour is the following:—

$$\mathfrak{a} = \text{golden yellow};$$
$$\mathfrak{b} \text{ and } \mathfrak{c} = \text{dark sea-green.}$$

This seems to be due to a commencing chloritization rather than to a variation in the chemical constitution.

The hornblende is green in colour, and not infrequently shows twinning upon the orthopinacoid (100). The pleochroism is strong:

$$\mathfrak{a} = \text{straw yellow};$$
$$\mathfrak{b} = \text{grass green};$$
$$\mathfrak{c} = \text{bluish green.}$$
$$c \gamma b \gamma a.$$

Maximum extinction angle $= 15°$.

Sphene is a constant accessory, and usually occurs in rounded grains, although the wedge-like form in cross-section may at times be observed. It was one of the earliest minerals produced in consolidation, having formed after the iron ores but before the biotite. Sphene is particularly characteristic of granitites. Its pleochroism is fairly strong, the play of colours being from pale yellow to reddish yellow.

Other accessory minerals are zircon, epidote, iron pyrites and apatite. The latter is found in the orthoclase with its columns broken, although the two parts usually lie in proximity to each other. This dismemberment is to be attributed to the movements of the fluid mass prior to the consolidation of the rock, and must not be referred to mechanical forces acting after solidification. None of the granites examined from the Dunaff district, as already mentioned, show the slightest traces of mechanical deformation.

Biotite-granite or granitite is the association of quartz, felspar and dark mica (biotite); when amphibole or hornblende occurs in conjunction with these three constituents, the rock is designated an amphibole-granitite.

A very interesting feature of the amphibole-granitites is the frequent occurrence in them of small, dark-coloured nodules and patches, which differ in aspect, and apparently in composition, from the main mass of

* The term biotite is considered as synonymous with black mica.

the rock. In the field they present the appearance of included fragments of foreign rocks, more or less altered and impregnated with granitic materials. Sections across the junctions show their composition to be essentially the same as that of the granite, although the minerals are associated in different proportions. The patches are richer in hornblende and biotite, and finer grained than the main mass. It would therefore appear that these patches are "the result of differentiation accompanying the crystallization of the original magma."* On the other hand, one nodule has the aspect of a true inclusion, and microscopical examination confirms this view. The inclusion is a biotite-hornblende schist. It is strongly foliated, the division of the rock into layers of different mineral substances being well marked. The microscopical appearance is that of an altered igneous rock. Complete granulation of the felspar has occurred, and the hornblende and biotite are resolved at the edges of the aggregates into minute grains, which are found scattered sporadically through the felspar mosaic. The hornblende is compact, and dark green in colour. Granular sphene is also present, and fringes the edges of the ilmenite plates. A certain amount of resorption of the included rock by the granite seems to have occurred, for it is not infrequent to find in the granite, near the contact, hornblende aggregates similar to those peculiar to the inclusion. It would therefore appear that the foliation of the included rock, as well as the mineralogical change associated therewith, is due to contact-metamorphism. Had the rock been originally a hornblende rock, the corrosive action of the fluid granite would have altered the hornblende into a pyroxene. As no such change is to be observed, we may consider the hornblende as probably secondary, and due to the influence of contact metamorphism upon a pyroxene. This conclusion agrees with the observations made by Allport at Land's End, Lossen in the Hartz, and Michel-Lévy in the Mâconnais. The inclusion was originally a plagioclase-pyroxene rock.

The Rev. Dr. S. Haughton† has made an analysis of the granite of Urrismenagh, a locality situated about two miles S.E. of the hamlet of Dunaff. It is stated to be a "medium-grained granite, containing :—

(*a*) Quartz ; not very visible.
(*b*) Pink felspar, probably orthoclase ($\frac{1}{8}$-in. crystals).
(*c*) Grey felspar, probably oligoclase ($\frac{1}{8}$-in. crystals).
(*d*) Black mica, $\frac{1}{16}$-in. crystals, occasionally passing into a dark blackish-grey mica, in small nests, and resembling a mixture of chlorite and hornblende."

The analysis gave the following result :—

SiO_2	=	65·80
Al_2O_3	=	12·80
Fe_2O_3	=	6·64
FeO	=	0·18
CaO	=	2·92
MgO	=	1·78
Na_2O	=	4·16
K_2O	=	4·40
H_2O	=	1.20
		99.88

It will be observed that the relation of soda and potash to each other is not normal.

* *Teall.*—British Petrography, p. 311.

† "Experimental Researches on the Granites of Ireland." Part III., on the Granites of Donegal; Quart. J. Geol. Soc., Vol. XVIII., p. 408., and Report, British Association, 1863, p. 59.

(*b.*) *Granitites of Ardmalin and vicinity*—These granitites are much coarser in grain than those of Dunaff Head. Macroscopically they are seen to consist of predominating pink orthoclase, milky to transparent quartz, and a dark green mica. One variety of this granite-facies is a rock which consists almost entirely of quartz and felspar, with rare indications of the presence of a mica. The exact localities from which specimens were collected are $\frac{1}{3}$-m. along coast W. of Ardmalin South, and Ineuran Bay $\frac{3}{4}$-m. S.E. of the promontory of Malin Head (Sh. 1).

These granitites are seen under the microscope to bear every evidence of having suffered from the general metamorphism of the district. The quartz is fractured and granulated. A grain now resolves itself under crossed Nicols into several smaller grains, no longer in optical continuity with each other. The directions of fracture are usually indicated by the subsequent infiltration of hydrate of iron. Not infrequently a line of fracture runs through a grain without disturbing the optical continuity on either side of the fissure, so that actual fracture does not necessarily produce discontinuity in the optical characters. The phenomenon is more probably due to a re-crystallization induced by mechanical stresses. The extraordinary number of liquid inclusions, and the frequency of the fracture lines, possibly cause the milky aspect which the quartz possesses in hand-specimen.

The orthoclase is generally well formed. There are indistinct traces of microclinic structure, but the phenomenon may be due to strain. The pinkish colour is due to hydrate of iron. The crystals are mostly decomposed into a kaolinic mass. The triclinic felspar, which is present in small quantity, belongs to the oligoclase group. Fringing the felspars and quartzes it is not uncommon to find a small secondary mosaic of felspar and quartz, due to the granulation of these constituents.

The dark mica is not fresh, and its polarisation-colours point to commencing alteration. The pleochroism is usually:

$\mathfrak{c}$ = dark-green.
$\mathfrak{a}$ and $\mathfrak{b}$ = light-yellow.
$\mathfrak{c}$ varies between dark and grass-green.

The lamellæ are frequently somewhat twisted and bent. In an advanced stage of decomposition, the mica appears bleached, and almost colourless. The alteration seems to consist in the extraction of the iron which subsequently becomes hydrated. The mica contains numerous inclusions of little rutile (TiO_2) needles, often arranged in the curious reticulated aggregates known as sagenite; the angles of the meshes are 60° and 120°. The iron ores are altered into limonite; apatite and zircon are also present. There is no trace of hornblende. The Rev. Dr. S. Haughton* has made an analysis of the granite of Ardmalin, which he describes as "a coarse-grained granite, consisting of quartz ($\frac{1}{4}$-in. crystals), red orthoclase felspar ($\frac{1}{4}$-in. crystals), and green mica in nests resembling chlorite."

The analysis is as follows:—

SiO_2	=	70·00
Al_2O_3	=	16·36
Fe_2O_3	=	2·80
FeO	=	0·08
CaO	=	1·12
MgO	=	0·71
Na_2O	=	4·13
K_2O	=	4·66
		99·86

* L. c., p. 408.

The granite on the shore at Ardmalin South is intruded into by a fine-grained dolerite. Near the contact the granite is seen to become very compact, and almost devoid of mica. A section across the junction is observed under the microscope to show a fine pegmatitic intergrowth of the felspar and quartz, a structure which is not present in the unaltered granite. The dolerite has, therefore, melted up these two constituents which then re-crystallized simultaneously. Along the junction a chloritised mica is observed. The influence of the contact upon the dolerite is well marked. Its constituent materials have undergone re-assortment; none of the original component minerals remain, and the structure is entirely obliterated. The rock now consists of granular felspar and quartz, and patches of chlorite. The mineralogical change is probably due to an absorption by the dolerite of granitic materials. Carbonates are present both in the granite and the dolerite.

(2.) Pegmatites (Hauy).

In conjunction with the granites on the W.S.W. cliff along Dunaff Head, the writer observed a few veins of rose-coloured pegmatite. The pegmatitic structure is mostly a microscopical one, although the intergrowth of the felspar and quartz can occasionally be recognised in the field. In section under crossed Nicols the rock presents an excellent example of the well-known structure of graphic granite. The felspar is mostly unstriated and rarely shows true microclinic structure. The quartz is skeleton-like in appearance; it is mostly present in either rod-like forms or hollow, imperfect crystals, which are elongated in the direction of the prism-face. This elongation was observed eventually to cause the formation of a kind of pseudo-microclinic structure. The various quartzes in each felspar extinguish simultaneously, and thus show that they are parts of one and the same quartz crystal.

The relation of the quartz and the felspar to each other point to the contemporaneous formation of these two minerals, a manner of growth demanded by the name "Pegmatite" as understood by Hauy.

There is no trace of white mica, but a few threads of a dark brown, pleochroic substance suggest the existence of a dark mica in this rock.

(3.) Quartz-Diorites.

On the W.S.W. side of Dunaff Head there occurs a medium-grained rock, which proves itself upon microscopical examination to be a true quartz-diorite containing dark mica. It is the only typical diorite with original hornblende found amongst the Inishowen collection. In hand-specimens its black colour is particularly striking.

In section under the microscope the hornblende is seen to be a dark-green variety with strong pleochroism between very dark-green, deep grass-green and yellow. As usual there are two varieties of hornblende present—the one with the absorption just described, the other with feebler pleochroism. This constituent sometimes shows a well developed form, but mostly occurs with irregular outline and uncertain terminal endings. It is always compact, and has a tendency to form granular aggregates.

Twinning upon the orthopinacoid (100) can be observed; the extinction-angle varies between 14° and 20°.

The dominant felspar is a striated plagioclase; orthoclase also occurs. Neither constituent is fresh, kaolinization having usually commenced.

The biotite is not in that quantity which would justify its being considered an essential component. Its infrequency as compared with the hornblende shows it to be an accessory. It occurs in little patches and plates, which have the following pleochroism :

a = yellow ;
b and c = bronze-brown.

Along the cleavage fissures, granular epidote has been deposited.

The quartz is sparingly developed, and is invariably interstitial, being the last product of consolidation. Iron-oxides and apatite are found as inclusions in the hornblendes and felspars.

The rocks bear no evidence of having suffered from stresses.

Both structure and mineralogical composition bring these rocks into close relation with the hornblende-granitites so frequent along the cliff.

(4) Lamprophyres (Camptonites).

Along the eastern shore of Lough Swilly, about three miles S.E. of Dunree Head (Sh. 5), there are a few small dykes running N.E. and S.W., and penetrating the schists of the townlands of Meenalooban and Glebe. Specimens were collected from two dykes, about $\frac{1}{3}$ mile W. of the village of Meenalooban and $\frac{1}{2}$ mile N.W. of Mount Peter on the coast-line. The striking resemblance of the rocks to a grey, fine-grained granite, and their massive appearance immediately attract the attention of the observer, and render them conspicuous objects on the section.

Macroscopically the rocks are seen to be of a greyish colour, and to consist of hornblende, felspar, and quartz. They are mostly fine-grained, but show at times a tendency to become porphyritic. This latter texture is then due to the ferro-magnesian constituent. In section under the microscope, the brown hornblende is observed to be generally well formed. The exterior outline exhibits the usual faces, cross-sections at right-angles to the prism, showing (110), (010). Twinning is very common and follows the law ; twinning plane is (100). Sections of such crystals at right-angles to the c-axis show that the twinning has been repeated, so that as many as three lamellæ are intercalated between the two halves. The pleochroism is usually brown, brownish yellow and light yellow. The extinction angle is 15°. There are two felspars in the rock : the one possesses direct extinction and is therefore orthoclase, whilst the other shows triclinic striae and is accordingly a plagioclase. The latter is the predominating type in one of the dykes. In the other dyke, the relations are somewhat obscured owing to considerable decomposition having occurred, but the prevailing felspar appears to be an orthoclase. The felspars are generally lath-shaped in form, but rectangular sections also occur. The terminal endings are not always well defined. Dust-like inclusions are common. Zonal structure is also to be observed. The decomposition of the felspar leads to the formation of muscovite, but the felspathic constituent withstands alteration remarkably well. The quartz possesses the habit of the quartz in granite, but is not so frequent as in that rock. It sometimes shows indications of crystalline faces. There is no trace of mica as a constituent of these rocks ; but there are greenish patches of a chloritic nature, which may perhaps point to the original presence of such a constituent. These chloritic patches occur quite distinct from the hornblende. When the rock is decomposed, the hornblende entirely disappears, its place being taken by a similar chloritic substance. Epidote is common and not infrequently well formed. The pleochroism is so weak as to be hardly perceptible. Other accessory

minerals are apatite, carbonates, and iron-pyrites. There is no trace of olivine—a mineral which is hardly to be looked for in presence of orthoclase and primary quartz. The rocks are holocrystalline and are posterior to the earth movements which have affected the district. In character and geological occurrence they bear every resemblance to rocks of the Lamprophyre group.* This name was first introduced by Gümbel to define rocks which occur as a series of dykes (usually running N. and S.) in the Palæozoic strata of the Fichtelgebirge, Thüringer-wald und Voigtland. They occur as high as the Culm measures, are mostly dark-coloured, and bear a strong resemblance to "diabase" (dolerite), though they differ from that rock in containing much dark mica.† It is worth noting that Gümbel's Lamprophyres are similar in composition, geological age, and mode of occurrence to the mica-traps of Cornwall and Devon.‡ Rosenbusch§ extends, however, the signification of Gümbel's term, and distinguishes between the syenitic and dioritic lamprophyres according as orthoclase or plagioclase is the dominant felspar. The general name "Lamprophyre" he applies to rocks which occur as dykes in disturbed regions, and which, so far as the composition is concerned, have affinities on the one hand with syenites and on the other with diorites. The frequent occurrence of carbonates is mentioned as particularly characteristic, and he especially refers to the possible absence of iron oxides.

The dioritic Lamprophyres are separated into two groups, the kersantites and the camptonites. As the dominant ferro-magnesian constituent the former contain dark mica, the latter hornblende. It thus appears, that there is little or no mineralogical or textural difference between camptonite and diorite; their difference consists rather in their mode of occurrence.‖ It follows then, that, according to the nomenclature proposed by Rosenbusch, the dykes of Inishowen should be designated camptonites. M. A. Michel Lévy in his recent work¶ is of opinion that the camptonites of Rosenbusch correspond to the French amphibole-porphyrites ("porphyrites amphiboliques"), which are found notably in the Beaujolais and near Thiers: he allots them a place in the diorite family.

The occurrence of dykes of this nature amongst the schists in Ireland is a new observation; but an extensive development of such rocks may be expected.**

(5.) Dolerites (Ger. Diabase).

Undisturbed rocks belonging to this group are rare; but typical representatives are to be met with at the following localities in Sheet 5 :—

Near Keeloges Bridge, large quarry on road from Buncrana towards Dunree Head.

On Dunaff Head.

King of the Mintiaghs.

Carndonagh.

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*Mr. Teall has been good enough to examine a section for me, and to concur in this classification.

† "Geognostiche Beschreiburg des Fichtelgebirges," p. 189.

‡ Teall. "British Petrography," p. 351.

§ "Mikroskopische Physiographie der massigen Gesteine," 1887, p. 308.

‖ Teall, op. cit., p. 351.

¶ "Structures et classification des roches éruptives." Paris, 1889, p. 54.

** As bearing upon the resemblance of our Irish rocks to fine-grained grey granites, it may be interesting to bring under notice, that Gümbel especially mentions, that the stone-masons are accustomed to call the micaceous lamprophyre "granite;" it is almost the only "diabasic" rock, which can be utilised for building purposes. ("Die palæolithischen Eruptivgest. des Fichtelgebirges," München, 1874, p. 37.)

Macroscopically, as well as microscopically, the resemblance of the rocks from the two last-named localities is striking. They are medium-grained; no foliation is observable. Where considerable chemical alteration has occurred, veins of chlorite, intermingled with calcite, run through them, and at the same time they become dark-green in colour (Carndonagh).

The lath-shaped felspar is a plagioclase, showing under the microscope an almost universal striation after the albite type. Twinning according to the periclinic law is not infrequently represented; such periclinic striæ are always very fine. Star-like aggregates of felspar crystals are common Zonal structure is not very apparent. In its decomposed condition the felspar contains little granular aggregates of a mineral which appears to be epidote. A certain amount of silica is set free by the alteration and thus accounts for the few grains of secondary quartz present in the rock.

In its fresh condition the monoclinic augite is of a very pale brown colour and mostly appears in irregular forms, well developed crystals infrequent. It alters at the periphery into green, pleochroic hornblende, which itself may eventually become transformed into chlorite. The alteration of the augite into an earthy, amorphous substance rarely occurs. Biotite is at times to be observed, but its frequent occurrence embedded in the altered augite possibly indicates its secondary character. This dark mica is pleochroic between light yellow and dark chesnut-brown, the latter colour being sometimes dull yellowish-red (Carndonagh). The ilmenite often possesses a fringe of chlorite.

The structure of all these rocks is ophitic, the lath-shaped felspars piercing the bi-silicates in all directions. There is no evidence of mechanical deformation. The felspar is unbroken, and the alteration of the pyroxene appears to be due to chemical agencies only. The decomposition of the augite may finally result in a complete paramorphosis; greenish aggregates of hornblende taking the place of the augite, but still exhibiting the external outline of the latter constituent. This molecular change is particularly well marked in sections cut from the dolerite on Dunaff Head. Although a pseudomorph of hornblende after augite now represents this bi-silicate, the felspars are remarkably free from alteration products. Mineralogically this rock might be classed amongst the epi-diorites; but its structure is essentially that of a dolerite, and it appears more logical to retain it amongst this group.

The dyke near Keeloges Bridge is traversed at various points by faults. In the neighbourhood of these faults, the massive dolerite has been converted into a hornblende-schist. A thin section cut along the schistosity planes shows a well-defined flow-structure which, although macroscopically apparent on hand-specimens, is best studied under the microscope. The green hornblende aggregates wind in and out amongst the felspathic material, and thus produce the schistose character. There has been a complete obliteration of the micro-structure of the dolerite. The pale brown augites have been transformed into aggregates of greenish hornblende; the lath-shaped felspars have been almost entirely granulated. The new felspar formed by this process is probably a soda-felspar, as this appears to be the stable type under this kind of metamorphism. Epidote granules are found scattered through the schist; whilst the ilmenite is mostly altered into sphene. When the pseudomorphism is complete, the aggregates of sphene take part in the general movement.

At the actual fault-line, where the metamorphism has been most intense, the rock is transformed into a chlorite-schist, the chlorite representing the ultimate product resulting from the alteration of the augite. Quartz-veins appear in conjunction with the chlorite-schist. Under the microscope the vein-quartz is observed not to be free from molecular tension, undulose extinction being present. It is studded with fluid-inclusions, some of which possess a geometric form corresponding to that of the quartz; such inclusions are designated "negative crystals." Many of the inclusions are secondary, due to the injection of liquid matter along the minute fissures which seam the quartz. In conclusion, it should be stated that copper-pyrites occurs in the quartz-veins. It is rarely fresh, and usually decomposes into bluish covelline (CuS), intermixed with which is probably some malachite. Indications of copper in Inishowen are not confined to the dolerite of Keeloges Bridge. Sir R. Griffith, in his well-known catalogue,* records, for instance, the occurrence of traces of copper at Clonca, a locality N. of Carndonagh (Sheet 5).

(6.) Epi-diorites.

This is the prevailing type of basic igneous rock throughout Inishowen, and may be defined as consisting essentially of fibrous, needle-like, light green hornblende and a plagioclastic felspar. The quantity of hornblende is usually so large as to exceed that of the felspar, and to constitute the larger portion of the rock. The rocks are to be regarded as dolerites, whose mineralogical constitution and structural development have been modified by the agency of regional metamorphism. They form an intermediate stage in the metamorphism of dolerites into amphibolites or hornblende schists. In fact, at one locality, Patrick O'Donnell's Bridge, S. of Mintiaghs Lough, the epi-diorite was observed to pass by gradations into a typical hornblende-schist. Dolerites containing uralitised augites, are not always to be classed amongst the epi-diorites. The structural differences between the two rocks are sufficiently well-marked to permit of their separation in a petrological sense. In the dolerites containing uralitised augites there is not, for instance, that reconstruction of the felspars and movement of the constituent particles which is so preeminently characteristic of the epi-diorites

The subjoined microscopical analysis of the epi-diorites is based upon specimens collected from the following localities :—

Under bridge at cross-roads behind corn mill, S. of Buncrana.

Sheet 5.—Patrick O'Donnell's Bridge, 1 mile S.W. of Carroghill, and about 2 miles S. of Mintiaghs Lough; ¼ mile N. of Mintiaghs Lough, dyke across road; about 1 mile from Carndonagh along Moville road.

Sheet 1.—Kenagh Bridge, about 1 mile S. of Park House, on road from Malin Town to Slievebane.

No foliation is observable in the hand-specimens; but that molecular reconstruction can occur without such a structural development has of late years been abundantly demonstrated. The colour of an epi-diorite is lighter than that of a dolerite, the prevailing tint being decidedly greenish, owing to the uralitisation of the pyroxene. The grain is always medium. Under the microscope the hornblende is green in

*Catalogue of the several localities in Ireland where mines or metalliferous indications have hitherto been discovered up to June, 1854. Reprinted 1884, by A. Thom & Co. (Limited), Dublin.

colour (sometimes with a brownish tone), and belongs to that variety known as uralite. It is evidently due to the paramorphosis of pre-existing pyroxene. The secondary hornblende at times possesses the prism-angle of augite, but generally the outer form is ragged, the individual fibres often becoming twisted at the margin of the outline. In some longitudinal sections the hornblende bears every evidence of secondary growth or enlargement subsequently to its formation. We have first a single individual of hornblende which has resulted from the alteration of the augite, and to this secondary hornblende the new hornblende has attached itself. There are then two hornblendes—one of which is paramorphic to the augite and possesses a fairly good outline, while the other is a new growth upon the first, and of irregular outline. Both hornblendes are in crystallographic continuity with each other, but not infrequently the new hornblende is more dichroic than the paramorphic. In every respect this secondary enlargement is identical with that described and explained by Becke,* Van Hise,† and others, as the result of growth after consolidation of the rock from the liquid state.

The hornblende is frequently twinned upon the orthopinacoid, but the twinning is that originally possessed by the augite. At the margins of the aggregate the hornblende is decidedly actinolitic in character, being pleochroic in bluish tones of yellow.

Intergrown with and often imbedded in the augite occur well-formed flakes and irregular patches of a dark mica (biotite). It is devoid of inclusions, and bears every evidence of its secondary nature; it apparently stands in a genetical relation to the hornblende. No inconsiderable quantity of this mica is scattered in very minute flakes through the felspar-quartz-mosaic of the rock. By the paramorphosis of the pyroxene a definite quantity of lime and silica has been set free. Part of the frequent aggregates of epidote and zoisite represent this quantity of lime, whilst the silica is accounted for by a portion of the secondary quartz, which occurs both as isolated grains and as small microscopic veins enclosing fibres of green hornblende and crystals of epidote. The remainder of the epidote-zoisite aggregates and of the secondary quartz is due to the alteration of the felspar, in which they often lie embedded. This alteration of the felspathic-mineral consists of that re-assortment of its component materials which finally results in the formation of a quartz-felspar (? albite)-mosaic and epidote with its isomorphic zoisite. The new felspar is granular in form.

The ilmenite is, as usual, altered into granular sphene.

Chlorite appears as a decomposition product, and is often seen running through the rock in thin veins.

(7.) Basalts.

On the shore, W. of Malin Pier (Sh. 1), there is a dyke of basalt which shows a tendency to become porphyritic through the development of a darkish mineral. In section under the microscope this mineral is seen to be "green-earth," the form of which not infrequently points to its being pseudomorphic after augite. The rock is much decomposed, but olivine was evidently an original constituent, the place of this mineral being now taken by calcite, which possesses the

* Tschermak's Min. und Petr. Mitt., 1883, V., pp. 158, 159, 171, etc.
† Am. J. Sci., 1887, xxxiii., p. 385.

exact form of olivine, and which still retains the vitreous enclosures so commonly observed in that mineral. The felspar is lath-shaped, often very minute, and has withstood decomposition remarkably well. Other constituents are magnetite and dark mica in innumerable little flakes. The rock is a porphyritic olivine basalt containing dark mica.

In Ineuran Bay, near the promontory of Malin Head (Sh. 1), numerous basalt-dykes run in a N.W. direction. Their surfaces are at times vesicular, the cavities being drawn out parallel to the edges of the dykes. They are formed of a fine-grained rock, which shows no porphyritic tendency, and which under the microscope is seen to be very much altered, calcite having been largely formed.

As the forms of the pseudomorphs are not well defined, it is impossible to say whether olivine was once present. Biotite is frequent in minute flakes; the felspars are wonderfully fresh, and show the usual slaggy enclosures. Interstitial vitreous matter was originally present, but devitrification and decomposition have ensued. These dykes were, of course, intruded subsequently to the metamorphism of the district.

8.—Biotite-schists.

N. of Mintiaghs Lough, on road to Lough Naminn (Sh. 5), there occurs a greyish, biotite-bearing rock, which is much jointed and effervesces freely with acids. In hand-specimens it shows a rude foliation, but this structure becomes more decided under the microscope. In thin section the rock is observed to consist essentially of biotite (*i.e.*, dark mica), unstriated felspar and quartz. Latter two minerals are present in granular form. The biotite is strongly pleochroic:

a= straw yellow;
b and c=dark brown.

It is rich in inclusions, in the neighbourhood of which the pleochroism is much intensified, the colour being almost black.

The inclusions consist of magnetite, apatite, and pellucid, strongly polarising grains, which are either sphene or zircon. Pyrrhotine takes the place of the usual iron-pyrites; hence the rock gives off sulphuretted hydrogen upon immersion in hydrochloric acid. Carbonates are present in no small quantity.

The micro-structure is that of a deformed rock. The original igneous nature of the mass cannot be definitely asserted, although in the field it has every appearance of being a dyke-like protusion. If it is an igneous rock, it is most probably an altered micaceous lamprophyre such as minette, for the mica appears to be primary. The rock is overlain by a biotite-amphibole-schist containing a highly pleochroic amphibole, the change in colour of the rod-like longitudinal section being from yellow to blue. The relations between these two rocks could not be ascertained.

9.—Actinolite-schists.

At Castleross Waterfall, near the coast-line of Lough Swilly (Sh. 5), there occurs a dyke-like mass, which is a typical actinolite-schist. In hand-specimen it is a green, satiny rock, consisting of alternating white and green layers.

In thin section the rock is seen to consist of long needles of actinolite pellucid felspar and quartz, calcite and a small quantity of iron ores. The pleochroism of the needle-like actinolite is well marked, the change of colours being from pale yellow to bluish sea green. The needles are arranged with their longest axis approximately parallel to each other, and in the plane of schistosity. When the needles encounter grains of felspar or calcite, they sweep round them in graceful curves. The felspar is granular, and only in rare instances does it show lamellation. The calcite is twinned, whilst, along the plane of schistosity and embedded in the actinolite, white mica has been developed.

10.—Hornblende-schists and Amphibolites.

Under 'hornblende-schist' are grouped all those reconstructed rocks, which contain hornblende, felspar, and a varying amount of quartz, and which possess a more or less well defined, schistose character. When little or no foliation is observable, the macro-structure becomes almost massive, and the rocks then partake of an igneous character. Such masses should under these circumstances be designated amphibolites. Typical rocks of this latter class occur as dykes along the coast at ½ mile S. of Ineuran Bay and at Ineuran Bay (Sh. 1). The amphibolite of the first named locality is a biotite-amphibolite; the amphibole being compact, and appearing in thin section strongly pleochroic between very dark green and yellowish green. The biotite is possibly secondary; it possesses the following pleochroism:

$\mathfrak{a}$=yellow;
$\mathfrak{b}$ and $\mathfrak{c}$=dark brown.

The felspar is nearly all granular; but a few rudely lath-shaped sections are still to be observed, although they possess no striation. Iron ores are rare; but there is a little sphene present.

The amphibolite from Ineuran Bay is unquestionably igneous, for it has indurated the contact rock, quartzite, portions of which it also includes. Its structure and mineralogical constitution have, however, suffered considerable modification. In the centre of the dyke-like mass no foliation is observable; but in section under the microscope the rock is seen to have undergone complete rearrangement, the constituent minerals being now a strongly pleochroic, dark green, compact hornblende, unstriated felspar, quartz, and an almost imperceptible quantity of dark mica. Felspar and quartz are present in granular form. At the edges of the dyke this rock passed into a hornblende-schist, consisting of alternating layers of dark hornblende and white felspar. A concentration of the hornblende has thus been affected, and an analogous process of aggregation is observable in the case of the felspar. Hence, the dyke, which in the centre is fine-grained, assumes through foliation the character of a coarsely crystalline rock. The natural order of things is that a dyke is finer grained at the edges than at the centre.

In thin section the hornblende of this highly foliated rock is mostly granular in form, with pleochroism between light yellow and very deep grass green. The dark mica is also strongly pleochroic:

$\mathfrak{a}$=light yellow;
$\mathfrak{b}$ and $\mathfrak{c}$=very dark brown, almost black.

On the cliff section this rock is seen to be intruded into by the pink granite (granitite) of the district. Immense patches (not infrequently five

feet in length) are caught up and included by the granite, whilst thin veins of granitic materials belonging to the main intrusive mass, branch through the dyke in all directions. Along the junction of the two masses there is noticed an aggregation or development of dark mica. The microscope does not detect in the granite any abnormal phenomena. But the dolerite is entirely changed in character; complete obliteration of the structure has occurred, and the resultant rock is in every way similar to the altered dolerite described on page 43 (line 9 from top).

Near Malin Tower, at a distance of three-quarters of a mile in an easterly direction (Sh. 1), there is a large dyke of bluish green rock running out to sea. It is observed in hand specimen to contain a large amount of dark mica, and to possess a rude schistosity. Under the microscope the rock is found to be highly deformed. The hornblende is mostly rod-shaped in form and actinolitic in character. The pleochroism is:

a=pale yellow;
b=light green;
c=bluish green.

The dark mica is mostly fresh and pleochroic:

a=straw yellow;
b and c=dark chestnut brown.

It alters into a micaceous chlorite, which is pleochroic between light yellow and green. Its laminæ are at times twisted and bent. It contains inclusions representing the various minerals in the rock, and may possibly be secondary. The numerous granules of felspar represent the ruins of the original felspathic constituent. Secondary quartz, epidote and zoisite are also present. Ilmenite is not absent, but is mostly altered into granular sphene.

Colourless garnets are of frequent occurrence. Little microscopic veins of quartz are seen to run through the rock and to strike the foliation planes at high angles.

The rock is undoubtedly of igneous origin. After a lengthened search, the writer discovered patches of foliated granite as large inclusions in the dyke. The granite is the usual pink variety of the district, but it is not exposed in the vicinity of the locality.

11.—Quartzites.

Along the cliff near White Strand Bay, a little S. of Ardmalin South (Sh. 1), rusty quartzites appear in an advanced state of alteration. Their rusty colour is seen under the microscope to be due to minute inclusions of ferric oxide and ferric hydrate. In thin section the felspars have often a fairly good, lath-shaped form. This mineral has undergone complete kaolinisation. There is a white mica present, but this is probably due to the bleaching of a dark mica. The quartzites of Ineuran Bay are pink in colour and very fresh. In section under the microscope the original quartz grains are seen to have been mostly well rounded; some are sub-angular, but the fragmental structure is still preserved. The rocks contain a large quantity of felspar, which often shows microclinic or microperthitic structure. The form of the felspar is often remarkably well defined. When interspaces between the quartz grains occur, they are occupied by secondary quartz. There is a little chlorite present which may possibly represent the decomposition of a dark mica.

E. of Malin Tower the pink quartzite has been subjected to intense metamorphism and becomes a silvery schist, gneissose in character. In thin section under the microscope, considerable—if not complete—reconstruction of the rock is seen to have taken place. The fragmental structure is not very apparent, the grains of quartz and felspar being now mostly irregularly angular. Still the outline of some of the larger grains, which have undergone granulation, shows evidence of having been originally round. Striated felspar, or felspar showing microclinic structure, is absent. The metamorphism has not given rise to a mosaic-like ground mass, such as results from the metamorphism of a felspathic grit (*vide infra*). There has been a great amount of mica developed along the grains. This mica is feebly pleochroic in tones of yellow. A dark mica is also present. The absorption of the latter is intense:

a=honey yellow;
b and c=black.

Garnets have also been formed. The direction of the longest axis of each constituent is mostly coincident with the direction of the schistosity.

12.—Grits (with Phyllites).

One mile E. of Carndonagh (Sh. 5) fine grits with intercalated bands of a black, satiny schist, show evidence of intense lateral compression. Under the microscope the grits are seen to have undergone great crushing. A fine quartz-mosaic has been formed, and plays, to some extent, the part of ground-mass to those grains, which have, more or less, escaped granulation. A considerable quantity of a light greenish mica has been developed, and winds in and out amongst the broken grains. The fragmental structure of the grit is still apparent. The black schist, with which the grit is intercalated, is a phyllite, and consists almost entirely of a light green mica, between the layers of which fine aggregates of minute quartz grains are to be observed. The mica is much folded and contorted, and there appears to have been some slipping along the axes of the folds. About two miles south of Carndonagh the grits are less fine in grain, but contain still the same large quantity of greenish mica. At Cloghan, about six miles S. of Carndonagh, the grits are more massive in grain, and the constituent pebbles can be recognised with the naked eye. These grits are felspathic, and the mica is darker in colour and hence stronger in its absorption.

Considerable granulation of the pebbles has occurred, but this is only observable under crossed nicols. The formation of the mica has usually prevented the migration of the several grains out of which a pebble now consists.

APPENDIX B.

On the presence of Coral-like forms in the Limestones of Inishowen, near Culdaff.*

The organic nature of the peculiar structures occurring in the limestone of Culdaff has been asserted by some observers, and denied by others. The earliest notice of these forms is that by Mr. Patrick Ganly in 1856,† who gives a clear description of them and their mode of occurrence, and concludes by expressing his opinion that they may be "rationally regarded as organic remains," and probably referable

* By Professor Hull.
† Journ. Geol. Soc., Dublin, Vol. VII., p. 163.

to genera allied to such forms as *Halysites catenulatus*, *Favosites Gothlandica*, and *Lithostrotion striatum*. In addition to the coral-like forms he mentions others occurring as "compressed cylinders" suggesting the idea of Encrinite stems or broken Orthoceratites; and in one case a bivale form like an ordinary *Productus*. It is greatly to be regretted that these forms have not been preserved to us.

The next reference to these forms is one by Mr. Robert H. Scott,* who describes the limestone in which they are found, but expresses his opinion that the forms are not of organic origin.

Professor Harkness, who visited the locality, and describes he structure of the rocks makes no reference to the peculiar forms contained in the Culdaff limestone.† On the other hand Professor W. King‡ states that, on visiting Culdaff, he obtained what he believed to be true fossils, and considered them identical with *Ptilodictya dicotoma* described by Gen. Portlock as occurring at Desertcreat, Co. Tyrone.§

Opinions on Specimens collected by the Survey.—The late Mr. W. H. Baily, Acting Palæontologist, had opportunities of examining specimens of the forms from Culdaff, and identified them as probably *Halysites catenulatus*, and has left drawings of portions of the specimens, which are in my possession. On the other hand, Messrs. Sharman and Newton, who have examined a large series of specimens from Culdaff, have been unable to recognize among them any satisfactory evidence of organic structure.

Photographs of specimens having been forwarded to Dr. J. S. Newberry, of the U. S. Geological Survey, were handed by him to Mr. Charles D. Walcott, who, on examining them, says "Numbers 1 and 9 of the photographs recall very strongly specimens of a Lower Silurian Coral that occurs in the Trenton limestone and Cincinnati limestone of the Lower Silurian (Ordovician). I send you specimens of this coral from New York and Indiana that you may compare them directly with your specimens."‖

The above specimens have been received and are hereby gratefully acknowledged. They belong to the coral *Favistella*, Hall, a genus which apparently has not been recognized in British rocks, except as a synonym of *Columnaria*. I may add that Dr. Newberry in acknowledging the receipt of the photographs expresses his opinion that the forms are those of fossils.¶

Copies of the photographs having been sent to Professor Dr. Ferd. Roemer, the following reply was received from him.** "I give you with pleasure my opinion about the photographs which you have sent me. The photographs are very well executed, but of course they are not like the originals [meaning, not so good for purposes of determination], and the determination of the fossils will therefore not be of absolute certainty.

"I think the objects are really fossils and belong to the genus *Favosites* or an allied one.

Fig. 1 shows distinctly the radiating cells of a small coral of this genus.

[These numbers refer to Plate I.]

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* *Ibid.*, Vol. X., p. 14.

† Quart. Journ. Geol. Soc., Vol. XVII., p. 25. Unless his statement that fossils have not been found in the limestone may be so regarded.

‡ *Nature*, 29 August, 1878; and Brit. Assoc. Rep., 1878.

§ Rep. Geology, Londonderry, &c., p. 339.

‖ Letter dated 6 May, 1889.

¶ Letter dated April 27, 1889.

** Letter dated Breslau, 22 April, 1889.

Fig. 2 less distinct, shows the radiating cells of the coral. The white lines are the walls of the cells.

Fig. 3. The white radiating lines are again the walls of the cells.

Fig. 4 is on the whole not very distinct, but shows, at one spot, two very distinct transverse lines which I think are transverse septa of a cell.

No. 5 is not distinctly recognisable as a fossil.

The genus *Favosites* is equally frequent in Silurian and Devonian rocks. If the fossils, therefore, really belong to the genus *Favosites*, the rocks which include them may be either Silurian or Devonian."

On receipt of the photographs, Professor James D. Dana favoured me with the following reply* :—

"Your letter with the very interesting photographs was received two or three days since. I have examined and considered the forms in the photographs of the Culdaff Limestone, in connection with Mr. Charles E. Beecher, one of our best palæontologists, and the impression with each of us [is] that they are due to fossils, and possibly to a Lower Silurian *Columnaria*. With such forms inside, the rock ought to show somewhere over scattered surfaces indications of fossils that are still more distinct, and I wish you success in finding them."

The last letter on the subject is from Prof. James Hall, author of the *Palæontology of New York*, whose opinion will, I feel sure, carry great weight. He says†—"The photographs which you send me are, in my opinion, clearly of organic bodies, and I give you my best judgment in regard to their nature. No. 1 has a radiating columnar structure and reminds one of *Chætetes*. There is, however, above it a reticulated structure more like *Fenestella*, and it is quite possible it may belong to such an organism as the latter. No. 2 has the general aspect and structure of *Zaphrentis* or closely allied form of a cyathophylloid coral, the smaller end being the base. I have no doubt but that this is its true nature. No. 5 in its columnar structure with transverse septæ is undoubtedly a coral either a *Favosite* with large cells or a *Columnaria*. No. 4. The large figure presents the appearance of some cyathophylloid coral with coarsely vesicular central portion and more finely vesicular exterior. It is quite possible, however, that it belongs to a different organism, and I would not feel warranted in a positive opinion without seeing actual specimens of the fossils."

Professor A. C. Haddon states‡ "From a superficial examination of the specimens from Culdaff I can certainly see a general resemblance in some of them to the external appearance of certain fossil corals, but I could not discover any evidence which would enable me to assert their coral structure."

Professor H. Alleyne Nicholson,§ on examining some of the specimens sent to him for the purpose, "I fear I can give you little assistance in determining their nature. The specimen marked D certainly appears to be an Auloporoid or Syringoporoid coral, though it is too ill preserved to admit of a closer determination being made except as a conjecture.

"The three specimens marked A, B, and C, are all the same thing, but are greatly mineralised. I do not think these specimens are referable to *Halysites*, though I am not prepared to say what they are. They

* Letter dated 29 April, 1889.
† Letter dated 18 August, 1889.
‡ Letter dated 17 May, 1888. Additional specimens have since been found.
§ Letter dated Aberdeen University, December 13, 1888.

have the general aspect of the structure known as *Eozoon*, whatever that may be."

Professor James Hall having expressed a desire to see some of the specimens themselves, several were selected and forwarded to him, with a request to hand them on to Mr. Walcott, in order to have the opinion of both of these palæontologists as to their nature and affinities. The reply of Professor Hall is dated "Albany, January 10th, 1890." In it he gives a critical examination of each of the five specimens, in four of which he recognises species of *Columnaria*, and in the fifth a species of *Tetradium*; both being corals of the family of *Favositid* .

Mr. Walcott's reply is dated "Washington, January 3rd, 1890," and is in general agreement with that of Professor Hall. Four of the specimens he recognises as belonging to *Favistella* (*Columnaria*) *stellata*, and the fifth to *Tetradium fibratum*, or closely allied forms, adding that these species are often associated together in the Hudson Group of America, and that their occurrence in Donegal indicates rocks of Lower Silurian age.

The following from Dr. Alfred R. Selwyn,* Director of the Geological Survey of Canada, may be inserted as representative of those geologists who (at least from photographs) hesitate to offer a decided opinion:— "It is exceedingly difficult, if not indeed impossible, to express an opinion as to even the organic nature of such obscure forms from photographs. I would much like to see a section of the rock under the microscope to see whether it affords any unmistakable organic structure. I have shown the photographs to Whiteaves, Dawson, and others of our Survey, but they all agree that they might or might not be organic."

It is necessary to dispel a certain amount of prejudice which naturally arises in the mind against the view of the organic origin of these specimens from the fact that they are found amongst metamorphic strata. That fossils have been discovered in various metamorphic strata, and in several countries such as North America, the North of Scotland, Norway and Russia, has been placed beyond doubt, and the late Dr. John J. Bigsby has done good service by collecting together such recorded observations and by adding his own.† The most recent recorded examples are those of Dr. Reusch, who, in 1882, announced the occurrence of fossils in the crystalline rocks of the West of Norway.‡ He found at Ulven, south of Bergen, corals and trilobites in phyllite, or rather silvery mica schist, containing occasional flakes of black mica. In another neighbouring locality, namely, at Os, corals with a clear cross section are found in nodules of a dark-grey limestone, and in both cases the forms are distorted. During the summer of the present year (1889), Dr. A. Geikie, the Director-General of the Geological Survey, visited Dr. Reusch's localities, and brought home specimens of fossils from the same schists and limestones which he exhibited at Newcastle-on-Tyne.§ With such examples of the occurrence of distinct fossil forms in metamorphosed strata, we may be prepared for their occurrence in Donegal.

The evidence upon which the organic origin of the forms from Culdaff is based consists of two kinds, namely, direct evidence offered by form

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* Dated Ottawa, 29 April, 1889.

† Bigsby, "On the Organic Contents of the Older Metamorphic Rocks of various countries." Edin. New Phil. Journ., vol. xvii., n. s., p. 170, *et seq.* (1863.)

‡ Reusch, "Silurfossiler og pressede Konglomerater i Bergensskifrene." Christiania, 1882.

§ In Section C of the British Association, 1889.

and structure; and circumstantial, based on mode of occurrence. We shall deal with these two kinds separately.

Assuming for the moment that some of the forms are those of corals belonging, as Mr. Walcott supposes, to the genus *Favistella*, which also agrees with the views of Dr. Roemer, who regards the forms as belonging to the genus *Favosites, or one allied to it*, we have to ascertain whether the specimens from Culdaff exhibit the structure of this genus.

From the specimens sent by Mr. Walcott, the coral *Favistella* is seen to consist of groups of polygonal tubes forming branching pyriform masses increasing in number upwards by fission. The tubes are partitioned by numerous transverse tabulæ, sometimes very close together so that three or four occupy a space equal to the breadth of the corallum; short vertical septæ project inwards from the walls of the corallum; and at wide intervals there occur slightly convex bands, apparently due to interruption in the growth of the coral. I believe it can be shown that with the exception of the septæ, which are rudimentary in some of the *Astræidæ*, we have all the structural parts of the genus here described in the specimens from Culdaff.

But I do not regard all the specimens as belonging to one genus or species, there are probably several, though the majority are referable to the genus *Favistella*. One specimen at least, in my own opinion, can be recognized as belonging to the genus *Favosites*, and is almost identical in form with *Favosites fibrosus*, from the Lower Silurian (Caradoc or Bala Beds) of county Wexford. There are other forms which seem to have spread out in colonies horizontally, and consist of radiating columns arranged round a centre and crossed by tabulæ.

The specimen figured in Plate I., figs. 2, 3, 4, 5, shows polygonal branching forms radiating from a common base and increasing in size and number outwards. They are intersected by *apparent tabulæ* generally at short distances and perpendicular to the walls of the tubes or columns. These *tabulæ* are clearly seen in most of the specimens, and particularly those represented in figs. 2 and 5. In the specimen from which No. 2 is taken there occur several of these transverse detached plates not visible in the figure. They resemble portions of a dislocated tube. In another specimen (not figured) these tabulæ are particularly well developed, arranged perpendicularly to the walls of the tubes or columns. It is to be observed that these plates are not the cleavage planes of calcite, as they are perpendicular to the cell walls. In some places cleavage calcite planes are present—but they are invariably oblique, close, and uniform—and are very distinct from the tabulæ. The tubes are polygonal—but it is generally very difficult to determine the number of sides. In the specimen sent by Mr. Walcott the numbers vary from five to seven, and the cross section presents the appearance of a honeycomb. In the specimens from Culdaff the number of sides appear to be four or five; but the lateral view of the tubes seldom admits of the determination of the number of sides of the tube, as in the case of the fossil coral in solid limestone from the Trenton Limestone sent by Mr. Walcott. The general likeness of this specimen to that shown in fig. 5 is most remarkable. In both cases the tubes are dark, and are embedded in a greyish crystalline limestone, and anyone seeing the two specimens side by side might well suppose that they came from the same rock.

The radiating arrangement of the tubes is well shown in most of the specimens. Fig. 2 shows apparently a young specimen; it is nearly the natural size and the branching tubes, with their tabulæ, are very perfectly preserved. In older or adult specimens the tubes widen and

attain a size of a quarter of an inch in diameter, but it is possible these have been flattened out by pressure. In another specimen we have a central core of granular matter surrounded by radiating branches of darker material with intervening whiter spaces—which reminds one of coralline forms, and indicates growth outwards of a group of polyps. This structure of a central amorphous circular core with branching radial tubes is clearly shown in the case of more specimens than one.

Plate I., fig. 1.—This specimen is seven inches long by two inches across and differs very markedly from most of those associated with it; and the photograph taken of it has attracted the special notice of Professor James Hall, as already stated. It consists of a group of polygonal columns apparently emanating from a root or base, and multiplying outwards by branches. These branches are darker than the matrix from which they have weathered out in high relief. There is a cross structure indicating *tabulæ*; this structure is sometimes distinctly perpendicular to the walls of the coral and not to be mistaken for calcite-cleavage which is also developed. The specimen is much broken and dislocated towards the outer margin of the coral, and disjointed fragments are imbedded in the calcareous matrix.

Fig. 2.—Appears to be a very perfect group of coral-tubes, natural size, branching from a common base, and traversed by numerous *tabulæ*. The outward termination of the tubes is very clearly defined.

Fig. 3.—Portion of a group of tubes; the *tabulæ*, although not distinct in the figure, are sufficiently so in the specimen. The figure is of natural size, and the specimen is distorted.

Fig. 4.—This figure, which is somewhat reduced from the natural size, shows in section a series of curved white bands crossing the radiating columns at intervals, and suggestive of surfaces of interrupted growth, shown in the specimen of *Favistella stellata*.

Fig. 5.—Portion of group of tubes, crossed by *tabulæ*. The tubes are nearly black from the presence of bituminous matter, and are embedded in a light-grey limestone matrix. This specimen has a very strong general resemblance to one sent by Mr. Walcott, and is referred to above; it is somewhat distorted.

Plate II., fig. 1.—*Favistella stellata*, lent by Mr. Walcott for comparison. This figure has again been repeated in Plate II. Fig. 2 shows similar bands of growth.

In Plate III., fig. 1, we have a representation, natural size, of *Favosites fibrosus* from the Lower Silurian rocks of county Wexford, and a specimen (fig. 2) from the Culdaff limestone which bears a very strong resemblance to the former.*

In Plate IV., fig. 1, shows a portion of a form apparently of *Favistella* consisting of radiating columns (in tubes) crossed by *tabulæ* with intervening spaces of limestone. The columns are darker than the rock. The specimen is similar to those shown in figs. 2 and 3, Plate I, but has come out badly in the Plate.

Fig. 2 is a portion of rock—showing several groups of columns or tubes radiating from centres. These forms are suggestive of those of *Heliolites stenopora*, Hall.†

Fig. 3.—This specimen is not of much value except for its general form—which is very suggestive of coral growth.

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* Since the above was written Professor Hall and Mr. Walcott have determined this form to be that of *Tetradium*, of the "Trenton Group" of America.

† Palæontology of New York, Vol. II., Plate 36.

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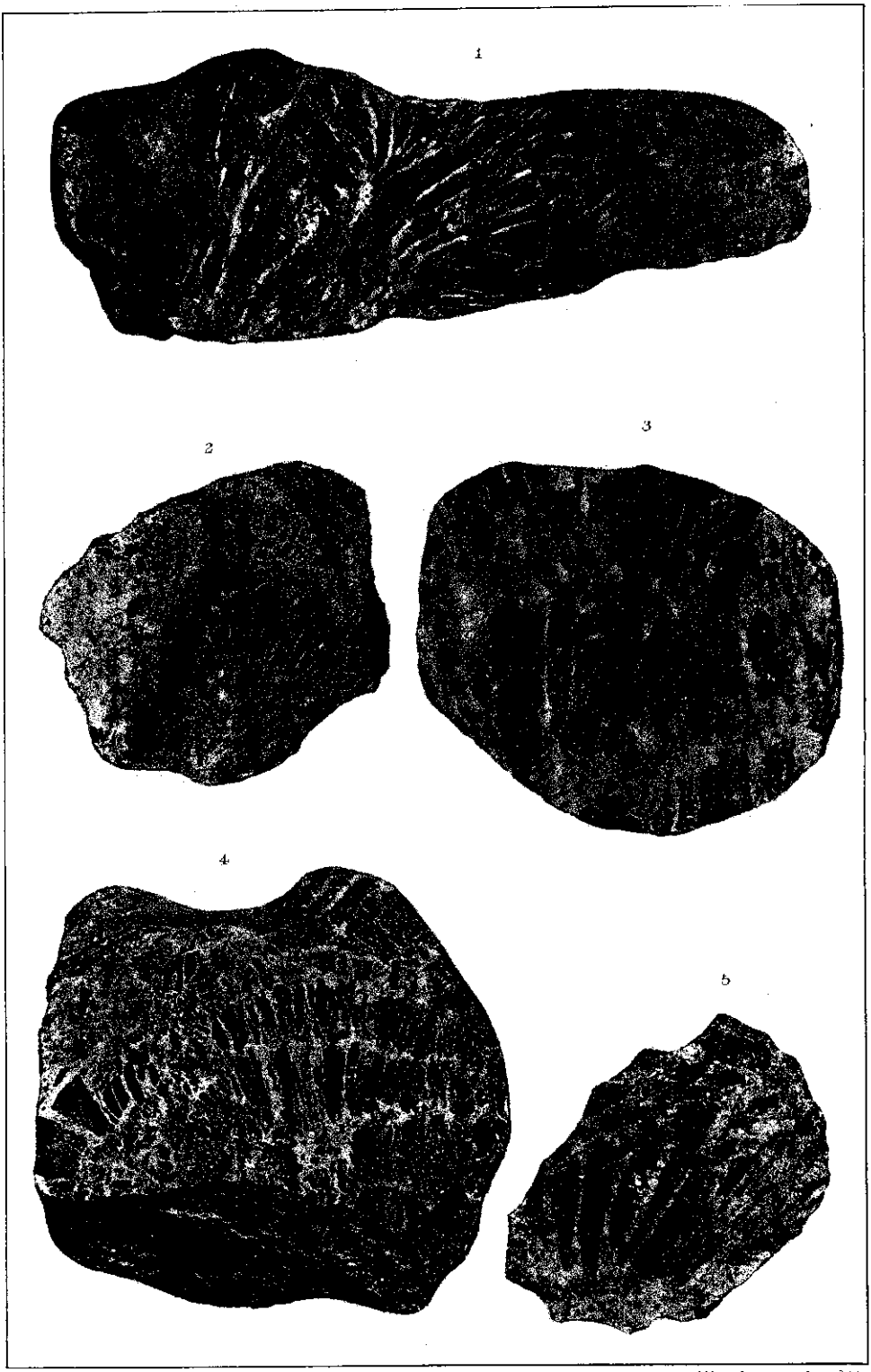
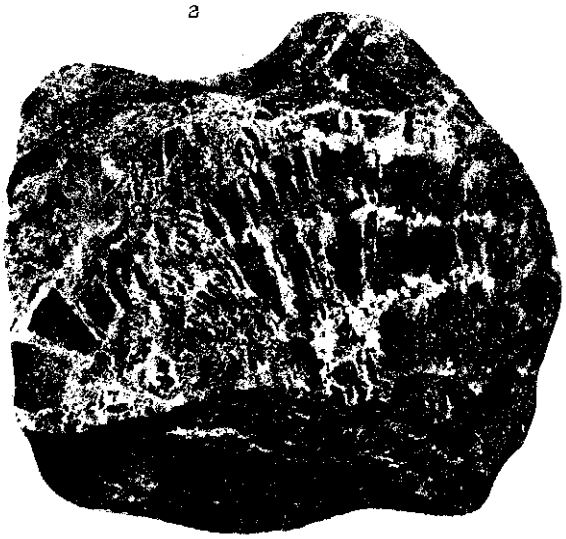


Geo West & Sons photo.lith.

CORAL-LIKE FORMS FROM CULDAFF LIMESTONE.

1

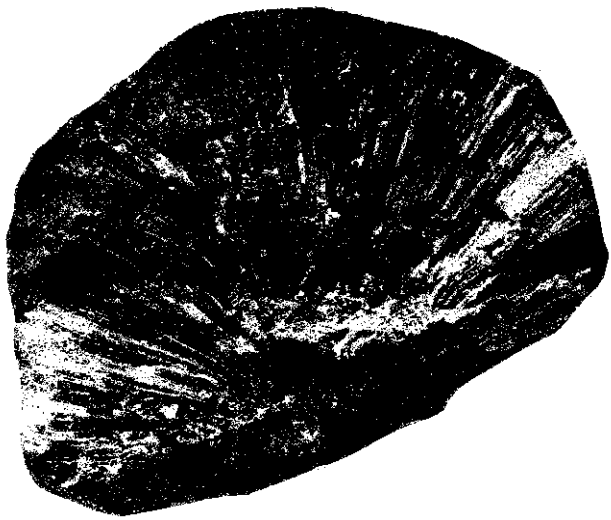
2



Geo. West & Sons photo.lith.

CORAL, FAVISTELLA STELLATA. (Fig. 1) FROM U.S. AMERICA AND CORAL-LIKE FORM (Fig. 2) FROM CULDAFF (× 2).

1



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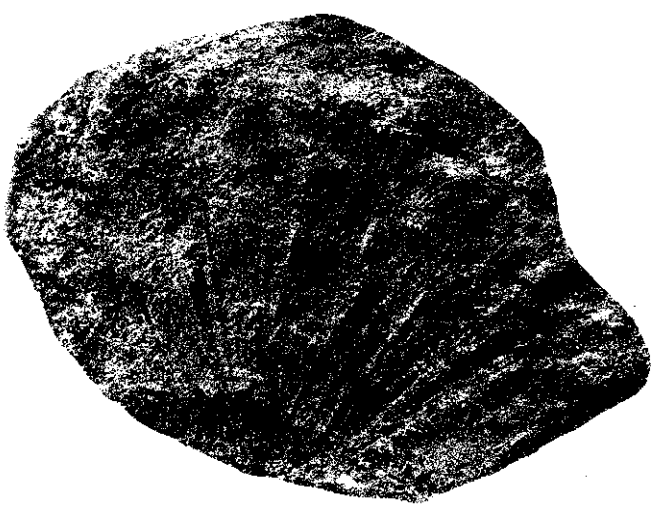

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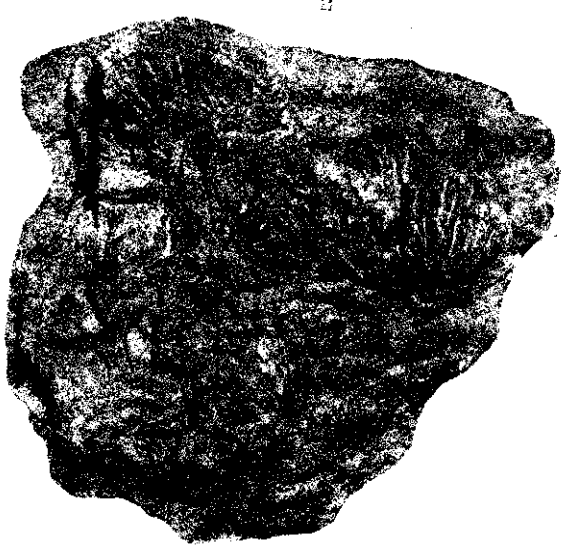
CORAL-LIKE FORM FROM CULDAFF LIMESTONE (Fig. 2)
AND CORAL, FAVOSITES FIBROSUS FROM WEXFORD. (Fig. 1)

1

2



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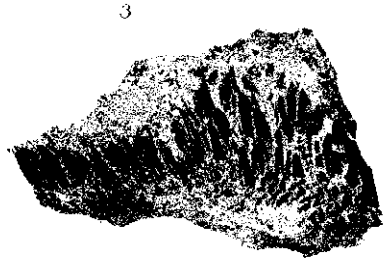

Geo. West & Sons photo-litho.

CORAL-LIKE FORMS FROM CULDAFF LIMESTONE.

FRONTISPIECE.

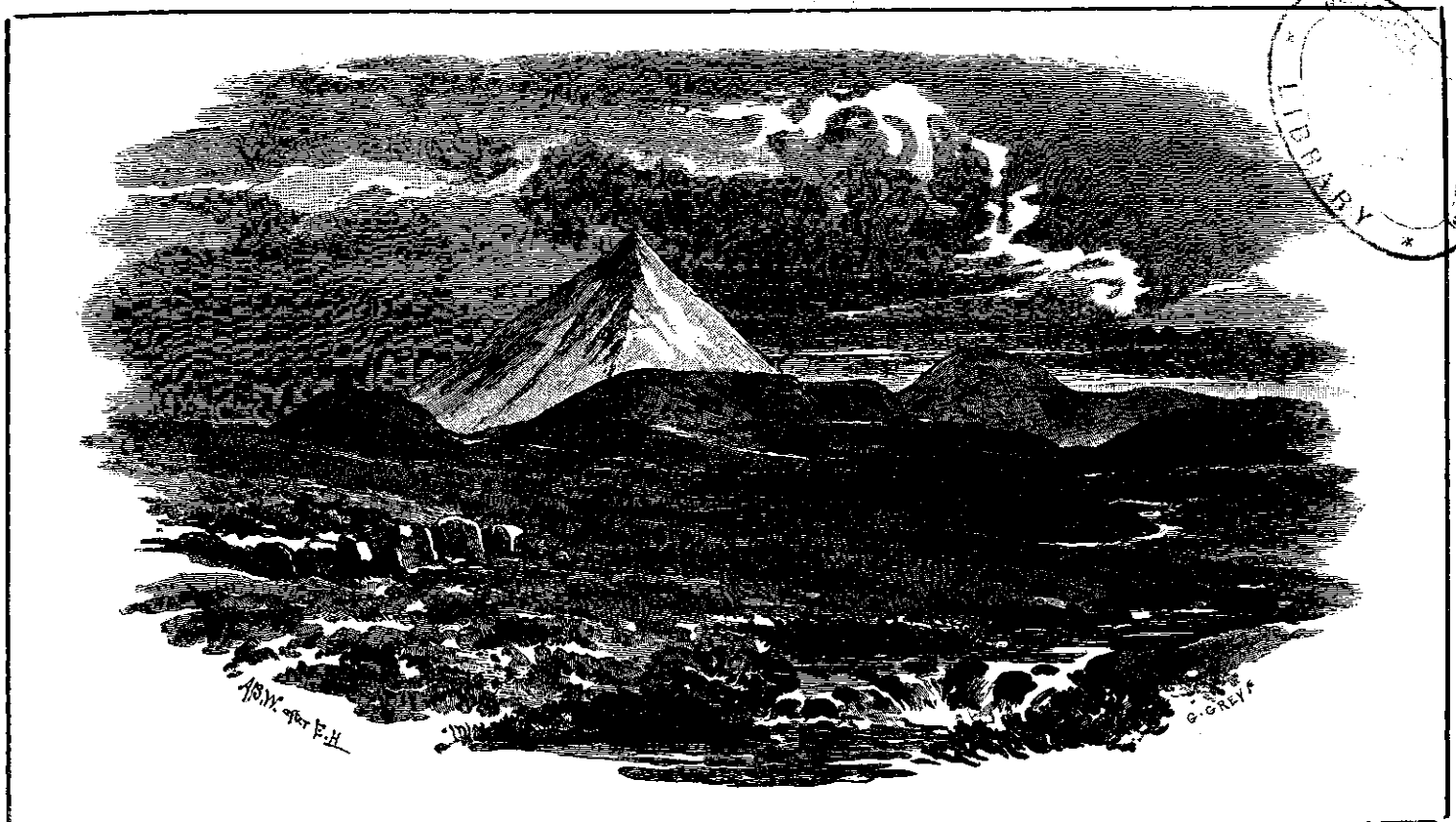

Fig. 1.—View of Errigal from the North.
Quartzite pyramid rising from a platform of diorite, schist, and limestone. In the distance to the right are the granite hills above the Poisoned Glen.