MEMOIRS OF THE GEOLOGICAL SURVEY.

IRELAND.

THE GEOLOGY OF THE COUNTRY AROUND BELFAST.

(EXPLANATION OF THE BELFAST COLOUR-PRINTED DRIFT MAP.)

BY

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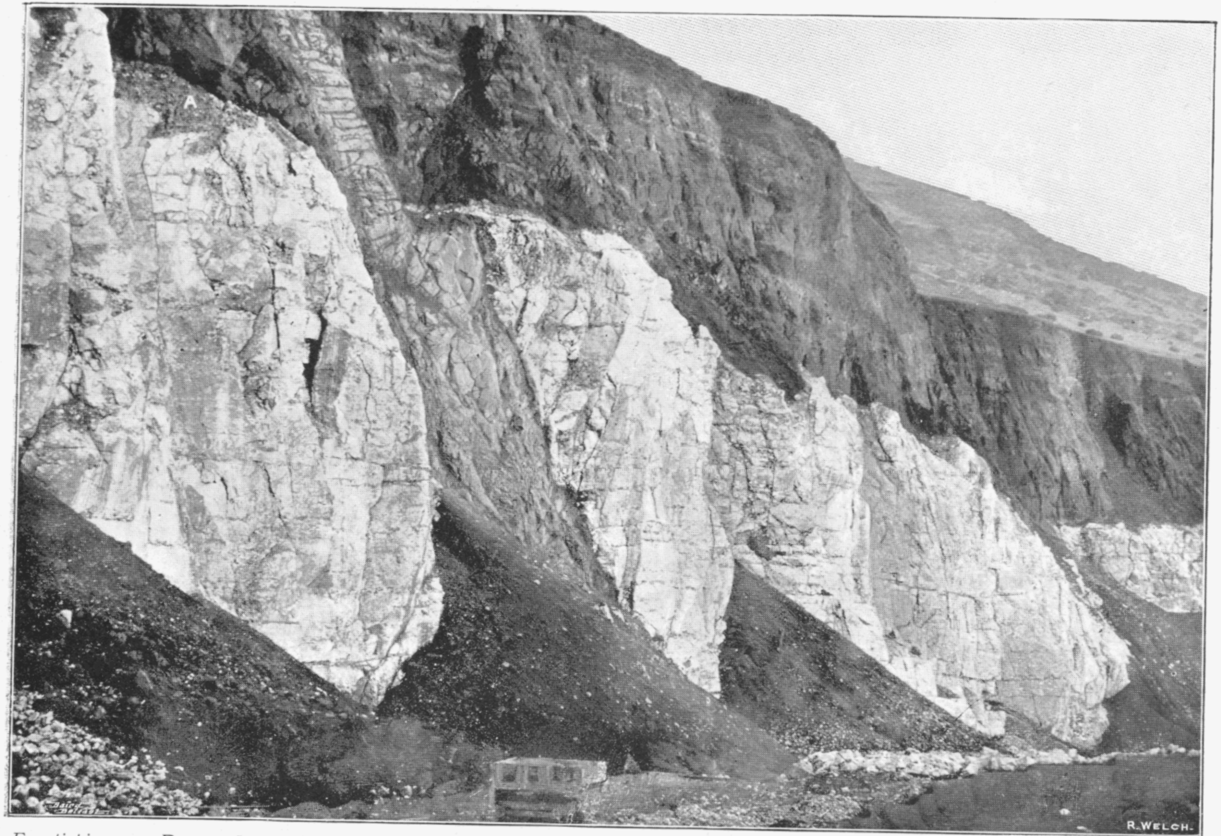

Frontispiece. PLATE I. CHALK OVERLAIN BY BASALTIC LAVAS, AND BOTH CUT BY A DYKE OF BASALT.
CAVE HILL QUARRIES, NEAR BELFAST.

PREFACE.

THE present Memoir has been prepared to accompany the new colour-printed drift map of the Belfast district. This map is a "special" sheet of the country surrounding the city of Belfast, and its boundaries do not coincide with the sheet-divisions of the previous "solid" geological maps.

As the recent work of the survey was devoted to the mapping of the drifts and other superficial deposits, the description of the solid rocks in the present Memoir has been for the most part compiled from previously published sources. The original sheet-explanations of the Geological Survey which relate to this district being still in print and obtainable through the usual channels, it has been thought desirable, in the present Memoir, to supplement the information contained in them by drawing largely from the later publications of private workers who have so materially advanced our knowledge of the geology of the area. The description of the solid rocks herein contained should therefore be regarded as a supplement to the previous sheet-explanations. The latter should be consulted wherever further local details regarding these rocks are desired.

The account of the solid rocks and the general description of the superficial deposits contained in Part I. of the present Memoir has been written or compiled by Mr. G. W. Lamplugh. Part II., which consists of the detailed description of the superficial deposits, has been written by Messrs. Lamplugh, J. R. Kilroe, A. M'Henry, H. J. Seymour, W. B. Wright, and H. B. Muff, whose respective share in the work is indicated by the initials after the paragraphs. Part III., dealing with the economic geology, is the work of the officers whose initials are given after their several contributions. The Appendix, dealing with the Petrology and Mineralogy of the district has been prepared by Mr. H. J. Seymour. The Plates are from photographs taken for the purpose by Mr. R. Welch of Belfast.

Among the numerous private workers whose results have been laid under contribution in the preparation of this Memoir, our acknowledgments are especially due to Sir A. Geikie, Prof. C. Lapworth, Mr. W. Swanston, Dr. W. F. Hume, Mr. R. Lloyd Praeger, and Mr. J. Starkie Gardner.

Our thanks are also due to Mr. W. Swanston, Mr. J. Wright, Mr. J. St. J. Phillips, Mr. R. Welch, Mr. R. Young, Mr. S. A. Stewart, Mr. R. Bell, Miss M. K. Andrews, Madame Christen, and to other Belfast friends, for their personal aid in the task of collecting information.

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Director.

Geological Survey Office,
28 *Jermyn-street, London,*
13*th February*, 1904.

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THE GEOLOGY

OF THE COUNTRY AROUND

BELFAST.

PART I.—GENERAL DESCRIPTION.

CHAPTER I.—INTRODUCTION.

Area of the Map.

The map to be described in the present Memoir includes an area in which the position of the city of Belfast is approximately central. The previously-published work of the Geological Survey on this district was reproduced on Sheets 28, 29, 36 and 37, of the one-inch map of the Ordnance Survey, wherein Belfast lay at the north-eastern corner of Sheet 36, with its suburbs extending into the contiguous corners of the three adjacent sheets. The new 'drift' map is of the same size as the previously-published 'solid' sheets, and includes about one-third of the area of Sheet 36, with the same proportion of Sheet 37, and about one-sixth of each of the Sheets 28 and 29. By this arrangement the explanation of the geology of the country surrounding Belfast on all sides is brought within the compass of a single map-sheet and a single memoir, instead of being distributed, as heretofore, in four maps and three memoirs.

The northern edge of the map passes through White Abbey, on the western shore of Belfast Lough; then crossing the entrance to the Lough, it includes the whole of the eastern shore, with the co. Down coast as far eastward as Ballyholme Bay. The seaside towns of Holywood and Bangor and the string of pleasant residential places lying between them are contained in this portion of the map. The eastern margin runs from Ballyholme to the head of Strangford Lough and across it, passing 1½ miles to the eastward of Newtown Ards and four miles east of Comber. The southern boundary cuts the village of Ballygowan, and crosses the hilly ground to the town of Lisburn which lies just within the map. The western edge, starting two miles west of Lisburn, traverses the upland to within 1½ miles of the village of Templepatrick.

Scope of the Map.

The previous work of the Survey in the district was concentrated upon the mapping of the older rocks, which alone are represented by colours on the published maps above mentioned. The glacial drifts, and other 'superficial' deposits by which the older rocks are concealed in most parts of district, are only roughly indicated on these maps by engraved stippling, without reference to variations of their lithological character.

The recent re-examination of the ground has been directed to the mapping of the superficial deposits according to their composition, so that the different types of these deposits might be separately coloured on the map.

This work was done in the field on the Ordnance maps of the 6 inches=1 mile scale, and has been reduced from these maps to the one-inch scale for publication. Manuscript coloured copies of the six-inch field-maps have been made, and may be consulted at the Geological Survey Office in Dublin.

The one-inch 'drift' map thus prepared has been completed by transferring the boundary-lines of the older formations from the maps of the previous survey, and by using representative colours for the older rocks in those tracts where 'drift' is either absent or reduced to a mere sprinkling. In a few places, to be mentioned subsequently, it was noticed that the boundaries of the Triassic rocks shown on the old maps were out of accord with evidence now available; and where the discrepancy was sufficiently marked, these boundary-lines have, in the present sheet, been altered from their position on the original maps; but with this exception no attempt has been made to revise the previous mapping.

The general account of the geology of the district given in this memoir is based, so far as its older rocks are concerned, on the descriptions contained in three previously published memoirs of the Geological Survey, viz., on Sheet 36 (published in 1871); on Sheet 37 (published, 1871); and on Sheets 21, 28 and 29 (published, 1876); but large use has also been made of the later researches of Mr. W. Swanston and Prof. C. Lapworth on the Silurian rocks[1]; of Dr. W. F. Hume on the Cretaceous rocks[2]; of Sir A. Geikie on the Tertiary Volcanic Series[3]; of Mr. R. L. Praeger on the Estuarine clays[4]; and

[1] "Correlation of the Silurian Rocks of the County Down," by W. Swanston and C. Lapworth, *Proc. Belfast Nat. Field Club, Appendix iv.* (1876–77), pp. 107–147.

[2] "The Cretaceous Strata of County Antrim," by Dr. F. W. Hume, *Quart. Journ. Geol. Soc.*, vol. liii. (1897), pp. 540–606.

[3] "The Ancient Volcanoes of Great Britain," (London, 1897), vol. ii., pp. 199–208.

[4] "The Estuarine Clays at the New Alexandra Dock, Belfast," by R. L. Praeger, *Proc. Belfast Nat. Field Club, vol. ii., Appendix ii.* (1886–1887), pp. 29–51; and "Report on the Estuarine Clays of the North-east of Ireland," *Proc. R. Irish Acad.*, 3rd ser., vol. ii. (1892), pp. 212–289.

of other investigators to whose work references will be found in the context. These materials have been combined in the light of the general knowledge of the district gained during the recent field-work.

The general account of the superficial deposits and the detailed description of these beds given in Part II. contain the results of the recent field-work, along with information derived from the previous literature of the subject.

The broader features of the topography of this district are shaped by the 'solid' formations, but the minor features are mainly due to the superficial deposits. The valleys at the head of Belfast Lough and of Strangford Lough would admit the sea much farther than at present if the glacial deposits were removed, as much of the rock-floor beneath the drifts lies below sea-level. For many purposes, therefore, the new drift map will be found preferable to the old 'solid' sheets as a guide to the character of the ground.

Table of Formations occurring within the Map.

STRATIFIED ROCKS.

RECENT.	Blown Sand. Recent Intake = Reclaimed Land. Alluvium. Peat. Estuarine Clay, &c. Raised Beach. River Gravel.
GLACIAL DRIFT.	Sand and Gravel. Boulder Clay.
TERTIARY VOLCANIC SERIES.	Upper Basaltic Lavas. Bole, Lithomarge, and Iron-ore. Lower Basaltic Lavas.
UPPER CRETACEOUS.	Chalk with Flints. Upper Greensand.
LOWER JURASSIC.	Lower Lias.
TRIASSIC.	Rhætic Beds. Red Marls with gypsum. White and Red Sandstones.
PERMIAN.	Magnesian Limestone, Conglomerate, and Marls (outcropping at Cultra only).
LOWER CARBONIFEROUS.	Carboniferous Limestone (outcropping at Castle Espie only). Lower Limestone Shales (outcropping near Cultra only).
UPPER SILURIAN (SILURIAN).	Llandovery Series.
LOWER SILURIAN (ORDOVICIAN).	Bala and Llandeilo Series.

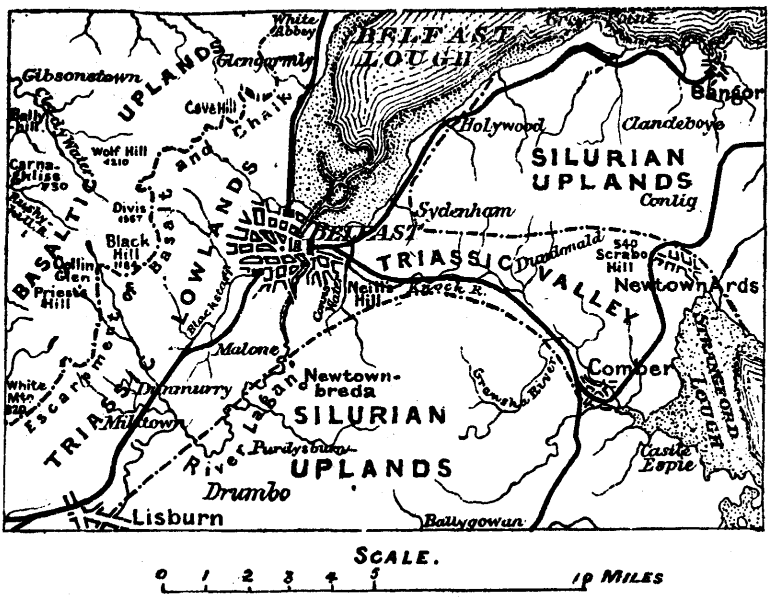
INTRUSIVE ROCKS.

TERTIARY.	Basalt and Dolerite in dykes and sills.
PRE-CARBONIFEROUS.	Lamprophyre in dykes.

Form of the Ground and its relation to the Geological Structure.

The geological structure of the district is very clearly expressed in its physical features. The great escarpment stretching south-westward across the corner of the map west of Belfast, which breaks at Cave Hill into mural precipices, marks the eastern edge of the Tertiary Basalts and the underlying Chalk, while the broad trough occupied by Belfast Lough and prolonged inland as the valley of the Lagan is underlain by soft Triassic marls and sandstones, and is bounded again on the east by hilly ground, where the more highly-resistant Silurian and Ordovician slate-rocks rise steeply from beneath the Trias. This eastern hilly ground is interrupted by a transverse hollow running from the head of Belfast Lough to the head of Strangford Lough, which marks the presence of an ancient trough lined with Triassic sandstones. The bold hill of Scrabo, at the north-western margin of Strangford Lough, shows the preservation of a portion of these sandstones by a protective covering of dolerite, probably intrusive.

These main features of the ground are indicated in the following outline-map (Fig. 1).



The country to the westward of the great escarpment is usually referred to as the "basaltic plateau"; but the term "plateau" is not strictly applicable, since the ground reaches its greatest elevation in hills near the escarpment and sinks steadily westward to the depression of Lough Neagh and the valley of the Bann. It would be more correctly described by the term "cuesta," adopted by Prof. W. M. Davis[1] for slopes of this character. The highest summits of the map occur in this tract, viz., Divis Mountain, 1,567 feet; Black Mountain, 1,272 feet; Squires Hill, 1,230 feet; Wolf Hill, 1,210 feet; and Collinward, 1,196 feet.

Except from some limited hollows near the edge of the escarpment, the drainage of this upland is carried westward in small streams to Lough Neagh.

At the foot of the escarpment, the Upper Greensand, Lias, and Rhætic formations are too thin and interrupted to have any effect upon the topography, and are indeed for the most part concealed under land-slipped masses, which are very numerous and extensive on the upper part of the slopes of yielding Triassic marl. The marls give place to Triassic sandstone in the lower eastern part of the depression, and sandstone is the underlying rock over the greater part of the present course of the River Lagan, though usually buried deeply under Glacial Drift.

As mentioned elsewhere in this memoir (p. 64), the present position of the Lagan has been determined by the surface-contours of the Glacial deposits, and in Pre-Glacial times the main drainage of the hollow probably lay to the westward of its present course. Indeed, the drainage system of all the low ground has been very greatly modified by the Glacial deposits, and, as hereafter shown (p. 50), part of the Lagan valley towards its present mouth has been banked off to form the separate basin of the Blackstaff stream. The Dundonald valley, between Belfast and Strangford Lough, is so choked with Glacial drift that it is impossible, with our present information, to form any opinion as to the character of its Pre-Glacial drainage. At present its waters flow over a floor of drift south-eastward to Strangford Lough, in the Comber river, but the watershed between the two loughs is clearly a 'superficial' feature (see p. 111).

The flat ground around the head of Belfast Lough, on which the lower central part of the city is built, is a Post-Glacial estuarine delta, mainly accumulated during a time when the sea stood ten to twenty feet higher than at present. This stage is similarly represented by the estuarine flat at the head of Strangford Lough, and is marked on the more open parts of the coast-line by a narrow shelf of Raised Beach.

The hilly Ordovician and Silurian ground which rises on the east above the hollow occupied by the Lagan River and Belfast Lough, is broken into two portions by the above-mentioned Trias-filled valley of Dundonald. The main features of

[1] "The Drainage of Cuestas." *Proc. Geol. Assoc.*, vol. xvi., p. 75: a Spanish word applied to hills and used in Mexico.

these hills are due to Pre-Glacial erosion, but the minor details of their topography are largely the result of Glacial and Post-Glacial agencies. The heaping-up of the boulder-clay into smooth oval 'drumlins,' and the rounding-off of the rocky eminences by the grinding force of ice have given rise to the flowing hummocky contours so characteristic of this ground, while the steep-walled little rock-gorges and deep V-shaped trenches in boulder-clay along the present stream-courses represent the effect of Post-Glacial erosion.

Within the present map the highest ground formed by the slate-rocks occurs in the ridge north of the Dundonald valley, south-west of Clandeboye, where it ranges up to 720 feet in height. In the massif south of the valley the greatest elevations fall slightly below 600 feet, between Gilnahirk and Knockbreckan. Both tracts are drained by small streams which diverge radially from the interior of the uplands to the hollows by which they are flanked.

CHAPTER II.—THE PALÆOZOIC ROCKS.

Lower and Upper Silurian Rocks.

These rocks, which occupy the hilly eastern portion of the map in co. Down, consist of grey, purplish or greenish-grey grits and flaggy greywackes, often micaceous and sometimes coarse-grained, interstratified with beds of green, purple and grey slates, and occasionally with bands of black carbonaceous shales containing graptolites and thin layers of chert (see Plate II.) When the district was first examined by the Geological Survey these rocks were supposed to be all of Lower Silurian—or, to use the modern nomenclature, of Ordovician—age. But it was shown by the later work of Swanston and Lapworth on the Graptolites of the series, published in 1877,[1] that the Upper Silurian period ("Silurian" of some authors) is also represented; and it was proved that the same order of succession could be traced in these rocks as in the rocks of similar character which are found on the Wigtownshire coast, on the opposite side of the North Channel, and farther eastward in the Southern Uplands of Scotland. As the result of further researches carried out by the Geological Survey, the division of the rocks into Upper and Lower Silurian was indicated on a later edition of the official map published in 1900. The main line of division runs inland in a W.S.W. direction from the coast near Donaghadee, the ground to the northward, including the Down coast-line of the present map, being composed of Lower Silurian beds, and the country to the southward, chiefly of Upper Silurian. If this line be prolonged in the opposite direction across the North Channel, it almost exactly strikes the main line of division between Upper and Lower Silurian in Wigtownshire, and pursues the same general direction.

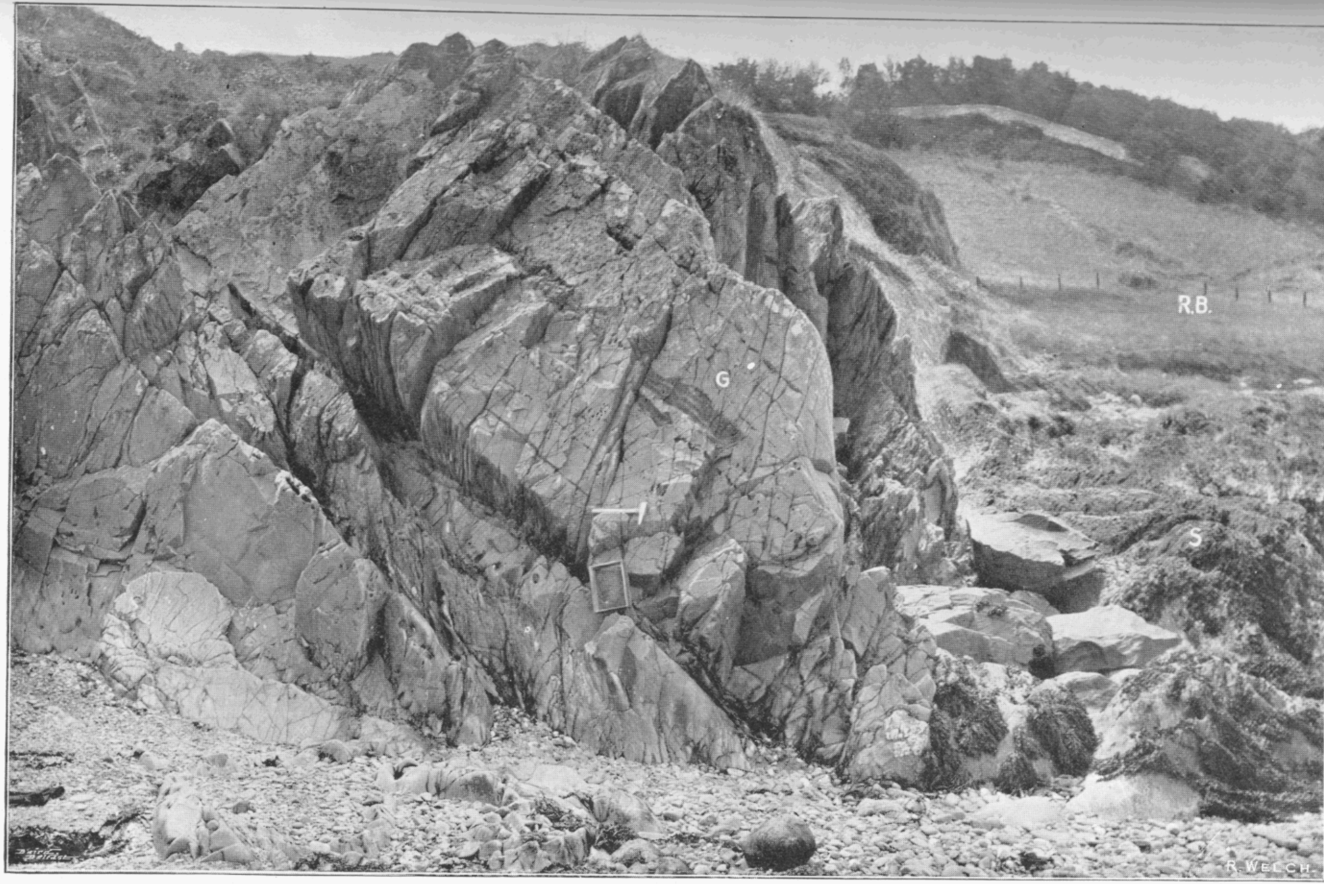
These rocks of the north-east of Ireland and of the south-west of Scotland represent the deposits of a sea-floor which extended far to the eastward and to the westward. This sea was probably margined by an ancient land at no great distance toward the north and north-west, from which its coarser sediments were derived.[2]

In Scotland and in Wales the Ordovician is separable, in ascending sequence, into the Arenig Series, the Llandeilo Series, and the Caradoc Series. Of these subdivisions the two last-mentioned alone have been recognised within the limits of our map; but as the base of the system is nowhere exposed in this tract, it is likely, also, that the lowest or Arenig Series lies hidden beneath the surface.

The Upper Silurian is similarly divided in Britain into the Llandovery, the Tarannon, the Wenlock, and the Ludlow

[1] *Proc. Belfast Naturalists' Field Club,* Appendix iv., pp. 107–148.

[2] See Mem. Geol. Survey, "The Silurian Rocks of Britain," vol. i., Scotland, (1899) chap. iii., p. 37, for discussion of general conditions of the Silurian seas; and chap. ii., p. 5, for previous literature of the subject.



To face p. 8.

PLATE II. ORDOVICIAN ROCKS ON THE COAST AT CARNALEA.

Thick-bedded slightly-cleaved Greywackes (G.) in the cliff, with crushed Graptolite-Shales (S.) on the shore. Raised-beach (R.B.) seen in the background.

Series, of which the Llandovery alone has been identified in this tract, although fossils denoting the presence of Tarannon rocks have been found within a mile or two beyond its southern margin, and representatives of the higher divisions occur in other parts of Ireland. As these rocks exhibit great sameness of composition throughout, it is principally by their fossils, and especially, as mentioned above, by their characteristic Graptolites, that the sub-divisions are recognised. These fossils, however, are absent from the coarser sediments —the flaggy grits and greywackes—which constitute the larger part of the formation, and are found only in comparatively thin bands of fine-grained mudstone or black carbonaceous slate which are sparingly interbedded with the flags.

The following localities for these fossils within the limits of the present map are mentioned in the Explanatory Memoir on Sheets 37, 38, and part of 29 :—Craigavad, in the railway cutting; Ballygrot, on the shore at Helen's Bay; Ballykillare, on the shore north-east of Crawfordsburn House, and again at Swineley Point, a little farther eastward; Carnalea, on the shore north of Carnalea House; and Ballyharry, in the railway cutting three-quarters of a mile north of Newtown Ards.[1] Mr. Swanston[2] has also recorded Graptolites from a locality just outside the southern margin of the sheet, 1½ miles west of Ballygowan station "in the bed of a small stream which flows eastward through the grounds of Tullygarvan House"; and the later researches of the Survey added another locality within the sheet—a small quarry in Holywood Glen.[3]

The relative stratigraphical position of the fossiliferous beds at these places is shown in the following account of the fossils, compiled from the records above referred to.

Upper Llandeilo Series.

The places which have yielded fossils of this stage are—(A) Ballygrot, (B) Craigavad, and (C) Holywood,[4] from which the following species have been obtained :—

B. Diplograptus bimucronatus, *Nich.*
A. „ tricornis, *Carr.*
A. „ dentatus ? *Bronn*
A. „ angustifolius, *Hall*
A. „ foliaceus, *Murch.*
A. C. Glossograptus Hincksi, *Nich.*
A. Clathrograptus cuneiformis, *Lapw.*
A. C. Climacograptus Schärenbergi, *Lapw.*
A. C. „ bicornis, *Hall*
A. „ „ *var.* peltifer, *Lapw.*
A. „ „ „ tridentatus, *Lapw.*
A. „ cœlatus, *Lapw.*
A. „ perexcavatus, *Lapw.*
A. B. C. Dicranograptus ramosus, *Hall*
A. B. „ Nicholsoni, *Hopk.*
A. B. „ formosus, *Hopk.*
A. C. Dicellograptus moffatensis, *Carr.*
A. „ „ *var.* divaricatus, *Hall*
B. „ elegans, *Carr.*
C. „ intortus, *Lapw.*
B „ Forchammeri, *Geinitz*
B. C. „ sextans, *Hall*
A. B. Didymograptus superstes, *Lapw.*
A. B. C. Cœnograptus gracilis, *Hall*
A. C. „ pertenuis, *Lapw.*
A. C. „ surcularis, *Hall*
A. Leptograptus flaccidus, *Hall*
A. B. Thamnograptus typus, *Hall*
A. B. Corynoides calycularis, *Nich.*
A. B. „ curtus, *Lapw.*

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[1] For further particulars, see above-mentioned Memoir, pp. 16, 17.
[2] *Op. cit.*, p. 112.
[3] R. Clark. "Notes on the Fossils of the Silurian Area of North-east Ireland," *Geol. Mag.*, dec. iv., vol. ix. (1902), p. 498.
[4] From Swanston and Lapworth's list, for localities A. and B., and from R. Clark's paper, *op. cit.*, for locality C.

BALA OR CARADOC SERIES.

The places where fossils of this stage have been found are—(A) Ballykillare (Crawfordsburn and Swineley Point); (B) Carnalea; and Ballyharry[1]. The following species have been recognised :—

B. Diplograptus truncatus, *Lapw.*	B. Climacograptus tubuliferus, *Lapw.*
B. " quadrimucronatus, *Hall*	A. Dicranograptus ramosus, *Hall*
B. " Whitfieldi, *Hall*	A. Dicellograptus elegans, *Carr.*
B. " bimucronatus, *Nich.*	B. " Forchammeri, *Geinitz*
B. Lasiograptus Harknessi, *Nich.*	B. Leptograptus flaccidus, *Hall*
B. Retiolites fibratus, *Lapw.*	A. Dictyonema moffatensis, *Lapw.*

LOWER LLANDOVERY SERIES.

No determinable fossils from this horizon have been found within the limits of the Sheet, though obscure traces of Graptolites were noticed during the revision-work on the Silurian rocks at places marked with asterisks on the revised editions of Sheet 29 and 37, in the former map at a place ¼ of a mile N.E. of Conlig, and in the latter, at Moneyreagh. At Tullygarvan, just beyond the southern margin of the present map, the following species were found :—*Monograptus lobiferus*, McCoy; *Mon. triangulatus*, Hark.; *Mon. attenuatus*, Hopk.; *Mon. tenuis* Portl.; *Dimorphograptus Swanstoni*, Lapw.; *Rastrites peregrinus*, Barr.; *Climacograptus scalaris*, His.[2]

The Ordovician and Silurian rocks of this district, like their equivalents in Wigtownshire, appear to represent a period of continuous accumulation, with minor changes of condition as regards depth of sea and distance from land, but without marked interruption until after the highest beds now visible were deposited. Toward the close of Silurian times this prolonged period of quiet sedimentation was brought to a close, and the whole region was profoundly disturbed by great earth-movements, during which the rocks underwent intense lateral compression, and were wrinkled up into innumerable folds. This compressive force, which apparently acted mainly from the southward, was continued until the folds were tightly packed together, with their long axes arranged in a general W.S.W. to E.N.E. direction, and their sides or 'limbs' almost vertical or dipping at high angles away from the axial line. Through the classical researches of Prof. Lapworth in the corresponding district of the Southern Uplands, we know that owing to this system of folding the beds are generally many times repeated at the surface on the same plane, though this repetition is often very difficult to detect. The thickness of the deposits in areas where this structure prevails has in most cases been greatly over-estimated, and the early measurements of these rocks in the coast-section, as given in the original Memoir on the district ("Memoir on Sheets 37, 38 and part of 29," pp. 22-23) are probably, from this cause, much in excess of the actual thickness of the series.

The same forces which effected the folding of these Silurian

[1] From the list given by Swanston and Lapworth, *op. cit.*
[2] Determined in the Palæontological Department of the Geol. Survey, from specimens collected by R. Clark.

rocks have also produced a secondary fissility or 'cleavage' structure, which is often well-developed in the argillaceous slates and fine-grained mudstones, but is obscure or absent in the more massive sandy flags and grits. The strike of this cleavage is mainly in the same direction as the axis of folding, but its angle of dip often diverges widely from the dip of the bedding planes. In some places the beds have been very greatly crushed and sheared during the folding; this is well seen in the coarser grits, wherein component pebbles of slate are flattened and drawn out into slivers, and even the quartz-grains are squeezed and elongated; sometimes, also, thin partings of shale between thick bands of grit have been torn up and incorporated into the adjacent bands. All these structural features of the rocks may be conveniently studied in the fine coast-exposures between Holywood and Bangor.

The intrusion of the oldest dyke-rocks of the district followed closely upon this period of movement. These occur as narrow dykes of hornblende-lamprophyre, which in most cases follow the bedding or cleavage planes of the slate-rocks; they are very numerous in the country immediately to the eastward and south-eastward of the present sheet, but have only been identified in one place (at Tullynakill, 1½ miles south of Castle Espie) within its limits. From the evidence in other parts of the country it is known that these intrusions are of Pre-Carboniferous age.

During the early part of the Devonian period, after the older rocks had been packed into folds as above described and brought practically to their present lithological state, the area appears to have formed part of a land-tract which stood at a considerable height above sea-level. Before the close of Devonian times, wide valleys had been carved out in this land by the ordinary agencies of sub-aerial erosion, and these hollows were afterwards wholly or partly filled by later accumulations. Owing to the less durable character of the infilling rock, these ancient valleys appear in some instances to have been partly re-excavated and re-filled two or three times in succession, and are even yet not completely obliterated.

The wide depression occupied in part by Strangford Lough and extending inland westward to Dundonald, affords a striking illustration of this kind, containing within it a partial infilling of Carboniferous Limestone, Triassic Sandstone, Tertiary Basalt, and Glacial Drift. The red and purple staining of the slate-rocks on the slopes of this valley, much above the present level of the red Triassic deposits by which this staining has probably been effected, points to the former existence of these red rocks up to the rim of the valley.

The presence of similar stained slates on the coast east of Holywood, where again there is evidence for the former overlap of Carboniferous, Permian, and Triassic beds, gave rise to the opinion that Cambrian sediments might possibly be represented in this quarter.[1]

[1] See reference to G. V. Du Noyer's views as to these rocks in "Explanation to Sheets 37, 38, and part of 29," p. 22; also G. H. Kinahan, "Oldhamia," *Sci. Proc. Roy. Dublin Soc.*, vol. v. (1887), p. 340.

Carboniferous Rocks.

Although, from the evidence of the remaining patches, we may surmise that marine sediments of the Carboniferous period were spread widely over the eroded surface of the Silurian rocks during a submergence of the land in early Carboniferous times, the greater part of these sediments were removed in this district by pre-Permian, or at least by pre-Triassic, erosion.

At present only two very limited patches of Carboniferous rocks are known to exist within the limits of our map, though other similar patches may lie deeply buried beneath the Triassic strata west of the Lagan or in the Dundonald hollow. One of these patches occurs on the shore of Belfast Lough, between Cultra and Craigavad; and the other on the southern margin of Strangford Lough at Castle Espie. There having been only slight addition to our knowledge of these rocks since the publication of the original Survey Memoir (on Sheets 37, 38, and part of 29) in 1871, the following details of these interesting exposures are mainly repeated from that Memoir, with supplementary notes and re-arrangement.

Lower Limestone Shales.

Belfast Lough.—On the shore at Cultra, 200 yards S.W. of the quay, a fault running nearly north and south, with an upthrow to the eastward estimated at nearly 300 feet, cuts out the Triassic Sandstones which occupy the foreshore to the westward, and brings in a series of grey calcareous sandy grits and flags, and dark grey, nearly black, fossiliferous shales full of *Modiola Macadami* and other well-known Carboniferous forms.

A little farther north, due N. of Cultra House, we find on the foreshore below high-water mark a different series of beds, dipping seaward, which have been proved by their fossils to be of Permian age; and these will be subsequently described.

These Permian rocks appear to rest unconformably on red and yellow Carboniferous shales containing *Modiola Macadami* in great abundance, which are seen at the edge of the low cliff bordering the shore. The Permian rocks are continuous for about four hundred yards, and are then cut out by a second north-and-south fault, along the line of which there is a narrow dyke of grey finely crystalline basalt. To the eastward of this fault the Carboniferous rocks, dipping seaward, again occupy the whole of the shore, and may be traced thence along the coast for about 600 yards. The lowest Carboniferous beds here exposed consist of thick red sandstones and conglomerates, which are overlain by grey, yellow, and reddish-brown shales and thin sandstones interstratified with thin earthy semi-calcareous layers of a pale grey colour, probably dolomitic.[1] Over these beds are dark grey and black fossiliferous shales, full of *Modiola Macadami* and other Carboniferous fossils.

[1] An analysis supposed to refer to this rock is given in the original Memoir, *op. cit.*, p. 20.

Then, after an interval of 300 yards in which no rocks are exposed, the Carboniferous shales are again seen on the shore immediately N. of Ardnalee House, and continue eastward for 500 yards. The highest beds here are red and green mottled highly calcareous sandstones, passing down into fine conglomerate, below which there is a thick pale yellow sandstone, these beds being probably the same as some of those seen in the last exposure. Underlying these are found several beds of red and green mottled calcareous sandstone, followed by about 100 feet of hard red grits, with red and yellow mottled shales, and the lowest bed of the series to be seen is a whitish finely-crystalline limestone.

Although the actual junction of these Carboniferous rocks with the Ordovician slates is not visible, the two formations are exposed in such close proximity on the shore that the boundary can be very accurately traced.

The following fossils were recorded in the previous memoir as having been obtained from the Lower Limestone Shale of these exposures[1] :—

Sphenopteris linearis ?
Lepidodendron (Sagenaria) Veltheimiana, *Sternb.*
Rhynchonella pleurodon, *Phill.*
Modiola Macadami, *Portl.*
Orthoceras cinctum, *Sou.*
Beyrichia multiloba, *Jones*
Estheria striata ? *Muenster*
Leperditia, Cythere, &c., (of undetermined species).
Strepsodus (Holoptychius) Portlocki, *Ag.*

To the above list the following species have since been added by Mr. J. Wright[2] :—

Pisces.

Palæoniscus Robisoni ? *Hib.*
„ sp.
Amblypterus punctatus ? *Ag.*
Psammodus rugosus, *Ag.*

Mollusca.

Cypricardia sinuata, *M'Coy*
Natica ampliata, *Phill.*
„ sp.
Pleurotomaria Yvanni, *Lev.*
Murchisonia angulata, *Phil.*
„ sulcata, *M'Coy*
Macrocheilus acutus, *Sow.*
Loxonema sulcatula, *M'Coy*
Euomphalus, sp.
Turbo appropinquans, *Portl.*
Orthoceras inæquiseptum, *Phill.*

Polyzoa.

Fenestella irregularis, *Phill.*

Crustacea :—Entomostraca.

Cythere jonesiana, *Kirby*
Leperditia Okeni, *Müns.*, var. scotoburdigalensis.
Kirbya costata, *M'Coy*
„ annectans, *J. and K.*

Annelida.

Spirorbis globosus, *M'Coy*

Actinozoa.

Lithostrotion junceum, *Flem.*

Another species of fish has also been added to the list by Mr. S. A. Stewart, viz., *Ctenacanthus denticulatus*, M'Coy.[3]

[1] From the list in the original Memoir, *op. cit.*, p. 17.
[2] "The Geology of Cultra, Co. Down," *Ninth Ann. Rep. Belfast Field Club*, 1871–72, pp. 33–37.
[3] *The Irish Naturalist*, vol. iii. (1894), p. 204.

Carboniferous Limestone.

Castle Espie.—This curiously isolated patch of Carboniferous Limestone occurs at a low level on the margin of Strangford Lough, two miles E.S.E. of Comber. It was at one time extensively quarried for lime-burning and other purposes, but the quarries are now abandoned and full of water, so that the rock is nowhere accessible; and only the heavy capping of drift, which covers the limestone to a thickness of 25 to 40 feet, is visible in the present sections.

The rock is described in the former memoir as consisting of a red or salmon-coloured finely crystalline limestone, occurring in beds varying from 6 inches to 4 feet in thickness, separated by thin partings of light green shale, and with a few layers of green and mottled shale from 3 to 4 inches thick. In the quarry these beds had a total thickness of 35 feet, and at the engine-shaft of 41 feet. Below the limestone, dark purplish red and green mottled shales, probably representing the Lower Limestone Shale, were penetrated to a depth of 6 feet without their base being reached; and at the engine-shaft the limestone was reported to rest on red sandstone, believed to be part of the same series.

Fossils, in good preservation, were abundant in the limestone, and still more numerous, though smaller and not so well preserved, in the interpolated shales, the entire assemblage indicating that the beds belong to the Lower Limestone. Some of the orthoceratites were of gigantic size, an imperfect specimen of *Actinoceras giganteum* now preserved in the Geological Survey Collection in the Dublin Museum, measuring 2 ft. 4 ins. in length, and 1 ft. in diameter at its widest part.[1] Many of the Brachiopoda, especially *Productus giganteus*, also attained large dimensions. This species, along with *Spirifera bisulcata* and *Streptorhynchus crenistria* prevailed in the limestone; while *Athyris ambigua*, *Orthis resupinata* and *Productus longispinus* were the most abundant fossils in the shales. The following is the list of Castle Espie shells given in the former memoir; traces of crinoids and corals were also recorded :—

BRACHIOPODA.

Athyris ambigua, *Sow.*
Orthis resupinata, *Mart.*
Productus giganteus, *Mart.*
" longispinus, *Sow.*
" semireticulatus, *Mart*
Rhynchonella pleurodon, *Phill.*
Spirifera bisulcata, *Sow.*
" glabra, *Mart.*
" striata, *Mart.*
Streptorhynchus crenistria, *Phill.*
Strophomena rhomboidalis, *var.* analoga, *Phill.*

LAMELLIBRANCHIATA.

Aviculopecten Forbesi, *M'Coy*

CEPHALOPODA.

Actinoceras giganteum, *J. Sow.*[2]

[1] This specimen has been cut and polished to show the interior, which is filled with a mass of well-preserved shells and fragments of encrinites in a matrix of red limestone.

[2] Castle Espie specimens of this species have been described and figured by Dr. A. H. Foord, in Monograph. Carb. Cephalopoda of Ireland. *Monogr. Palæont. Soc.*, vol. liii. (pl. ix., p. 28).

The figure of the Castle Espie section given in the previous memoir (fig. 4, p. 37) shows a thin band of Triassic Sandstone resting unconformably on the Carboniferous rocks, and intervening between the boulder-clay and the limestone. In the accompanying text-description, however, no mention is made of sandstone in this position; and from the notes recorded on the original six-inch working maps, it appears that the supposition at first held as to the presence of this bed was not borne out by subsequent investigation, nor was the sandstone observed by any of the Belfast geologists who visited the quarries[1] while the section was accessible. Moreover, the fact that the surface of the limestone was beautifully scored with glacial striæ is proof that glacial deposits must have rested directly upon the Carboniferous rock in some places, if not throughout the section. The drift at this place is very sandy, and the "sandstone" of the quarrymen may have been only an indurated layer of "calcrete" at its base, such as is often present where porous drift rests upon limestone. It should be added, however, that [Sir] R. Griffith, in describing the Castle Espie limestone in 1843,[2] mentioned that it was "covered by beds of red sandstone," and his account seems to imply that sandstone was actually seen in this position; and the same statement occurs in a paper on Carboniferous fossils by J. Kelly, published in 1856.[3]

It is, of course, probable that the limestone may extend northward beneath the New Red rocks; but there appears, on the other hand, to be evidence that the area of Carboniferous strata thus concealed must be limited, and that the New Red of the Dundonald valley usually rests directly upon the Silurian slate-rocks. At several points along the margin of the valley Triassic sandstone or breccia is seen in such close proximity to outcrops of slate that the absence of intervening beds is assured; and mining trials in the Newtown Ards district toward the end of the 18th century seem to have revealed the same conditions. The following account of these trials is given by Mr. W. Gray[4] from "a manuscript record of certain mining operations carried on around Scrabo Hill and neighbourhood from the year 1780 up to the year 1784":—

"This journal gives a detailed account of several shafts sunk in search for coal, some of the shafts being 240 ft. deep. The result of these experiments is embodied in a report by Mr. Joseph Jackson, dated 23rd March, 1786. . . . . . . In this report Mr. Jackson describes the several trials made, giving the position and depths of the shafts, and the strata

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[1] We are indebted to Mr. S. A. Stewart for this information: a fine specimen of the glaciated limestone is preserved in the museum of the Belfast Phil. and Nat. Hist. Soc.

[2] "On the Lower portion of the Carboniferous Limestone Series of Ireland," *Rep. Brit. Assoc.* for 1843, p. 46.

[3] "On Localities of fossils of the Carboniferous Limestone of Ireland," *Journ. Geol. Soc., Dublin,* vol. vii., p. 34.

[4] "An Inquiry into the possibility and probability of the occurrence of Coal in the neighbourhood of Belfast," *Ninth Ann. Rep. Belfast Field Club,* 1871–72, p. 32

met with, together with such information as he obtained by inquiry in the locality, and then describing the geology of the district, he concludes as follows :— . . . . . . 'We find, by quarries that are opened, as well as by borings, that the red freestone is incumbent on the white; we find also that the white freestone is incumbent on the primitive rock all round the Mountain of Scrabo; we find also that the freestone is incumbent on the primitive at Anderson's Hill, at Bowleren, at Killarn Glen, and Kirkdonnie Glen, and in James Chambers' land, as proved by the boring; we also find that the horizontal freestone beds rise towards the Mountain of Scrabo, and towards the primitive rock in the other places, which appearances are sufficient proofs, in my opinion, that there are no seams or bands of coal contained within the district described.' "

Permian Rocks.

The presence of a small patch of Permian rocks overlying the Lower Carboniferous shales on the shore at Cultra has already been mentioned. The occurrence of Magnesian Limestone at this place comparable to that of the north of England was first pointed out by J. Bryce in 1835,[1] who did not, however, recognise that Carboniferous rocks also were represented.[2] In 1852, Prof. W. King identified a few characteristic Permian species among the scanty fossils of the Magnesian limestone,[3] and established the correlation.

No other outcrop of rocks of this age is known in the district, and indeed there are only two other localities in Ireland where Permian strata have been recognised. This little isolated outlier therefore possesses great importance for the light which it throws upon the conditions that prevailed in the region toward the close of Palæozoic times. From its relations to the Lower Carboniferous rocks, and from the character of these rocks at Cultra and Castle Espie, it is clear that a considerable mass of Carboniferous strata must originally have been deposited upon the irregular surface of the Silurian rocks. But subsequent elevatory movements brought these Carboniferous strata within reach of the agents of erosion, until, as we have seen, in this area there remained only a few isolated patches of the lowest beds of this period, which lay sheltered within hollows of the enduring slate-rocks of the older land. Then followed the subsidence of late-Permian times, which may perhaps have been very local and irregular, but which certainly brought in the waters of the sea along the western border of the ancient massif, and permitted the accumulation of the Magnesian Limestone and its associated marls at Cultra,

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[1] "On the Magnesian Limestone and associated beds which occur at Hollywood, in the County of Down," *Journ. Geol. Soc. Dublin*, vol. i., p. 175.

[2] See discussion of Bryce's views by [Sir] R. Griffith, in "Annual Address," *Journ. Geol. Soc. Dublin*, vol. i., pp. 146–149; also in *Rep. Brit. Assoc. for* 1843, pp. 45, 46.

[3] "On the Permian Fossils of Cultra," *Rep. Brit. Assoc. for* 1852, p. 53; with further discussion in a later paper, "On the occurrence of Permian Magnesian Limestone at Tullyconnel," *Journ. Geol. Soc. Dublin*, vol. vii. (1857), p. 67.

and of similar beds at Tullyconnel in co. Tyrone,[1] and probably also of the conglomerates and breccias of Armagh,[2] which are believed to be of the same age. There is, indeed, strong reason to believe, as will presently be shown, that other deposits of this period may be concealed beneath the Triassic marls and sandstones of the Lagan valley, but for this we have as yet only fragmentary evidence from certain deep borings. (See p. 21.)

The following description of the Permian outcrop at Cultra is compiled from that given in a previous memoir.[3]

The highest beds are yellow and buff-coloured earthy magnesian limestone, below which are red sandy marls, the lowest beds being thin-bedded fossiliferous limestones and red and grey shales, with a thin breccia at the base containing fragments of Silurian and Carboniferous rocks. The whole exposure is below high-water mark on the shore opposite to Rosavo, and its area is only about 400 yards by 100 yards. On the S.W. the beds are sharply contorted, and then slightly rolling, while close to the fault which cuts them out on the east they dip steadily seaward at about 20°. They appear to rest unconformably on the Lower Carboniferous shales already described.

The fossils occur in the lower red and yellow sandy and dolomitic beds; the following species were collected at the time of the original survey, the specimens being now preserved in the Survey Collection at the Dublin Museum:—

Productus horridus, *Sow.*
Bakewellia antiqua, *Muenst.*
Schizodus Schlotheimi, *Gein.*
Arca cf. tumida, *Sow.*
Turbo helicinus, *Schloth.*

Prof. King also records

Pleurophorus costatus, *Brown.*

[Since the previous memoir was published, doubts have been expressed as to the age of the rocks at Cultra, and it has been suggested that the beds supposed to be Permian form part of the Lower Carboniferous series.[4]

I therefore took an opportunity, in May, 1903, after compiling the above account, to examine the Cultra exposure at low-water of spring tide. I found no difficulty in tracing the beds mapped as Permian and in verifying the main points of the above description, though being unable to devote time to the collecting of fossils, I can add nothing to the palæontological argument. The Carboniferous shales are, as usual, greatly stained and softened at their contact with the Permians, and the junction is further confused by having been implicated in sharp boat-shaped contortions of small amplitude, which repeat the beds; but indications of strong unconformity at this junction are still recognisable.

[1] Prof. W. King; *op. cit.*

[2] Prof. E. Hull. *Mem. Geol. Survey*; Expl. of Sheet 47, pp. 11–13, and *Quart. Journ. Geol. Soc.*, xxix., pp. 402–405.

[3] "Sheet 37, 38, and part of 29"; pp. 19, 20.

[4] J. Wright, "The Geology of Cultra, Co. Down," *Ninth Ann. Rep. Belfast Nat. Field Club*, 1871–72, pp. 33–37; and J. Anderson, "On the Geological Formations of the Co. Down," *Proc. Belfast Nat. Hist. and Phil. Soc.*, 1871–72, pp. 41–49. I am permitted, however, by Mr. J. Wright to state that he is now satisfied that the fossils collected by him were all obtained from the Carboniferous portion of the outcrop, and that his argument against the occurrence of Permian rocks at Cultra was based on a misunderstanding.—G. W. L.

The following downward succession was traced in the beds above the junction. At low-water, the highest beds visible were:—

	Feet.
Flaggy, dull red and slightly mottled sandy, slightly gritty, marls, with occasional ripple-marked layers. Thickness seen, about . .	10
Red, gritty, and finely pebbly marl—a fine-grained 'brockram'—the fragments chiefly crumbs of shale and sandstone, but with a few subangular bits of quartz toward base (the largest observed being 1½ inches in diameter) where the bed is coarser, and yellowish or greenish; the whole thins out westward and is probably a lenticle,	2
Band of yellow magnesian limestone, mostly soft and decomposed, but in places hard and showing traces of fossils; lumpy at the top as if nodular and waterworn, ...	1½–2½
Flaggy dolomitic yellow and reddish purple marly layers, impersistent and probably lenticular, Greatest thickness not more than, .	2
Gritty fine-textured 'brockram'; the fragments chiefly of sandy shale and sandstone, but with some angular and subangular pieces of quartzite, vein-quartz, slate, and chert (the largest observed, 3 inches in largest diameter); irregular in thickness and probably lenticular; resting unconformably on stained Carboniferous shales; about, .	2½

The stained Carboniferous rocks may be followed eastward on the foreshore for a short distance from the junction, and are then hidden by boulder-clay; they emerge again before we reach the Cultra boat-landing, but are here dark and quite unstained, and extend in this condition up to the fault which brings in the Triassic Sandstone, east of the landing. It is therefore probable that another fault occurs in the tract hidden by boulder-clay, bringing the stained and unstained Carboniferous rocks into juxtaposition.

The lowest part of the foreshore which I saw at the Permian exposure was occupied by a patch of boulder-clay, resting on the red marls, and I was unable to find the uppermost beds of magnesian limestone mentioned in the previous official account; but these may have been under water, and may only be visible at exceptionally low tides.

I was impressed by the resemblance of the section to that at the base of the New Red rocks on the opposite side of the Irish Sea, on the coast north of St. Bees' Head, near Whitehaven; and the palæontological conclusions as to the Permian age of the beds are certainly in accordance with the stratigraphical evidence.

The resemblance to the Cumberland sequence has also been greatly strengthened by the discovery of marls and bands of conglomerate beneath the main mass of the Triassic sandstone in at least three deep borings in Belfast (see p. 21 and Appendix II.), these marls being probably the upward continuation of the Permian marls exposed at Cultra.]

G. W. L.

CHAPTER III.—THE MESOZOIC ROCKS.

Triassic Rocks.

The lower part of the Triassic deposits of the Belfast district consists of cross-bedded sandstone and semi-indurated sand; and the upper part, of regularly stratified marls with seams and veins of gypsum, and, in the ground north of the present map, with thick beds of rock-salt. The sand and sandstones underlie the head of Strangford Lough, and extend thence along the ancient hollow in the slate-rocks which runs past Comber and Dundonald to Belfast, where the beds expand northward into the depression of Belfast Lough and southward along the Lagan valley to the southern margin of the map.

The marls which overlie these sandy deposits form a continuous belt of sloping ground at the foot of the great escarpment of basalt and chalk, their outcrop expanding northward and their base descending in this direction until, near the northern edge of the map, they reach the shore of Belfast Lough. Throughout every part of their extent these Triassic rocks are much obscured by drift, and as a rule they are only visible in shore-exposures, stream cuttings, or in artificial excavations. So far as is known the entire series is unfossiliferous.[1]

The older rocks around the margin of the hollows in which these Triassic beds occur, and upon which they rest, are stained red or purple to a considerable depth, this staining being as well-marked in the Silurian and Ordovician slates as in the Lower Limestone Shale of Cultra and the Carboniferous Limestone of Castle Espie above described. As already mentioned, this staining occurs on the slopes of the slate-massif high above the present level of the Triassic rocks, affording evidence that at no very distant period these rocks were of much greater extent than at present. This indicates also that some of the broader features of the present surface of the slate-rocks had their approximate equivalents in Pre-Triassic times. It is believed that, during the Triassic period, as the result of continental elevation at the close of Permian times, dry desert conditions prevailed over an extensive land tract covering the site of the north-western part of Europe and the Atlantic border, and that the British deposits of this period were accumulated in lagoons and salt lakes, which represented the deeper gulfs and inlets of the Permian seas that became landlocked.

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[1] Some obscure markings on the sandstone at Scrabo Hill have been supposed to represent reptilian footprints. R. Young, *Rep. Belfast Nat. Field Club*, 1881–82, ser. ii., vol. ii.; "Presidential Address," p. 117. Similar markings have been observed in the marls; see W. Gault, "Observations on the Geology of the Black Mountain," *Proc. Belfast Nat. Field Club*, 1876–77. Plate of sections.

Triassic Sandstones.

These sandstones are seen in a few places along the northern shore of Strangford Lough and in railway cuttings S.W. of Newtown Ards, but by far the best exposures in this district are those of the great quarries on the eastern and southern flanks of Scrabo Hill, where the sandstone has been protected by a thick capping of basalt to be subsequently described.

These quarries reveal about 120 feet of white, brown, and light purple sandstone, often micaceous, with thin partings and blotches of red marl or shale. The rock is in some parts massive and in others flaggy, and more or less cross-bedded; the surfaces of the beds are often ripple-marked, and occasionally are pitted, probably by rain-drops, and traversed by slight ridges representing the moulds of sun-cracks that were developed in the mud now forming the shale-partings. Besides being overlain by basalt the sandstone in these quarries is traversed by numerous intrusions of the same igneous rock, that take the form of sills and have forced their way almost horizontally along the bedding planes of the sandstone, as well as by vertical dykes that cut the sills along with the sandstone beds, as shown in Plate III.

There is, indeed, strong reason to suspect that the basalt above the sandstone in these quarries has itself been intruded as a sill, and that it was formerly overlain by sandstone which has been removed by denudation (see p. 45).

The sandstone of this locality has been correlated with the "Lower Keuper" Sandstone of Lancashire and Cheshire, and a smaller tract of corresponding age is believed to underlie another isolated mass of basalt exposed in the vicinity of Dundonald, while the softer sandstones and semi-indurated sands which occur at lower levels along the Dundonald valley and in the vicinity of Belfast, have been regarded as equivalent to the Bunter ("Upper Red and Mottled") Sandstone of the English series.[1] It should be noted, however, that to the west of the Lagan the Keuper Marls rest directly upon soft sandy beds presenting the lithological characters of the "Bunter Sandstone" without the intervention of beds like those of Scrabo Hill (see also p. 23).

A few other artificial openings in the Triassic sandstones occur between Scrabo Hill and Dundonald, and to the southward of Dundonald; and the rock is also occasionally visible in stream-sections on both sides of the Dundonald valley, in the latter localities being sometimes interbedded with thin bands of conglomerate or breccia composed of quartz pebbles and fragments of the underlying slates. The details of these exposures will be found in the original memoir on this district.[2]

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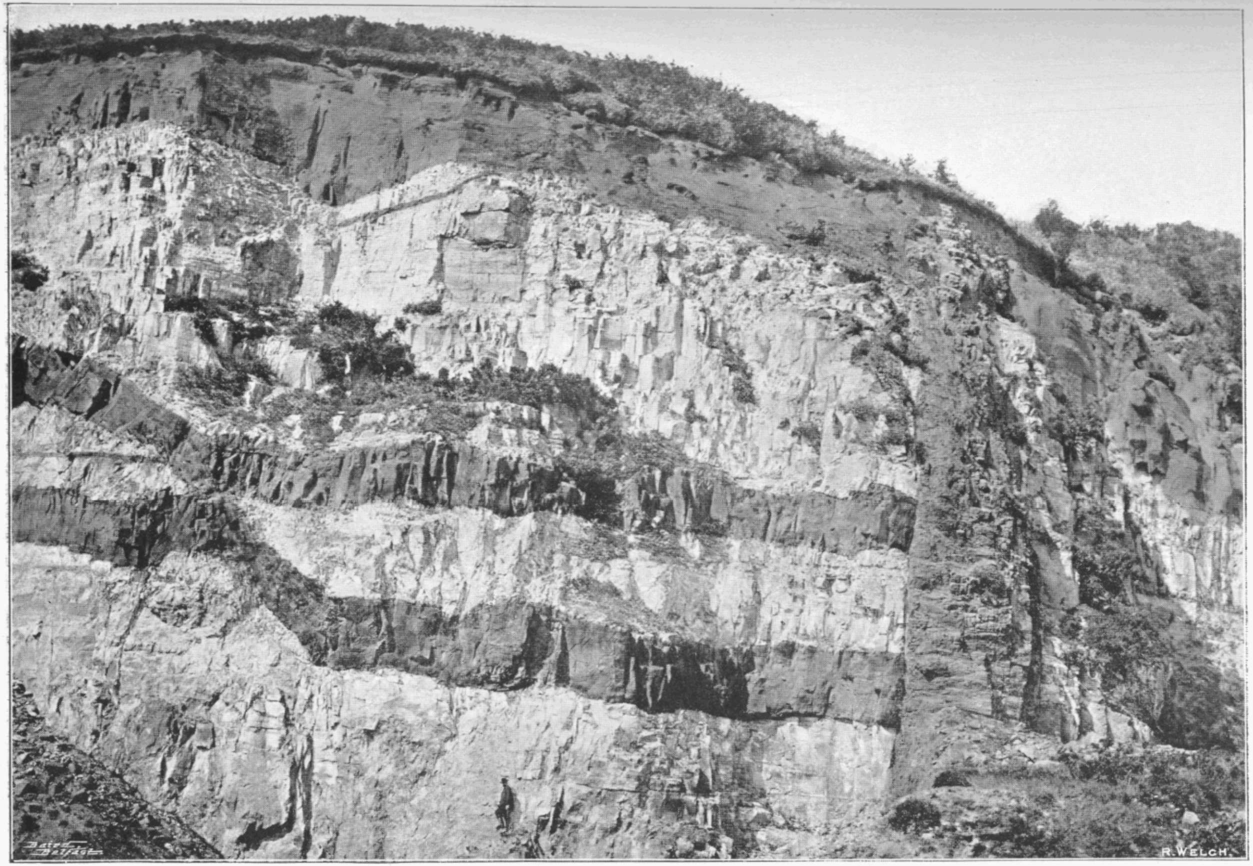
[1] *Mem. Geol. Survey,* "Explanation of Sheet 37, &c.," pp. 12, 13.

[2] The boundary-line of the original map between the Triassic and Silurian rocks of the Dundonald valley has been slightly altered on the new map to bring it into accordance with facts observed during the survey of the drifts.



To face p. 20.

PLATE III. TRIASSIC SANDSTONE VEINED AND CAPPED BY SILLS OF DOLERITE, INTERSECTED BY A BASALT DYKE.
SOUTH QUARRY, SCRABO HILL.

In the Lagan trough, Triassic sands and sandstones of the "Bunter" type are exposed in places on both the eastern and western shores of Belfast Lough, forming on the western side a low cliff at the inner margin of the strip of raised beach between Belfast and Greencastle. They have also been reached beneath the superficial deposits in many borings within the municipal boundary (see p. 85, and Appendix II., p. 145), and are well seen at the south-western suburbs of the city in artificial sections on the northern side of the Falls Road Cemetery and in the lower part of the ravines of the little streams south of Falls Park.

In the valley between Belfast and Lisburn the sandstones are best exposed in quarries and stream-courses around Milltown, and more sparingly to the southward and eastward of this place. As the deposit has accumulated in hollows of the older rocks its thickness must be very variable; deep borings in Belfast show that its total thickness in the valley must exceed 500 feet. In three of these borings toward the eastern side of the valley, viz., that at Lagan Vale (p. 146); that at Messrs. Inglis's in Eliza-street (p. 148); and that at the Municipal Electric Power Station, East Bridge-street (p. 145, and Fig. 12, p. 85), marls were found, as already mentioned (p. 18), below the main mass of the sandstone, associated with bands of pebbly conglomerate and hard calcareous layers, which are probably at or near the base of the Triassic rocks. Further reference to these sections will be found on p. 22.

Triassic Marls.

The lowest beds of this division consist of red and greenish-grey shaly marl, with thin layers of grey micaceous sandstone showing pseudomorphs after crystals of rock-salt; and for a few feet at the base, these beds are closely interstratified with the underlying sandstone, so that the line of division is not sharply defined. The higher part of the series consists of banded red, grey, and green-mottled marls, generally more or less streaked and veined with gypsum. No rock-salt is known to occur in these beds within the present sheet, but at Duncrue near Carrickfergus, four miles N. of its northern margin, where the marls are about 800 feet thick, they contain several important beds of salt, which are mined on an extensive scale, one of the beds being over 90 feet in thickness.

Around Belfast and in the valley to the southward, the marls are probably not quite so thick as at Carrickfergus. They are best exposed in the brickyards on the western and north-western outskirts of the city, where many deep excavations have been made in them, that usually also reveal examples of the basaltic dykes by which the marls are almost everywhere traversed. Smaller sections of these beds and their accompanying dykes are likewise visible in Collin Glen and in many other places in the beds of the little streams that flow from the Chalk escarpment to join the Blackstaff or the Lagan in the central valley. Owing to the presence of these soft clayey beds beneath the massive chalk and basalt, masses of the higher beds have slipped downward over the marls all along the foot of the escarpment, so that the highest part of Triassic deposits is rarely seen. In Collin Glen, however, where the top beds are sometimes sparingly exposed, the marls are found to pass upward into the marine Rhætic beds presently to be described. In the escarpment it is frequently difficult to decide whether the displacements of the rocks are due to slipping or to structural faulting, since both kinds of disturbance are prevalent.

On the later editions of Sheets 36 and 37 of the Survey Map showing the "solid" geology, an outlier of Triassic marl is indicated on the eastern side of the Lagan at Belfast, immediately south of Ballymacarret. The Trias in this quarter is deeply covered with drift, and the insertion of the outlier of marl was made on the evidence of a boring, 265 feet in depth, at Connswater in 1875, which passed through red clays resembling the Keuper Marls. Several more recent borings in the same district (for details, see Appendix II., p. 145), within the area shown as marl on the map, have reached Triassic sandstone immediately beneath the drift; and it is most likely that the "red clay" of the first boring has indicated the Lower Marls beneath the sandstone, to which reference has already been made. The more recent borings mentioned above have proved that the lower part of the New Red rocks in the Lagan basin includes thick masses of marl, which are probably confined to the deeper part of the basin, and are therefore not seen in actual outcrop, unless, as previously suggested, we suppose the marls of the small faulted-up patch of Permian at Cultra to represent the downward prolongation of these beds. At the same time, we may be sure, from the faulted character of the visible outcrops, that the structure of the Triassic rocks in the drift-covered valley S. of Belfast is much more complicated than the present "solid" map would indicate, though the evidence at present available is inadequate to enable us to follow the course of the faults beneath the drifts.

It was found during the mapping of the drifts that the marls extend farther eastward on the co. Antrim side of Belfast than is shown on the previous geological maps (Sheets 28 and 36). Brickyards and other artificial sections recently opened in the north-western part of the city prove that this district is underlain by marl, and not by sandstone as hitherto represented[1]; and the boundary of the beds has therefore been modified in accordance with this new evidence. At the Skegoneil brickyard the boundary is formed by a fault which brings up the sandstones on the eastern side. During the recent field-work, also, a small faulted inlier of marl, not

[1] **In the "Horizontal Section, Sheet 31," published in 1891, which traverses this ground the position of the boundary between the marl and sandstone is correctly shown.**

shown on previous maps, was found within the margin of the basaltic upland north of Collin Glen, the marls being seen for 100 yards in the bed of a small stream.

The marls have contributed very largely to the glacial deposits of the district, the matrix of the boulder-clay in the Lagan valley, and to a less extent in the Silurian ground to the eastward, having been mainly derived from them.

With regard to the correlation of the Triassic beds with those of Lancashire and Cheshire, to which reference has already been made, it is worthy of note that a series of deep borings made recently in the north of the Isle of Man proved the existence, below sea-level, of thick Triassic Saliferous Marl, closely resembling the beds above described, resting on over 700 feet of red and grey sandstone which almost certainly represents the St. Bees' Sandstone of the Cumberland coast.

Prof. W. B. Dawkins has pointed out that this discovery "links on the salt-field at Carrickfergus with those of Barrow and of Cheshire, and shows that the Irish Sea is a basin in which the salt-bearing Triassic marls were deposited."[1] Therefore, if the Triassic strata of the North of Ireland have been deposited in the same basin as the Trias of the Isle of Man and Cumberland, it is to this nearer quarter that we should look for the correlation, and not to the more distant area of Lancashire and Cheshire. And if this course be followed, the Triassic sandstones of this part of Ireland may be regarded as the equivalents of the St. Bees' Sandstone, underlain as in Cumberland by the Lower Marls and with an attenuated representative of the Permian, comparable to that at Whitehaven and in the Isle of Man, occurring in places at their base.

Rhætic Beds including the **"White Lias."**

The presence of these beds at the top of the Triassic Marls in Collin Glen has already been mentioned. They form an intermediate series between the marls and the overlying Lias, and are sometimes classed with the lower division and sometimes with the upper, the former grouping being more usually adopted.

No exposure of the Rhætic beds nor of the overlying Lias is known farther southward than ½ mile S. of Collin Glen, and it is probable that they are not continued in this direction; but to the northward, though concealed by land-slips, the Rhætic may be present as a capping to the Trias up to the northern margin of the map, as it has been observed at Cave Hill, three miles N. of Belfast, and still further north, at Woodburn, four miles beyond the limits of the present sheet. Our knowledge of these beds is principally due to the researches

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[1] *Rep. Brit. Assoc., Liverpool,* 1896, p. 778; and *Trans. Manchester Geol. Soc.,* vol. xxii., pt. xxi., pp. 147–159; see also *Mem. Geol. Survey,* "The Geology of the Isle of Man," pp. 291–295.

of the late Prof. R. Tate, who in 1863 published a detailed account of the exposures, and for the first time classified them as Rhætic.[1]

The following is a summary of the section formerly exposed in Collin Glen, but now much obscured; for full details Tate's original paper, above referred to, or the reprint of his section in the Geological Survey Memoir on Sheet 36 (p. 9), should be consulted :—

	Ft.	In.	Ft.	In.
"White Lias," consisting of :—				
Arenaceous marls with *Protocardium rhæticum*,	1	0	26	4
White limestone,	0	4		
Grey marls,	6	0		
Red marls,	9	0		
Grey arenaceous shales, passing down into—	10	0		
Black and bluish sandy fossiliferous shale with thin layers of argillaceous limestone,			10	2
Dark fossiliferous shale with thin layers of micaceous limestone,			2	10
Thinly-bedded shale with scattered fish remains and other fossils,			1	0
Sandy shale and stiff black clay on Keuper marls,			5	9
			46	1

The occurrence of "red marls" in the upper part of the Rhætic series is noteworthy, as similar beds on that horizon have been previously observed only in South Wales, near Bridgend, where, as remarked by Mr. R. H. Tiddeman, they indicate "a local recurrence of the sedimentary conditions which attended the deposition of the Keuper Marls."[2]

The fossils recorded from these beds by Tate, with the names modified to suit the later nomenclature of the species, are as follows :—

LAMELLIBRANCHIATA.

Avicula contorta, *Portl.*
Isodonta Ewaldi, *Born.* (=Axinus cloacinus, *Quenst.*)
Modiola minima, *Sow.*
Pecten valoniensis, *Defr.*
Placunopsis alpina, *Winkler*
Protocardium rhæticum, *Merian* (= Protoc. philippianum, *Dunker*).
Myophoria postera, *Bronn.*

GASTEROPODA.

Natica Oppeli, *Moore*
Trochus Waltoni, *Moore*

PISCES.

Gyrolepis Alberti, *Agassiz*
„ tenuistriatus, *Agassiz*
Acrodus minimus, *Agassiz*
„ n. sp.
Saurichthys apicalis, *Agassiz*
Hybodus minor, *Agassiz*

REPTILIA.

Ichthyosaurus (femur and teeth).

At Cave Hill, where the Rhætic beds were at one time well exposed in the cutting for the tramway at the entrance to the

[1] "On the Liassic Strata of the Neighbourhood of Belfast," *Quart. Journ. Geol. Soc.*, vol. xx., pp. 103–114.
[2] Summary of Progress of the Geological Survey for 1899, p. 132.

large quarry, but are now hidden by talus except in the uppermost part, the following section was observed by Tate :—

	Ft. In.
'White Lias' consisting of indurated shales and marls, yielding *Ostrea liassica*, Strickl. ; *Cardinia*, sp. ; *Monotis decussata*, Goldf., and a few other shells ; along with *Cardium Rhæticum*, *Axinus cloacinus* and *Modiola minima*, ...	12.0 to 14.0
Black shales, with *Axinus cloacinus* and *Avicula contorta*, . .	12.2
Argillaceous limestone, ...	0.1½
Shales, ...	2.8
Three bands of argillaceous limestone, ...	0.2½
Black shales, with *Avicula contorta* and fish, ...	0.10
Blue Keuper marls below.	

These Rhætic beds mark the beginning of a period of regional depression which affected the greater part of the British Islands and brought the waters of the sea once more over the land. Similar deposits, containing the same species of fossils, are found almost everywhere throughout England at the base of the Lias, and show the same transitional characters. With the gradual deepening of the sea, new forms of marine life were introduced, and the accumulation of the Liassic deposits commenced.

Lower Lias.

The Lias, like the Rhætic, is not known to exist under the southern part of the great escarpment, but is well exposed in Collin Glen and at several points to the northward.

Tate gives the following section of the Lias in Collin Glen[1] :—

	Ft.	In
1. Black shales, unfossiliferous, ...	16	0
2. Highly calcareous marls, with *Lima gigantea* and *Ammonites intermedius*, ...	1	0
3. Marls and shales, with Echinus-spines and *Modiola minima ?* .	17	0
[Trap dyke, 2 feet.]		
4. Alternations of shelly limestones with *Ostrea liassica ?* and *Modiola minima*, ...	4	3
5. 'White Lias.' (See p. 24.)		
	38	3

The fossils recorded by Tate from this section are as follows :—

Ammonites [Ægoceras] intermedius,[2] *Portl.*
Avicula (Oxytoma) inæquivalvis, *Sow.*
Cardinia ovalis, *Stutchb.*
Gryphæa arcuata (=incurva, *Sow.*)
Lima acuticosta, *Goldf.*
" gigantea, *Sow.*
" Hermanni, *Voltz*
Lima punctata, *Sow.*
Modiola cuneata, *Sow.*
" minima, *Sow.*
Nuculana (Leda) rostralis, *Goldf.*
Ostrea irregularis, *Muenst.*
Pleuromya unioides, *Agassiz*
Hemipedina, sp.

[1] *Quart. Journ. Geol. Soc.*, xx., p. 109.
[2] This is probably the form which Dr. W. F. Hume mentions as *Amm.* (*Arietites*) *Johnstoni*, Sow., at this locality, *Quart. Journ. Geol. Soc.*, liii., p. 549.

At Cave Hill, as already mentioned, only the passage-beds of the series seem to have been exposed (see p. 25); but in the townland of Ballyaghagan, on the southern side of Cave Hill, the Lias can be traced for some distance along the foot of the bluffs, the best exposure being in the bed of a little stream which notches the escarpment between Cave Hill and Squires Hill. Among the fossils collected for the Survey from this place were *Ammonites* [*Psiloceras*] *planorbis*; *Lima gigantea*; *Modiola minima*; and *Astarte Geuxi*.[1]

We can form no estimate as to the original thickness of the Lias in this district, since only the lower part of the Lower Lias now remains, any higher beds which may have existed having been swept away during a subsequent period of denudation before the overlying Cretaceous rocks were deposited. The greater part of the beds above described appear to belong to the "Zone of *Amm. planorbis*," the lowest of the Ammonite-zones of the Lower Lias; and the only other zone which has been recognised within the present area is the next overlying "Zone of *Amm. angulatus*," which is believed by Tate to be represented by the "highly calcareous marl with *Lima gigantea* and *Amm. intermedius*" of the Collin Glen section.[2] Farther north in Antrim, slightly higher zones are also represented; but the Lower Lias series is still incomplete, while of the Middle and Upper Lias no trace is known to exist, except in the form of boulders in the drift.[3]

Between the Lias and the rocks which here overlie it we encounter another great gap in the succession, comparable to those which we have recognised between the Silurian and Carboniferous and between the Carboniferous and Permian systems. At some period between Lower Jurassic and Upper Cretaceous times the region had again been elevated above sea-level, with the result that again were great masses of strata stripped away from the land, leaving only remnants of Lias here and there as proof of the Lower Jurassic submergence.

The stratigraphical record remains blank in this region until the wide-reaching submergence which affected the British Islands in Upper Cretaceous times began to bring the sea once more over the country, and thereby led to the accumulation of the shallow-water sandy and pebbly "Greensand" beds which underlie the White Chalk.

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[1] See *Mem. Geol. Survey* on Sheets 21, 28, and 29, pp. 39, 40.

[2] "On the Lower Lias of the North-east of Ireland," *Quart. Journ. Geol. Soc.*, xxiii., p. 302.

[3] Prof. W. J. Sollas and R. L. Praeger have recorded the presence of transported Middle and Upper Lias fossils in the drift near Dublin, and suggest that these may have been carried from the Hebrides. *Irish Nat.*, vol. iv., p. 326. It is more probable, however, that they indicate the existence of these divisions somewhere in the northern part of the bed of the Irish Sea. Middle Lias fossils have also been found in boulders in North Antrim.

Upper Cretaceous.

The north-east of Ireland is the only part of the island in which Cretaceous rocks have been preserved, though they may at one time have covered a large part of the country, and were probably continuous with the rocks of the same age which are so widely developed in the east and south-east of England.

Their persistence in the North of Ireland is due to the great outpouring of basaltic lava by which they were covered early in Tertiary times; but denudation had already made great inroads upon them before they were thus protected.

It is for the most part only in a narrow belt around the edge of the dissected basaltic plateau that the Cretaceous rocks are now exposed. In the present sheet their outcrop occupies the lower bluffs of the great escarpment west of the Triassic lowland. Along this bold feature the chalk has been extensively quarried for lime-burning and other purposes, so that the formation is exposed in numerous fine artificial sections as well as in the stream-courses which descend from the basaltic upland. As compared with the development of the Upper Cretaceous in England, where the chalk alone in some parts attains a thickness of 1,600 feet[1], the Irish series is much attenuated, the representatives of the Chalk and Upper Greensand combined not exceeding 80 to 100 feet in the district under description, and even where thickest, farther north, not exceeding 200 to 300 feet.[2] The lithological character of some portions of the formation also differs widely from that of the corresponding horizons in England, and much difficulty has arisen in establishing the correlation between them.

The early contributions to our knowledge of these rocks have been comprehensively reviewed by Prof. R. Tate in his paper on the correlation of the series, published in 1864,[3] and to this literature no further reference need here be made. In the paper just mentioned Tate classified the deposits under two divisions—Hibernian Greensand, and Upper Chalk; and again subdivided these into zones according to their fossils and lithological characters. Further advances in the comparative stratigraphy of the formation were made in 1876 by Dr. C. Barrois

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[1] A. J. Jukes-Browne, *Mem. Geol. Survey. The Cretaceous Rocks of Great Britain*, vol. ii., (1903), p. 2.

[2] *Mem. Geol. Survey*, Expl. of Sheet 20, p. 9.

[3] *Quart. Journ. Geol. Soc.* vol. xxi., pp. 18–20.

in his classical monograph on the Upper Cretaceous rocks of England and Ireland,[1] and by Mr. W. Gault, of Belfast.[2] The Microzoa of the deposits have also been studied and catalogued with great care by Mr. J. Wright.[3]

More recently an exhaustive study of these rocks has been made by Dr. W. F. Hume,[4] who has shown that the Upper Cretaceous sequence is more fully represented than had been supposed, but that there are great local variations in the character and thickness of the beds in different parts of Antrim.

As no work has been done by the Geological Survey on these Upper Cretaceous rocks since the original examination over thirty years ago, before the modern methods of subdividing the Chalk had been established, the brief description now to be given will be drawn mainly from Dr. Hume's paper on the subject.

Dr. Hume divides the Cretaceous district into five areas—Southern, Central, Eastern, Peninsular (N.E. corner of Antrim), and Northern—in which the strata present well-marked local differences of development; but of these only the Southern, Central, and a small part of the Eastern divisions come within the limits of our map. Within these limits, it is in the "Central Division" of Dr. Hume, as represented by the section in Collin Glen, that the Upper Cretaceous sequence is most fully developed. This section will therefore be described first; and a short account will then be given of the changes which the beds undergo when traced southward and northward from this place.

The following figure (Fig. 2), reproduced with the author's permission from Dr. Hume's paper, represents the vertical succession of the rocks occurring in the Collin Glen section. These beds are twice repeated along the course of the stream as the result of the faults shown on the Survey map, by which a wedge-shaped mass of strata is brought up on the west, so that the Keuper marls reappear on this side and abut against the Chalk and Greensand.[5] (Plate IV.).

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1 "Recherches sur le Terrain Crétacé Supérieur de l'Angleterre et de l'Irlande," *Mem. Soc. Geol. du Nord Lille.*

2 *Proc. Belfast Nat. Field Club*, 1876–77, pp. 251–262.

3 "Irish Cret. Microzoa," *Proc. Belfast Nat. Field Club*, ser. 2, vol. i., (1879-80), p. 74.

4 "The Cretaceous Strata of Co. Antrim," *Quart. Journ. Geol. Soc.*, vol. liii. (1897), pp. 540–606.

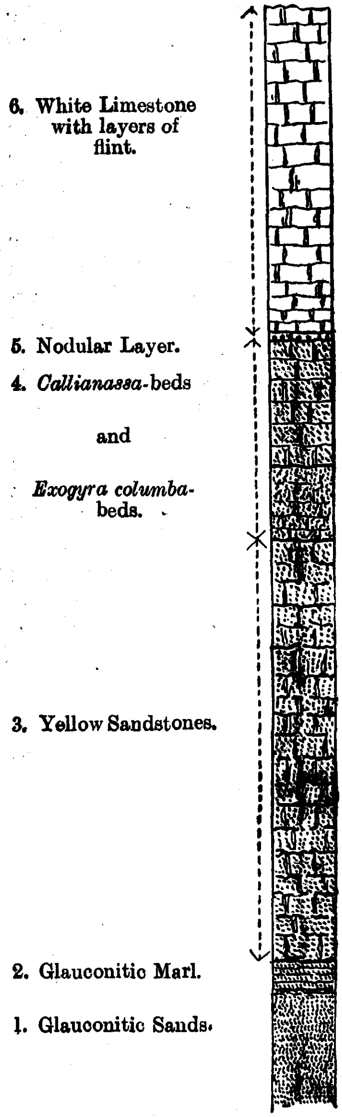
5 See *Mem. Geol. Survey*, "Sheet 36," p. 28 and Fig. 1.

To face p. 28.

PLATE IV. FAULTED CRETACEOUS AND TRIASSIC ROCKS IN COLLIN GLEN.

Yellow Sandstones (Y.S.) faulted against Glauconitic Sand (Gs.) and Red Marl (R.M.)

Fig. 2.—Section of Upper Cretaceous Rocks in Collin Glen (*Dr. W. F. Hume*).
Scale 1 inch =15 feet.



Resting on the Liassic shales in these sections Dr. Hume finds :—

(1.) Eight or 10 feet of deep-green *Glauconitic Sands* with quartz pebbles and a band of phosphatic nodules. They contain many well-preserved fossils, including *Exogyra conica* var. *lævigata*, *Pecten* (*Janira*) *quinquecostatus*, *Pecten* (*Amusium*) *orbicularis*, *Cucullæa carinata* ; teeth of fishes, &c. These sands are overlain in Collin Glen by :—

(2.) About 2 feet of grey *Glauconitic Marl* containing *Vermicularia concava* and *Vermicularia quinquecarinata* in great abundance.

(3.) The calcareous buff-coloured *Yellow Sandstones* which overlie the marl are about 30 feet thick, and contain masses of chert and fossiliferous bands, containing *Ostrea* (*Alectryonia*) *carinata*, *Pecten* (*Janira*) *quadricostatus*, *Pecten* (*Janira*) *quinquecostatus*, *Lima semisulcata*, *Lima globosa*, *Panopæa mandibula*, and many other lamellibranchs; *Vermicularia quinquecarinata*, &c.

(4.) A series of alternating hard and soft calcareous glauconitic sandstones and greensands ("The Chloritic Sands and Sandstones" of Tate), about 15 feet thick, forms the next member in the upward succession. In this series fossils are most abundant in the softer beds, in the lowest of which *Vermicularia concava* is plentiful, and at a slightly higher level *Exogyra columba*, of large size, along with species of *Trigonia*, *Pecten* (including, rarely, *Pecten asper*), *Ostrea*, and other lamellibranchs, with teeth of fish, &c., while the highest of the softer beds is characterized by the remains of a crustacean referred to *Callianassa*, along with *Natica* and polyzoa.

(5.) The uppermost part of the sandy series in Collin Glen is obscure, and there is supposed to be a gap in the succession at this place before the next stratum was formed, either through stoppage of deposition or through erosion of beds already deposited. Dr. Hume quotes Mr. Gault's description of the overlying rock as "hard green speckled chalk, coarsely conglomeratic at the base; large rounded pebbles of quartz and other rocks; the glauconitic grains are large and thickly scattered throughout, giving the bed its well-known name of mulatto-stone. The fossils, except the sponges and brachiopods, are broken and worn, being probably derived from the waste of an older bed. Sponges are numerous, but other fossils are rare." This bed is supposed to represent the "Chloritic [glauconitic] Chalk" of Tate, which expands to a thickness of 20 feet or more in the eastern part of the "Eastern Division" of Dr. Hume.[1] The rock contains *Belemnitella* (*Actinocamax*) *vera*, *Echinocorys scutatus*, many *Ventriculites*, and teeth of fish. It is overlain by—

(6.) Hard white Chalk about 20 feet thick, with flints in regular rows except in the lowest 2 feet, which contain few flints. *Belemnitella mucronata* is the characteristic fossil.

In tracing the above succession southward it is found that all the beds below No. 5 soon disappear, so that from White Mountain south-westward the sections show the White Chalk with flints resting almost directly upon the Triassic marls, with only a thin band of the conglomeratic "mulatto-stone" (No. 5) between them. On the original Survey map (Sheet 36) the Upper Greensand outcrop is indicated as continuous in this quarter, owing to the "mulatto-stone" having been included as part of the greensand series. Tate and Hume have shown, however, that this method of classification cannot be sustained.

Northward from Collin Glen the Glauconitic Sands (No. 1) are continued, with the same thickness, to the margin of the

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[1] *Op. cit.*, p. 564 and Pl. XLV.

map; but southward, after swelling to 12 feet or more in a stream-section just below the large chalk-pit on the hill-slope one mile S. of Collin Glen, they disappear, and cannot be traced in the more southerly part of the escarpment.

The overlying beds up to the base of the White Chalk (No. 5) become much attenuated and altered in lithological character, when traced northward from Collin Glen. In the section revealed by the Forth River, Dr. Hume notes the occurrence of *Belemnitella* (*Actinocamax*) *Alfridi*, "a species of rare occurrence in England," at the base of a band of hard glauconitic sandstone directly below the White Chalk; in the quarries at Squires Hill it is observed that the "Yellow Sandstones" (No. 3) are only 18 feet thick, and the overlying "Glauconitic Sandstone and Sands" (No. 4) only 4½ feet; at Cave Hill the beds are still thinner; and at Woodburn Glen, a few miles farther northward, beyond the limits of the present map, these subdivisions are represented only by 4 feet of grey marl with chert nodules.[1]

The beds above No. 4, on the other hand, become thicker northward, partly by expansion of the lowermost band and partly by the addition of higher beds which in the Collin Glen section appear to have been removed by denudation before the outpouring of the basaltic lavas. Thus, at Squires Hill the White Chalk (No. 6) has a thickness of about 50 feet, and at the northern end of Cave Hill, of about 100 feet; while in the eastern part of the "Eastern Division" of Dr. Hume, the basement bed itself (No. 5) expands into a series of sandy glauconitic limestones 20 feet in thickness.

The correlation of these beds with their equivalents in England, as established by Dr. Hume, is shown in the following table.[2]

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[1] Hume, *op. cit.*, p. 555 and Pl. XLV.

[2] Great advances have been recently made in the palæontological zonal classification of the English Chalk (see Dr. A. W. Rowe's papers in *Proc. Geol. Asso.*, vol. xvi., pp. 289–369; vol. xvii., pp. 1–76; vol. xviii., pp. 1–51), and the application of the same methods to the Irish succession will probably necessitate some modification of the scheme here reproduced.

[Table

Divisions or Stages.	Palæontological Zones.	Equivalents in Belfast District.		
		"Southern Division."	"Central Division."	"Eastern Division."
Senonian or Upper Chalk.	Zone of *Belemnitella mucronata.*	White Limestone with regular layers of Flint; 40 feet. Mulatto Stone resting on Triassic Marls.	White Limestone with regular layers of Flint; 40-50 feet; rich fauna at base. "Mulatto Stone" sometimes occurs at base.	White Limestone with regular bands of Flint; large Ammonites at base.
	— of *Bel. (Actinocamax) quadrata.*		Nodular Chalk with *Bel. quadrata.*	Not recognized as distinct.
	— of *Bel. (Actin.) vera*, or of *Marsupites.*		Spongiarian zone with *Bel. vera.*	Spongiarian zone with *Bel. vera.*
	— of *Micraster coranguinum.*		Not represented,	Glauconitic sandy Limestone with *Echinocorys gibbus* and *Camerospongia.*
	— of *Micraster cortestudinarium.*		Not represented,	Glauconitic Limestone and sandy beds, with *Terebratula carnea, Serpula filiformis, Spondylus spinosus,* etc., and *Rhynchonella*-band at base.
Turonian or Middle Chalk.	— of *Holaster planus.*[2]		Not represented,	Glauconitic band (at Barney's Point, Islandmagee) with *Micraster breviporus*?[1]
	— of *Terebratulina gracilis.*[3]		*Callianassa* - beds and yellow greensands with fish-teeth; and the *Exogyra columba* band may belong here.	Part of the yellow-green sands with *Ostrea semiplana* may belong to the Turonian.
	— of *Inoceramus labiatus* or of *Rhynchonella Cuvieri.*			
Cenomanian or Lower Chalk.	— of *Bel. (Actinocamax) plenus*		?	?
	— of *Ammonites [Acanthoceras] rotomagensis.*		Major portion of *Exogyra columba* zone should be referred here.	Yellow-green sands with *Exogyra columba* and *Catopygus columbarius* and
	—of *Amm. [Schlœnbachia] varians.*		*Trigoniæ, Ostrea carinata* and *Orbitolina* at base.	Glauconitic calcareous sandstone with *Rhynch. Schlœnbachi.*
	"Chloritic Marl,"		Scattered brown nodules.	?
Selbornian (pars) or Upper Greensand.	— of *Pecten asper,*		Yellow Sandstone with large *Ostrea carinata, Panopæa mandibula,* etc.	Yellow Sandstone with *Pecten quadricostatus, Discoidea subucula* and *Micrabacia coronula.*
	— of *Ammonites inflatus (=rostratus).*		Glauconitic Sands,	Glauconitic Sands.

[1] Compare Hume, op. cit., p. 560 and Table facing p. 568.
[2] The *Holaster planus* beds are now included in the Upper Chalk by the Geological Survey.
[3] The true *Terebratulina gracilis* occurs only at a much higher horizon; this division is now termed "*Terebratulina* zone" by the Geological Survey.

From the above table it will be seen that in the "Southern Division" of the Antrim Upper Cretaceous rocks, only the highest zone of the English Chalk is represented, but that in going northward we find a fuller, though still imperfect succession, in which, however, the lithological aspect of the beds is for the most part very different from that of their equivalents in England and it is still only in the uppermost portion of the series that the typical Chalk or "White Limestone" with flints is developed. Thus the greater part of the English Chalk is either absent or is represented by attenuated beds of glauconitic sand, marl, and limestone lithologically resembling the beds which in England are found only in the "Upper Greensand" stage at the base of the Chalk.

These beds probably denote much shallower water than that in which the Chalk was accumulated; and thus it would appear that the great submergence of Upper Cretaceous times was much later in attaining its maximum effect in Ireland than in England, so that shore or shallow-water deposits were being formed in one country while all the southern and eastern parts of the other were deeply sunken beneath the sea.

Indeed even within the limits of our district we seem to be able to trace local modifications of sea-depth. Thus, Dr. Hume gives reasons[1] for believing that the rocks of the "Eastern Division" were accumulated in deeper water than those of the "Central Division"; and also that three great phases of movement during the period may be traced, comparable to similar phases which he had previously traced in the English series. The first of these was a phase of depression, lasting throughout the Upper Greensand stage and into Cenomanian times; the second was a period of partial elevation, during which some of the beds already accumulated may have been swept away, especially in the "Central Division"; and the third, a period of renewed and augmented depression which is marked both by overlap and unconformity in the highest Turonian and lowest Senonian strata. Some conglomeratic beds in the north of the county, beyond the limits of our map, appear to represent true beaches of the Cretaceous sea, formed during the beginning of the later period of depression; and the "mulatto-stone" of the Southern and Central Divisions above-described is probably the equivalent deposit within our district.

Dr. Hume obtained some interesting results from the examination of the insoluble residues of various members of the Upper Cretaceous series after treatment with acid. These residues represent detrital material derived from the ancient land, with the exception of the glauconite, iron-pyrites and flint which have been formed by chemical reaction and segregation in the sediments. A sample of the Glauconitic Sands (No. 1) from Woodburn Glen was found to consist of 24·4 per cent. carbonate of lime, and 75·6 per cent. heavy residue; the latter

[1] *Op. cit.*, p. 599.

was characterized by the abundance and large size of the glauconitic grains which in most, if not all, cases could be recognised as the casts of foraminifera or other microzoa; it also contained much quartz in well-rounded grains, along with specks of muscovite, biotite, rutile, zircon, and (rarely) tourmaline. The Glauconitic Marl (No. 2) of the same locality yielded 63·91 per cent. carbonate of lime, &c., and 36·19 per cent. residue, the latter consisting partly of sandy clay and partly of glauconite, quartz-grains, &c., with the same minerals as the last, and also iron-pyrites, garnet, and kyanite. The Yellow Sandstone (No. 3) from Collin Glen consisted of 36·75 per cent. carbonate of lime and 63·25 per cent. residue containing mainly small quartz-grains, with thin flakes of muscovite, tourmaline in beautifully preserved crystals, rutile in more or less rounded grains, and zircon. The "Chloritic Chalk" of Woodburn Glen yielded 93·95 per cent. carbonate of lime, and only 6·05 per cent. residue; and the White Chalk of Divis Hill proved to be an almost pure limestone, showing 99·323 per cent. carbonate of lime, ·672 per cent. clayey material, and ·005 per cent. heavy residue, "almost entirely of limonite, with one or two quartz-grains (probably windblown)."

The following fossil-lists are compiled from Dr. Hume's paper, those species only being included which are mentioned by him as occurring in the "Central" and "Southern" areas; these lists while serving to illustrate the fauna are known not to be exhaustive.

Fossils of the Glauconitic Sands (No. 1).

Reptilia.

Vertebræ of Plesiosaurus.

Pisces.

Corax falcatus, *Ag.*
Lamna appendiculata, *Ag.*

Cephalopoda.

Ammonites [Hoplites] catillus, *Sow.* (probably).
Belemnites ultimus, *D'Orb.*

Gasteropoda.

Littorina ?

Lamellibranchiata.

Avicula, sp.
Exogyra conica, *var.* lævigata, *Sow.*
" " *var.* undata, *Sow.*
Pecten (Amusium) orbicularis, *Mant.*
" (Neithea) quinquecostatus, *Sow.*
Cucullæa carinata, *Sow.*
" ligeriensis, *D'Orb.*
Cyprina, sp.
Trigonia, sp.
Thetis Sowerbyi ? *Röm.*

Fossils of the Yellow Sandstones (No. 3).

Lamellibranchiata.

Pecten (Neithea) quadricostatus, *Sow.*
" " quinquecostatus, *Sow.*
" " æquicostatus, *Lam.*
Ostrea (Alectryonia) carinata, *Lam.*
Lima semisulcata, *D'Orb.*
" globosa, *Sow.*
Trigonia scabricula, *Lyc.*
Pleuromya mandibula, *Sow.*
Cucullæa ligeriensis, *D'Orb.*
Avicula, sp.
Pinna, sp.

BRACHIOPODA.

Rhynchonella dimidiata, *var.* convexa. *Sow.*

ANNELIDA.

Vermicularia [Serpula] concava, *Sow.*

Vermicularia [Serpula] quinque-carinata, *Röm.*

FOSSILS OF THE "CHLORITIC SANDS AND SANDSTONES" (No. 4).

PISCES.

Oxyrhina Mantelli, *Ag.*
Ptychodus latissimus, *Ag.*
 „ decurrens, *Ag.*
 „ mammillaris, *Ag.*
Corax falcatus, *Ag.*
Lamna sulcata, *Ag.*
 „ appendiculata, *Ag.*

CEPHALOPODA.

Amm. [Pachydiscus] lewesiensis, *Mant.* (*fide* Tate).

GASTEROPODA.

Natica, sp., and others undescribed.

LAMELLIBRANCHIATA.

Exogyra columba, *Lam.*
Ostrea (Alectryonia) carinata, *Lam.*
 „ canaliculata, *Sow.*
 „ semiplana, *Sow.*
Pecten (Chlamys) asper, *Lam.*
 „ (Neithea) quinquecostatus, *Sow.*
Pecten (Neithea) æquicostatus, *Lam.*
Trigonia crenulata, *Lam.*
 „ dædalea, *Park.*
Cardium gibbosum, *Tate*
Anatina Royana, *D'Orb.*

BRACHIOPODA.

Waldheimia hibernica, *Tate*

ANNELIDA.

Vermicularia [Serpula] concava, *Sow*

CRUSTACEA.

Callianassa, sp.

FORAMINIFERA.[1]

Patellina (Orbitolina) concava, *Lam.*

FOSSILS OF THE "CHLORITIC CHALK" (No. 5).

CEPHALOPODA.

Belemnitella (Actinocamax) vera, *Mil.*
 „ „ quadrata, *Blainv.*
Belemnitella (Actinocamax) Alfridi, *Janet*

GASTEROPODA.

Trochus sp.

LAMELLIBRANCHIATA.

Spondylus sp.

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[1] For full list of Cretaceous Foraminifera and other Microzoa from the North of Ireland, comprising over 150 species or forms, see tables and notes by Mr. J. Wright, in *Proc. Belfast Nat. Field Club*, vol. I., Appendix iii., pp. 71–100.

Brachiopoda.

Terebratula carnea, *Sow.* (*fide* W. Gault).

Echinodermata.

Micraster cor-anguinum, *Forbes*
Echinocorys scutatus, *Leske*

Porifera.

Etheridgia mirabilis, *Tate*
Camerospongia fungiformis, *Goldf.*
Ventriculites decurrens, *T. Smith*
Ventriculites radiatus, *Mant.*
„ alternans, *Röm.*

Fossils of the Chalk or "White Limestone" (No. 6).

Reptilia.

Mosasaurus gracilis, *Owen*[1]

Pisces.

Notidanus microdon, *Ag.*

Cephalopoda.

Belemnitella mucronata, *Schloth.*
Baculites aff. anceps.
Nautilus Atlas, *Whiteaves*
„ largilliertianus, *D'Orb.*
„ deslongchampsianus, *D'Orb.*
Hamites sp.
Anisoceras sp.
Amm. [Pachydiscus] Griffithsi, *Sharpe*
„ „ Oldhami, *Sharpe*
„ „ peramplus, *Mant.*
„ „ Portlocki, *Sharpe*
„ „ gollevillensis, *D'Orb.*

Gasteropoda.

Calliostoma sp.
Pleurotomaria perspectiva, *Mant.*
Turritella unicarinata, *Tate*
Trochus sp.
Cinulia catenata, *Tate*

Lamellibranchiata.

Pecten cretosus, *Defr.*
Ostrea vesicularis, *Lam.*
Lima Hoperi, *Defr.*
Inoceramus sp.
Pholadomya cordata, *Tate*
„ Stewarti, *Tate*

Brachiopoda.

Magas pumilus, *Sow.*
Terebratula carnea, *Sow.*
„ obesa, *Sow.*
Terebratulina Defrancei, *Brongn.*
„ abrupta, *Tate*
Terebratulina striata, *Wahl.*
Rhynchonella plicatilis, *var.* octoplicata, *Sow.*
„ limbata, *Dav.*
Megerlia (Kingena) lima, *Defr.*

Actinozoa.

Parasmilia centralis, *Mant.*

Echinodermata.

Catopygus columbarius, *Lam.* (*var.*)
Holaster planus, *Mant.*
Galerites conicus, *Breyn.*
„ abbreviatus, *Lam.*
Echinocorys scutatus, *Lam.*
Echinocorys scutatus, *var.* pyramidatus, *Portl.*
Cardiaster ananchytis, *Leske*
Cyphosoma corollare, *Park.*

Porifera.

Cœloptychium belfastiense, *Tate*
Guettardia stellata, *Mich.*
Ventriculites sp.
Porosphæra globularis, *v. Hag.*

[1] From the Whitewell Quarry, see W. Swanston, *Proc. Belfast Nat. Hist. and Phil. Soc.*, 1886, pp. 18, 19.

CHAPTER IV.—THE TERTIARY BASALTS.

After the close of the Upper Cretaceous period, the North of Ireland was once more affected by elevatory movements which raised the region to some height above sea-level and allowed the wasting of its surface to begin afresh. The uppermost beds of the Chalk were thus removed, leaving an irregular surface littered with partially-worn flints and clayey insoluble rain-wash. A period of great volcanic activity then set in, with the result that the country was invaded by a succession of wide-spreading lava-flows that overwhelmed the whole district and covered the land with heavy molten floods, which consolidated as sheets of dark basalt. This volcanic episode forms one of the most striking chapters in Irish geology, and has given rise to a voluminous literature.[1] The latest and most lucid description of the phenomena is that given by Sir A. Geikie, the late Director-General of the Geological Survey, in his great work on "Ancient Volcanoes"[2]; and so far as this description relates to the present map, it will be reproduced in the following account of the volcanic rocks.

These basaltic lava-flows form the upper part of the bold escarpment west of Belfast Lough and the Lagan valley, and extend thence to the western and northern margins of the map. Two small outliers of basaltic rock occur at Scrabo Hill and Dundonald, in the hollow between Belfast and Strangford Lough, but as will be subsequently shown, these appear to be of somewhat different character from the main mass. The basaltic upland west of Belfast forms part of the great Antrim lava-plain which stretches unbrokenly north-westward to Lough Foyle and the Giant's Causeway, and south-westward to beyond the southern margin of Lough Neagh, covering an area of about 1,200 sq. miles.

This lava-sheet, as Sir A. Geikie remarks, is not only the largest in the British Islands, but is also the most continuous and regular. As to the original contours of this sheet the same author notes :—"I have found some difficulty in the attempt to ascertain what was the probable form of the surface over which the volcanic rocks of this plateau began to be poured out. The Chalk sinks below sea-level on the north coast, but, in the outlier of Slieve Gallion, three miles beyond the western

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1 For analytical review of the earlier literature of this subject see Portlock's "Report on the Geology of the Co. of Londonderry, &c.," pp. 22–82, Dublin, 1843; and for the later work see *Memoirs of Geol. Survey of Ireland*, Explanations of Sheets 7 and 8; Sheet 12; Sheet 13; Sheet 14; Sheet 18; Sheet 19; Sheet 20; Sheets 21, 28, and 29; and Sheet 36.

2 "The Ancient Volcanoes of Great Britain" (London, 1897), vol. ii., pp. 199–208.

base of the escarpment, it rises to a height of 1,500 feet above the sea. On the east side also, it shows remarkable differences of level. Thus, below the White Head at the mouth of Belfast Lough, it passes under the sea-level, but only sixteen miles to the south, where it crops out from under the basalt, its surface is about 1,000 feet above that level. If these variations in height existed at the time of the outpouring of the basalt, the surface of the ground over which the eruptions took place was so irregular that some hundreds of feet of lava must have accumulated before the higher chalk hills were buried under the volcanic discharges. But it seems to me that much of this inequality in the height of the upper surface of the Chalk is to be attributed to unequal movements since the volcanic period, which involved the basalt in their effects, as well as the platform of Chalk below it. Had the present undulations of that platform been older than the volcanic discharges, it is obvious that upper portions of the basalt-series would have overlapped lower, and would have come to rest directly on the Chalk. But this arrangement, so far as I am aware, never occurs, except on a trifling scale. Wherever the Chalk appears, it is covered by sheets of the lower and not of the upper of the two groups into which the Antrim basalts are divisible." Then, after referring to instances of extensive post-basaltic faulting and displacements, Sir A. Geikie writes :—" It is evident, therefore, that the present position of the Chalk platform is far from agreeing with that which it presented to the outflow of the sheets of basalt. But, on the other hand, there can be no doubt that its surface was not a level plain. It was prob ably a rolling country of low bare chalk-downs, like parts of the South-east of England." . . . .

" The floor on which the basalt lies is remarkably irregular, rising into ridges and sinking into hollows or trenches, but almost everywhere presenting a layer of earthy rubbish made of brown ferruginous clays, mixed with pieces of flint, chalk, and even basalt. The flints are generally reddened and shattery. The chalk itself has been described as indurated, and its flints as partially burned by the influence of the overlying basalt. But I have not noticed, at any locality, evidence of alteration of the solid chalk, except where dykes or intrusive sheets have penetrated it. There can be no doubt that the hardness of the rock is an original peculiarity, due to the circumstances of its formation. The irregular earthy rubble, that almost always intervenes between the chalk and the base of the basalt, like the ' clay with flints ' so general over the Chalk of Southern England, no doubt represents long-continued subærial weathering previous to the outflow of the basalt. Even, therefore, if there were no other evidence, we might infer with some confidence from this layer of rubble, that the surface over which the lavas were poured was a terrestrial one." . . . .

Lower Basalts.

"The total thickness of volcanic rocks in the Antrim plateau exceeds 1,000 feet; but, as the upper part of the series has been removed by denudation, the whole depth of lava originally poured out cannot now be told. A well-marked group of tuffs and clays, traceable throughout a large part of Antrim, forms a good horizon in the midst of the basalts. The Lower Basalts have a thickness of from 400 to 500 feet. . . . They are distinguished by their generally cellular and amygdaloidal character, and less frequently columnar structure. The successive flows, each averaging perhaps above 15 feet in thickness, are often separated by thin red ferruginous clayey partings, sometimes by bands of green or brown fine gravelly tuff."

In the portion of the basaltic plateau included in the present map, these Lower Basalts are the only beds preserved, except in two places presently to be mentioned, where small outliers of the Upper Basalts and intermediate beds have escaped erosion. They are well exposed in numerous quarries and stream sections all along the edge of the escarpment, and form the fine mural precipices of Cave Hill, overlooking Belfast. In the interior of the plateau, though generally covered with drift in the valleys, they are close to the surface in most of the hilly ridges, forming tracts of rocky ground with a little peat and rain-wash in the hollows. Their maximum thickness in this district may range somewhat higher than above stated, having been estimated at 684 feet in Black Hill.[1] The basalt weathers readily to a soft brown rock often showing a granular texture owing to its amygdaloidal structure, and breaks down finally into a sandy earth or loam. Its petrographical characters are described in Appendix I., p. 140.

Interbasaltic Beds.

The only places within the map where the higher beds of the Volcanic series now remain are on Divis Mountain, and at Lyles Hill in the north-west corner of the map, two miles S.E. of Templepatrick. In both cases patches of the Upper Basalts, forming the highest ground, are separated from the Lower Basalts by beds of red clayey earth ("bole and lithomarge"), including also, at Lyles Hill, a band of pisolitic iron-ore into which some mining trials have been carried (see Fig. 3). In other places farther north, especially at Ballintoy, these intermediate beds also include thick bands of lignite.[2]

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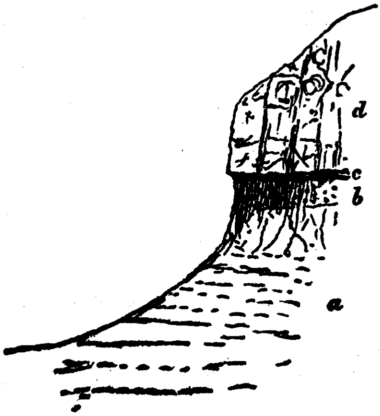
1 *Mem. Geol. Survey on Sheet* 36, p. 11.
2 *Mem. Geol. Survey,* Explanation of Sheets 7 and 8; pp. 24-27.

The following figure (from the Survey Memoir on Sheets 21, 28, and 29) shows the section exposed in excavations at Lyles Hill.

Fig. 3.—Section at Lyles Hill, Templepatrick.



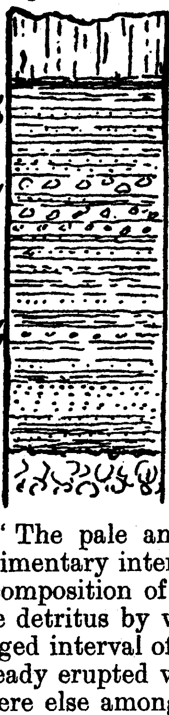
(*d*)	Massive basalt, rudely columnar, . .	10 to 12 feet.
(*c*)	Band of clay, ...	4 inches.
(*b*)	(2) Pisolitic red iron-ore, . . .	14 to 18 inches.
	(1) Red aluminous ore (bole) of inferior quality,	4 feet.
(*a*)	Purple and reddish bole, lithomarge and clay passing downwards into amygdaloidal trap,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

The most interesting development of these intermediate beds occurs, however, a little beyond the limits of our map, at Ballypalady, 2¼ miles N. of Lyles Hill, where numerous plant-remains have been obtained from the series. As these fossils afford the best evidence as to the age of the Volcanic episode, it seems essential that some reference to this section should be included in the present memoir. We will therefore quote the general account of these deposits given by Sir A. Geikie (" Ancient Volcanoes," vol. ii., p. 204).

After dealing with the evidence for the lapse of time between the successive flows of which the basaltic masses are composed, the author writes :—" But an attentive study of the plateaux discloses other and even more remarkable indications that the pauses between the consecutive basalt-beds were frequently so prolonged as to allow extensive topographical changes to be made in a district. Nowhere is the long duration of some of these intervals more impressively taught than in the central zone of sedimentary strata in Antrim.

" This persistent group of tuffs, clays, and iron-ore is generally from 30 to 40, and sometimes as much as 70 feet thick. From the occurrence of the ore in it, it has been explored more diligently in recent years than any other group of rocks in the district, and its outcrop is now known over most of the plateau. The iron-ore bed varies from less than an inch up to 18 inches in thickness, and consists of pisolitic concretions of hæmatite, from the size of a pea to that of a hazel nut, wrapped up in a soft ochreous clayey matrix. Where it is absent its place is sometimes taken by an aluminous clay, worked as 'bauxite,' which has yielded stumps of trees and numerous leaves and cones. Beneath the iron-ore or its representative, lies what is called the 'pavement'—a ferruginous tuff, 8 to 10 feet thick, resting on 'lithomarge,'—a lilac or violet mottled aluminous earth sometimes full of rounded blocks or bombs of basalt. The well-known horizon for fossil plants at Ballapallidy is a red tuff in this zone. The section of strata between the two basalt groups at this locality may serve as an illustration of the nature and arrangement of the deposits." . . .

Fig. 4.—Section at Ballypalady, 1½ miles north-east of Templepatrick.[1]



UPPER BASALT.

	Feet.
Brown laminated shale and volcanic ash (?) / Laminated brown impure earthy lignite, .	2 to 3
Brown and red variegated clays, marls, and sandy beds, with irregular layers of coarse conglomerate, composed of rounded and sub-angular fragments of trachyte and basalt, ...	3 to 4
Brown, red and yellowish laminated marl, mudstone and bole, with occasional layers of fine conglomerate (trachytic and basaltic), pisolitic iron-ore band and plant-beds, .	8 to 10

LOWER BASALT (amygdaloidal).

"The pale and coloured clays that occur in this marked sedimentary intercalation have doubtless been produced by the decomposition of the volcanic rocks and the washing of their fine detritus by water . . . They seem to indicate a prolonged interval of volcanic quiescence when the lavas and tuffs already erupted were denuded and decomposed. . . . Nowhere else among the Tertiary basalt plateaux of Britain has any trace been found of so marked and prolonged a pause in the volcanic activity as is indicated by the Antrim zone of tuffs and clays."

Sir A. Geikie concludes that these deposits represent the sediments of a lake formed during the volcanic period by a subsidence of the floor of Lower Basalts (*op. cit.*, p. 205), while Mr. J. Starkie Gardner, who has made a careful study of their fossil-plants,[2] considers that the beds more probably "indicate the bed of a shifting river subject to variations in volume."

[1] Reproduced from Mr. A. M'Henry's paper "On the Age of the Trachytic Rocks of Antrim." *Geol. Mag.*, dec. iv., vol. ii. (1895), p. 263. The workings for iron-ore at this place have been long abandoned, and the sections are much obscured; but the plant-beds are still visible in two or three limited exposures in the old pits.

[2] "The Lower Eocene Plant-beds of the Basaltic formation of Ulster," *Quart. Journ. Geol. Soc.*, vol. xli. (1885), p. 82: and *Monogr. Palæont. Soc.*, vol. xxxviii. (1884), *Eocene Flora*, vol. ii., pt. ii., pp. 77–82, *et seq.* These plants had been previously studied by W. H. Baily and others; for bibliography consult Mr. Gardner's papers.

Among the plants from Ballypalady determined by Mr. Gardner are the following:—

Cupressus Pritchardi, *Goepp.*	Pinus Plutonis, *Baily*
Cryptomeria Sternbergi, *Goepp.*	„ Bailyi, *J. S. Gardner*
Taxus Swanstoni, *J. S. Gardner*	Tsuga Heeri, *J. S. Gardner*

Mr. Gardner also mentions the occurrence of a fern, a water-lily, a deeply-notched leaf assigned to *Quercus*, and the fruit and leaves of an arctic fossil *Alnus*.[1]

The Antrim volcanic episode had been relegated, on slender data, to Miocene or Middle Tertiary times, but Mr. Gardner's researches led him to the conclusion that it should be dated back to the Eocene or Early Tertiary period, his opinion on the fossil evidence being expressed as follows:—"I am able . . . to demonstrate on simple palæontological data that the plant-beds are actually very low down in the Eocene series."[2]

Upper Basalts.

The Upper Basalts which cap these interesting 'intermediate beds' are slender outliers from the great mass in North Antrim which is thus described by Sir A. Geikie (*op. cit.* p. 206). "Immediately above the iron-ore of Antrim, or separated from it in places by only a few inches of tuff, comes the group of Upper Basalts, which varies up to 600 feet in thickness, though as the upper portion has been everywhere removed by denudation, no measure remains of what may have been the original depth of the group. The general character of these basalts is more frequently columnar, black and compact, and with fewer examples of a strongly amygdaloidal structure than in the lower group. But this distinction is less marked in the south than in the north of Antrim, so that where the intervening zone of tuffs and iron-ore disappears, no satisfactory line of division can be traced between the two groups of basalt."

In discussing the source of these immense lava-flows, the same author remarks:—"It is obvious that nowhere in Antrim does any trace exist of a central vent or cone from which the volcanic materials were discharged. There is no perceptible thickening of the individual basalt-sheets, nor of the whole series in one general direction, in such a manner as to point to the site of some chief focus of eruption. Nor can we place reliance on the inclination of the several parts of the plateau. I have pointed out that the varying dip of the beds must be attributed mainly to post-volcanic movements, or at least to movements which, if not later than all the phases of volcanic action, must have succeeded the outpouring of the plateau-basalts. There has been a general subsidence towards the central and southern tracts now occupied by the valley of the

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[1] "The age of the basalts of the North-east Atlantic," *Proc. Belfast Nat F. C.*, 1883–84, pp. 255–285.

[2] *Quart. Journ. Geol. Soc.*, vol. xli., p. 83.

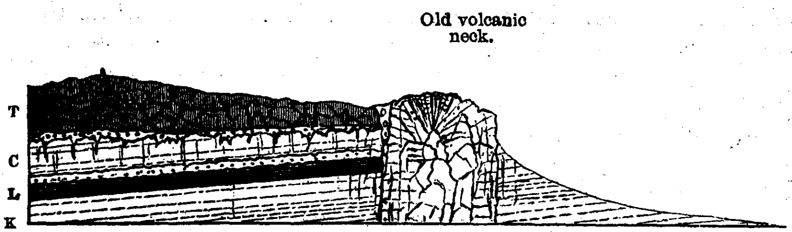
Bann and Lough Neagh. But nowhere in the depression is there any trace of the ruins of a central cone or focus of discharge."

From these considerations Sir A. Geikie concludes that the Antrim lavas have not been poured out from large conical volcanoes of the Vesuvian type, but from numerous minor orifices arranged along lines of fissures by which the ground was broken during the volcanic episode. "Fissure-eruptions" of this kind are known to have been the source of some of the recent lava-fields of Iceland, which are analogous to the Antrim basalts; and similar conditions appear to have given rise to the vast basalt-fields of Post-Tertiary age in the Western States of North America[1] (*op. cit.*, pp. 260-269).

"Necks."

In a few places on the Antrim plateau, however, traces of true vents or foci of eruption have been detected. One of these occurs within the northern border of the present map; the following figure and description of the locality are reproduced from the Survey Memoir on Sheets 21, 28 and 29: (see also Geikie's "Ancient Volcanoes," vol. ii., pp. 272-273):—

Fig. 5.—Carnmoney Hill.



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

"One of these old 'necks' may be clearly made out at the southern edge of Carnmoney Hill, where it forms part of the escarpment, cutting through the basalt beds, the Chalk and the Keuper marls. It is about 400 yards across, and on its northern side is associated with volcanic ash, or agglomerate. The rock is a highly crystalline dolerite, the facets of the augite crystals being well developed and glistering; it also contains cavities filled with a curious pitchstone-like mineral of uncertain composition,[2] and has consolidated with a radiate columnar structure. Mr. Du Noyer has recorded his opinion regarding the nature of this mass in the following note:—'I believe that this mass of columnar basalt represents one of the great pipes

[1] Recent researches have, however, thrown some doubt upon the occurrence of "fissure eruptions" in this region; see I. C. Russell, "Geology and Water Resources of the Snake River Plains of Idaho," *Bulletin of the U. S. Geol. Survey*, No. 199 (1902), pp. 62, 63.

[2] See Appendix I., p. 142, for petrographical description of the Carnmoney dolerite and of the supposed mineral.

or feeders of the basaltic flows, and that the Chalk is absent here, but is present beneath the basalt on the flank of the hill in continuation of its observed outcrop.' It is in fact observable on the eastern flank of the hill, which is often dislocated by land-slips."

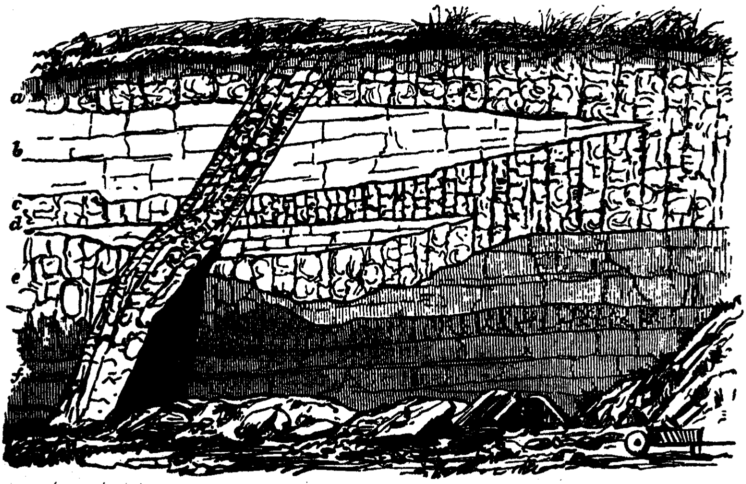
A rounded boss or 'plug' of dolerite (observed by Mr. M'Henry during the recent survey of the drifts) which breaks through the Ordovician rocks near Ballymoney, two miles east of Holywood, deserves mention here as being possibly the denuded stump of a smaller pipe or conduit of the lava.

Sills.

The outlying sheets of dolerite occurring in the depression east of Belfast, at Dundonald and around Scrabo Hill, have already been referred to. It has long been recognised that these, though in part occurring in horizontal sheets between masses of Triassic Sandstone, are of similar character to the Tertiary basalts, especially to the intrusive sheets or sills that invade Carboniferous rocks at Fair Head and the Lias at Portrush, and that they must be considered as forming part of the Tertiary Volcanic series.

At Scrabo Hill the rocks are magnificently exposed in great sandstone-quarries along the steep southern and western sides of the eminence. In these sections it is seen that while the sandstone is overlain by a great mass of dolerite, and is vertically gashed by several doleritic dykes, it is also penetrated by horizontal sheets of the same rock which have been intruded in a direction nearly parallel to the bedding planes of the sandstone, as shown in the following figure (reproduced from a previous Memoir), and in Plate III. :—

Fig 6.—Section shown in South Quarry at Scrabo Hill.



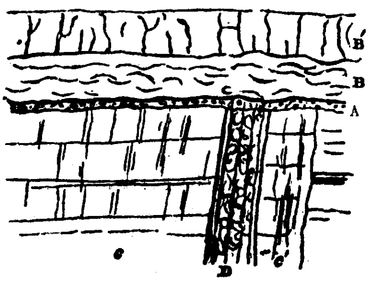
Nearly horizontal beds of purple and white sandstone of the Trias (*b. f.*) overlaid (*a.*), and penetrated (*c. d.*) by sheets of amygdaloidal dolerite and basalt, weathering into large spheroidal masses—the whole traversed by a nearly vertical dyke of dark amygdaloidal basalt also showing spheroidal weathering.

The main mass of dolerite overlying the sandstones has usually been regarded as an outlying portion of the lavas of the Antrim plateaux[1]; but from the structure of the rock, the absence of local detritus or any other indication of sub-ærial weathering at its base, and its topographical position, it is more probable that this and the smaller mass at Dundonald have never escaped at the surface as lavas, but have formed underground reservoirs or 'sills,' which have spread out laterally among the yielding Triassic rocks, and have consolidated while still deeply buried,[2] like the long-recognised sills of the North Antrim coast. Under this interpretation Scrabo Hill might indeed be regarded as a small laccolite.[3] (For petrographical notes, see Appendix I., p. 142.)

Dykes.

The approximately vertical basaltic dykes by which the sedimentary rocks in so many parts of the district are streaked, represent the rise of molten rock into a great system of more or less parallel fissures which were formed in the earth's crust at different stages during the volcanic episode. From a section figured in the original Memoir on Sheet 36, reproduced in Fig. 7, it appears that certain of these dykes have been injected

Fig. 7.—Sketch at quarry on White Mountain, showing vertical dyke of basalt penetrating the Chalk to the base of the flint-gravel.



A. Flint Gravel. B. Soft Amygdaloidal Basalt. B'. Harder Amygdaloidal Basalt. C C'. Chalk, indurated along the sides of the Dyke. D. Vertical Basaltic Dyke.

and afterwards exposed at the surface by erosion prior to the outflow of the Lower Basalts; more frequently they are seen to intersect these Basalts as well as the underlying sedimentary

[1] Prof. E. Hull, "On the Volcanic Phenomena of Co. Antrim" (Presidential Address to Section C.), *Rep. British Assoc.* for 1874, p.71.

[2] This view is expressed in Sir A. Geikie's "Map of the Tertiary Volcanic District of North-east Ireland" (Map vi., vol. ii., "Ancient Volcanoes"), though the localities are not referred to in the text.

[3] Some changes have been made in the boundary-line between the dolerite and the sandstone around Scrabo Hill on the present map, as the line on the original "solid" map was not, in some places, in keeping with the evidence now available. In many parts, however, this boundary is concealed under thick drift and must necessarily be hypothetical.

rocks, as in fine sections at the Cave Hill quarries (Plate I.), and elsewhere; and where the Upper Basalts are present, many dykes are found to penetrate these also, and in such cases constitute the latest rocks of the basaltic series.

The great majority of these dykes take a north-westerly course, or to some point between W.N.W. and N.N.W.; and it is only here and there that exceptions to this direction are found. They vary in size from mere strings an inch or two in width to broad bands 10 or 20 yards wide. They are so numerous in the Triassic rocks around the city of Belfast that most of the brickyards or other wide excavations in the marls reveal at least one and often several of them; and they are no less frequent in the Triassic sandstones, being often struck in borings for water into this rock, as well as being seen at the surface in most of the quarries. Owing to their small size and the limited extent of the rock-exposures in which they occur, only a few of these dykes have been marked on the one-inch map, as it is impossible to show them clearly on a map of this scale.

In the Silurian and Ordovician tract included in the Belfast sheet these dykes appear to be much less abundant, although part of this ground lies in the line of strike of the thickly-clustered dykes that occur in the Trias. Being rather less durable than the 'country-rock,' instead of more durable as when they traverse the Trias, it is probable that their outcrops may in many cases lie hidden in hollows among the slates; but even taking this into account the difference is remarkable. As a possible explanation, it may be suggested that some of the dyke-clusters in the Trias have sprung from sills above the base of the Trias such as the masses of Scrabo Hill and Dundonald, and may not be prolonged downward into the Silurian rocks.

Rhyolite.

All the volcanic rocks within the present district are of basic composition; but at Templepatrick, one mile north of the north-west corner of the map, a small patch of an acid intrusive rock, a rhyolite, is exposed,[1] and at Tardree Mountain, six miles farther north, similar rocks cover an area of about ten square miles.

In the Survey Memoir on that district (Mem. on Sheets 21, 28, and 29) these rocks, described as "trachyte-porphyry," are supposed to be older than the basalts, but more recent work has shown that the rhyolites are almost certainly newer than the Lower Basalts, having apparently been irrupted during the interval between the Upper and Lower Basalt series.[2]

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[1] The quarry at Templepatrick in which this rock is best seen is at present deeply flooded, so that the section is difficult of access.

[2] See A. M'Henry, "On the Age of the Trachytic Rocks of Antrim," *Geol. Mag.*, dec. iv., vol. ii. (1895) p. 260; G. A. J. Cole, "The Volcano of Tardree," *ibid.*, p. 303; and "On the Rhyolites of Co. Antrim," *Sc. Trans. Roy. Dublin Soc.*, vol. vii. (1896), p. 77; and Sir A. Geikie, "Ancient Volcanoes," vol. ii., p. 426.

CHAPTER V.—THE "SUPERFICIAL" DEPOSITS.

After the outpouring of the Tertiary lavas there followed a long period of which no direct record is preserved in this district. During the greater part, if not during the whole, of this period the area continued to form an elevated tract of land on which the destructive elements of subaerial erosion played unceasingly, so that a great thickness of basalt was carried away from the surface of the plateau, and its original limits were enormously curtailed on all sides, again laying bare the underlying rocks and creating the bold escarpment at the edge of the remaining portion of the lava-fields. Some poorly-exposed deposits of clays with lignite—the "Lough Neagh Beds"—which surround the southern part of Lough Neagh, six or seven miles to the eastward of the present map, were doubtfully assigned in a former memoir[1] to one part of this period on the supposition that they were of Pliocene age; but it has since been urged by Mr. W. Swanston[2] and by Mr. J. S. Gardner[3] that these beds more probably belong to the same series as the Ballypalady plant-beds, and are of inter-basaltic or Eocene age. If the latter view be correct, no deposits are known in the North of Ireland to represent the long interval between the Tertiary Volcanic episode and the accumulation of the Glacial drifts. The relative length of this interval may be roughly gauged from a comparison of the effects of denudation during this time with the same effects in the district since the close of the Glacial period. It is clear from the arrangement of the drifts that the great escarpment and all the main valley-systems are Pre-Glacial features, and have been only slightly modified since that period; and that except for the partial infilling of some of the depressions by Glacial detritus and the carving out of a few narrow gorges by Post-Glacial drainage, the broader outlines of the country are still essentially those of the Pre-Glacial cycle of erosion. While, however, the relative brevity of the interval between the close of the Glacial period and the present time is thus shown, we must remember that this gives us no measure of the length of the Glacial episode itself; for if during the greater part of this period the whole area was buried under an ice-sheet, as is indicated by the evidence to be subsequently presented, it was protected during the duration of this ice-sheet from direct subaerial erosion, and underwent only the more partial and probably much less rapid waste from the passage of the slowly-moving mass.

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[1] *Mem. Geol. Survey,* "Explanation, Sheet 35," by E. T. Hardman; see also same author in *Geol. Mag.*, dec. ii., vol. iii. (1876), p. 556.

[2] "On the supposed Pliocene Clays overlying Basalt, near the shore of Lough Neagh," *Geol. Mag.*, dec. 2, vol. vi. (1879), pp. 62–65; and *Proc. Belfast Nat. F. C.*, 1878–79, pp. 348–350.

[3] "On the Lower Eocene Plant-beds of Ulster—The Lough Neagh Formation." *Quart. Journn. Geol. Soc.*, vol. xli. (1885), p. 87.

In referring to the 'brevity' of the Post-Glacial period, also, it must be understood that the term is only relative, and that this period, if measured by ordinary historical standards, would be considered very long.

For the conditions during the Glacial period and during subsequent times, we find adequate records in the 'superficial' deposits. The detailed description of these deposits, giving the information acquired during the recent field-work of the Survey, will be found in Part II. of this memoir; and it is only necessary here to give a short summary of the results to complete the "general description" of the geology of the neighbourhood.

The Glacial Drifts.

No part of the district is free from glacially transported materials, though these are very unequally distributed, being accumulated to a great depth in some places, and in others merely sprinkled thinly in hollows among uneven surfaces of bare rock. These drifts also vary greatly in composition in different localities, their chief ingredients being sometimes derived from the subjacent rock, and sometimes transported from outcrops of rocks of different character, the direction of main transport being, in general terms, from northward to southward.

Boulder Clay.

The most wide-spread material is a tough red or purplish-brown clay, irregularly studded with stones of diverse shape and size, derived from various sources. This boulder-clay occurs both in nearly flat sheets deeply covering the 'solid' rocks and levelling up inequalities of the ancient surface, and in elliptical mounds, known as 'drumlins,' in which the boulder-clay is heaped up to a depth sometimes reaching 100 feet or more, with intervening spaces of bare or nearly bare rock. The drumlins are most numerous and most definite on the hilly Silurian ground east of the Lagan, and are comparatively rare on the basaltic upland and in the valleys. In the last-mentioned positions the tracts covered with boulder-clay more usually exhibit smooth, gently-sloping outlines.

The boulder-clay of the Lagan valley and of the lower slopes of the surrounding hills has derived its matrix mainly from the Triassic marls, and indeed it is sometimes almost entirely composed of this material, with only here and there an extraneous stone, usually of basalt or chalk.

Even on the hilly ground to the eastward the boulder-clay still appears to be derived in part from the marls, though as we go southward in this district the proportion of slaty Silurian *débris* increases until it becomes the predominant ingredient. On the western plateau, decomposed basalt enters largely into the composition of the boulder-clay which is consequently browner and rather more loamy than the boulder-clay of the Lagan valley; but here again, in the deeper sections, as described in the context, the lower part of the clay frequently contains much marl and calcareous matter, which in this case may have been mainly derived from the chalk.

In a few places, as at Castle Espie and in the Lagan valley north of Lisburn, where the boulder-clay has been largely made up from the Triassic sandstones, its matrix is principally a compact loamy sand, with boulders scattered through it.

In some parts of the district the boulder-clay, whatever its thickness, appears to form a single mass, of nearly the same composition from top to bottom or broken only by impersistent streaks and pockets of gravel, sand, or silt, without definite arrangement; but in other places, as will be subsequently described, it is separable into a lower and an upper portion, showing well-marked differences of composition, and with the junction between them sharply defined. Sometimes, also, thick beds of stratified sand and gravel are intercalated with the boulder-clay, as at Neill's Hill (Fig. 9, p. 75); or thick masses of stratified material rest on the main portion of the sheet of boulder-clay and are capped by a thin layer of the stony clay, as in parts of the southern suburbs of Belfast.

Besides fragments of chalk, basalt, sandstone, and other rocks of local derivation, the boulder-clay usually contains a few stones of distant origin, such as quartzite, gneiss, granite, &c., most of which appear to have been transported from the small tract of metamorphic rocks in North Antrim, along with an occasional fragment of more distant origin, such as riebeckite-granophyre from Ailsa Craig, and other rocks supposed to have been derived from Arran and the west of Scotland.

Much information regarding the boulders of the district has been collected and recorded by the members of the Belfast Naturalists' Field Club, and we are indebted to their reports for many of the notes on the boulders given in the context.

Fragments of marine shells also occur, sprinkled sparingly through the clay in a few localities, along with foraminifera and other marine micro-organisms. A large collection of these shells, made by Mr. Hyndman and others, is preserved in the Museum of the Belfast Natural History and Philosophical Society, and has been carefully worked out by Mr. S. A. Stewart, whose list, so far as it relates to the area lying within the present map, is reproduced in the context (p. 69). Our knowledge of the microzoa of the Glacial deposits is due to the assiduous researches of Mr. J. Wright, whose lists of these fossils have been published by the Belfast Field Club.[1] The presence of these organisms has given rise to the opinion that the boulder-clay represents a marine deposit, but, as will presently be shown, the fossils are almost certainly derivative like the boulders, and the boulder-clay is probably the direct product of land-ice.

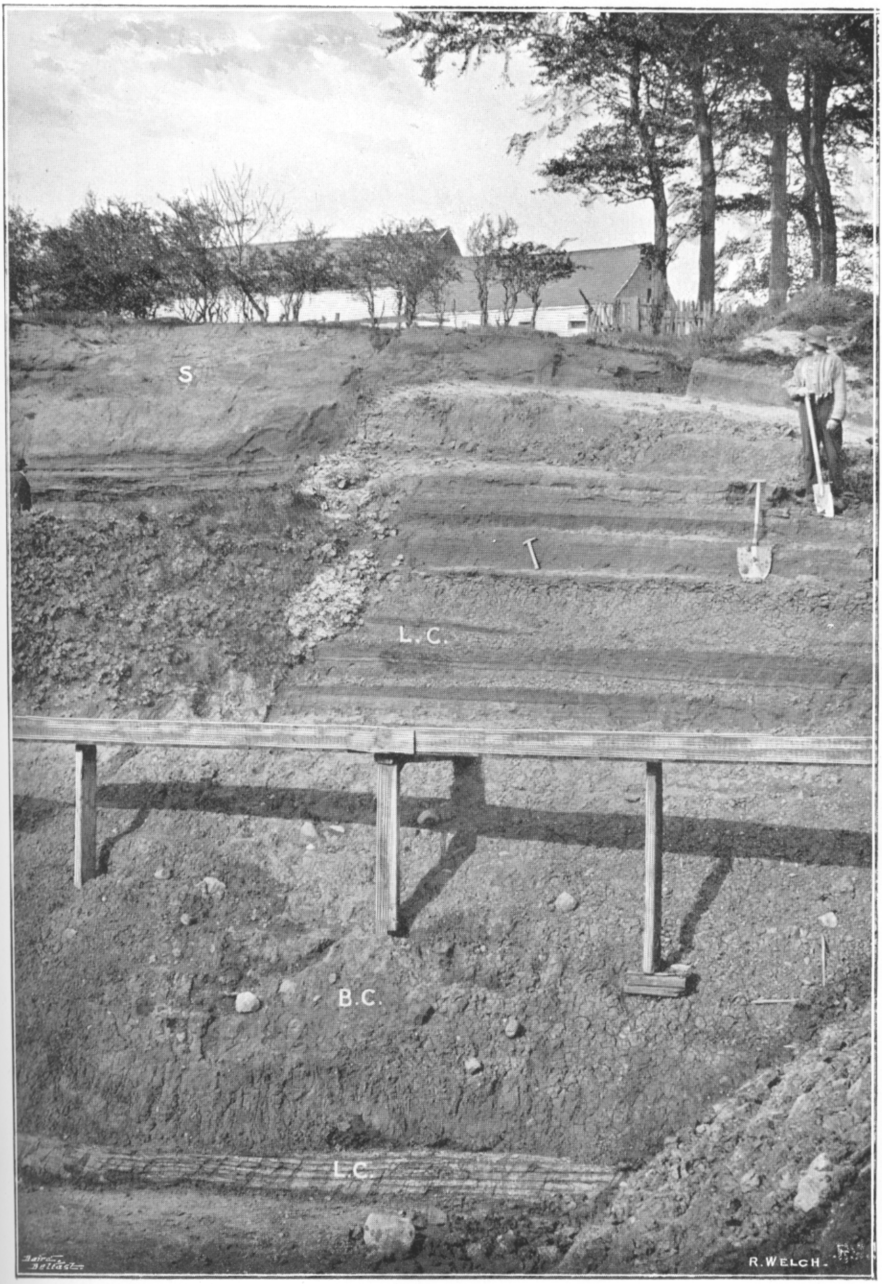
[1] "Post-Tertiary Foraminifera of the North-east of Ireland," *Proc. Belfast Nat. Field Club* for 1879–80. Appendix, pp. 149–163.

Glacial Sands and Gravels.

The stratified glacial drift, though locally developed in thick masses, is much less prevalent than the boulder-clay, and is found principally on the lower ground. As subsequent details will show, isolated patches of sand and gravel occur here and there in the hollows among the Silurian hills; and they are more widely spread in some of the westward-draining valleys of the basaltic upland. But the stratified drift attains its greatest development in the valley of the Lagan (Plate V.) and in the Dundonald Valley.

In the Lagan valley around Lisburn, in the south-eastern portion of the map, along with some wide stretches of fine sand there is much coarse shingly gravel, in places heaped up into sharp esker-ridges, while terrace-like patches of gravel also occur on the lower slopes of the hills bordering the valley on the east. In passing northward along the depression the gravels disappear, and are replaced by fine, loamy, stratified sand, sometimes 40 or 50 feet thick, with a few feet of finely laminated silty clay or "warp" at the base, the whole resting on a floor of boulder-clay. In the northern part of the valley these sandy beds, which we propose to term the "Malone Sands," lie midway in the broad depression and form a smooth low ridge which cuts off the subsidiary basin of the Blackstaff from the main river. On this ridge stand the pleasant southern suburbs of Belfast. On both flanks of the ridge the sands are partly overlain by boulder clay, which breaks up into patches and thins out on the upper slopes. From the sections exposed in the brickyards on the eastern bank of the Lagan, and from other sections to the westward, we find that the sands diminish rapidly in thickness in both directions transverse to the ridge, and pass laterally into fine silt and laminated clay, which is finally reduced to a mere streak in the boulder-clay. It will presently be shown that these stratified deposits were probably accumulated in an ice-dammed lake during one of the later stages of the Glacial period.

East of the Lagan the sands, though diminished in thickness, cover a considerable area between Newtownbreda and Ormeau Park. A similar series also sets in immediately to the eastward of Conn's Water and extends northward in a much-dissected platform along the shore of Belfast Lough to Holywood, where it gives place to the boulder-clay. Along the foot of the hills between Holywood and Knock these stratified beds become gravelly, corresponding in this respect to the gravelly condition of the margin of the sands in the Lagan valley, in both cases probably indicating a shore-line of the glacial lake. The gravelly character becomes still more pronounced as the series is followed into the entrance of the Dundonald valley, and in this quarter the beds lose their platform-features and become heaped up in irregular mounds and



To face p. 50.

PLATE V. GLACIAL DEPOSITS AT ANNADALE BRICKYARD, BELFAST.

Sand (S.) passing downward into Laminated Clay (L.C.) overlying and interbedded with Boulder-clay (B.C.).

ridges resembling short eskers. Here, also, the series becomes complicated by the intercalation of bands of boulder-clay, under conditions which are well seen in the section at Neill's Hill, described and figured on p. 75. The stratified series appears to be still further continued down the valley between Dundonald and Comber, chiefly in the form of rude much-dissected terraces lying within a trough of boulder-clay; and east of Comber we find a wide delta-like expanse of sand and silt with a little fine gravel, extending to the shore of Strangford Lough, which though at a lower level than the rest is probably essentially part of the series. The arrangement of the stratified drift along the hollow indicates a strong outpouring of waters down the valley to the Strangford depression. Some smaller delta-terraces around Newtown Ards, at the northern extremity of the Lough, are connected with drainage-channels in the Silurian upland south of Bangor, which were probably active at about the close of the Glacial period.

The only organic remains known in the stratified drift of Belfast are microzoa, which have been found by Mr. J. Wright in scanty numbers in the sands.[1] In the easterly extension of the beds, however, where they become gravelly and are associated with shelly boulder-clay, they have yielded shell-fragments in several localities, especially at Neill's Hill, Dundonald, and near Larch Hill (see pp. 75, 112, and 113).

Glacial Striæ.

Throughout the district, when rock-surfaces are of sufficient hardness they usually show the smooth rounded contours characteristic of glacial erosion; and where they are still covered by boulder-clay or have until recently been so covered, the surfaces are frequently scored in a definite direction by grooves and scratches. These markings are indicated on the map by a short line cutting a circle, the circle showing the spot where the striæ were observed. They occur most frequently in the Ordovician and Silurian country, where the hard fine-grained greywackes are particularly well adapted to receive and preserve the scorings; while the basalts, owing to the prevalent decomposed condition of the rock, show the markings more rarely, and the Triassic beds are mostly too soft to show them, except very occasionally on the sandstone. As these striæ demonstrate the direction of movement of the abrading agent, they afford important evidence in regard to the glaciation.

The following sketch-map of the district, showing the position and orientation of most of the striæ observed during the

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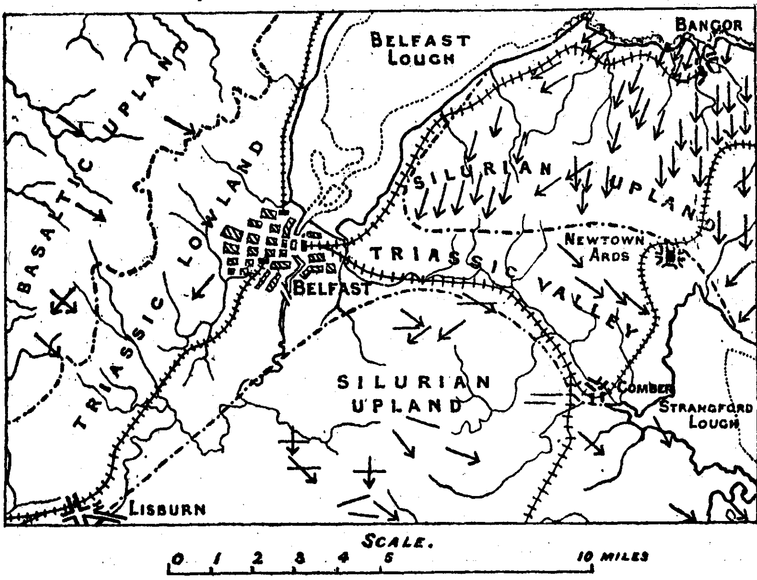
[1] Mentioned by R. L. Praeger in "Estuarine Clays at the Alexandra Dock," *Proc. Belfast Field Club*, vol. ii., Appendix ii., p. 32.

recent survey, will illustrate the general character of this evidence :—

Fig. 8.—Sketch map of the Belfast District, showing the Glacial Striæ.



The points of the arrows show the places where the striæ were observed. The unpointed strokes show the orientation of striæ in which the direction of flow is uncertain.

It will be seen from the direction of the arrows in this map that the main current has been southward over the central and eastern part of the district, and south-eastward over the western part, with local modifications in the vicinity of the steeper features, tending to divert the flow along the great hollows of Belfast Lough and Strangford Lough. The curious cross-striæ running approximately east and west, which occur here and there in the southern part of the map, are believed by Mr. Kilroe to denote an earlier movement of the ice in a direction nearly transverse to the later flow (see p. 97).

Glacial Drainage Channels.

The presence of gullies in close connection with the drift-deposits, carved through rock in positions where no stream could have originated from the normal land-drainage, has an important bearing in the discussion of the mode of formation of the drifts. These features, though not so prominent in the Belfast district as in some other parts of Ireland, *e.g.*, the country south of Dublin,[1] are yet sufficiently in evidence to deserve mention here. A small, but characteristic example

[1] *Mem. Geol. Survey*, "The Country around Dublin" (1903), pp. 40 and 50.

occurs on the southern outskirts of Holywood, where the spur of Ordovician slates forming the western boundary of Holywood Glen is notched by a steep-sided gully (marked "DRY GAP" on the map), which appears to have been at one time the overflow-channel for the impounded waters of Holywood Glen. Several gullies of similar character, sometimes crossing the watersheds between drainage-basins, were noted on the basalt plateau, in the north-western part of the map, as subsequently described (p. 90).

Post-Glacial Deposits.

Before entering upon the discussion as to the origin of the Glacial drifts, we will complete the short description of the superficial deposits by dealing with the beds which are newer than the drift.

After the close of the Glacial period the land must have stood relatively higher than at the present day, as proved by the occurrence of "Submerged Peat" and by the channel of the Lagan below Belfast having been excavated to some depth below present sea-level. At a somewhat later time subsidence took place, bringing the sea to a slightly higher level than that which it now holds, with the result that the mouth of the valley was converted into an estuary and choked with a muddy and silty deposit containing marine shells—the "Estuarine Clays" or "sleech" on which the lower part of Belfast stands—while on the more open part of the coast-line a shelf was cut and shore-deposits accumulated at 10 to 15 feet above the present high-water mark.

This sequence of events is best represented in the deposits at the head of Belfast Lough, where, fortunately, they have been carefully studied by local observers when deep sections were exposed in the excavation of docks, &c.

The latest and most complete investigation of these deposits has been carried out by Mr. R. L. Praeger, who has combined all the available information on the subject in a valuable series of papers[1] to which we are mainly indebted for the following account of the beds.

Mr. Praeger, whose classification agrees with that proposed by Mr. S. A. Stewart,[2] arranges the Post-Glacial deposits of the Belfast sections as under, in descending sequence :—

Upper Estuarine Clay and Raised Beach.
Lower Estuarine Clay.
Submerged Peat.

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[1] "On the Estuarine Clays at the new Alexandra Dock, Belfast," *Proc. Belfast Nat. Field Club*, ser. 2, vol. ii., Appendix for 1886–87, pp. 29–52; "Report on the Estuarine Clays of the North-east of Ireland," *Proc. Roy. Irish Acad.*, ser. 3, vol. ii. (1892), pp. 212–289; "Report on the Raised Beaches of the N.E. of Ireland," *ibid.*, ser. 3, vol. iv. (1897), pp. 30–54.

[2] S. A. Stewart, "The latest Fluctuations of Sea-level on our own Coast" (abstract), *Eighth Ann. Rep. Belfast Nat. Field Club*, for 1870–71, pp. 55–57.

Submerged Peat.

In deep sections around Belfast this bed appears to rest almost directly upon the Glacial deposits, though sometimes underlain or mixed with a few feet of muddy gravel. In excavations for the Alexandra Dock it was found by Mr. Praeger to lie at a depth of 27 feet below high-water mark, having a maximum thickness here of 18 inches (for full details see p. 80). Similar peaty beds have been seen between tide-marks near Conn's Water and at Tillysburn, Holywood, and Ballyholme Bay (p. 110), but it is doubtful whether these represent the same horizon. At the Alexandra Dock the peat yielded "a flora of marsh plants—sedges, flags, and rushes; branches and fruit of hazel, alder, oak, willow, and Scotch fir, especially the first-named; elytra of beetles are frequent, and mammalian remains occur. It is the first bed showing the ushering in of the temperate conditions still existing, and may be considered the base of the estuarine clay series."[1]

Lower Estuarine Clay.

"Resting on the peat, in the typical section [Alexandra Dock] which is being described, is the estuarine clay proper, which displays two zones, differing both in lithological and in faunal characters—a lower bed, which is essentially a littoral clay, and is known as the Scrobicularia zone, and an upper bed, which has been deposited in at least five fathoms of water, and which Stewart has named the *Thracia convexa* zone, from the abundance of that bivalve at Belfast. . . .

"The Scrobicularia clay typically consists of brownish-blue, somewhat sandy clay, containing abundance of the roots and leaves of the grass-wrack, *Zostera marina*, and charged with a vast number of shells belonging to a comparatively limited number of species which have their habitat between tide-marks. The following are characteristic :—*Mytilus edulis*, *Cardium edule*, *Tapes decussatus*, *Tellina balthica*, *Scrobicularia piperata*, *Hydrobia ulvæ*." . . .

"The opportunities afforded for the study of the estuarine clays are few and far between, since the deposits lie almost without exception below tide-level, and are consequently inaccessible except when excavations or other artificial means permit their examination."[2]

From the above extracts it will be understood that this Lower Estuarine Clay is nowhere visible in this district at the surface, and is known only from its occasional exposure in deep sections. At the Alexandra Dock, this clay varied in thickness from 6 inches at the northern end of the excavation to 6 feet in other parts; in the foundations for the Albert Bridge it was 14 feet in thickness.

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[1] Praeger, "Report on the Estuarine Clays, &c.," *op. cit.*, p. 213.
[2] Praeger, *op. cit.*

Upper Estuarine Clay.

"The upper or Thracia clay is remarkably pure, fine, and unctuous, and light blue in colour. Its fauna is less in actual numbers, but much greater in variety, and is characterized by shells belonging to the laminarian and coralline zones, such as *Montacuta bidentata*, *Cardium echinatum*, *Lucinopsis undata*, *Scrobicularia alba*, *Thracia convexa*, *Turritella terebra*. The raised-beaches which fringe our north-eastern shores are in general contemporaneous with these deep-water clays, and frequently, like them, repose on clays of the Scrobicularia zone."

The thickness of the Upper Estuarine Clay at Alexandra Dock varied from 1½ to 6 feet. Among its commoner shells were *Pecten maximus*, *Cardium echinatum*, *Lucinopsis undata*, *Thracia convexa*, *Scrobicularia alba*, *Aporrhaïs pes-pelicani*, *Nassa pygmæa*, *Scalaria turtonæ*, all of fine size.

"Between the upper and lower clay was a zone characterised by Pholades, the occurrence of which was noticed also by Stewart in his investigations on the opposite side of the Lagan, and, as he points out, is the first indication of the subsidence which resulted in the deposition of the upper clay. Three species occur—*Pholas crispata*, *P. candida*, and *P. dactylus*; the shells all still in their natural vertical position. The enormous size which the first-named reached has been noticed by several writers."[1]

The Upper Estuarine Clay was covered in this section by 2 feet of yellow sand and 5 or 6 feet of 'surface clays.' The sand contained a large number of shells, many of which had apparently been derived from the washing down of the underlying bed; "the 'surface clays' consisted of blackish clayey and sandy layers, with abundance of *Mya arenaria*, *Cardium edule*, *Tellina balthica*, *Mytilus edulis*, and were still in course of deposition."

Raised Beach.

The coast-line of the district almost everywhere shows proof, in one form or another, that at a comparatively recent period the land stood 10 to 20 feet lower in relation to the sea-level than at the present day. The shore-line of this period, generally known as "the 25-foot Raised Beach," is well marked all round the northern and eastern coast of Ireland, at least as far southward as Dublin Bay, and is recognisable also on the opposite coast of the Irish Sea—in the south of Scotland and the north of England, as well as in the Isle of Man. In the present map, evidence for this relative submergence is found

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[1] Praeger, *op cit.*, p 224

at the head of the Loughs of Belfast and Strangford, in the low-lying tracts of mud and silt only slightly above the level of high spring-tides. On the more exposed portions of the coast, the period was marked by erosion rather than by deposition, a rock-shelf backed by an ancient sea-cliff having been carved out on the headlands, above the reach of present wave-action, while the little bays are frequently lined with banks of sand and gravel containing shells of existing species, piled up to a corresponding level. From the presence of artificially chipped flints of Neolithic age on and beneath the surface of this beach in several localities in the north of Ireland,[1] it is apparent that at least some parts of the beach were in existence in Neolithic times. As already mentioned, R. L. Praeger, who has made a careful study of these beaches and their fauna,[2] is of opinion that the higher portion of the Raised Beach is of the same age as the Upper Estuarine Clay of the Belfast sections. The principal results of Mr. Praeger's researches are incorporated in subsequent detailed descriptions of the beach-deposits.

River-Gravels.

Post-Glacial gravels of fluviatile origin are developed only on a restricted scale in this district, and principally along the courses of some of the smaller streams. The channel of the Lagan is too narrow and too deeply trenched through perishable drifts to preserve noteworthy terraces of river-gravel, its waters having apparently been able to carve out its Post-Glacial course almost down to the base-level of erosion with comparative rapidity. Some of its tributary streams which descend from the edge of the basaltic plateau on one side, and from the Silurian upland on the other, have thrown down small deltas of stony wash on reaching the low ground; and from the high level of some of these deltas on the slopes on the eastern side of the Lagan, they appear to have begun to form in Late-Glacial times, when the depression was still partly occupied by an ice-blocked lake (see p. 99).

Alluvium.

The Lagan is bordered throughout its course with strips of low-lying alluvial 'bottom-land,' much of which is still within reach of the river-floods. In composition, this alluvium is mainly a fine sandy loam, derived from the sandy and clayey

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[1] "Report of the Larne Gravels Committee," *Proc. Belfast Nat. F. C.*, 1890, pp. 198-209.

[2] "Report on the Raised Beaches on the North-east of Ireland," *Proc. Royal Irish Acad.*, 3rd ser., vol. iv. (1897), pp. 30-54.

drifts through which the valley is excavated. Similar, but narrower alluvial strips border the west-flowing streams of the basaltic plateau and the stream which flows from Dundonald to Comber. But the broadest tract of fresh-water alluvium within the map is that which covers the floor of the wet hollow immediately to the south-westward of Belfast, in the basin drained, in part artificially, by the Blackstaff.

The material in this case consists of a 'warpy' clay, washed from the Triassic Marls and Boulder Clay of the steep slopes below the great escarpment; it varies from 6 to 10 feet or more in thickness, with fine gravel and streaks of woody peat at the base. From the manner in which the Estuarine Clay runs up into the mouth of this depression and merges into the fresh-water alluvium, we may conclude that the deposition of this alluvium commenced during the period of depression indicated by the Raised Beach and Upper Estuarine Clay; but it must still be in progress, as the hollow is occasionally flooded by muddy torrents from the escarpment, thereby causing much inconvenience and loss in the low-lying parts of Belfast around its mouth (see p. 127).

In the hilly slate-country, the heaping up of the drift in drumlins appears frequently to have obstructed the Pre-Glacial drainage-channels, so that the Post-Glacial streams have often had to cut new courses through barriers of the solid rocks in passing from one hollow to another across the obstructed country. The drainage when thus arrested has in many cases formed small lakes, ponds, or swamps in the hollows until the depression was filled in with alluvial wash and peat, or until it was drained by the deepening of the outlet. In the southern part of the map some of these lakelets still persist, while in other places their former site is marked by small peaty flats which have been artificially drained and are still subject to floods in wet weather. Similar conditions have prevailed to less extent in some of the westward-draining valleys of the basaltic upland, as subsequently described (p. 90).

Peat.

Besides the above-mentioned small tracts of bog-land in the hollows among the Silurian hills, the only part of the district in which peat occurs in sufficient quantity to be shown on the map is on the high ground near the edge of the basaltic escarpment, where it spreads as a thin ragged covering over the rocky slopes and summits, generally only a few inches thick, but occasionally attaining a depth of 5 or 6 feet. Both in the hollows and on the hills, where accessible it has been cut away for fuel in many places where it formerly existed. The occurrence of "submerged peat" at a few places on the coast below high-water mark has already been noticed.

Intake.

Around the head of Belfast Lough large tracts of the low flat shore have been reclaimed from the sea by artificial means in recent times, and this work is still in full progress. On this reclaimed land some of the most important shipyards and other industrial enterprises of Belfast are situated.

From old plans of the city preserved in the Linenhall Library at Belfast, and from other old maps,[1] we have been able, by a red line on the present map, to indicate the outline of the shore of Belfast Lough before reclamation had made much headway.

Similar operations have taken place on the foreshore at the head of Strangford Lough, where the land is reclaimed for the purposes of agriculture.

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[1] Our thanks are due to Mr. G. Maxwell, the Librarian of the Linenhall Library, for his assistance in this matter. The shore-line on the Antrim side in the immediate vicinity of the city has been transferred from a MS. plan, preserved at the above-mentioned library, entitled "The Mapp of Belfast, as survey'd an, no, 1715, by John Maclanachan," and this line has been extended southward from another MS. map in the same collection—"A map of Belfast, surveyed in 1791 by James Williamson." For the shore-line beyond the limits covered by these maps, the first six-inch Ordnance Survey Map of 1833 has been taken. The alterations at present in progress on the east side of the harbour have been inserted from a plan obtained at the Harbour Board Office through the kindness of Mr. Redfern Kelly, C.E.

CHAPTER VI.—ORIGIN OF THE GLACIAL AND POST-GLACIAL DEPOSITS.

The early discovery of marine shells in the Belfast drift by J. Bryce and others,[1] at a time when the glacial character of the "diluvium" was only just beginning to be recognised, naturally led to the conclusion that the boulder-clay and its associated stratified beds were of marine origin.

The valuable later work of Canon J. Grainger,[2] Mr. S. A. Stewart,[3] Mr. J. Wright,[4] and other observers, in collecting and recording the marine organisms from the drift, has been carried out along the same general lines and is held to have confirmed the original view.

But the Belfast drifts are not exceptional in this particular, as similar marine remains are found scattered among the glacial deposits almost everywhere along the eastern side of Ireland, and occur under analogous conditions in the drifts which border the eastern margin of the Irish Sea—in Lancashire and North Wales, and also in the Isle of Man. Although differences of opinion are still expressed, it is now widely acknowledged that the presence of marine fossils in the drifts is not sufficient in itself to establish the view that the deposits have been accumulated beneath the sea, since the organisms may have been transported to their present position along with the other materials of which the drifts are composed. Moreover, it has been shown that in most cases the circumstances under which these shelly drifts occur are such as to render it extremely improbable that they can represent marine accumulations. On the other hand, the deposits are readily explicable under the view that they have been formed when the basin of the Irish Sea was filled up by a great ice sheet, which is supposed to have covered the greater part of the British Isles and the surrounding shallow seas in the same way that Greenland is now covered. Thus, in the recent mapping of the drifts around Dublin by the Geological Survey, it was found that although shells and foraminifera, like those which occur at Belfast, were present in many

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1 "Notice of an elevated deposit of Marine Shells of the Newer Pliocene epoch, lately discovered near Belfast," by J. Bryce and G. C. Hyndman. Appendix to Portlock's "Geology of Londonderry, &c.," (1843), pp. 738–740.

2 "On the Fossils of the Post-Tertiary deposits of Ireland," *Rep. British Assoc.* for 1874, pp. 73–76.

3 "The Mollusca of the Boulder-clay of the North-east of Ireland," *Proc. Belfast Nat. F. C.*, Appendix, 1879–80, pp. 165–176.

4 "Post-Tertiary Foraminifera of the North-east of Ireland," *Proc. Belfast Nat. F. C.*, Appendix for 1879–80, pp. 149–163; "The Occurrence of Boulder-clay on Divis," *ibid.*, for 1894–95, pp. 215–216. *Rep. British Assoc.* for 1902, p. 598 and *Irish Naturalist*, vol. xii. (July 1903), pp. 173–176.

parts of the glacial deposits at elevations ranging from sea-level to over 1,200 ft. above O.D., it was impossible to explain these drifts by the marine hypothesis.[1]

The same result has followed the examination of the Belfast drifts, and the reasons which were given for rejecting the marine hypothesis in favour of the "land-ice theory" in the former case may be repeated, with slight modification, in the present case. These reasons may be briefly summarized as under:—

1. The relation of the drift deposits to the topographical features, their peculiar distribution, and their structural characters are inexplicable by the marine hypothesis, but are consistent with the view that the beds represent the successive stages of glaciation by land-ice.
2. The present surface-features of the district, as described in the context, can only have been produced by subærial agencies, and could not have been developed if the whole country had been submerged to the level of the shelly drift, either during or since the accumulation of this drift.
3. The transport of the boulders and matrix of the boulder-clay from the parent-outcrops in definite streams, often running transverse to the contours of the old surface, is incompatible with the view of marine submergence.
4. The position and direction of glacial striæ on rock-surfaces at elevations varying from sea-level to about 1,000 feet above O.D. prove that the glaciating agent, while moving in a definite direction, enwrapped the inequalities of the land after the known manner of an ice-sheet, and with results unlike any known effect of floating-ice.
5. The shell-bearing drift occurs at levels varying from considerably below Ordnance datum in wells and borings[2] to 1,400 feet above O.D. on Divis Mountain,[3] without showing any essential difference in character, and without any trace of that zonal distribution of the shells according to depth of water which must have obtained in case of submergence. The shells are sporadic in their distribution, and the greater part of the drift at corresponding levels contains no shells.
6. The majority of the shells are merely fragments, which are sometimes striated; and they occur sparsely scattered in the boulder-clay and glacial gravels in exactly the same manner as other materials known to be derivative, such as fossils from the Lias, Chalk flints,

[1] See *Mem. Geol. Survey*, "The Geology of the Country around Dublin" (1903), pp. 42–52; also, *ibid.* "The Geology of the Isle of Man" (1903), pp. 389–399.

[2] J. Wright, "Post-Tertiary Foraminifera," &c., *op. cit.*, p. 153.

[3] J. Wright, "Boulder-clay on Divis," *op. cit.*, p. 215.

and fragments of the riebeckite-rock from Ailsa Craig. The condition and distribution of these shells is incompatible with the view that the beds containing them are of marine origin; they are absent from the fine sands and laminated clays of the glacial series, and are found in stratified drift only where the beds contain transported *débris* of about the same specific gravity as the shell-fragments; the more perfect shells are found in the boulder-clay, the larger bivalves almost invariably as single isolated valves, but the small Leda occasionally perfect and with valves united. It is known that land-ice in passing over marine sediments will incorporate and distribute such material[1]; and the whole evidence indicates this origin for the shelly drift.

If at some future time Belfast Lough were again invaded by an ice-sheet, we should expect that its recent estuarine clays would be transported and intermingled with glacial detritus in the same manner that the Pre-Glacial and Early Glacial marine deposits have been intermingled with the boulder-clay. The smaller shells and foraminifera would be likely to escape the shearing stresses in the ice during this process more readily than the larger organisms.

Thus there is no evidence within the district itself which is incompatible with the view that the drifts are the product of land-ice; and when we take a wider field of observation, and find that in all the tracts surrounding the Irish Sea basin there is confirmatory evidence that during the Glacial Period an ice-sheet filled this basin and covered the surrounding lands, it seems reasonable that we should proceed, with further elaborating the argument, to apply the land-ice hypothesis to the explanation of the Belfast drifts.

Application of the 'Land-ice Theory.'—From the direction of the striæ on the uplands on both sides of the Lagan hollow, and from the presence of patches of boulder-clay and transported fragments of flint and other foreign material on the highest hills near the border of the basaltic plateau, we may conclude that at the period of maximum glaciation the whole of this district was overwhelmed by an ice-sheet which moved slowly southward along the sea-basin and over the adjacent land, with subsidiary currents within its mass dependent to some extent upon the form of the buried land (see Fig. 8, p. 52). It would appear that farther southward the Mourne Mountains were not completely overwhelmed but constituted an opposing buttress to this ice-stream, and diverted the current to the eastward and westward around their flanks.[2] By the prolonged action of this ice-sheet, all the loose

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[1] For references to observed examples of this process in existing glaciers, see *Dublin Memoir* (footnote), p. 45.

[2] W. A. Traill in *Mem. Geol. Survey,* "Sheets 60, 61, and part of 71," p. 44.

detritus of the Pre-Glacial land-surface, together with the unconsolidated deposits of the sea-floor, and also with much material dragged from the subjacent 'solid' formations, was carried slowly forward and kneaded together, to form the masses of boulder-clay with which the country is now overspread.

This boulder-clay appears to have accumulated chiefly as a 'ground-moraine' beneath the ice. Where the subjacent rock-surface was fairly smooth, as on the Triassic marls and over most of the basaltic country, the boulder-clay was overspread upon it in broad smooth sheets, in the same way that it is overspread upon the plain of Carboniferous Limestone around Dublin.[1] But where the original surface was broken by rocky hummocks, as among the slate-rocks east of the Lagan, the boulder-clay has been heaped up in rounded 'drumlins,' giving the characteristic "basket-of-eggs" aspect to the county of Down which has been so often commented on in topographical descriptions of that county. As subsequently noted, however (p. 118), these heaps of boulder-clays are not often directly moulded upon a rocky prominence, but seem to have been built up more or less independently, from the effect of the unequal pressures at the base of the ice-sheet in crossing hummocky ground.

With the decadence of the ice-sheet, there ensued a set of conditions that have impressed themselves strongly upon many parts of the district, but more especially in the principal valleys. As in most parts of the British Islands, where there are few hilly tracts sufficiently elevated or extensive to have nourished true valley-glaciers during this stage, the waning ice-sheet seems to have lingered in the deeper basins after it had already disappeared from their dependent valleys.[2] Thus, on the basaltic upland we find evidence that the lower parts of some of the westward-draining valleys were blocked after the normal streams had already resumed their flow in the upper portions, so that the waters were ponded back in temporary lakes that were compelled to establish overflow channels across the subsidiary watersheds (pp. 89, 90). In some places, also, the escaping waters made their way across portions of the ice-sheet, either in channels on its surface or in tunnels in or under its mass, their gravelly deposits now forming the esker-ridges so conspicuous in the country around Lisburn (p. 100). And later, when the Lagan valley was nearly free from ice, the sea-basin appears still to have been occupied by the waning sheet, so that an ice-barrier extended from side to side across Belfast Lough, resting against the slate-hills at Holywood on the one side and against the foot of the great escarpment on the other, and thus preventing the escape of the waters through the mouth of the valley. This ice-barrier appears to have led to the accumula-

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[1] *Mem. Geol. Survey*, "Dublin" (1903), p. 37.

[2] For full discussion of this point, see *Mem. Geol. Survey*, "The Geology of the Isle of Man" (1903), pp.

tion of a lake in the Lagan valley, which extended southward beyond Lisburn, and into which heavy flood-waters, laden with sediment, poured from all sides. Until the drifts of the country to the southward of the present map have been surveyed, it would be premature to attempt to discuss the probable topography of this lake, as its southern limits have not yet been traced and the course of its outflow is still uncertain. It is possible that at one time some of its waters may have escaped across the low watershed between Knock and Dundonald, and so have passed down the Dundonald valley to the hollow of Strangford Lough, as there is evidence that free drainage to the southward was established along this depression while Belfast Lough was still blocked; but in the present state of our knowledge this suggestion can be merely tentative.

The former existence of a "Lake Belfast" in the Lagan valley renders the character of the stratified drifts of the low ground between Belfast and Lisburn easy of explanation, which otherwise would present an extremely difficult problem. The 'Malone Sands,' and their associated finely laminated 'warp' clays represent the sediments of the deeper central part of the lake, while the marginal fringes and intercalations of gravel approximately mark the old shore-lines and the deltas of inflowing streams. The distribution and composition of these stratified drifts, of which the details will be found in the context, are throughout consistent with this view of their origin. The presence of the little 'dry gap' at Holywood, with its accompanying delta of gravel, to which reference has already been made, is especially important in this connection; Holywood Glen, when dammed by the same barrier as the main valley, appears to have held a separate lakelet at a higher level than "Lake Belfast;" of this lakelet an indication remains in a curiously isolated patch of gravel within the Glen; and the 'dry gap' was cut by the overflow from the lakelet across the ridge to the main water. All these factors show that the land cannot have been submerged beneath the sea during this stage.

The thin boulder-clay which occasionally overlies the Malone Sands and their associated warp-clay on the lower ground near Belfast, like the intercalated bands of boulder clay in the gravels at Neill's Hill (Fig. 9, p. 75), may denote a partial re-advance and encroachment of the ice-margin upon the site of the main lake, but there is no evidence that the whole hollow was re-occupied by ice after the stratified deposits had been accumulated within it. In this as in almost every glaciated district, there is often a well-marked difference in colour and texture between the upper and lower bands of the boulder-clay, the upper part being redder from more thorough oxidization; looser and more pebbly in composition; more frequently showing incipient stratification; and sometimes passing laterally into stratified or water-washed material. This difference is best explained by the view advanced by Mr. J. G. Goodchild, in his description of the drifts of the Eden Valley,[1] that while the lower boulder-clay was accumulated as 'ground-moraine,' the upper boulder-clay usually represents the material which was actually incorporated in the ice and was left as the residuum on its gradual melting. The frequency with which the upper clay is found to encroach upon stratified deposits that were apparently laid down on land outside the margin of the waning ice-sheet has not yet received adequate explanation; it appears to denote a rapid re-advance of the ice-border during the final stages of the period, and may perhaps indicate some change in the physical condition of the ice, by which its rigidity was weakened.[2]

Post-Glacial Conditions.—The changes through which the district has passed since Glacial times have already been outlined in the foregoing descriptions of the Post-Glacial deposits and need be only briefly summarized here. After the disappearance of the ice-sheet, the land stood for some time higher than its present level, as shown by the 'submerged peat' and by the erosion of Post-Glacial stream-channels below the present low-water mark. The old valley of the Lagan, as we have already seen, was choked with drift, and when the main drainage of the country was re-established along the hollow, its 'superimposed' course was determined by the contour of the glacial deposits, and did not coincide with the Pre-Glacial rock-channel. This is clearly shown by deep borings at Belfast, where Triassic Sandstone is found beneath estuarine clay in the bed of the river at the Albert Bridge at only about 20 feet below O.D.,[3] whereas a little to the westward, near the middle of the city, borings have to be carried through estuarine clay and glacial deposits to a depth of about 200 feet below O.D. before the Sandstone[4] is reached (see Fig. 12, p. 85). Higher up the valley, between Edenderry and Lisburn, we find, also, indications that the river when first re-established has swung to and fro over the drift-covered ground before settling into its present channel.

For some time after the Glacial Period all the streams seem to have been much more powerful than at the present day, and as already described, they have carved deep gorges in the solid rocks of the high ground, and have spread out deltas of flood-gravel and wash around their debouchures in the main valleys that are quite disproportionate to their present capacity.

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1 "Ice-work in Edenside," *Trans. Cumberland Assoc.*, No. 12 (1886–7), p. 141.

2 For an instance of exceptional advance in an ice-lobe owing to peculiar local conditions during decadence, see the description of the Booming Glacier of Spitzbergen, given by Garwood and Gregory, in *Quart. Journ. Geol. Soc.*, vol. liv. (1898), pp. 206–208

3 Praeger, "Estuarine Clays," *op. cit.*, p. 232.

4 J. Wright, "Post-Tertiary foraminifera," *op. cit.*, p. 152.

It is, indeed, somewhat remarkable that the minor drift-features—the esker-ridges and drumlins, with their associated hollows—should have remained so sharp while denudation has been so active in the drainage-channels. But I think the explanation may be that the greater part of the erosion was wrought by floods from the melting of accumulated winter-snows, for snow in falling has little or no denuding effect, and actually affords protection to the surface, while in melting it drains off steadily to concentrate into vigorous floods in the stream-courses.

It has been supposed that during the Post-Glacial elevation the greater part of the basin of the Irish Sea was dry land, and that Ireland was not at that time insulated; but there is still some doubt regarding this point. However this may be, depression soon again set in and brought back the sea to approximately its present limits; and at a later stage, as shown by the researches of Mr. Stewart and Mr. Praeger on the Estuarine Clays, this sea became deeper, invading the estuaries and encroaching slightly upon the margin of the land. The record of this encroachment is preserved in the Raised Beach which fringes the coast-line, and in the Upper Estuarine Clays of the Belfast sections. So far as our present evidence goes, the advent of man into the district probably took place during the later part of this period.

With regard to the Post-Glacial climate as indicated by the fauna of the Belfast beds, Mr. Praeger remarks that "the northern fauna of the Glacial period appears to have passed away by the time that the peat was formed. Southern species immigrated till the molluscan fauna acquired a distinctly southern character in the upper blue clay; then the seas became again colder, and the present local molluscan fauna has a distinctly northern aspect."[1]

With the re-elevation of the land to its present level in prehistoric times, we reach the latest stage in the geological history of the district. The more recent changes are mainly those due to man's intervention, whereby portions of the foreshore have been embanked and made into land, and the drainage of the inland country improved and brought under partial control. But where the open sea beats upon parts of the coast composed of unconsolidated material, as around Cultra (see p. 106), there is a steady loss of land to set against the gain in the estuaries.

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[1] *Rep. Brit. Assoc.* for 1902, p. 612. The "southern character" must, however, be taken comparatively in a local sense only, as in a previous paper Mr. Praeger writes:—"While the species found in the local boulder-clays which do not now exist on our present shores are generally of northern types, the corresponding forms yielded by the estuarine-clays have usually now their habitat further southward. But there is very little in the latter point; for the estuarine-clay fauna differs to no material extent from that now existing within a short distance."—"Report on Estuarine Clays," *op. cit.*, p. 215.

PART II.

CHAPTER VII.—DETAILED DESCRIPTION OF THE SUPERFICIAL DEPOSITS.

Introduction.—In describing the local details of the Glacial drifts and Post-Glacial deposits, the area comprised within the map will be divided into the following districts:—

1. The City of Belfast and its suburbs.
2. The country north and west of the city, in County Antrim.
3. The valley of the Lagan south of Belfast, with the bordering hills on both sides.
4. The country between Belfast Lough and Strangford Lough, north of the Dundonald Valley.
5. The Dundonald Valley and the head of Strangford Lough.
6. The hilly ground south of the Dundonald Valley.

These districts roughly correspond with the areas mapped by the individual officers of the Survey, and the initials appended to the descriptions indicate the authorship of the reports.

1.—The City of Belfast and its suburbs.

On the rising ground to the west of Belfast the drift consists of stiff red boulder-clay of variable thickness, with here and there the usual included wisps of sand and gravel, overlying the Triassic marl. The Estuarine Clays ("sleech") of the lower part of the city terminate against a steep bluff which marks the limit of Post-Glacial submergence, but in places this feature has been graded down by artificial means or is interrupted by the small valleys opening upon the flat. North of the terminus of the old Cave Hill tramway, where the Triassic Sandstone emerges from beneath the marls, this ancient sea-margin still retains a cliff-like aspect, the vertical face of sandstone being visible here and there in the bank, with a thin capping of boulder-clay.

At the Skegoniel brick-works the Triassic marls, which are here let down against the sandstone by a small fault, are almost bare of drift, boulder-clay and gravelly wash occurring only in patches at the top of the pits, though numerous boulders of basalt, etc., are strewn over the ground. Several dykes of basalt are revealed in these pits, including one of more than average thickness—eighteen to twenty feet across—with well-marked horizontal columnar structure. The adjacent stream also reveals good sections in marl traversed by basalt dykes.[1] At Fort William, immediately to the north of the stream, the ground rises in a steep hillock which has the appearance of a drumlin but may be a 'solid' feature due to the basalt dykes, with only a "facing" of boulder clay. Similar though less prominent features are also seen about 300 and 500 yards farther southward. Many shallow sections in boulder-clay were observed in the cuttings for new streets in this quarter. Shell-fragments appear to be widely distributed in the lower unweathered part of this clay, as they were noticed in most of the deeper section farther north, and besides their occurrence at the well-known "Water-works" locality, 300 or 400 yards to the westward, presently to be described, they have been recorded by J. M'Adam[2] from an excavation at The Grove, where he obtained "*Cardium, Tellina, Ostrea, Mactra, Nassa, Patella, Littorina, Cerithium*, and some others in fragments."

Good sections in tough red boulder-clay up to ten feet in thickness are revealed in the banks of the little stream quarter of a mile south of Oldpark Print Works, and a gully in the lower part of its course, 200 yards north of Shankhill Road, shows over twelve feet of similar material, which is also exposed to about this depth in the bank of an old brick-field at Mount Eden. But the average thickness of drift on the slope around the north-western suburbs of the city is probably less than this, and the Triassic marls are reached within a few feet of the surface in many excavations. Thus, in the brick-yard at Old Park, where the marls, traversed by several dykes of basalt, are worked, the capping of boulder-clay varies from three feet or less on summit of the knoll to eight or ten feet on the slopes, showing that the hill at this place is not a true drumlin; in the extensive brick-yards at Springfield, along the east bank of the Forth River, where the marls, again traversed by numerous dykes and veined with gypsum, have been deeply excavated, the drift is for the most part from three to six feet thick, but occasionally ten feet or more; and similar conditions prevail in the brick-yards on the slope west of Forth River; while the stream itself between Springfield Road and Shankhill Road has trenched deeply into the marls, leaving here and there patches of Post-Glacial terrace-gravel in the little valley to mark the stages of erosion. The marls were reached both at the old and new Waterworks Reservoirs west of Antrim Road, and are exposed in the valley between the old Waterworks and the sea, being deeply excavated on the southern bank at the brick and tile works at Mount Collyer, where numerous basalt dykes are revealed. They are also stated to have been entered in the foundations for the County Gaol on Crumlin Road, beneath about ten feet of boulder-clay in which "large lumps of fine sand were dispersed in a confused way."[3]

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[1] In the 'solid' edition of the Geological Survey Map the boundary of the sandstone has been carried too far inland here.

[2] "Supplementary Observations on the neighbourhood of Belfast," *Journ. Geol. Soc., Dublin*, vol. iv. (1850), p. 267. In the Survey Memoir on Sheet 36 (p. 37) an incorrect reference is made to these shells.

[3] R. Young, "The Boulder-clay of the Belfast District," *Eighth Ann. Rep. Belfast Nat. F. C.* (1870–71), p. 33.

It was during the excavation of the old Waterworks that, as already mentioned, shells were first obtained from the drifts of the district, and this section therefore deserves special notice. The first account of the discovery was given by J. Bryce and G. C. Hyndman in 1843, in an Appendix to Portlock's "Geology of Londonderry, etc." (pp. 738-740); and two years later a fuller description was published by Bryce,[1] from which the following information is drawn.

The shelly deposit was 106 feet above low-water mark, and was exposed in the cutting for the Cave Hill tramway as well as in the Waterworks section. It is described as consisting "in the lower part of a very tenacious compact gravelly clay, of bluish-grey colour, from eight feet to twelve feet thick; and in the upper part of stratified red sand and red clay five or six feet thick; and above this is a thick recent alluvium" [the reservoir being constructed in the valley of a little stream]. "The lower blue clay rests immediately on the gypseous marls of the new red sandstone, and is the chief repository of the shells, a few only being found in the upper sand and clay. The shells are in every state of preservation: some are rolled and polished; some, though strong shells, are broken into fragments, while others, though of a fragile nature, are in a state of perfect preservation."

Referring to the abundance of species which was obtained here as compared with the scanty lists at that time on record from other parts of Ireland, Bryce remarks:—"This is, I suppose, to be explained less by any original difference in the conditions under which the deposit took place than by the watchfulness of various collectors during the removal of the great quantity of matter, about 10,000 cubic yards, which was taken from these beds alone."

"In the lower clay, in which shells chiefly occur, rounded fragments of almost all the primary and secondary rocks of this country are found, with many fossils of the latter class."

The shells obtained from this section are now preserved in the Museum of the Belfast Nat. Hist. and Phil. Society, and have been carefully catalogued by the curator, Mr. S. A. Stewart, with the assistance of the late Dr. J. Gwyn Jeffreys in the identification of such shells as were in any degree doubtful. Though containing more good specimens than one usually sees in a collection of shells from the boulder-clay, there is, as Mr. Stewart remarks, no reason to infer that the deposit at this spot was exceptional, the selection of the best specimens from the quantity of material examined being sufficient to account for the results. The following list of the shells is reprinted from Mr. Stewart's paper.[2] Mr. J. Wright has also recorded six species of foraminifera obtained by him from clay washed out of a few shells of the whelk in this collection.[3]

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[1] "Notice of a Tertiary Deposit lately discovered in the neighbourhood of Befast," *Phil. Mag.*, 3rd ser., vol. xxvi. (1845), pp. 433–436.

[2] "The Mollusca of the Boulder-clay of the North-east of Ireland," *Proc. Belfast Nat. Field Club*, Appendix for 1879–80 (1881), pp. 165–176.

[3] "The Post-Tertiary Foraminifera of the N.E. of Ireland," *ibid.*, pp. 149–163.

LIST OF SHELLS FROM THE BOULDER-CLAY AT BELFAST OLD WATERWORKS.

LAMELLIBRANCHIATA.

Anomia ephippium, *Linn.*
Ostrea edule, *Linn.*
Pecten maximus, *Linn.*
Mytilus edulis, *Linn.*
Nucula nucleus, *Linn.*
Leda minuta, *Müller*
„ pernula, *Müller*
Pectunculus glycimeris, *Linn.*
Arca pectunculoides, *Sacchi*
„ lactea, *Linn.*
Cardium echinatum, *Linn.*
„ nodosum, *Turton*
„ edule, *Linn.*
Astarte sulcata, *Da Costa*
„ „ *var.* elliptica, *Brown*
„ compressa, *Mont.*
„ „ *var.* globosa, *Möller*
Astarte borealis, *Chemn.*
Venus gallina, *Linn.*
„ ovata, *Pennant*
Tapes aureus, *Gmel.*
„ decussatus, *Linn.*
Tellina balthica, *Linn.*
„ calcarea, *Chemn.*
Mactra subtruncata, *Da Costa*
„ solida *var.* truncata, *Mont.*
„ „ „ elliptica, *Brown*
Scrobicularia piperata, *Bellon.*
Mya truncata, *Linn.*
Saxicava rugosa, *Linn.*
„ „ *var.* arctica, *Linn*
Pholas crispata, *Linn.*

GASTEROPODA.

Emarginula fissura, *Linn.*
Trochus tumidus, *Mont.*
Lacuna pallidula, *Da Costa*
Littorina litorea, *Linn.*
Turritella terebra, *Linn.*
Natica affinis, *Gmelin*
Aporrhais pes-pelicani, *Linn.*
Purpura lapillus, *Linn.*
Buccinum undatum, *Linn.*
„ „ *var.* fusiforme
Murex erinaceus, *Linn.*
Trophon clathratus, *Linn.*
„ „ *var.* Gunneri, *Loven*
„ truncatus, *Stromer*
„ latericeus, *Möll.*
Fusus antiquus, *Linn.*
„ „ *var.* cinctum
„ gracilis, *Da Costa*
Nassa reticulata, *Linn.*

In a brick-pit at the western end of the mill-dam at Springfield, boulder-clay ten feet in thickness directly overlies the Triassic marl at the top of the slope, but a wedge of stratified clay, loam and fine gravel sets in between them as the ground falls, attaining a thickness of about two and a half feet, with a capping of five feet of boulder-clay; and in this stratified drift small fragments of shells were observed. In the valley of the Forth River below this place we find still more pronounced indications of the setting in of the stratified drift which becomes so important farther southward. Some low mounds on the slope of the valley immediately below the above-mentioned mill-dam appear to be composed of gravelly wash, but this may have been a product of Late-Glacial flood-waters along the present line of drainage. The stratified drift exposed in the bottom of the valley 100 yards farther south at the Blackwater brick-yard is, however, more clearly part of the Glacial series. The pit is mainly in Keuper marls, covered at the east end by three to six feet of boulder-clay; fine loam and beautifully stratified 'warp' clay then set in above the boulder-clay and thicken rapidly westward, attaining a thickness of sixteen to eighteen feet at the west end of the excavation. This stratified clay has apparently been accumulated within an old valley in the marls to the westward of the present stream-course; it contains small concretions of 'race' and closely resembles the warp-clays exposed in brick-yards east of the Lagan presently to be described. Where thickest it is covered by about four feet of unstratified red clay containing a few stones, but whether this represents an upper boulder-clay or is the result of weathering and soil-cap movement is not evident. Among the stones which had been picked out of the boulder-clay in this pit an exceptionally large fragment of the riebeckite-rock of Ailsa was observed, measuring two feet by one and a half feet, along with other far-transported boulders of red granite, gneiss, quartzite, etc.

Boulder-clay continues to clothe the slopes farther southward, between the foot of the great escarpment and the alluvial flat drained by the Blackstaff, covering both the Triassic Sandstone which here occupies the lower part of the slope and the marl on the higher part. It seems probable that a lobe of ice has lingered on the slope while the central and eastern portion of the Lagan Valley held the waters in which the stratified drift was accumulated. Numerous sections of the boulder-clay, up to twelve feet in depth, are revealed in the banks of streams, road-cuttings, etc., in this tract; and from one of these, in the stream at the western edge of Falls Park, Mr. Stewart records the following shells:—

Astarte sulcata, A. compressa, A. triangularis, Mont. (the only locality in the district where this species has been found), *Tellina balthica, Saxicava rugosa* var. *arctica, Trophon clathratus* var. *Gunneri, T. truncatus,* and *Balanus* sp.

The western part of the City Cemetery is on boulder-clay; but sandstone, traversed by basalt dykes, comes to the surface on the steep slope in its eastern portion, and is well exposed in sand-pits immediately north of the Cemetery. The ravines at Milltown and Mary Burn are also excavated in sandstone; and it is difficult to decide whether patches of sandy ground around Mary Burn and Fruithill represent stratified drift or the weathered top of the Triassic rock. At Broom Hill, wells at the brewery have passed through the boulder-clay into gypsiferous marl.

Passing eastward over the alluvial flat of the Blackstaff, which will be described subsequently in dealing with the Estuarine Clays, we reach the rising ground of boulder-clay which forms the western slope of the broad ridge separating the Blackstaff basin from the Lagan valley. This ridge appears to be entirely a drift-feature, and the Pre-Glacial course of the Lagan probably lies buried beneath it, the river, as previously mentioned, having been thrown into the eastern slope of the old valley for its present channel.

Up to the Lisburn Road boulder-clay alone is seen at the surface, but in many places this is evidently only a comparatively thin upper band overlying fine yellow loamy sand like that which forms the greater part of the ridge. Thus, at the small brick-yard 200 yards north of the Reformatory, soft yellow sand has been reached beneath three to six feet of boulder-clay; and sand was also seen in foundations for buildings on Lisburn Road 400 yards farther eastward; and in new streets west of the railway, south of the road-bridge leading to Broadway; and in the adjacent railway-cutting. In other places, however, ten feet or more of boulder-clay have been dug without reaching sand. The streets immediately south of the Union Workhouse are built partly over the sites of old sand-pits, and this sand is overlain on the southern side by about four feet of clay.

East of the Lisburn Road, south of Wellington Park, although the attenuated boulder-clay creeps in places for 200 or 300 yards up the slope, as may be well seen in some of the new road-cuttings, the greater part of the ground is sandy almost across to the Lagan valley. Thus, Malone Road, after leaving the lower clayey slope just above the Methodist College, has sandy ground on both sides up to the tramway terminus, though here and there small patches of boulder-clay, rarely more than two or three feet in thickness, overlie the sand. On the higher ground the sand is probably at least forty or fifty feet thick, and is surprisingly free from stones; it was formerly exposed to a depth of twenty-five feet in an old sand-pit, now a nursery garden, near Lennoxvale, and appears to thicken rapidly southward from this place. The only organisms known from it are the scanty foraminifera obtained by Mr. J. Wright, as previously mentioned.

At their base these Malone Sands probably pass into laminated clay in the same manner as in the sections on the eastern side of the Lagan; and the deep little valleys by which the eastern side of the ridge is dissected appear to have been cut down into this clay and sometimes into an underlying boulder-clay, through the action of springs thrown out at the base of the sands. Two of these little ramifying glens open out upon the Lagan valley north and east of Stranmillis.

On the eastern slope of the ridge, as it descends towards the Lagan, the sands are again overlain by patches of the upper boulder-clay, best seen in the cuttings for new streets east of Stranmillis Road, this clay in some places becoming stratified at the base and merging gradually in loamy sand, and in other places resting on the sands with a sharp irregular junction and cutting down into them. Small flat concretions of calcareous 'race' are plentiful in the clay for a foot or two above the junction. From the manner in which this upper clay falls towards the Lagan it is clear that the valley-slope is not entirely due to river-action, but is in part an original surface-feature of the drift-deposits. Nevertheless the river since Glacial times has greatly deepened the original depression, cutting sharply into the drifts all along its course.

The north-eastern slope of the ridge, north of the Botanic Gardens, down to the low flat composed of Estuarine Clay, appears to be composed mainly of soft loamy sand; but along Botanic Avenue boulder-clay sets in and extends westward to Lisburn Road. All this ground is, however, obscured by buildings, so that boundaries are difficult to trace.

In the Lagan valley south of Stranmillis a lower boulder-clay rises above the river-alluvium and displaces the sands; and, as we shall presently see, similar boulder-clay occupies the opposite or eastern bank of the river as far northward as Ormeau Bridge. At the brick-works at Lagan Vale the section shows twelve feet of red-purple boulder-clay with included streaks and patches of brighter red clay, and with about three feet of loamy stony clay, more or less stratified, at the base. The record of a deep well-boring at the adjoining factory, given at p. 146, adds a further seventy feet to the thickness of the boulder-clay at this locality, carrying its base about sixty feet below high-water mark.[1] Only 300 yards west of the brick-yard section there is a large sand-pit, in the new Golf Links, showing fifteen feet of sand and loam with thin streaks of

[1] The presence of thick marls immediately below the drifts in this boring has been previously discussed (pp. 21-22.) An examination of some of the cores which had been preserved showed that part of the marl was much mixed with grit, and differed in character from the Keuper marl at its outcrop west of Belfast.

clay, overlain, with an ill-defined junction, by about five feet of boulder-clay. When traced at the surface this boulder-clay *over* the sands appears to be conterminous with that of the brick-yard, which when followed for quarter of a mile up the valley, is found to *underlie* the same sands, the explanation being that the stratified beds thin out in lenticular fashion between boulder-clays, and we are here tracing the edge of a lenticle. Similar conditions were observed in several places east of the Lagan, where the sands are thinner.

Southwest of Stranmillis the crest of the ridge becomes moundy and less regular, indicating the effect of current-action during the deposition of the sands; and south of Malone intercalated bands of gravel begin to make their appearance, giving further proof of running water. In this tract, too, its surface is dinted here and there by 'kettle-holes,'—irregular depressions without natural drainage. The country south of Malone falls within the district described subsequently (pp. 94-104).

Passing now to the east bank of the Lagan we find a fine series of sections in the brick-yards between Annadale and Ormeau Bridge, which are worked entirely in the Glacial deposits, partly boulder-clay and partly stratified warp-clay. The sections in these pits vary from point to point, owing mainly to the changeable character of the beds, but in part also according to the distance to which they have been carried back into the slope, which is capped by a prolongation of the Malone Sands.

In the most southerly, the Annadale Brick-works, the section (see Plate V.) showed:—

	Feet.
Yellow laminated sand and loam, about . . . . . passing into—	10
Finely laminated warp-clay, about	10
Reddish-purple boulder-clay, with included masses of more stony brown clay, about	9
Laminated warp-clay, ...	1 to 2
Dark greenish-red boulder-clay with gravelly patches . . .	at base.

The next pit northward, the Prospect Brick-works, shows a band of stratified clay connected with the sands, thinning out below a wedge of boulder-clay which here forms the top of the section. In one place the section was as follows:—

	Feet.
Dull purplish-red boulder-clay, apparently derived almost entirely from Triassic marl, with few stones but much concretionary 'race.'	5 to 15 (thickening southward)
Laminated warp-clay, with thin stony layers; resting in one place on a floor of boulders apparently washed from the underlying bed.	0 to 2 (thinning out southward)
Dark greenish-red boulder-clay, with many stones, including Ailsa Craig rock and others far transported.	+ 5 (to bottom of pit)

In another part of this pit two bands of stratified clay were seen with nine feet of purplish boulder-clay between them; and stratified and unstratified material are more or less intercalated throughout the sections.

In the adjacent yard on the north, the Marquis Brickworks, the upper boulder-clay of the last section has disappeared and the stratified beds have correspondingly thickened, the cut on the north side of the pit showing:—

Grey sand and orange sand,	? Post-Glacial.	3 to 5 feet.
Peaty sand,		1 inch.
Sandy loam,		1 foot.
Laminated warp, silt, and loam, penetrated by vertical roots from above, with a streak of pebbly clay containing crumbs of marine shells.		6 to 7 feet.
Tough purple-red boulder-clay, with slickensides running through the mass.		+ 9 feet to bottom of pit.

At first sight the peaty layer near the top appears to belong to the stratified drift, but it more probably marks the existence after Glacial times of a swampy hollow at the surface, which has been nearly obliterated by sandy down-wash and wind-drift from the rising ground to the south, represented by the top bed of grey and orange sand. A sample of the peaty material was prepared for microscopic examination by Mr. H. J. Seymour, but yielded no identifiable remains. A similar peaty layer was noticed half a mile farther south in the little gully close to the wall of the demesne, 300 yards south-east of Annadale, but the peat-band was here about one foot in thickness, and was covered by five feet of loamy sand. In this band Mr. Seymour found the macrospores of *Isoetes*,[1] and some obscure fragments of insects.

The Ulster Brickworks, north of the last, were not being worked at the time of our survey, and the sections were obscure but appear to have been almost entirely in boulder-clay. Close to the bank of the Lagan, however, yellow sand was exposed in one place beneath ten feet or more of boulder-clay. Fragments of marine shells occur, though very sparingly, in this clay.

In all these pits the great heaps of rejected boulders afford a fine field for the study of the transported stones of the drift. Basalt and chalk largely predominate; and among the far-travelled blocks the following were recognized by Mr. M'Henry, from his knowledge of the rocks of North Antrim:—Quartzite, Gneiss, Garnet-schist, etc., from North Antrim; Red Porphyry of Cushendun; Old Red Sandstone of Cushendall; Dolerite like that of Fair Head; Sandstone like that of the Ballycastle Carboniferous tract; Carboniferous Limestone, dark and flaggy; Silurian Grits, stained and unstained; a few fragments of Riebeckite rock like Ailsa Craig; etc.[2]

To the eastward of the Lagan valley a low plateau of fine loamy sand, dissected by little streams which reach the underlying clay, stretches beyond the Newtownbreda main-road, but is broken by a belt of clay between Ormeau Park and Ballynafeigh. At Knockbreda the sands are continued up to the foot of the steep hill-side which marks the edge of the Silurian massif, and here attain a higher level, rising in steep mounds, often with flat summits, above the lower ground. We seem here to have indications of a much-dissected higher sand-plain, which may represent the stage when the impounded waters of the Lagan valley reached their highest level.

It may here be mentioned that the absence of contour-lines and the great sparsity of levels on the Ordnance Maps of the district have

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[1] Determined by Mr C. Reid, F.R.S.

[2] See also lists compiled by members of the Belfast Naturalists' Field Club. *Proc. Belfast Nat. Field Club*, 1895–96, ser. 2, vol. iv., p. 306; and *Report British Assoc.* for 1902, p. 258.

been severely felt in working out these stratified drifts, especially along the margin of the high land, where there is supposed to have been a shore of the Glacial lake.

Numerous pits have been opened in this easterly sandy tract, which show fine yellow sand, probably derived from the Triassic Sandstone, with streaks of loam and clay, especially in the lower part where there is often a passage into silt and laminated clay, and with thin seams of small gravel in places in the upper part. This arrangement of the sediments agrees well with the supposition that they represent the infilling of a temporary lake.

The sands again occupy the surface over the greater part of Ormeau Park and in a small outlier at Mount Pottinger, but eastward from Ravenhill Road there is a wide tract of stiff red boulder-clay which extends up to the slate hills at Cregagh, Castlereagh, and Carnamuck, and to the Conn's Water valley at Avoniel. In the northern part of this tract the boulder-clay is exposed up to a depth of ten feet in small brick-yards and in cuttings for new streets, etc.; the occurrence of shell-fragments in the clay at the now dismantled Raven Hill Brickworks is noted on the field-map of the original survey. Where the drift rises up toward the slope of the Silurian rocks farther south, deep gullies are cut into it at Cregagh and Carnamuck, revealing excellent sections of the boulder-clay, usually with an irregular capping of slaty stream-wash. The best exposure is in Carnamuck Glen, south-east of the cross-road to Knock, where the precipitous walls of the narrow gully reveal from twenty to forty feet of very firm tough calcareous boulder-clay, red in the upper part and purple below, with thin intercalated streaks and wisps of sand and silt. From this section Mr. Stewart has recorded four species of shells[1]:—*Astarte sulcata* and var. *elliptica*, *Leda pygmæa* and *Leda minuta*—specimens of the two last species being obtained perfect and with valves united.[2] Another good section in this locality may be seen at the Knock Brickworks (at present disused), where ten to twenty feet of red boulder-clay with streaks and patches of loam, sand and gravel is exposed, though the slate-rocks emerge at the surface in a quarry 250 yards farther west. Drift of similar character extends southward into the depression in the hills at this place, and it is possible that a lobe of ice may have persisted around the opening of this depression later than on the tracts occupied by sands to the westward and northward.

As we approach Knock and the entrance to the Dundonald valley, stratified drift sets in again in strong force, forming steep moundy features around Knock House and flatter ground at Orangefield and Eden Vale, bordering the south bank of Knock River. The material is chiefly fine loamy yellow or orange sand, like the Malone Sands, passing down into silt and stratified warp, but with some streaks of gravel. In the cutting for a new road 350 yards west of

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[1] *Proc. Belfast Field Club*, Appendix, 1879–80, pp. 166–72. The occurrence of shells in this locality had been mentioned previously by J. MacAdam, *Journ. Geol. Soc. Dublin*, vol. iv. (1850), p. 268.

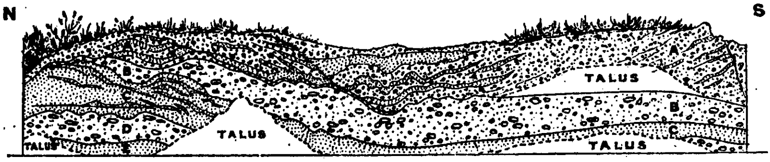
[2] In shelly boulder-clays generally, the small Ledas are more frequently found in this state than any other shell; this may be explained partly by their small size and oval shape, but is no doubt principally due, as Mr. P. F. Kendall has suggested, to the effect of the numerous tightly interlocking hinge-teeth in preventing the separation of the valves under lateral shearing.

Knock House the sand sinks to a lower level and disappears beneath a few feet of boulder-clay; and, from the emergence of small springs on the slopes east of Knock, bands of clay are probably intercalated with the sand.

This interdigitation of the stratified and unstratified drift is indeed actually visible on the opposite side of the stream, a few hundred yards farther north, in the large pit adjoining the railway station at Neill's Hill, which shows irregular alternating beds of sand, boulder-clay and gravel. The following figure and description of this section are reproduced from a report by Miss S. M. Thompson (Madame Christen)[1] published in 1894, when the exposure was in better condition than at present.

Fig. 9.—Section at Neill's Hill (from figure by Miss S. M. Thompson, in *Proc. Belfast Field Club* for 1893-94, p. 114).

Length, 43 yards. Height, 24 feet.



Description of Section.

A. Coarse gravel with dark red sandy and clayey layers; bedding very irregular, many blocks of New Red Sandstone near the top; stones rounded and waterworn; striated stones very scarce; one large fragment of *Astarte borealis* found; rests unconformably upon B. Thickness towards north, 4 feet 2 inches, increasing towards south to 10 feet.

B Hard compact fine dark red boulder-clay, becoming blacker towards base; intercalated with gravel (A.) in upper portion; boulders striated and polished, with long axes E.—W. to S.E.—N.W.; of 100 boulders, all were erratics; shells (fragmentary) rather rare, including *Astarte sulcata, A. borealis, Leda pernula, Mactra subtruncata, Tellina balthica, Buccinum undatum, Trochus* (*cinerarius ?*), *Balanus tulipa-alba*, and fourteen species of foraminifera; rests unconformably on C. Thickness at south end of section, 3 feet 6 inches.

C. Fine bright red sand, very irregularly current-bedded, with intercalated layers of gravelly earth; no shells and no foraminifera; rests unconformably on boulder-clay. Thickness, at N. end, 8 feet, and at S. end, 4 feet 6 inches.

D. Boulder-clay, on the north dipping at 24°, but in extending southward becomes horizontal, resting upon an apparently old surface of sand; boulders striated and polished, with long axes N.E.—S.W.; 97 per cent. were erratics; shells more abundant than in B., including *Leda pernula, Tellina balthica, Balanus tulipa-alba;* and thirteen species of foraminifera. Thickness, 5½ feet.

E. Fine red sand, like C.; no shells and only two species of foraminifera. Greatest depth exposed, 4 feet, but base not visible.

Among the erratics noted by Miss Thompson from the section were:—Silurian grits and slates, vein-quartz, basalt (some large), chalk (some large), mica-schist, quartzite and sheared igneous rocks, probably from North Antrim, and riebeckite-rock (Ailsa Craig). It was also observed that lumps of stony clay from fourteen to thirty inches in diameter, and lenticular masses of gravel

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[1] *Proc. Belfast Nat. F. C.*, 1893-4. "Report of Geological Committee," pp. 122-124.

occurred in the sand, thirty-five feet deep, which forms the south-eastern half of the hill; and that a cutting across the hill encountered a mass of boulder-clay containing a pit of sand sixty feet wide and twelve feet deep.

In a boring at the Tramway Company's stables at Knock, of which the details are given in Appendix II., p. 150, the glacial deposits had a thickness of 161 feet, consisting in the upper part mainly of sand and gravel, and in the lower part of stony clay resting on the Triassic rocks.

The deep railway cuttings west of Neill's Hill are sloped and grassy, but were described by J. MacAdam in 1850, from observations made during the construction of the line.[1] From this source we learn that the most westerly cutting was "almost wholly in sand, having some veins of clay through it, with small quantities of fine gravel: . . . . a few fragments of shells were obtained from it."

The next cutting eastward was in "an almost pure sand, in which an increased number of shells were found"[?]. The third—apparently the cutting at Neill's Hill—is described as in "sand mixed with clay, having a few shells."

The valley of Knock River has been excavated through these sands to the underlying boulder-clay; and at its mouth, known as the Conn's Water, the boulder-clay expands and covers most of the lower ground east of Bloomfield, as may be seen in the cuttings for the new streets. It is probable that in this quarter the sands die out between overlying and underlying boulder-clay, in the same manner as at Lagan Vale (see p. 72).

To the northward of the railway-line, stratified drift, chiefly yellow loamy sand, extends in an undulating platform dissected here and there by brooks, over the low Triassic ground as far as Holywood. This platform ends off rather abruptly eastward at the foot of the steep hillsides swathed in boulder-clay which mark the emergence of the Silurian rocks, the deposits becoming gravelly along this margin, where we may suppose the shore-line of the Glacial lake to have been situated. Westward the platform is truncated by the cliff of the Raised Beach, which, though much weathered, is still a steep bluff. South of Garnerville the base of this cliff has been excavated in laminated warp-clay and boulder-clay underlying the sands, as water is thrown out along the bank, though the clay is obscured by talus and is rarely visible; the same conditions also prevail in the numerous little valleys by which platform is broken. Around Ballyhackamore many pits have been opened in the sands; the site of the largest, 250 yards E.N.E. of Ballyhackamore House, has now been built over, but a note on the working map of the earlier survey describes the section as showing "finely stratified sand and obliquely laminated fine brownish-red sand with thin clayey layers and occasional very thin layers of gravel, thirty feet exposed." A pit at present being worked, 300 yards S.E. of Ballyhackamore House and adjacent to the main road leading to Knock, shows about ten feet of fine red sand with streaks and pockets of

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1 "Observations on the neighbourhood of Belfast, with a description of the cuttings on the Belfast and Co. Down Railway," *Journ. Geol. Soc., Dublin*, vol. iv. (1850), pp. 250-265.

sharper grey sand and fine gravel; some patches of clayey soil containing boulders of basalt, etc., occur at the top of the section, and are probably the relics of an overlying band of boulder-clay which has been destroyed by denudation.

Between Ballyhackamore and Belmont the sandy platform is interrupted by an irregular tract of boulder-clay, as shown on the map, which rises in one place into a decided ridge with its axis striking nearly N.-S. The relation of this clay to the sand is obscure, but there seem to be intercalations around the margin, as at Neill's Hill; small brick-fields were formerly worked in this tract.

Toward the northern termination of the platform, immediately south of Holywood, the stratified drift is evidently greatly diminished in thickness, and becomes confusedly intermingled with boulder-clay, as subsequently described (p. 106). It is in this quarter that we may suppose the edge of the ice-barrier to have lain during the accumulation of stratified deposits in the lake to the southward. The 'dry gap' across the spur of slate that rises above the northward termination of the sandy platform at Holywood, and the moundy gravel, apparently its delta, extending nearly down to the platform, have already received notice (p. 63).

Estuarine Clays and other Post-Glacial Deposits.

The general succession of the Post-Glacial deposits at the head of Belfast Lough, where they are most extensively developed, has been given in the foregoing general description (pp. 53-56). Some further details of their distribution, with typical sections compiled from the published work of Mr. R. L. Praeger and others, or obtained by the Survey from sources to be duly acknowledged, will now be added.

The strenuous activity of the Harbour Board of Belfast in the improvement of the port has rendered available a large mass of information regarding the superficial deposits of the estuary. At the offices of the Board, records have been preserved of the numerous shallow borings, over 170 in all, which have been made during the last thirty years to test the substrata of the bed of the Lagan and the ground adjacent to it at the head of Belfast Lough. Through the courtesy of the engineers-in-charge[1] we have been allowed access to these records, and have taken copies of a large number of the sections. The details of a few of the deeper of these borings will be given in the context, and the general character of the whole series of sections will be briefly summarized.

In a series of eighteen borings, ranging in depth from nine to sixteen feet, in the bed of the Lagan between the first lock at Lagan Vale and the Ormeau Bridge, 'sleech' or estuarine clay, probably representing the silting up of the river-bed during the Post-Glacial depression, was proved to a depth of from seven to fourteen feet, usually resting on gravel, but in two places resting directly on clay [? boulder-clay]. In a further eighteen borings in the river-bed between Ormeau Bridge and Albert Bridge, of which the deepest was twenty-one feet, similar conditions were found, but the 'sleech' thickened toward the Albert Bridge to sixteen or

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[1] Our thanks are particularly due to Mr. Redfern Kelly, C.E., for his assistance in this matter.

seventeen feet, and was in one place underlain by about a foot of peat.

From a section recorded by Mr. Praeger[1] we learn that in the foundations for the Albert Bridge the gravel at the base of the estuarine deposits was found to rest directly upon Triassic Sandstone, the record being as follows:—

	Feet.
River-mud and coarse sand, ...	10
Lower estuarine clay, ...	14
Gravelly bed, ...	1
New Red Sandstone, ...	—

"High-water mark is here thirteen feet above the surface of the estuarine clay. The upper clay, if ever present, has been washed away, and the bed that replaces it is the recent creation of the river. The estuarine clay was typical lower clay, brownish in colour, rather sandy in texture, and full of *Cardium edule, Tapes decussatus, Tellina balthica, Scrobicularia piperata*; hazel nuts and elytra of beetles were noticed in it, and the pelvic bone of a red deer occurred near its junction with the underlying gravels. Foraminifera were very rare in the clay, and the specimens poor."

The sandstone has also been reached in excavations for a gasometer at the Belfast Gas Works on the west bank of the river, half a mile south-west of Albert Bridge, at depths varying from twelve to sixteen feet below the surface on one side to thirty-five feet on the other side of the premises, being covered in some places with boulder-clay containing well-glaciated stones and in other places with very finely laminated warp-clay.[2]

Near the east bank also, south of Albert Bridge, the Triassic sandstone, here capped by Glacial drift, has been reached in borings at only from eight to thirty feet below high-water mark (see Appendix II., p. 151), whereas at about half a mile to the westward of the river a boring has been carried nearly 200 feet below O.D. before reaching the sandstone. (See Fig. 12, also Section 1 at foot of map).

The borings of the Harbour Board between Albert Bridge and Queen's Bridge show similar sections to those above the former bridge, except that the 'sleech' is more variable in thickness and is apparently in part replaced by sand on the County Down shore of the river. Three borings on Queen's Quay below Queen's Bridge show two feet sand, on fourteen to fifteen feet 'sleech,' on twenty-five to thirty feet sand and clayey sand; and on the opposite side of the river, about 100 yards to the west of Donegal Quay, the base of the 'sleech' was not reached at twenty-four feet, but in this quarter we have fuller information from deep borings for water which show that the base of the drifts is here at least 140 feet below the surface. (See p. 147).

Near the western side of Clarendon Dock, a boring proved:—

	Ft.	In.
"Sleech,"	40	0
Peat, ...	2	6
Blue clay and gravel, ...	2	0
Red sand with clay, ...	+ 6	0

[1] "Report on Estuarine Clays," *Proc. R. I. A.*, ser 3, vol. ii., p. 232.

[2] From information given by the manager, Mr. J. Stelfox.

At 600 yards and at 800 yards farther northward, near the Northern Counties Railway Station, and at the Timber Ponds to the north of it, the base of the 'sleech' was not reached at twenty-four feet; but in Duncairn Street, 150 yards north-east of the railway station, records of the main-drainage sections preserved at the Town Hall show "sandstone" (possibly Glacial sand) under about thirty feet of 'sleech.' The last-mentioned records also show twenty to twenty-eight feet 'sleech' on three to eight feet sandy clay at the main-drainage pumping station, and fifteen to thirty-eight feet 'sleech' on stiff red clay at the outfall works on the intake, about three-quarters of a mile farther north.[1]

Three borings made by the Harbour Board between the main-drainage outfall and the Victoria Channel, at about 100, 300 and 500 yards respectively west of the Channel embankment, gave the following results:—

No. I.		*No. II.*			*No. III.*		
	Ft.		Ft.	In.		Ft.	In.
Sleech,	22	Sleech,	30	9	Sleech,	36	0
Red sand,	13	Grey sand,	2	0	Gravel,	4	6
Red clay,	26	Red sand,	2	0	Red clay,	13	6
Red clay and stones,	15	Red clay,	20	0	Clay and stones,	2	0
		Clay and stones,	7	0	Red clay,	1	6
		Red sand,	4	0	Red sand,	11	6
		Green sand,	7	0			
	76		72	9		69	0

It is possible here that the bottom sands of No. 2 and 3 may represent the soft Triassic Sandstone rising nearer the surface on the western side of the buried valley, as the rock crops out above sea-level at the foot of the old cliff half a mile to the westward.

In the excavations for the Spencer Basin the Estuarine Clays had a total thickness of about twenty feet, and Mr. S. A. Stewart, who investigated the section, found that three well-defined zones could be recognized in them, viz.:—1. Surface-clays, abounding in littoral species; 2. Zone of *Thracia convexa*, characterized by shells which live in five to ten fathoms of water; 3. *Scrobicularia* zone, in which littoral species again predominate.[2]

Crossing now to the eastern side of the Victoria Channel we reach the Alexandra Graving Dock, of which, as already mentioned, the section was carefully investigated by Mr. R. L. Praeger while the excavations were in progress. Though not here attaining their greatest thickness, we must regard this as the typical section of the Post-Glacial deposits of the estuary, and will therefore reproduce the details given by Mr. Praeger, together with his lists of the fauna. The accompanying figures of the sections at the north and south ends of the dock are reprinted from Mr. Praeger's paper[3] by the kind permission of the author and of the council of the Belfast Naturalists' Field Club.

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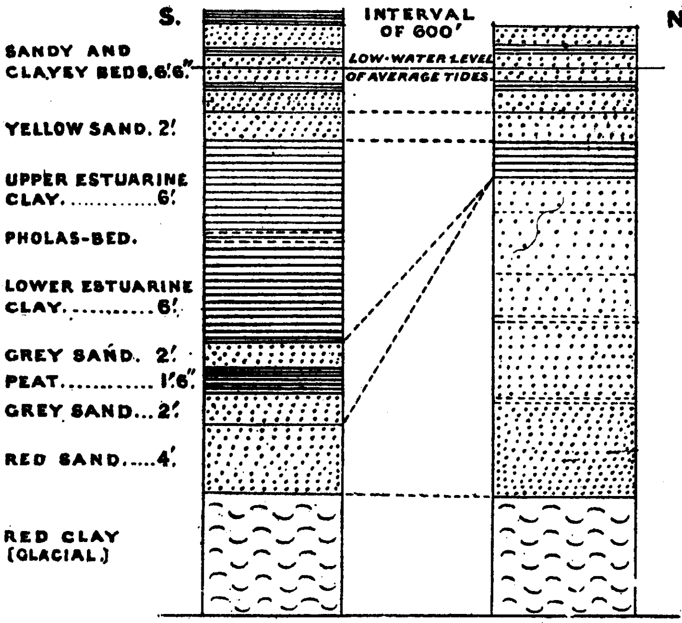
[1] We are indebted to the Assistant City Surveyor for access to these and other drainage records.

[2] Praeger, *op. cit.*, p. 314.

[3] "The Estuarine Clays at the New Alexandra Dock, Belfast, with list of Fossils." *Proc. Belfast Nat. Field Club*, Appendix, 1886-87, pp. 29-51.

Sections at the Alexandra Dock, Belfast (R. L. Praeger, *Proc. Belfast Field Club*, 1886–87).

Fig. 10.—Section at Inner Entrance. Fig. 11.—Section at Entrance Basin.



The strata shown in the section at the southern end of the dock (Fig. 10) are described as follows in descending sequence by Mr. Praeger:—

"1. Blackish clay, with sandy layers, of a depth of 6 to 7 feet, the surface between tide-marks" [" still in course of formation when the works were commenced "]. Characteristic shells of this deposit are:—*Mya arenaria, Cardium edule, Tellina balthica, Mytilus edulis. Mya* occurs in beds of thousands, the shells all in the position in which they lived and generally with the siphonal tube preserved. *Cardium* is also very abundant." . . . . . .

"2. Two feet of coarse yellow sand, with abundance of shells, and also thin layers of twigs and hazel nuts. The shells are often much worn, and generally occur as single valves, and the deposit has all the appearance of an old sandy beach. *Pecten opercularis, Littorina litorea, Mytilus edulis* occurred here abundantly, and fine specimens of *Tapes pullastra, T. decussatus,* and *Thracia convexa,* which two latter species are not now found living in Belfast Lough . . . ."

3. The Upper Estuarine Clay, here about 6 feet thick, underlies the yellow sand with a sharp line of demarcation. It "consists of a very fine homogeneous blue clay . . . . remarkably rich in shells, both large and small, many of which do not now exist in our waters, and they are for the most part in a beautiful state of preservation. *Thracia convexa, Lucinopsis undata, Cardium echinatum, Scrobicularia alba, Ostrea hippopus, Acera bullata,* are abundant, and characteristic of the deposit. . . . Near the top of the deposit a shell-layer occurred, made up almost entirely of *Scrobicularia alba* and the spines of two echinoderms—*Amphidotus cordatus* and *Echinus miliaris.* At the base . . . . is a narrow zone in which the boring shells, *Pholas crispata* and *P. candida,* occur in profusion" (see *ante*, p. 55.)

4. The Lower Estuarine Clay in this section had a depth of between 6 and 7 feet. "It is of a more sandy nature, and has a yellower colour than the upper bed, and is full of the remains of the Grass Wrack, *Zostera marina,* which furnishes further proof, if such were needed, that this

is a shallow water deposit . . . . *Scrobicularia piperata* is the leading shell of this bed; . . . other characteristic fossils are:—*Littorina litorea, Cardium edule, Tapes decussatus.* . . . At the base the bed becomes very sandy, and *Tellina balthica* is abundant, along with quantities of *Cardium edule* of small size. The lowest zone consists of grey sand, and is quite unfossiliferous."

5. The bed of peat, one to two feet thick, which immediately underlies the basal sandy layer of the Estuarine Clays, is now some 27 feet below high-water mark, but Mr. Praeger points out that its depression below sea-level must have been at least 25 feet more than at present during the stage of depression indicated by the Upper Estuarine Clays. "The peat is . . . . very much compressed, and had originally a much greater depth, as is shown by the flat ellipses into which round branches have been pressed. It is full of trunks and boughs of trees, some of which extend upward into the grey sand. Among the vegetable remains, Willow, Hazel, and Alder are easily recognisable. Hazel nuts occur, and the cones of the Scotch Fir. The broad leaves of the Iris are frequent, with remains of rushes and sedges. But the most interesting fossils which the submerged peat yielded were the bones of large quadrupeds—a tusk and two portions of the jaw of the Wild Boar, and a rib, vertebra, and a leg bone of the Red Deer. Wing-cases of insects are of not infrequent occurrence, and in a tolerable state of preservation. In one place a layer of grey sand occurred in the middle of the peat, rapidly thinning out in all directions. A sample of this was kindly examined microscopically by Mr. Joseph Wright, F.G.S., but no organic remains were found. That the vegetation which formed this peat flourished on the spot on which it now rests, and was not drifted thither, is proved by the abundance of fine roots which descend several feet into the underlying deposit."

Besides the above-mentioned mammalian remains Mr. Praeger also records[1] the occurrence of the greater portion of the skull and other bones of the Irish Elk from the same peat-bed in later excavations at the floating dock opening off the Spencer Basin on the opposite side of the river; and a fragment of an antler of the same species was found in preparing the foundations of the Albert Bridge in 1890.

6. "Grey sand, some two or three feet deep, very fine on the top, coarser below. In addition to the roots from the peat, of which the sand is full, the only organisms which this bed yielded were Foraminifera and Ostracoda, of which Mr. Wright, who has very kindly examined samples of all the deposits at the Dock for microscopic forms, detected seven species . . . . The grey sand merges into fine red glacial sand, a deposit of which is largely developed all around Belfast. It is very barren in organic remains, the only fossils detected being two Foraminifera and two. Ostracoda. . . . . This sand, which contains occasional clayey layers, had a thickness of about four feet, and rested on very tough red clay, of glacial age, the base of which was not reached in the deepest excavation at the Dock—the foundation of the rudder-well, over 50 feet below H.W.M.—although 15 feet of it had then been passed through. No organic remains were discovered here, but this was probably due to the small sample submitted for examination." . . . .

"If we now turn to the section at the outer entrance to the Dock, some 600 feet north of the one just described, some striking differences will be noticed. At the west side of the entrance-basin the Estuarine Clay is only 4 feet thick and below it is 1 foot of yellowish clay, which represents the bed of peat. This rests directly upon the fine red sand, the surface of which is here 12 feet higher than at the upper end of the works. At the east side, while making excavations for the inlet culvert, an interesting section was exposed (see Fig. 11). Beneath some feet of clay and sand was a bed of coarse blackish sand, with abundance of shells, at the base of which were some 2 or 3 inches of almost pure shells. In this layer *Littorina litorea* was in great abundance, along with *Cardium edule, Lucinopsis undata,* and *Thracia convexa*—some littoral and some deep-water forms, it will be noted. This mixture of species is curious, but I think there can be little doubt that the 5 to 20 fathom shells which occur here in profusion were washed out of the upper clay. . . . . . . Immediately below the shell-layer is the Estuarine Clay, which at this point is only 2 feet thick. The deposit is very sandy, except at its upper surface, and is replete with species which have lived and died in what was then the sandy bottom of a bay several fathoms deep. . . .

[1] "Report on Estuarine Clays, &c.," *Proc. R. Irish Academy,* 3rd ser., vol. ii. (1892), p. 268; also *Proc. Belfast Field Club* for 1892, p. 423.

At the base of the bed, where it is quite sandy, there is abundance of *Cardium edule*—this stratum evidently corresponds with the lower clay of the first section. Below this we come directly upon the red sand; there is no trace of the peat bed. The sand is nearly 20 feet in thickness and rests on the red clay."[1]

The following list of shells of the Estuarine Clays of Belfast is reproduced from Mr. Praeger's list published in his "Report on the Estuarine Clays of the north-east of Ireland," *Proc. R. Irish Academy*, 3rd ser., vol. ii. (1892), pp. 270-282. This Report, which incorporated the work of previous observers,[2] contains a full list of the foraminifera obtained by Mr. J. Wright from the same deposits.[3] It also indicates the present distribution of the shells, and includes critical notes on many of the species and shows the relative abundance of each species in the deposit. These particulars have not been reprinted, as they can be referred to the original paper.

SHELLS OF THE ESTUARINE CLAYS OF BELFAST

CONCHIFERA.

Anomia ephippium, *Linn.*
„ patelliformis, *Linn.*
and *var.* striata.
Ostrea edulis, *Linn.*
and *vars.* parasitica and hippopus.
Pecten pusio, *Linn.*
„ varius, *Linn.*
and *var.* purpurea.
„ opercularis, *Linn.*
„ maximus, *Linn*
Lima hians, *Gmel.*
Mytilus edulis, *Linn.*
and *var.* pellucida.
„ modiolus, *Linn.*
„ adriaticus, *Lam.*
and *var.* ovalis.
Modiolaria marmorata, *Forbes*
Nucula sulcata, *Bronn.*
„ nucleus, *Linn.*
and *var.* radiata.
Leda minuta, *Müller*
Lepton nitidum, *Turton*
Montacuta bidentata, *Mont.*
„ ferruginosa, *Mont.*
Lucina borealis, *Linn.*
Axinus flexuosus, *Mont.*
Cyamium minutum, *Fabr.*
Cardium echinatum, *Linn.*
„ exiguum, *Gmel.*
„ nodosum, *Turton*
„ edule, *Linn.*
and *var.* rustica.
„ norvegicum, *Speng.*
Cyprina islandica, *Linn.*
Venus exoleta, *Linn.*
„ lincta, *Pult.*
„ fasciata, *Da Costa*
„ gallina, *Linn.*
and *vars.* laminosa and gibba.
Tapes aureus, *Gmel.*
and *var.* ovata.
„ virgineus, *Linn.*
„ pullastra, *Mont.*
„ decussatus, *Linn.*
Lucinopsis undata, *Penn.*
Tellina balthica, *Linn.*
„ tenuis, *Da Costa*
„ fabula, *Gron.*
„ squalida, *Pult.*
Psammobia ferröensis, *Chem.*
„ vespertina, *Chem.*
Mactra solida, *Linn.*
and *vars.* truncata and elliptica.
„ subtruncata, *Da Costa*
Lutraria elliptica, *Lam.*
„ oblonga, *Chemn.*
Scrobicularia alba, *Wood*
„ tenuis, *Mont.*
„ piperata, *Bellon.*
Solecurtus antiquatus, *Pult.*
Ceratisolen legumen, *Linn.*
Solen pellucidus, *Penn.*
„ ensis, *Linn.*
„ vagina, *Linn.*
Thracia papyracea, *Phill.*
and *var.* villosiuscula.
„ pubescens, *Pult.*
„ convexa, *W. Wood*
Corbula gibba, *Olivi*
Mya arenaria, *Linn.*
„ truncata, *Linn.*
„ binghami, *Turton*
Panopæa plicata, *Mont.*
Saxicava rugosa, *Linn.*
and *var.* arctica.
Gastrochæna dubia, *Penn.*
Pholas dactylus, *Linn.*
„ candida, *Linn.*
„ crispata, *Linn.*
Teredo norvegica, *Speng.*

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[1] R. L. Praeger, *Proc. Belfast Nat. Field Club*, 1886–87, Appendix II., pp. 30–34.

[2] See also "A list of the fossils of the Estuarine Clays of Counties Down and Antrim," by S. A. Stewart, *Proc. Belfast Nat. Field Club* for 1870–71, Appendix, pp. 27–40. Earlier lists were published by Canon J. Grainger, *Rep. British Assoc.* for 1852, pp. 43–46, and *Nat. Hist. Review*, vol. vi. (1859), pp. 135–151.

[3] See also "Post-Tertiary Foraminifera of the N.E. of Ireland," by J. Wright, *Proc. Belfast Nat. Field Club* for 1879–80, Appendix, pp. 149–163.

GASTEROPODA.

Patella vulgata, *Linn.*
Helcion pellucidum, *Linn.*
Tectura virginea, *Müller*
Fissurella græca, *Linn.*
Capulus hungaricus, *Linn.*
Trochus helicinus, *Fabr.*
„ magus, *Linn.*
„ cinerarius, *Linn.*
„ umbilicatus, *Mont.*
Lacuna divaricata, *Fabr.*
and *var.* quadrifasciata.
„ puteolus, *Turton*
„ pallidula, *Da Costa*
Littorina obtusata, *Linn.*
and *var.* æstuarii.
„ neritoides, *Linn.*
„ rudis, *Maton*
and *var.* tenebrosa.
„ litorea, *Linn.*
Rissoa parva, *Da Costa*
„ inconspicua, *Alder*
and *var.* sublævis.
„ albella, *Lovén*
and *var.* Sarsii.
„ membranacea, *Adams*
„ violacea, *Desmar.*
„ striata, *Adams*
„ vitrea, *Mont.*
Hydrobia ulvæ, *Penn.*
Jeffreysia opalina, *Jeff.*
Homalogyra atomus, *Philippi*
Caecum glabrum, *Mont*
Turritella terebra, *Linn.*
Scalaria turtonæ, *Turt.*
Aclis supranitida, *S. Wood*
Odostomia albella, *Lovén*
„ pallida, *Mont.*
Odostomia conoïdea, *Brocchi*
„ acuta, *Jeff.*
„ insculpta, *Mont.*
„ indistincta, *Mont.*
„ interstincta, *Mont.*
„ lactea, *Linn.*
Eulima bilineata, *Alder*
Natica catena, *Da Costa*
„ alderi, *Forbes*
Aporrhaïs pes-pelicani, *Linn.*
Cerithium reticulatum, *Da Costa*
Purpura lapillus, *Linn.*
Buccinum undatum, *Linn.*
Murex erinaceus, *Linn.*
Fusus antiquus, *Linn.*
„ gracilis, *Da Costa*
Nassa reticulata, *Linn.*
„ pygmæa, *Lam.*
Defrancia gracilis, *Mont.*
Pleurotoma attenuata, *Mont.*
„ costata, *Donov.*
„ brachystoma, *Philippi*
„ septangularis, *Mont.*
„ rufa, *Mont.*
„ turricula, *Mont.*
Cypræa europæa, *Mont.*
Cylichna nitidula, *Lovén*
„ cylindracea, *Penn.*
Utriculus mammillatus, *Philippi*
„ obtusus, *Mont.*
„ hyalinus, *Turton*
Acera bullata, *Müller*
Actæon tornatilis, *Linn.*
Scaphander lignarius, *Linn.*
Philine scabra, *Müller*
„ aperta, *Linn.*
Melampus bidentatus, *Mont.*

LAND AND FRESHWATER SHELLS

Zonites nitidulus, *Drap.*
„ crystallinus, *Müller*
Helix nemoralis, *Linn.*
„ rotundata, *Müller*

The variability of the deposits which fill the old river-channel, so well shown by the sections in the Alexandra Dock, is further exemplified by borings which have been made by the Harbour Board on the same side of the Channel. Three borings in the shipyard 100 yards east of the north end of the dock gave the following sections:—

(*a*) *Boring* 100 *yards E. of Alexandra Dock entrance*	Ft.	In.	(*b*) *Boring* 100 *yards N. of* (*a*).	Ft.	In.	(*c*) *Boring* 200 *yards N. of* (*a*); *at* 6*ft. lower surface-level,*	Ft.	In.
'Sleech,'	25	6	'Sleech,'	27	9	'Sleech,'	25	0
'Sleech' and sand	2	0	Red sand,	34	0	Red Sand,	21	0
Grey sand,	8	0	Red clay,	13	0	Peat,	0	9
Brown sand,	27	0				Red sand,	9	6
Sand and clay,	1	0				Sand and clay,	3	0
Red clay,	12	0				Red clay,	16	0
	75	6		74	9		75	3

In the foundations for Messrs. Harland and Wolff's new Electric Power Station, a little to the south of these borings, the estuarine clay was only twelve feet thick, resting on sixteen feet of red sand.

The presence of twenty-one feet of sand above the Peat-bed in section (*c*) is exceptional, as this bed is usually found close to the base of the estuarine clay. It seems to imply that a considerable thickness of the pre-existing Glacial sand has been re-distributed in places by the currents of the estuary during early stages of the Post-Glacial subsidence.

A series of four borings along the western side of the new Musgrave Channel, 400 to 500 yards east of those above-described, gave the following results:—

(1) *Boring between Abercorn-road and Hamilton-road—(probably partly in "made ground").*

	Ft.	In.
Vegetable mould,	2	6
Red sand,	11	0
Red clay,	2	9
Red sand,	4	0
Red clay,	16	0
Red sand,	2	6
	38	9

(2) *Between Hamilton-road and Musgrave-road.*

	Ft.	In.
'Sleech,'	14	0
Peat,	0	6
Grey sand,	1	3
Red sand,	2	0
Red sand and clay,	2	3
Red sand,	1	0
Red clay,	16	0
	37	0

(3) *At end of Hartland-road.*

	Ft.	In.
'Sleech,'	24	6
(*No peat noticed.*)		
Red sand,	7	0
Red clay,	6	0
	37	6

(4) 500 *yards N. of* (3).

	Ft.	In.
'Sleech,'	21	0
Peat,	0	6
Grey sand,	1	6
Red clay,	9	3
Red clay and pebbles,	6	0
	38	3

A boring on the site of the original Ballamacarrett foreshore, south of the Musgrave Channel and about 200 yards north of the County Down Railway main-line showed the thinning out of the estuarine clay in this direction, the section being:—'Sleech,' 1 foot; red sand, 12 feet 9 inches; red clay, 1 foot 6 inches; red sand, 2 feet; red clay, 9 feet 6 inches; red sand and clay, 3 feet; red sand, 4 feet.

In all these borings on the eastern side of the Victoria Channel the greater part of the "red clay" appears to have been practically stoneless, and similar material was dredged from the bed of the Musgrave Channel. It is probably a glacial 'warp'-clay, lying at the base of the Malone Sands, like that found in some of the brick-yards (p. 72), and overlying an irregular surface of the true boulder-clay which seems to have been reached in only two or three places.

The silting up of the head of the estuary by the estuarine clays has, as already stated, formed the low ground on which the central part of Belfast is established. From the numerous borings for water which have been made in this tract and from other artificial sections we can trace the varying thickness of these deposits and of the underlying Glacial drifts, by which the ancient hollow is filled to its present level. The details of many of the borings are given in Appendix II. (p. 145), and it will be sufficient here to combine the information in diagrammatic form in the following section across the lower part of the city.

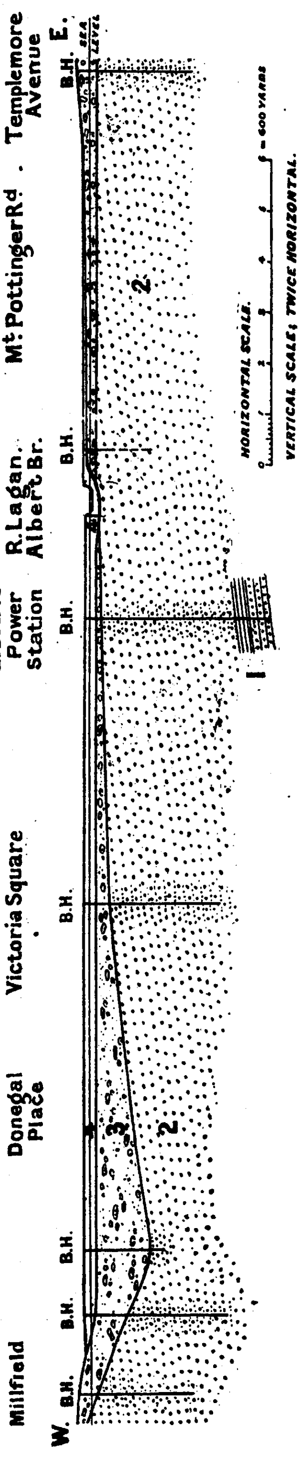

Fig. 12.—Section across Belfast, showing thickness of the superficial deposits.

1. Lower Marls, &c. 2. Triassic Sandstone. 3. Glacial Drift (boulder-clay, sand and gravel, &c.) 4. Estuarine Clay and Alluvium. B.H. = Bore-hole.

In the present valley of the Lagan the estuarine clays contract rapidly above Ormeau Bridge and pass into ordinary river-alluvium above the first lock at Lagan Vale. In the parallel valley of the Blackstaff a narrow strip of flat ground, from 200 to 300 yards wide, underlain by alluvial clay and silt which may be considered as the prolongation of the estuarine clays, bounded by gentle slopes of boulder-clay, extends from Distillery Street to Broadway, and then expands into a wide boggy flat known as The Meadows, over half a mile wide and a mile and a quarter long, which is underlain by similar clay. Mr. Praeger found many foraminifera in blue sandy clay in the bed of the Blackstaff at Broadway, but it is uncertain how far the marine clays may extend beneath The Meadows. The drains in the northern part of the flat show sections of stiff red or brown alluvial clay, up to eight feet or more in thickness, such as might be deposited by the muddy waters draining from the adjacent slopes of Triassic Marl and boulder-clay, by which large tracts of this low ground are still occasionally flooded. But it is very probable that beneath this fresh-water alluvium there may be a clay of brackish water or estuarine origin, and that the flat may have been caused through the ponding back of the streams during the period of subsidence, by which their load was deposited here instead of being carried into the Lough.

A ditch-section near the southern end of The Meadows, 600 yards east of Blackwater Bridge, showed four feet alluvial clay, on six inches ferruginous gravelly wash, on two feet grey mud (like 'sleech'), on six inches (or more) peat, with sticks.

Some years ago mammalian remains were discovered in a section near the border of this alluvial tract, of which the following account was given by Mr. R Young :—"In excavating a small reservoir at the junction of the Clowney Stream with the Blackstaff, after passing through a stratum of estuarine silt and shells, at a depth of fifteen feet from the surface, an immense accumulation of bones and horns of ox and deer were found [in July, 1867]; these were mixed with the trunks and branches of small trees, some being yews, and coarse subangular trap-gravel, and imbedded with them were found a wrought deer's horn and a wrought rib bone, which I now exhibit."[1] The same writer has recorded the occurrence of bones of Irish elk, horse, and sheep from drainage-sections in Castle Place, Belfast,[2] and has given interesting details regarding some of the main-drainage sections in Belfast.[3]

In one case when peaty gravel beneath the estuarine clays was pierced in sinking a well at Police Square, Belfast, a quantity of inflammable gas ("marsh-gas") was given off. From the investigations of Prof. T. Andrews we learn that the section at this place showed thirty-three feet of "silt," resting on seven feet of gravel charged with water and containing a quantity of organic debris, with a thick deposit of very tenacious clay [? boulder-clay] below. The gas "flowed freely at the rate of forty cubic inches per minute through the upper end of the pipe, and when ignited burned with a yellow flame which could scarcely be distinguished from ordinary coal-gas."[4] On analysis the gas showed the following composition:—

	Percentage.
Marsh gas ($C.H_4$),	83·75
Carbonic Acid gas,	2·44
Oxygen,	1·06
Nitrogen,	12·75
	100·

Gas has also been found to issue from this horizon in other borings in Belfast (see p. 148, 149).

G. W. L.

2. The Country north and west of Belfast, in County Antrim.

Boulder-Clay of the Plateau.—The range of mountains, whose south-easterly slopes are abruptly terminated by the great escarpment, gives place in a north-westerly direction to a series of lower hills, which, in turn, merge into a gently sloping plain, the drainage of which passes west into Lough Neagh. This plain is more or less thickly covered with boulder-clay, which sweeps up between the hills and on to their lower slopes. It forms

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[1] "Presidential Address." *Proc. Belfast Nat. Hist. and Phil. Soc.* for 1877–78, p. 19. In the same address Mr. Young mentions the occurrence of rudely-squared and morticed pieces of oak timber in the "boulder-clay" of a brickyard at Dover-street.

[2] "A recent find of Irish Elk bones in Belfast." *Ibid.* for 1893–94, p. 77.

[3] *Ibid.* for 1890–91, p. 89.

[4] Prof. T. Andrews "On the composition of an inflammable gas issuing from below the Silt-bed of Belfast." *Proc. Belfast Nat. Hist. and Phil. Soc.* for 1873–74, pp. 93-94.

a wet clayey soil on which rushes abound. In most sections it can be seen to consist of two layers—an upper, 5 to 10 feet thick in which the matrix and stones are almost exclusively composed of basalt, and a lower, with a large proportion of chalk as well as basalt. The upper band also contains a few flints and other far-travelled stones. It is generally more loamy than the lower band. This lower boulder-clay is a stiff red clay with well glaciated stones, and a matrix which is generally calcareous, but becomes more markedly so in the neighbourhood of chalk pebbles. One or other of these bands may, however, be absent, and the line of junction, though generally sharp, is sometimes ill-defined, owing to the admixture of the lower clay with the upper. The chalky boulder-clay was not in any case seen to overlie the basaltic clay.

The boulder-clay stretches well up on to the higher hills, and is well defined at a height of 1,000 feet on Collinward Hill, 1,020 feet between Wolf Hill and M'Ilwhans Hill, and 1,100 feet on Divis Mountain, with traces considerably higher. On the outstanding hills of Budore and Carnaghliss it only attains a height of 650 to 700 feet. The boulder-clay slopes are characteristically smooth, there being a remarkable absence of drumlins. In the neighbourhood of Gibsonstown, however, there is a ridge of loamy morainic drift, somewhat resembling the upper boulder-clay.

The drift of this area contains numerous erratic blocks all from districts lying to the north. The following is a list, with localities in which similar rocks are found *in situ*, and from which they are most probably derived :—

Riebeckite rock, similar to that of Ailsa Craig, .	Abundant everywhere.
Vein quartz, and quartzite, from Cushendun, Cushendall, or Torr Head District.	Abundant everywhere.
Pebbly grit, from Torr Head or possibly Argyleshire,	Common everywhere.
Mica schist and other metamorphic rocks, from Torr Head District.	Common everywhere.
Eurite, from Cushendun, ...	Near Rushy Hill, in the townland of Ballymacward Upper.
Baked carboniferous shale, from Carrickmore, near Fair Head.	Near M'Ilwhans Hill.
Rhyolite, similar to that of Templepatrick, .	Near Lyles Hill.
Granophyre[1] probably from Arran, . . .	Near Gocraigs.

Marine shells are very rare in the boulder-clay of the Basalt Plateau, and were found only at two places on the extreme westerly margin of the map ; they consisted of :—

A broken valve of *Astarte sulcata*. A small unidentifiable fragment, showing the nacreous layer.	From a section cut by the Clady water in the drift-ridge in the neighbourhood of Gibsonstown, at a height of 460 feet.
A hinge of *Astarte sulcata*.	In chalky boulder-clay in a section on the Rushy Hill River, at a height of 760 feet.

[1] This rock has a general resemblance to the Mourne granite, for which it may have been mistaken in occasional records of "Mourne Granite" boulders from the Belfast district.

These are the most westerly points at which marine shells have been found in the boulder-clay. Mr. Joseph Wright had, however, in the year 1894, obtained marine organisms in washings from boulder-clay found at heights of 1,300 and 1,400 feet on Divis Mountain. These consisted of two fry of mollusca,—one of *Buccinum undatum* and the other doubtfully referable to *Littorina litoralis*, also a foraminifer, *Nonionina depressula*, and six ostracoda, too young to name with certainty. In another sample of boulder-clay examined by Mr. J. Wright, from Wolfhill, at 800 feet above the sea, three specimens of *Nonionina depressula* were found.[1]

River Sections.—The principal streams carrying the drainage of the district in the direction of Lough Neagh are the Ballymartin Water and its tributary, the Blackwater; the Clady Water and its tributary, the Back Burn; the Crumlin River; and some small tributaries of the Glenavy River, including the Rushyhill River. In the banks of this latter river, sections 8 to 10 feet deep are exposed, showing a compact red chalky boulder-clay from which the marine shells already mentioned were obtained.

The valley of the Crumlin River is interesting, as some very fine cliff sections are exposed, showing boulder-clay with beds of interstratified silt, some of which persist for a considerable distance. A typical section, 300 yards above Budore Bridge, is given below:—

	Feet.
Silt and sand with lenticles of boulder-clay, . . .	3
Boulder-clay, ...	8
Stratified clay, ...	½ to 1½
Boulder-clay, ...	4

The upper and lower boulder-clays can also be seen in a number of sections on this river, the following being typical sections:—

1. Close to the margin of the map.

	Feet.
Boulder-clay (mostly basaltic), ...	10
Stratified clay, ...	4
Chalky boulder-clay, ...	2

2. 300 yards below Budore Bridge.

	Feet.
Coarse basaltic boulder-clay, ...	7
Finer chalky boulder-clay, ...	1 to 2

The passage between these clays is gradual, the chalky boulder-clay being mixed up with the other in places.

Somewhat similar sections, in which two layers of boulder-clay can be seen, and which often show rude stratification and silty bands, occur along the banks of the Clady Water. These can be well seen both above and below Clady Bridge on the Old Crumlin Road.

About a mile below the point where the Antrim Road crosses the Clady Water two sections are to be seen showing horizontally-bedded coarse gravel, five feet thick, probably a Late-glacial flood-gravel, overlaying finely laminated clay, silt and sand, exposed in one place to a depth of nine feet without revealing the base.

[1] "The Occurrence of Boulder clay on Divis." *Proc. Belfast Nat. Field Club*, 1894-95, pp. 215-16.

Close to Black's Bridge on the Ballymartin Water fine sections 10 to 15 feet deep are visible in a tough red chalky boulder-clay.

Gravels.—The drift-covered slopes of the lower hills of the plateau and the drift-filled valleys which lie between them are irregularly strewn with gravel mounds. These cluster more thickly and attain a much greater size along the courses of the streams. Striking examples of this arrangement are presented by the valleys of the Clady Water and Back Burn, and of the Crumlin River. The mounds are often found lying in the angle between two confluent streams.

Glacial Lake in the Valley of the Clady Water.—The Clady Water, after its junction with the Back Burn, flows in a north-westerly direction through a wide valley flanked on both sides by high ground thinly and irregularly covered with drift. A depression in the south-westerly watershed of this valley occurs between Carnaghliss and Ballyhill. This is trenched at its lowest point by a steep-sided valley about thirty-five feet deep, which now only serves to carry off the drainage of a small bog in the Clady Water depression. It is cut in one place entirely in the solid rock, and is obviously a Glacial drainage-channel.[1]

In the Clady Water valley, just opposite this channel, is a large deposit of gravel having the characteristic flat-topped and steep-sided form of a lake delta. Its surface corresponds in level, to within a few feet, with the top of the sides of the drainage-channel. This striking coincidence leaves little doubt that the retreating ice-edge held up, in the valley of the Clady Water, a sheet of water which had its overflow between Carnaghliss and Ballyhill, and in which the delta was deposited by the Clady Water and the Back Burn.

About a mile lower down the stream the hills converge, and between Lyles Hill and Kilcross two barriers of rock stretching one from each side partially block the mouth of the valley. This blocking is further effected by a low ridge of rather loose (morainic) boulder-clay capped by gravel, which extends across the valley between these rock-barriers. Through this drift-ridge the stream has cut a gap of remarkable appearance. Above this barrier of rock and drift is a complicated area of gravel mounds, forming in places steep-sided linear ridges. The rock of the barrier is trenched through in two places, once on the north-east side of the stream and again on the north-west. The ridge-like character of the gravels, however, make it impossible to consider them as the shore deposits of a lake which was drained by either of these channels. It is more likely that they were laid down either as eskers or moraines by a lobe of the decaying ice-sheet when it projected further up the valley. Many of the ridges run in a north-east to south-west direction, that is across the valley. Now the direction

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[1] The following considerations have rendered this conclusion necessary :—

1. It is steep-sided and recent looking.
2. The stream flowing through it is an obvious misfit.
3. There is no permanent barrier, such a drift or rock, sufficient to hold in a lake at a height at which it would drain across the col before it was trenched.

of ice motion in the district is N.W. to S.E., and it is extremely probable that the front of the retreating ice would be perpendicular to this, and hence parallel to the transverse ridges. This would point to their being terminal moraines. The abundance of boulders on their surfaces seems also to point to this. As there would always be a certain amount of water in front of an ice-face retreating downhill along the course of a valley, as in the present instance, it is probable that such morainic material would become, in places, very well assorted. It is indeed probable that some of the ridges are moraines and others true eskers. It would be difficult, however, to separate them from one another.

The two Glacial-drainage gorges which trench through the rock-barrier are very different in character. That on the north-east side is a short gap cut through a narrow ridge. It is the higher, and therefore probably the first of the two to be cut. Its floor is marked 502 feet on the ordnance map; its intake was probably a little higher, say 510 feet. The other is a long winding channel. A point at the upper end of its floor is marked 484 feet, its intake was probably from 490—495 feet.

Post-Glacial Lake at Gibsonstown.—The drift-barrier which blocks the valley between these ridges of rock must, in Post-glacial times and before it was cut through by the stream, have caused a lake to form in the neighbourhood of Gibsonstown. Certain laminated clays exposed in the stream-banks just above the barrier may be the quiet-water deposits of this lake. In the sections where they are best seen, these laminated clays are overlain by five feet of horizontally-bedded gravel, having the general appearance of Late-glacial flood-gravels. They must, however, be of later date than the laminated clays, and were deposited by the stream after the barrier had been cut through. The laminated clays, however, seem to be indicated by the occurrence of black mud throwing out springs in the banks about 150 yards further down the stream than the limit of these gravels. Here they would be overlain by the Glacial gravels of the district, and it is quite possible that they may only be the basal portion of these gravels. Along the Back Burn, silts and laminated clays were observed in places occupying a position at the base of similar gravels.

The drainage channel between Carnaghliss and Ballyhill has its intake at a height of 527 feet. It retains its steep and straight character for at least a mile below the intake. There seems to have been no ice to check the torrent to the south-west of the ridge. This would be the case if the ice-edge were retreating towards the north-west, a direction which seems to be indicated by the striæ of the district and the north-easterly trend of the moraines in the Clady Water valley.

Dry Gaps.—A number of other drainage-channels were observed in the district surveyed. One of these at a height of about 600—650 feet, possibly higher, occurs about a mile to the south-east of Lyles Hill. It is a broad and shallow, but very decided, gap in the ridge which forms the easterly watershed of the Clady Water valley. The direction of flow in it was probably from east to west. It is now quite dry. A somewhat similar gap at a height of 650 feet occurs immediately to the north-east of Lyles Hill. If this latter is a Glacial drainage-channel it has an evident north-westerly direction of flow. There is some difficulty; however, in seeing its connection with the gaps just mentioned to the south-east.

The spur which stretches north-east from M'Ilwhans Hill to within half a mile of Black's Bridge is cut by three dry gaps, which evidently served in Glacial times to carry off water impounded by the ice in the upper portion of the valley of the Ballymartin River. The direction of flow, as indicated by the slope of their floors, is from south-east to north-west. There is also a small Glacial drainage-channel in the neighbourhood of Priest's Hill.

Glacial Striæ.—Only four glaciated surfaces were found in the portion of the basalt plateau now being described. These have not been previously recorded, and the striæ noted on the previous map on Divis Mountain and at Lyles Hill have evidently been obliterated by weathering. The striæ have all a N.W.—S.E. trend. Near Priest's Hill, however, there is one locality in which cross-striæ reading N. 45 E. occur in the shelter of a small knob of rock.

Boulder-clay Slopes below the Escarpment.—The hummocky ground formed by the Triassic marl immediately below the great escarpment soon gives place to a more even slope covered with boulder-clay. The boulder-clay forming this slope stretches from Carnmoney Hill (where foraminifera have been detected in the clay)[1] and Cave Hill eastward to the sea, and sweeps up the low ground between these hills to merge with the boulder-clay of the plateau. It has a matrix composed largely of the underlying marl, and contains large quantities of basalt and chalk, as well as quartz, red and white quartzite, grit and Ailsa Craig rock. In several places it was found to contain shell-fragments. In a section investigated by members of the Belfast Field Club, in a subway under the railway at Greenisland Station, where the boulder-clay is twenty-five feet thick, fragments of *Tellina, Astarte* and *Balanus* were found, along with bored stones of chalk and twenty-one species of foraminifera.[2] It sometimes merges insensibly into Keuper marl, still stratified but with embedded foreign boulders. It forms a stiff clayey soil on which rushes flourish, and retains this character even when overlying the sandstone in the cliffs. It has a very similar character in the neighbourhood of Wolf Hill and Divis. A thin stony wash accumulates here and there in hollows on its surface.

River-Gravels and Alluvium.—The rivers which traverse the country in a north-westerly direction from near the escarpment to Lough Neagh have for the most part cut rocky gorges in the upper portions of their courses, but lower down wind through more or less extensive alluvial flats. Of these the most northerly is the Ballymartin Water. From its head waters to a little north of Hyde Park this stream has evidently not hit off its pre-Glacial course, as in several places it has cut through the thin drift into the

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[1] See next reference, p. 120–21.

[2] Miss S. M. Thomson, *Proc. Belfast Nat. Field Club*, for 1893–94, pp. 116–17, ; the description also includes a list of erratics, among which were several Lias fossils.

rock, forming a steep-sided gorge. Next in order to the south-west comes the Clady Water. The valley of the Dandry Burn, a small tributary of the Crumlin River, opens at its head into that of the Clady Water in such a manner as to suggest that the latter originally flowed through it. Immediately below the junction of the valleys the Clady Water cuts into the rock, and a very small obstruction at this point would send the stream down the Dandry Burn. About a mile or two further down, the Clady Water receives as tributaries the Back Burn and another stream, and its alluvium below this point attains a width of from 100 to 300 yards. The river-gravels here and elsewhere can be divided into two divisions, passing into one another, but in general characterised as follows:—

1. A more recent series of terraces formed of a moderately coarse and fine gravel, from 2 to 3 feet thick, with from 2 to 4 feet of loamy alluvium on top (excepting, of course, where gravel is still being accumulated), and having their upper boundary always marked by a feature.
2. An older series of terraces of coarse bouldery gravel, about five feet in thickness, with two feet or less of alluvium on top, and having their upper boundary often unmarked by any feature.

Upon considering the mode of formation of these river-gravels by the continual removal of the gravel from the concave banks, and its deposition on the convex, it seems evident that the 5-feet gravels indicate a period of much greater rainfall than the immediate past. The fact of their often lacking an upper boundary and thus partaking in one particular of the character of Late-glacial flood-gravels indicates that they represent the first gravel terraces formed after the Glacial period.

The Crumlin River to the south-west of this has an alluvium from 50 and 150 yards wide. The head waters of the Rushyhill River, which rises in Brown Moss, also lie within the sheet.

The streams which flow from the escarpment in a south-easterly direction have cut deep gorges in the Triassic marl and in the overlying chalk and basalt. Where the stream leaves the hard basalt there is often a steep fall of twenty to forty feet. The sides of the gorges are often precipitous.

Peat.—The peat of the district has been almost entirely removed. Bogs of considerable extent and fair thickness appear to have formerly existed at Carnmoney, Lyles Hill, in the townlands of Ballymacward Upper (Brown Moss) and Tornagrough, and between Divis and Black Mountain. There is at present about five feet of peat on top of Divis.

W. B. W.

In the strip of country south of that above described, including the ground around Collin Glen and the eastern slopes of Black Hill, red marly boulder-clay spreads in a continuous sheet over the low ground and extends well up the lower slopes of the escarpment, where its upper limit is masked by slips and hillwash from the basaltic escarpment above. It forms smooth wet grassy slopes for the most part, but its surface becomes rather moundy below the landslips fringing the escarpment. The boulders in the clay are chiefly of chalk, flint and basalt, those of the last rock sometimes reaching a length of five feet. A few inches of laminated clay may be seen at the bottom of the boulder-clay in the stream-section just south of Rose Lodge.

Good sections of boulder-clay are not commonly seen in Collin Glen owing to the cover of vegetation and to numerous small slips; but below the point where the mill-race leaves the Glen, west of Glenville, about twenty feet of boulder-clay is exposed in a gully. Boulder-clay containing a good deal of chalk and some basalt rests on a brown boulder-clay containing a large number of basalt boulders. Near the base an irregular drawn-out lenticle of Triassic marl more than twenty-five feet long lies horizontally in the brown clay. Several boulders have been squeezed into it on its edges.

The boulder-clay is prolonged up the hill-slopes on both sides of Collin Glen. It covers a larger area on the north-east side of the Glen than on the south-west, where there is a considerable tract of basalt free from drift. The deposit becomes generally thinner and a gradual change takes place in its character as it is traced upwards on to the basalt plateau. From the state of red marly clay it passes into a yellowish, or reddish-brown, clay, which is sometimes pellety. This clay is derived almost entirely from the basalt, and the boulders which it contains are chiefly of basalt and flint. The riebeckite-eurite of Ailsa Craig was found at an altitude of 875 feet above O.D. line in a stream-section three-quarters of a mile east of Priests Hill. The red boulder-clay extends further up on to the basalt upland on the north-west side of the Glen than on the south-east. This unequal distribution is perhaps due to the presence of an inlier of Triassic marl a quarter of a mile above Tornaroy Bridge.

The stream flowing through the upper part of Hannahstown lies in a shallow bed cut into the basalt, until it reaches a point 200 yards below the road, where it plunges into a deep ravine having precipitous walls. Just at the head of the ravine a hollow filled with boulder-clay is seen in section. This drift-filled valley is of about the same depth as the gorge, and is doubtless its pre-Glacial upward continuation, whilst the shallow channel above is a post-Glacial course cut only three to four feet into the rock.

A quarter of a mile above Tornaroy Bridge an irregular grassy hillock consists of a fine gravel composed of basalt pebbles, with a small admixture of flints. In both banks of the river near the gravel mound a few feet of laminated clay is seen to rest on red boulder-clay, containing basalt, chalk, glauconitic chalk, and flint (some baked). The stream below this point cuts through a gorge in the basalt.

The streams are rapid, and the alluvium, where it occurs along their banks, is of coarse material. The stream-detritus in Collin Glen is for the most part a very coarse boulder-gravel, and the river does a considerable amount of damage to its banks when it is in flood.

H. B. M.

3. The Valley of the Lagan south of Belfast, with the bordering Hills.

The area included in this district extends across the valley of the Lagan from the west margin of the sheet, to Castlereagh and Clontonakelly, in Co. Down; and from Slievenacloy, Ballycollin, and Castlereagh, to the south margin. It includes the important town of Lisburn and the manufacturing villages of Dunmurry, Lambeg, and Hilden.

The drifts of this tract are of diversified character, their composition being largely dependent upon their topographical situation. They may be classified as in the accompanying table; but as the boulder-clay may be subdivided into some five different kinds, and the sands into two or three, while the solid formations include some five or six divisions, it will be seen that the district is one of great geological complexity.

Table of Superficial Deposits; and Exposed Rock and modified Local Detritus (areas in square miles).

County.	6-inch Map, Sheet	Boulder-clay.	Sands and Gravels.	Old River Gravels.	Recent Alluvium	Bog and Moory Ground.	Rock and Modified Detritus.	Totals.
Antrim, . .	64	12·43	3·14	·21	·73	·08	1·64	18·23
. .	65	·13	·07	—	·09	—	—	·29
. .	68	·32	·91	—	·13	—	—	1·36
Totals, . .		12·88	4·12	·21	·95	·08	1·64	19·88
Down, . .	8	·11	·69	·04	·14	—	—	·98
" . .	9	9·86	3·11	·26	·83	·04	3·7	17·8
" . .	14	·16	·30	—	·04	—	—	·5
" . .	15	1·75	·10	·03	·12	·06	·97	3·03
Totals, . .		11·88	4·20	·33	1·13	·10	4·67	22·31

Boulder-Clays.—This division of the drifts forms by far the most important in the district. It clothes a large portion of the sloping ground which rises from the banks of the Lagan, and the basalt plateau west of the escarpment; and it forms a partial and unevenly distributed covering upon the Silurian uplands eastward. The matrix of the deposit derives its character for the most part from the underlying rock; but exceptions to the rule exist, as will be pointed out.

Except where the basalt forms the crest of the escarpment along the Mullaghglass ridge, connecting White Mountain and Collin Hill, the plateau is covered with a reddish-brown boulder-clay, consisting almost wholly of weathered and disintegrated basalt. Rock fragments foreign to the locality commingle with those of basalt, in the deposit; and their occurrence, together with the glaciated appearance of many of the basalt boulders, is in accord with the origin attributed to the rock-covering—namely, one of glacial transport. Amongst the travelled fragments are those of flint, chalk, quartz, mica-schist, chloritic schist, granite and quartzite. Pebbles of Ailsa Craig rock also were found west of Mullaghglass ridge, and on the north slope of White Mountain.

Several well-formed drift mounds (drumlins) are noticeable west of the ridge mentioned; and of these, two are especially conspicuous near White Mountain; the others occur near Slievenacloy; and all lie with their longer axis trending W. 20 N. except in the case of one lying to the west of Groganstown gap, which trends due east and west.

Travelled fragments of chalk flint have been met with almost at the summit (1,081 feet) of Collin Hill, that is about 400 feet higher than the undulating ground west of Mullaghglass hill, and nearly 800 feet higher than the ground stretching away from the escarpment foot eastward. The fragments lie upon the local basaltic detritus devoid of clayey matrix, and indicate that but for the excessive erosion, which accompanied the melting of the ice sheet, and the more moderate ordinary denudation which since obtained, drifts would be much more widely spread than they now are.

Descending from the plateau, basaltic boulder-clay is found clothing the escarpment, almost concealing the outcrops of chalk, Greensand, and the uppermost beds of Triassic marl. In the vicinity of these outcrops chalk fragments are numerous, a circumstance which gives the boulder-clay, though of considerable thickness, in some sense a local character. Probably much of the material is rearranged. The basalt-derived clay continues downward to the foot of the escarpment, and thence outward over the Triassic outcrop, gradually changing to a variety in which the matrix contains much marl, while boulders of basalt abound, many of them being glaciated.

The deposit maintains the character just described, from Ballymacoss demesne north-eastward, by Milltown to Poleglass, and may be seen in a deep cutting on the railway, three-quarters of a mile north by east of Dunmurry. The matrix of the deposit here is quite calcareous to within about eighteen inches of the surface, and contains concretionary "race" in abundance as well as small fragments of purple marl, quartz, flints, etc., and very few of chalk. The only large stones observed were those of basalt. Exactly similar boulder-clay is to be seen at an abandoned brickfield a mile south-eastward of the last point, near Red Hill, where it dovetails with the Malone sands. The rarity of chalk fragments in the deposit, and the absence, so far as observed, of shells, are remarkable, seeing that red chalky boulder-clay, with shells, occurs east of the Lagan. Clay pits have been opened and are worked at the Model Brickworks near Balmoral Railway Station. The matrix of the deposit here is highly calcareous, and contains very few stones in certain parts of the pits; in other parts the clay is pebbly and contains some large boulders of basalt. The pebbles consist of basalt and chalk, with a few of other varieties.

A point worthy of notice is the manner in which the boulder-clay prevails south-east of Suffolk, as compared with the adjacent area in which sand prevails. The latter forms a reciprocal extension northward from Lisburn. The explanation which may here be offered, is that while the dammed waters in which, as will be seen, the sands were deposited, were gaining strength and encroaching upon the area north of Lisburn, submerging boulder-clay already deposited there, as is to be seen at Lambeg, ice-borne debris continued to move south-eastward through Collin gap, to mingle with ploughed-up marl, and form a glacial "fan" between Suffolk as apex, and Conway, Taughmonagh and Balmoral at the outskirts.

The boulder-clay at Lisburn is characteristically gravelly, in certain places difficult to distinguish from material which is obviously associated with, and for this reason is mapped as, gravelly sand. This arenaceous variety of the deposit may be seen at Lisburn New Road, facing Wallace Park on the west, near Bridge End on the Down side of the Lagan, and at Magheraleave cross-roads, about a mile north of Lisburn. The same kind of gravelly and sandy clay forms the undulating ground south of Ballymacoss demesne, that east of Ballylessan, and the Sheepwalk between Purdysburn and Knockbreckan.

Although the deposit just described is exceptionally poor in its clayey component, brick-making was attempted with it on Lisnagarvy Hill, immediately north of the Wallace Park, Lisburn; and at Bridge End. At the former place it is seen to contain some ice-scratched stones, numerous roundish pieces of grit, quartzite, flint, chalk, and other varieties. It forms drumlins near Lisburn and in Ballymacoss, some of which are especially conspicuous. They are disposed with their longer axes either east and west, or a few degrees to the south of west.

It will be remembered that the drumlins north-west of the escarpment, trend approximately east and west—neither closely corresponding[1] with the direction of the glacial striæ in Mullaghglass, nor with the lines of the present drainage. The same may be said of the drumlins in the valley, for the prevailing direction of striæ on the ground east of the valley is also south-easterly, and the main drainage is north-easterly, while the secondary drainage runs south-east and north-west.

At Milltown, near Malone, south of Belfast, occurs a red calcareous boulder-clay, with flint and chalk fragments and basalt boulders, accompanied by shells (*Astarte*, etc.). A similar shell-bearing clay was noticed at Harper's Bridge, one and a half miles east of Purdysburn (with *Turritella* and *Cyprina*). In the former place the boulder-clay passes under the Malone sands; and in the latter it is overlain by a red sandy boulder-clay, with partial stratification and gravelly layers. This latter clay is also to be seen along the stream towards Purdysburn, and is associated with warp clay, highly calcareous, at the sluice of the old mill pond near

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[1] The late Rev. M. H. Close many years ago pointed out the remarkable relation to be observed between the directions of ice-striæ, and the prevailing trends of drumlins throughout wide areas of Ireland. This relation involves, as an apparently necessary implication, the assumption that movement of the ice-sheet has been the disposing cause of the drumlins, as well as the cause of the glacial striæ. Why it should be so is not obvious; and there are instances, as in the Belfast area, where the assumption is negatived. The writer considers that the trend of the drumlins in this area must have been determined by the courses taken by water flowing upon the surface of a melting ice-sheet—the drumlins representing the interfluvial portions of the sheet, which, on finally melting, left the contained boulder clay in the uneroded spaces. The very gravelly nature of the boulder-clays along the valley is suggestive, if not proof, of the circumstance that the material has undergone a degree of washing in the way mentioned, prior to deposition; and, conformably with the circumstance, it is not uncommon to observe that the uppermost layers in many drumlins is more sandy than their interior.
J.R.K

Charity Bridge. The boulder-clays to be seen at several points along the river banks, passing under the Malone sands, contain some chalk fragments, but have not yielded shells.

The deposit which partially covers the Silurian area, east of the Lagan valley, forming irregularly-shaped and promiscuously-placed drumlins, consists of red and brown boulder-clay, usually very stony, especially where it is shallow. The boulders and fragments are mostly of grit and slate derived from the rocks of the formation, many of the grit boulders being well striated. Basalt boulders and fragments are not numerous, though sufficiently so to preclude the assumption that they are derived wholly from local dykes. They have, no doubt, chiefly come from the basalt plateau to the north-west, a conclusion which is in accordance with, if not necessitated by, the circumstance that the prevailing direction of glacial striæ east of the Lagan as well as west of the escarpment is south-easterly. It is doubtful, however, if the boulders came by direct transport; both they, and the few chalk fragments met with on the Silurian uplands, may have otherwise reached their destination, as will appear later. The colour of this clay varies from red to brown, the former being mostly the colour of it along the brow and westward slopes of the high ground, and to be accounted for by an admixture of Triassic material or by the colouration of the originating Silurian rocks—especially the slate—by the Triassic rocks which once covered them. The representations of glacial striæ on the map show that the prevailing direction is N.N.W.—S.S.E., resulting, there can be no doubt, from a south-easterly ice-movement. The existence of such striæ north of White Mountain, proves that the ice sheet was continuous over the whole area, as has been assumed in this description. If the extent of the movement were such as to transport Antrim basalt wholesale across the valley, there would probably be a greater admixture of travelled rocks with the local Silurian material, than there is, along the brow of the high ground, and a large proportion of chalk and Triassic debris would also be found well into the County of Down. Instead of this there is practically no Triassic debris and very little of chalk or basalt to be observed in the area here under description, except what has been preserved in hollows as a lower boulder-clay, and the boulder-clays of the valley maintain a fairly local character. If we may assume the existence of a former drift covering over the Silurian ground, such as is represented in the lower boulder-clay now preserved in hollows, this would have furnished the necessary conditions for a boulder-clay of the present character, in which scanty foreign materials mingle with a preponderance of locally derived matter.

Reverting to the glacial striæ, it will be noticed that divergences from the south-easterly direction occur in this region, the most striking and persistent being those pointing east and west—*from* east to west according to the judgment of the writer. This direction accords with that of an ice-flow across Ulster pointed out upon the basis of numerous data collected by the writer from the Survey maps some years ago,[1] and is in accordance with the occurrence of foraminifera and other shells in the lower boulder-clays of the region—these presumably having been carried in over the land from the Irish Sea; and with the discovery of Riebeckite rock of Ailsa

[1] Paper by J. R. Kilroe. *Quart. Journ. Geol. Soc.*, Nov., 1888, p. 827.

Craig in many places inland.[1] That westerly striæ representing an ice-flow prior to the south-easterly, and at the same points where these are found, should have escaped erosion, seems strange; yet not more so than the supposition that westerly striæ could be formed concurrently with the others, without adequate cause for such diversion of movements as might account for the phenomena; for the currents indicated by the striæ are widely divergent in direction. It is, moreover, difficult to understand how a clay so different in character to that seen north of Dunmurry and at Red Hill, previously mentioned, could be deposited at Milltown and Harper's Bridge, unless by an ice-flow prior to the south-easterly flow which carried the former. The latter ice-movement placed an upper clay upon the lower, east of Purdysburn.

The clays associated with Malone and Lisburn sands, though in some cases true boulder-clays, are more distinctly connected with the period of melting than the clays previously described. They are products of thorough re-arrangement of ice-sheet contents, and consist for the most part of warp-clays frequently devoid of pebbly contents and usually contain little sand. They not infrequently alternate with and graduate into clays with a good proportion of fine sand, and these are often, when dry, with difficulty distinguishable from fine sand and silt. As forming part of the valley-series, the clays, as well as the sands, might easily be mistaken for post-glacial flood deposits; but that ice was still in the immediate vicinity is proved by the intercalation in the sands of boulder-clay layers, one of the best instances of which has been observed at Sandymount, near Lambeg, where the clay covers more than twenty-five feet in thickness of fine red sand, and is covered with about three feet of the same. That thick ice was still in the region is rendered further obvious by the sand-and-clay-series having been deposited in waters of a lake temporarily dammed along the sea-board—most probably by ice; as well as by the frequent occurrence of erratics upon the sands, to be referred to presently.

Glacial Sands.—The important development which this member of the drift-series presents, has already been alluded to. Entering the district from the south, at Lisburn, it spreads out on each side of the Lagan so as to cover an area of almost three miles in width, contracting to something over a mile near Milltown and Malone House. The deposit attains considerable thickness here and there in the central portions of its area near the river, being more than thirty feet in depth on the Co. Down side, opposite Lambeg, while towards the margin it thins out over, or mingles with, the boulder-clay. It is to be seen resting upon drumlins near Lambeg, forming quite a thin covering near the summit of one, and occasionally presents a shingly base, as is to be seen on the private road at the rear of Conway House, and at Shaw's Bridge near Malone. It has previously been stated that boulder-clay is associated with the sands, as in the instance at Sandymount. Other instances are seen in patches of boulder-clay which rest upon the sands between Derryaghy and Manor Court. The deposit consists of fine red sand

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[1] In addition to the discovery of such pebbles mentioned elsewhere in the memoir, it may be added that the writer found some in boulder-clay at Brookmount and in gravel at Maze, both places west of this sheet; and some have been found further inland still.

occasionally graduating into and containing layers of gravel. This may be seen at Sandymount, where a good section some twenty-five feet in depth is laid open in a sand-pit, no gravel being seen; while, quite close by, an equally good section is exposed, showing stratified gravel and shingle with red sand. Between Edenderry and Milltown the sand contains a large proportion of gravel and some coarse shingle. South-west of Lisburn, however, there seems to be a considerable thickness of uniformly fine sand. Secondary drainage, entering the valley from its sides, played a large part in the formation of the deposits. Floods descending towards the low levels, while the ice-sheet in the valley was melting, and probably washing the exposed portions of the rock-slopes may account for sands and gravels occurring at such high levels as those at which they are now occasionally found. A curious fragmentary patch occurs at 360 feet above datum on the west side of the valley, one mile due north of Milltown, and two others near Ballylessan and in Ballycowan, south-west of Purdysburn, at about 250 feet, on the east side. The highest general level of the sands is about 180 to 190 feet on the west side and somewhat less than this on the east. It is therefore probable that the tributaries of the Lagan may account for the width attained by the deposit on the west side; and on the east side, the floods descending from the Silurian uplands, which left a gravelly and shingly deposit along the margin of the supposed lake, from Hillhall north-eastward to Newtonwbreda, accounts for the gravelly condition of, and the gravel layers in, the sands in certain places—especially near Edenderry, where important streams debouch on the present valley.

These streams have subsequently cut their way through terraces of sand, gravel, and shingle, a striking instance of which is to be seen in the steep river-banks at Purdysburn Asylum, some fifty feet above the stream. The shingle, gravel, and sand, are there seen to rest upon a considerable thickness of boulder-clay, which has also been cut through by the stream, exposing the underlying rock.

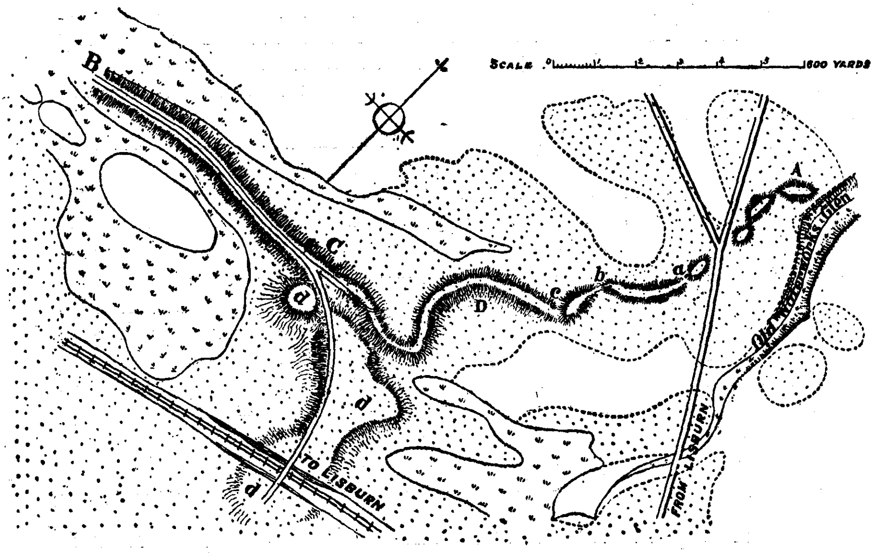
One of the strongest proofs that ice of considerable thickness existed in the neighbourhood until after the sands were deposited, is found in the presence of erratics scattered over the surface of the sands, chiefly on the east side of the Lagan. Some of these are of large size, and could only have been carried to their destinations by ice, which, in the form of bergs probably, floated in the hypothetical lake. The erratics consist almost in every case of basalt, and, accompanied by a few of Tardree trachyte, they point to an origin in the high grounds of Antrim, from which proceeded glaciers to fill the gaps in the escarpment, and shed the ice-bergs mentioned.

Confirmatory evidence for the presence of such masses of ice in the Glacial lake is found in the existence of several hollows or "kettle-holes" met with in the sands east of the Lagan, two or three at Andrewstown east of Edenderry House, and a striking instance in Kilroosty Lough, at Sandymount near Lambeg. This small lake has no visible outlet; it lies thirty to fifty feet below the level of the sands; and has an underground channel of discharge flowing northward, to empty in a spring near the Lagan. Its site could have been formed by the grounding of an iceberg upon the spot, and its remaining there while the sands were being deposited around it—to melt subsequently and leave its cast in the form of the present hollow.

Ballydrain Lake, east by south of Dunmurry, is probably another instance of this class of phenomena. The only visible channel leading from it is that by Wilmont House, which is usually dry, though it may have permitted of the escape of flood-water when the lake has been unusually high. It could not drain the lake; the ordinary drainage from it seems to pass off by an underground channel issuing in an important spring 300 yards distant, between Ballydrain House and the Lagan. This spring, by erosion of the sand, has formed a remarkable amphitheatre-shaped hollow some seventy or eighty feet in depth.

Eskers.—Amongst the most interesting traces of Glacial phenomena in this district are the ridges and irregular mounds of sand and gravel, which occur on each side of the Lagan; those on the west side are by far the most striking. One ridge is traceable from about half a mile north by east of Dunmurry, in a tortuous course, by that village, to Lisburn, adhering to the line of railway which cuts through it at some six or seven points. Another, which follows a curved, though less tortuous, course, from a mile south by west of Milltown (Antrim), to Redhill west of the sheet, as shown in the accompanying plan, Fig. 13.

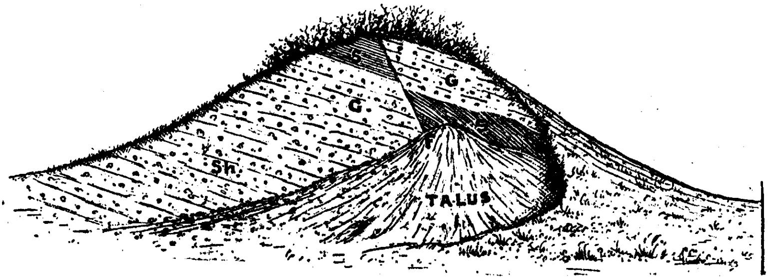
Fig. 13.—Plan of Esker north-west of Lisburn.



The esker has a curvilinear course from A. to B.; with nodes at *a*, *b*, *c*,; and deltas or fans of sand, more than 40 feet in thickness at *d*. A road known as Causeway End runs along the summit from B. to C. Alluvium indicated by wide-spaced markings, with continuous boundary-lines; sand and gravel by fine stippling, with broken boundary-lines; boulder-clay, blank.

The former has to a large extent been removed, to supply Belfast and suburbs with building sand; the original form of the latter is fairly well preserved, especially that portion of it which carries a roadway running westward, known as the Causeway End. When the ridges are intact they are steep-sided, and rise abruptly from the boulder-clay and alluvial ground on either side, and their internal structure, where best seen, presents alternating layers of sand, gravel and shingle, now regularly bedded, now false bedded, here, containing contorted seams of extremely fine sand or clay, there, small, almost unaccountable, dykes of sand, crossing some main layers, while merging with others—presenting, indeed, all the well-known characteristic features and structures of true eskers. Faulting is frequent, and to be well seen in the esker north-west of Lisburn, half a mile due west of Domville's Bridge. The faulting consists usually in a slipping away of the sides from the central axis, indicative of a settling down of the upper and outer portions of the mass after its formation. Such faulting is presented in the view here given, Fig. 14, a sketch taken at the point just referred to.

Fig. 14.—Section across esker in sandpit at Tonagh, N.W. of Lisburn (at D. of Plan, Fig. 13) showing Fault due to side-slipping.



S.—Sand. G.—Gravel. Sh.—Shingle. F.—Fault.

This will be seen to bear out the hypothesis that eskers represent ancient river-gravels and sands, accumulated along cañons gouged in ice-sheets by glacial streams—settling and side-slipping of the materials taking place upon the melting and disappearance of the retaining walls of ice.

Tracing the history of the eskers from this well-established standpoint, we find confirmation of the hypothesis in a tributary esker, joining the main course, in the valley opposite Lambeg, and in incipient eskers in the form of mounds of sand, gravel, and shingle, which rest upon the west side of the boulder-clay bank, east of Dunmurry; and which seem to have been formed by water issuing from the great tongue of ice which almost crossed the Lagan valley from Collin Glen, as previously explained. In consonance with the same hypothesis, we perceive in the great mounds of sand heaped up between Hilden and Lisburn, the deltas of the eastern esker-river where it debouched upon the area then covered by the waters of the hypothetical lake. In the opinion of the writer, therefore, the river which formed this eastern esker flowed southward, and judging from the presence of red sandstone blocks in the esker-gravels, it would seem that the river cannot have flowed at a high level above the present ground, and may, in places, have actually touched hummocks of sandstone from which the blocks in the gravel have been detached. The only place, however, where the bottom of the esker is to be seen in good sectional view is in an artificial watercourse a little north of Dunmurry, and there esker-sand and gravel rest upon boulder-clay.

The data presented in the second esker, west of Lisburn, are of similar character, and large friable blocks of red and yellow sandstone occur amongst its components. East of Laurel Hill, beside the road leading to White Mountain, a remarkably coarse shingle-deposit occurs, associated with the esker, and it was seen to rest upon basaltic boulder-clay, in which no red sandstone blocks were seen. Following the course of the esker south-westward from the point last mentioned it presents a beautifully noded and tortuous outline for about half a mile. The contents are observed to undergo a change, in the more rounded shapes taken by the larger stones; and the sandstone blocks, above referred to, become at Causeway End much more rounded and smaller, showing the effects of longer attrition. The westerly course of the esker-river is indicated by the conditions at Red Hill, where the esker, at what we must regard as its *termination*, contains no shingle and very little gravel. The hills at that point consist apparently almost wholly of red sand. The highest point at Red Hill, moreover, is about 185 or 190 above datum, while, at the north-eastern end, the esker is traceable to a point about 250 feet above datum; even at a point east of Laurel Hill its summit is 227, that is, some forty feet higher than the summit of the sand mounds at Red Hill. There is, moreover, no source from which the sandstone blocks could be derived at so high a level as 200 feet above datum, west of Red Hill.

The writer considers that Red Hill represents the delta of the esker-river where it entered the lake, at one stage of melting of the ice-sheet. As melting proceeded, the barrier between the river and lake became weakened, and reached the stage where it gave way. This stage was marked by a new delta being formed at Causeway End, where the railway now cuts through a great mound of red sand, more than forty feet deep.

Almost at the west margin of the sheet, esker-sand and gravel is to be seen resting upon boulder-clay, but as this may represent a portion of the ridge which may have slipped down laterally it cannot be regarded as affording conclusive proof that the esker-river bed here was boulder-clay, though it probably was.

In a gravel pit in the esker at Causeway End, a curious black deposit of oxide of iron and manganese was observed in a layer of shingle some thirty feet below the summit.

A small ridge, probably of esker-origin, occurs near the bank of the Lagan, half a mile south-west of Malone House, and about 80 to 100 feet above the river. It consists of red sand and gravel, and rests upon red clay.

On the east side of the river, mounds of sand and gravel, probably of esker origin, are to be met with in a few places. One remarkable group of such hillocks occurs at Ballyskeagh, where the Canal is cut through about fifty feet of sand.

East of Lisburn, half a mile north-east of Bridge-end, such a mound has almost entirely been removed for sand and gravel. It has presented a good section, which shows the usual characteristics of esker-gravels.

Post-Glacial Drainage.—With the disappearance of the ice-barrier in the region to the eastward, and the lake to which it had given rise, the present drainage regimen was introduced. The main stream—the Lagan—has since cut its way through the sands, warp-clays, and boulder-clays, down to the rock at some points, as at Lambeg. The secondary streams have also deeply trenched those deposits, cutting through the eskers in several places, usually reaching the rock at the higher valley-contours, and at a few points probably forming new channels. The depths to which these streams have cut their way is well exhibited at Purdysburn, as previously pointed out; and in another instance, which may here be mentioned, the stream flowing southward towards Lisburn has eroded a channel through the esker and the underlying boulder-clay. An instance of where one of the secondary streams has made a divergence through rock for a short distance, may be seen one mile east of Hillhall. The shingly and gravelly products of such erosion were distributed along the slopes of the Silurian high ground, prior to the recent drainage regimen, as already mentioned —erosion was then greatest, and the results of subsequent stream-erosion are perceived in old-river and recent alluvial deposits, to which reference will now be made.

Old-River Alluvium.—The most important area of this deposit is that at the exit from Collin Glen. At the Fortfield Bleaching Company's premises, the foundation of a new chimney-stack is reported to have been sunk through twenty feet of alluvial matter, sands, gravels, etc., without reaching a bottom. Hazel-nuts were found at the depth named, and trunks of timber, probably oak, were met with in sinking. The outlines of two stages of deposition, at least, are traceable, margining this important stream, besides those of the recent alluvium; and the deposit consists of shingle, gravel and sand, crowned with fine earth, and more or less humous soil.

On the opposite side of the valley similar deposits are to be met with. One of these, three-uarters of a mile north-east of Hillhall, is made up chiefly of Silurian grit gravel, and a deposit of similar character occurs at Drum Church, along the same stream, indicating that the mode and time of formation of both deposits, was probably identical. On both sides of Belvedere hill, similar gravelly deposits are to be found.

North of this point and nearer to the river, about Edenderry and New Grove, an old-river alluvium, though crossed by more recent deposits, may indicate a former loop of the Lagan, which has been abandoned for its present more direct course, though the feature might perhaps be otherwise explained as representing the action of the tributary streams at this point.

Opposite Messrs. Barbour's Mills at Hilden, four stages of alluvial deposition are distinctly to be observed; first, recent alluvium which stands about twelve feet higher than the present river-bed below the weir; then two stages of old-river alluvium, which are grouped together on the map, the higher of which is about three feet above the recent alluvium. Then, in the bank bounding this deposit, is to be observed a section showing a stratified peaty deposit with a greater or less proportion of grey sand. The top of this is at least ten feet higher than the previous old-river alluvium, so that, at the time of the formation of the oldest river-deposit, the bed of the Lagan was some twenty-five feet higher than its present bed; the water may have stood several feet higher still.

Recent Alluvium.—Deposits of this class do not attain any degree of importance in this area; the only instance in which they do not margin obviously originating streams, is that to the north-east of Moss Side near Dunmurry. Judging from the name Moss Side, the area may have been that of peat-bog; it seems more certainly to have been a marsh within very recent times. The alluvial matter is seen at the margins to rest upon clay—probably a warp-clay of the Glacial series, which at Moss Side is seen to protrude along a slope from beneath sand.

Peat.—In the southern portion of the sheet two small areas of peat occur, from which the peat has been almost entirely cut away. The areas are mapped to indicate the nature of the soil in those places, rather than because of any economic importance attaching to it as a fuel deposit, and both areas are marshy.

J. R. K.

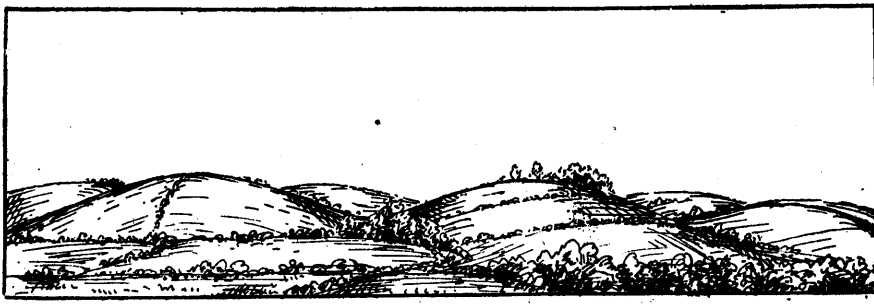
4. The Country between Belfast Lough and Strangford Lough, north of the Dundonald Valley.

Boulder-Clay.—Boulder-clay occupies all the low ground in the district, and is of considerable thickness in places. In the railway-cuttings between Marino and Helen's Bay stations sections showing up to twenty-five feet of drift are laid open. On the high ground, however, the drift becomes gradually thinner till it occurs only as sprinklings left amongst the hollows on the uneven rock surface. The drift continues round the western spur of Crons Hill with a varying thickness till it overlaps the southern slopes of the rock-ridge, and the ravines of the short streamlets running south from the hills have in places trenched deeply into the boulder-clay without the rock being reached. Thus, the small streams to the north of Stormont Castle show fifty feet of this drift, whilst the two flowing east and west of Ballyregan reveal fully eighty feet of boulder-clay. On the sloping ground south of Carrowreagh and Lieutenant Hill, at Killarn and Milecross, the clay is also of considerable thickness, being exposed to a depth of from ten to twenty feet by some of the streamlets.

Continuing eastward along the Dundonald valley towards Newtown Ards we find the hill-slopes everywhere thickly covered with boulder-clay, which extends also over the lower ground of Cronstown and Drumhirk.

On the north of the Crons Hill and Carngaver rock-ridge the clay appears to be thickly and fairly evenly spread over the gently undulating plain, except where the rock protrudes in hummocks of elongated shape. The same drift-material extends down to the sea-coast and eastward to Bangor, and beyond to the edge of the map, being well seen in the railway-cuttings between Bangor and Holywood. In many places it attains a considerable thickness, as, for example, on the coast between Craigdarragh Coastguard Station and Grey Point, where there are bluffs of boulder-clay from twenty to twenty-five feet thick; also at Helen's Bay, Carnalea, and Smelt Mill Bay, where it ranges from twenty to fifty feet in depth. In the Clandeboye district the clay covers the entire northern portion of the demesne. The lake there is artificial, having been formed by damming the small stream flowing north past Fonthill on the south side of the public road, so that all round the shore boulder-clay occurs without any of the usual alluvial deposits that are generally found margining natural sheets of water. The boulder-clay is very often deposited in the form of short 'drumlin' ridges, the longer axes of which are always arranged in the same direction as the glacial striæ. (See Fig. 15).

Fig. 15.—View of Drumlins of Boulder-clay, south of Craigavad Station.



In many instances these drumlins appear to be made up entirely of drift, without a rock-core, although other cases occur in which the rock does extend up through the hill as a core for some distance. An example of the latter mode of occurrence can be seen in the railway-cutting a little east of Carnalea Station, where the Ordovician slate-rock, though buried under a mound of drift, forms the centre of the hillock; and similar instances occur in other parts of the line. At Irish Hill, a little south-west of Helen's Bay Station, the rock appears to come close up to the surface, being covered by only a thin coating of stony clay. Drumlins of the boulder-clay are very prevalent in the districts of Ballydavey, Ballygilbert, Ballymullan, and Ballymoney, as well as in the country to the south of Bangor. They also occur in the country to the south-east, in the neighbourhood of Drumhirk. On the south side of the previously-mentioned rock-ridge the drumlin character of the drift is not so pronounced, although low mounding is evident on the sloping ground north and east of Stormont Castle.

On the hill-slopes west and south of Bangor Bay the clay is of considerable thickness, probably thirty feet or more. Sections of it are laid open in the two brickfields south-east and east of Bangor town. In the one to the south-east eight or nine feet of stiff red stony till overlies four feet or more of finely laminated warp. The pits east of Bangor and a little south of Ballyholme show ten to twelve feet of red till of the usual character, with lenticular layers of laminated warp six inches to one foot in thickness, and also close to and on both sides of the road beside the pit there occurs a deposit of very stiff brown clay, seen to a depth of six feet, which contains very few stones, and is well adapted for pottery and brick-making.

The sections of boulder-clay in the railway-cuttings in many instances show thin lenticular layers or wisps of gravel and sand. A little east of Marino Station the following drift-section was noticed:—red gravelly till with scratched stones, eight to nine feet; resting on red gravel and sand four to five feet; on red till with scratched boulders and stones six feet.

Again, half a mile north-east of Craigavad Station, on the west of the bridge over the railway, a band of brown sand three feet thick rests directly on the rock, and is covered by two feet of red gravel and sand, while the topmost bed is six feet of red boulder-clay. In the railway-cutting just south of Craigavad House fifteen to twenty feet of boulder-clay is seen, with narrow interbedded streaks of gravel and sand or of stratified clay, rarely more than one foot thick. So also in the cutting south of Rockport House there are sections showing twenty-five feet of boulder-clay resting on the glaciated rock-surface, and containing thin streaks of gravel, sand and warp, the warp at one place resting directly on the rock. Here the boulder-clay is brown in colour instead of the usual strong red tint.

The cutting south of Craigdarragh show fifteen to thirty feet of brown and red till, with irregular wisps and streaks of gravel, sand and warp. South of Crawfordsburn House the cuttings show ten to fifteen feet of brown (the lowest) and red till, with gravel and sand streaks, the whole resting on crushed Ordovician rocks. Continuing along the railway, the drift becomes thinner in the direction of Bangor, and the rock emerges free from it for a couple of hundred yards at a point a mile west of the town, and again at the railway sheds outside the town. The boulder-clay appears to occupy a deep hollow in the rock in and about Bangor, as excavations have been carried down for twenty to thirty feet without reaching the base of the clay. It also seems to be fairly thick in the vicinity of Ballyholme, where it mainly occurs in the moundy form. In composition the boulder-clay shows little variation in this district either in the character of its matrix or of the contained stones and boulders. Of the latter fully eighty to ninety per cent. are of Silurian grit and shale, next in order of abundance being basalt and chalk, with others of chalk flints, Old Red sandstone, Carboniferous sandstone, Trias, and Lias, and also a few of schist, porphyry and felstone resembling those that occur *in situ* in the north of County Antrim. There are also occasional examples of metamorphic and other rocks, which have probably been derived from Scotland, including the Ailsa Craig and Arran granophyres, and pebbly felspathic grits resembling those of south-western Scotland.

On the foreshore at Holywood the boulder-clay extends in places down to and below low-water mark, while in other places, where the 'solid' rocks rise above sea-level, it occurs in the cliffs as a thick covering to the older formations, as in the following section (Fig. 16) in the cliff a little north of Holywood, where the clay is seen resting on the broken-up Triassic sandstones, on the surface of which faint striæ were observed at one or two places.

Between this place and Cultra the sea has made great inroads upon the land within recent times, owing to the destructible character of the cliffs. Miss M. K. Andrews has shown, by the relative position of the site of an old quarry now covered to a depth of three feet by the sea at high-tide, that the loss of land at Cultra Point, a mile north-east of Holywood, during the last century was not less than 100 feet; and it is estimated that at Cooper's Bay, near Holywood, the sea has advanced more than 150 feet within living memory.[1]

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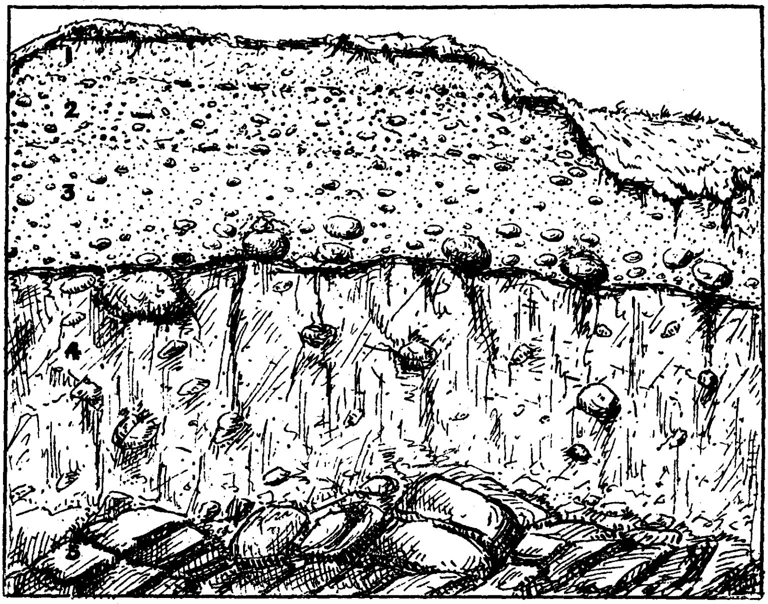
[1] Miss M. K. Andrews, "Denudation at Cultra, Co. Down," *Proc. Belfast Nat. Field Club*, for 1892–93, p. 529.

Glacial Striæ.—The numerous glacial striæ observed in the district, at the places indicated on the map, all denote a southward movement of the ice-sheet. These are particularly well seen in some of the railway cuttings between Craigavad and Bangor,

Fig. 16.—Cliff-section north of Holywood.



1. Modern surface, clay, ashes, bones, shells, &c., 1 foot to 2 feet.
2. Original stony and gravelly soil, 1½ feet.
3. Raised Beach gravel, 1½ feet to 2 feet.
4. Boulder-clay, 4½ feet.
5. Red Triassic sandstone.

and on the extensive rock-surfaces laid bare in the excavation for the Bangor Water-works reservoir near Conlig. In a glaciated surface on the high ground half a mile west of Bangor, in a field where the clay has recently been cleared off the rock, the direction of movement of the ice-sheet was remarkably well indicated by the presence of minute crag-and-tail on the rock-surface, as well as by the long and gradually deepening furrows which show the shallow beginning of the grove and its abrupt termination, where it became so deep that the stone which made it was rolled or forced up again into the ice.

Along the margin of the boulder-clay boundary on the northern crag-slope of Carngaver Hill, where fine striæ are common on the rock-surface, we find, along with the main striæ, a secondary scratching going south-west, as if the ice were diverted in part by the rock-bluff.

The glaciation and planing down of the rock-surfaces is also well seen at several places along the shore, especially in the vicinity of Bangor and Ballyholme Bay.

In the northern and western portions of the district the striæ swing round to a little west of south, but over the eastern area and on the high ground they are always nearly due south. The westerly deflection may indicate that the ice-sheet, in its lower portion at least, was diverted slightly from its main course by the rock-ridge of Carngaver. The upper part of the sheet, however, appears to have maintained a pretty constant and regular southerly movement over the ridge and down Strangford Lough.

Stratified Drift.—Masses of gravel and sand set in to the south-west of Holywood and skirt round by the high ground of Redburn and Ballymiscaw till they join up with the main gravels of the Dundonald valley, to be subsequently described (p. 111). In the low ground near Holywood, in the vicinity of the Military Barracks, the stratified drift takes the form of a fine red sand. At higher levels, however, and on the lower slopes of the ridge, along the marginal boundary of the deposit, the material becomes a coarse gravel with finer layers and lenticular beds of sand. Sections of this variety occur in the road cuttings near Barn End and in the stream a little to the south of it, also in the vicinity of Garnerville and in Kennel Burn to the south of Moat House. There are good sections in the stream just west of Killeen Cottage and in the two burns that flow south from the hills on both sides of Stormont Castle demesne. In the streams to the east and west of Dunlady House the gravels tail down in fan-like manner till they coalesce with the main deposits in the Dundonald valley. The northern margin of the gravels forms bays in the stream-valleys, as at Killeen Cottage and to the east and west of Dunlady, also in the vicinity of the Calico-printing Works north of Newtown Ards. A little N.N.W. of Killeen Cottage, in the stream, a good section shows five to eight feet of coarse gravel and sand resting on stiff red till, which is exposed to a depth of five feet.

To the east of Garnerville the gravel and till appear to graduate into each other, as the gravel is very clayey in texture. A hundred yards south of Garnerville, where the road branches eastward, there was a pit opened which showed eight feet of coarse gravel with sandy layers, the bottom of the pit being in red sand. Some of the stones in the gravel were six inches in diameter.

The gravel-pit 100 yards to the south of the above, mentioned by Du Noyer as containing shells, is now filled up and under tillage.

South of Milecross Lodge, at Killysuggan Graveyard, there are pits showing ten feet or more of coarse and fine gravel and sand, and 250 yards to the west a deep drain shows two feet of gravel resting on six feet of red till.

In the eastern part of the district the moundy gravels and sand that set in to the south of Bangor are of considerable extent, the northern portion of Bangor Castle demesne being mainly occupied by them, and many sections being laid open to view. Pits close to the road show thicknesses up to twelve feet of irregularly-bedded coarse and fine gravel and red sand, sometimes very clayey and with clay-layers. Again in the prolongation of the ridge southwards, a pit in the centre of the low ridge shows eight feet of similar material, but not quite so clayey. Detached spreads of the gravel occur in the low ground southwards, extending along what is evidently an old drainage-channel, although at the present time no streams flow through the flat, except in deep ditches made to drain the land.

Just north of Drumhirk there is a fair extent of gravel which forms low mounds on the higher ground bordering the old drainage-channel, in which a pit close to the road shows five feet of gravel and sand, and half a mile to the south-west another low mound shows three feet in a pit alongside the road. At Spring Hill, a mile south-west of Bangor, there is a small spread of gravel and sand about five feet thick, which rests on the rock from which the striæ have been rubbed off. On the south side of the road, in the car-track down to the quarry, the large stones in the gravel show glacial scratchings quite plainly. Near Conlig, on the south side of the Bangor Waterworks Reservoir, there is a small deposit of clayey gravel, 150 by 60 yards in extent, which is almost in contact with the rock, a very thin streak of gravelly clay separating them.

In Holywood Glen, just north of the Holywood Reservoir, there is a prominent ridge or mound of gravel which rests on boulder-clay. A pit at this place shows twenty-five feet of obliquely-laminated shingly gravel and sand, with clayey layers, greatly mixed with red clay towards the base. Immediately south-west of the Holywood 'Dry Gap' (see p. 53), a moundy patch of sandy and slaty gravel occurs, the deposit, 450 by 75 yards in extent, being elongated in a north-east and south-west direction.

Small patches of clayey gravel a foot or two in thickness, too small to be shown on the map, were noticed in a few places in the area included as solid rock.

In all cases the stones in the gravel-deposits correspond in character and relative abundance of the various kinds with those in the boulder-clay, and are usually well-rounded and water-worn. They may all be assigned to the agency of Glacial drainage.

Alluvium, etc.—None of the streams of the district are large enough to develop river-gravels sufficiently extensive to be shown on the map, though in a few places patches of coarse flood-gravel in the valleys have been included with the alluvium. The alluvial deposits are mainly confined to the eastern part of the district, along the low ground which sweeps round the rock-ridge between Bangor and Newtown Ards, and in the low-lying ground west of Clandeboy. In the former area they occur as a dirty gravelly wash, generally covered by loamy alluvial clay-washes. Along the small streams running north from "The Primacy" to Bangor the alluvium is continuous, though scanty, with a thickness of two or three feet. Similar deposits are found along the series of drains or tiny streamlets that flow north-east from Drumhirk past Six Roads, and from Drumhirk south-westward to Newtown Ards.

Along the courses of the streamlets and drains in the low lands to the west of Clandeboye the alluvium sometimes broadens out considerably, and shows in places a thickness of four feet or more. Where the two small streams join, half a mile west of Ballysallagh House, a low mound has been formed, in which there is a pit showing three and a half feet of dirty or clayey gravel and sand. The alluvium of the other streams in the district are of similar character, and do not require further description.

On the high ground a few small deposits of peaty alluvium occur, "Holywood Moss," one and a half miles to the south-east of Holywood, 500 by 250 yards in extent, being the most extensive.

Raised Beach.—The so-called "twenty-five foot" Raised Beach forms a distinct feature all round the coast. It is particularly well marked in the vicinity of Holywood, Marino, Cultra, Ardnalee, and between Craigdarragh Coastguard Station and Grey

Point, from whence it can be clearly traced by Crawfordsburn, Smelt Mill and Bangor Bays to the eastern margin of the map at Ballyholme. Sections are laid open in it at many points. On the Kinnegar gravel-ridge, which has been fully described by Mr. R. L. Praeger,[1] who obtained many species of shells from the sand at its base, numerous pits have been opened in the deposit. The tract of foreshore lying inside the Kinnegar has been intaken from the sea by a rampart running south from the extreme point of the ridge to the mainland, and is now used as a rifle range. In the trenches opened here and there over it, marine foreshore shells are abundant. This tract is shown on the Ordnance Survey map of 1839 as sea.

In some of the exposures along the coast, the old beach-material, usually only two or three feet in thickness, is seen to rest on the eroded surface of the boulder-clay, while in other places it rests on a sea-worn shelf of the solid rocks. In Ballyholme Bay the feature and gravels are very well marked. Here over the Raised Beach deposit a higher or "storm beach" accumulation of sand (probably in part blown-sand) with layers of well-rounded but flattish beach-shingle has been heaped up, in some cases to the altitude of thirty-seven feet above Ordnance datum, or at least twelve feet above the topmost layers of the ordinary Raised Beach. Good exposures of the "storm beach" occur on both sides of the Ballyholme stream and to the west of Folly Bridge.

The recent blown-sand which occurs over the Raised Beach along the shore at Helen's Bay and Crawfordsburn has almost obliterated the old cliff feature, and has also greatly obscured it at Ballyholme.

Submerged Land.—On the coast at Ballyholme Bay, a little west of where the Ballyholme stream enters the sea, and just above low tide mark, a small deposit of black peat six inches thick and about 200 yards in extent occurs. Underneath the peat-layer a few inches of blue-grey loamy and sandy marl is found, and beneath the marl a thin layer of loose shingly breccia, composed of re-arranged material from the boulder-clay, the peat having evidently been accumulated on a boulder-clay surface. Roots and stems of fir and other trees are found in the peat.[2]

A. McH.

5. The Dundonald Valley and the head of Strangford Lough.

The broad depression of the Dundonald valley runs eastwards from Neill's Hill to near Dundonald, where it divides into two. The main branch turns to the south-east, rounding the southern side of Scrabo Hill, and entering Strangford Lough below Comber; while the smaller branch, trending north-eastwards and then south-eastwards to Newton Ards, separates the dolerite-plateau of Scrabo from the Silurian hills on the north.

The main branch of this depression is occupied by the sluggish Comber River, which flows in an alluvial flat, generally broad, but contracted here and there, where gravel mounds occupy the floor of

[1] "Report on the Raised Beaches of the North-east of Ireland," *Proc. R. I. Academy*, 3rd ser., vol. iv. (1897) p. 34.

[2] *Mem. Geol. Survey*, Sheets 37, 38, 39, p. 43. See also R. Young "Some remarks on the recent changes of coast-level at Ballyholme Bay." *Proc. Belfast Nat. Hist. and Phil. Soc.*, 1871–72, pp. 39–41.

the valley. The present shed between the waters flowing into Strangford Lough and those flowing into Belfast Lough crosses the valley at the new Belfast Cemetery works, three-quarters of a mile west by south of Dundonald Church.. The alluvium of the Comber River, however, is prolonged across the watershed westward for half a mile, where the upper waters of the Knock River pass through an artificial cut in boulder-clay, which probably marks the watershed previous to draining operations. From this point westwards a reddish or yellowish-brown loamy sand forms a fairly uniform sheet continuous with the Malone sands, and extending up to the foot of the Silurian hills on the south. Boulder-clay appears below the sands in the bed of the stream near Knock Railway Station; and from the bridge east of the station to Thorn Hill a red boulder-clay with few stones overlies the sands. Boulder-clay probably overlies sand south of Belmont College. To the north of Thorn Hill and eastwards along the line of the Newton Ards Road the ground becomes moundy, the loamy sands of Knock being replaced by hillocks of sharp sand and gravel. In the pit 300 yards east of Thorn Hill one to five feet of fine-bedded gravel rests on an even surface of sharp red sand more than five feet thick. The section in the pit behind Castle Hill is obscure; only about six feet of coarsely-stratified boulder-gravel with a sandy matrix is to be seen. The boulders are commonly about six inches long, and amongst them were noticed basalt, flint, red jasper, Ailsa Craig eurite, and granite. Silurian rocks are less plentiful in the above pits than in those situated further to the east, but blocks of Triassic sandstone are not uncommon. The pit 200 yards east of Rose Park shows eight feet of fine gravel with sharp sand and very thin loamy bands. The section is arch-bedded and one or two beds of loamy sand are exposed near the base and sides of the pit. Current-bedding is present, but is not conspicuous owing to the uniform composition of the gravel. The pebbles are chiefly of Silurian rocks, mixed with a fair number of basalt. Flints are common, and andesite, porphyrite, granite, Ailsa Craig eurite, quartz, quartzite, and Triassic sandstone were noted.

The flat-bottomed hollows lying between Castle Hill and Summer Field are floored with boulder-clay which is partly covered by a foot or two of clayey alluvial wash sometimes containing a few stones.

Excavations made in connection with the new Belfast Cemetery prove that the conspicuous mound south of Summer Field is a drumlin of boulder-clay having gravel banked against its eastern side and extending as a thin and interrupted coating over its top. A trench cut alongside the railway exposed twenty-two feet of boulder-clay, of which the lowest five feet was of a purplish colour, and almost all the boulders in it were of Silurian rocks. The upper portion was of a redder colour and contained the usual assortment of stones, but there was no appearance of a sharp junction between the two kinds of clay. Excavations near the middle of the mound have shown about seventeen feet of boulder-clay, the upper five or six feet red and in places very stony, and the lower part purple and full of Silurian debris along with conspicuous fragments of chalk. In these sections the upper clay is seen to follow the contour of the hill. Trenches cut at the north-western corner of the hill revealed gravel resting on a fine sand or loam of an orange colour, which in turn was seen to lie on boulder-clay. The loam died out up the slope and when traced westwards. The gravel also thinned out in the same manner, so that the boulder-clay came to the surface on the western slope of the hill.

The railway cuttings between this point and Knock Station are now overgrown, but the sections of boulder-clay and sand seen in them were described by MacAdam.[1] The cutting immediately east of the station appears to be in sand overlain by boulder-clay; the next one appears to be chiefly of boulder-clay, but with some sand; whilst the third is probably a drumlin of boulder-clay with gravel banked against its eastern end.

The large gravel-pit a quarter of a mile W.S.W. of Dundonald Church shows coarse and fine current-bedded gravel with sandy layers passing down into loamy and sharp sand with beds and streaks of fine gravel. The thickness seen is between thirty and thirty-five feet. The fine gravel was found to contain a few shell-crumbs, amongst which fragments of *Cardium edule* and the columella of a gasteropod were recognisable. Pebbles of Ailsa Craig eurite, as well as porphyrite and chalk, were noted in the gravel, which, however, consists largely of Silurian rocks, basalt, and flint (some of the red 'baked' kind). The larger boulders are generally placed near the top of the gravel, and include blocks of Triassic sandstone one foot in length. The bedding in a general way conforms to the slope of the hill, but shows a sagging down at what would otherwise be the top of the 'arch.' At Dundonald village the gravel mounds take on a south-easterly direction, and are prolonged down the valley to the east of Dundonald Railway Station, where they become broad nearly flat-topped mounds resting on the boulder-clay. In a disused gravel-pit south of Ballybeen House the gravel is composed very largely of Silurian rocks, and is usually cemented by pinkish calcareous matter. The other rocks noted were basalt, flint, mica-porphyrite, chalk, Triassic sandstone, granite (white), quartz, micaceous quartz-schist, and Ailsa Craig eurite.

From this mound a narrow steep-sided ridge of gravel runs in a south-easterly direction for half a mile, resting on and apparently crossing over the rather flat-topped mounds mentioned above. It is composed of well-rolled gravel, and has the appearance of an esker.

Northwards from Ballybeen House a line of gravel mounds extends up to Dunlady House. To the east and west gravel lies banked against the lower slopes of the Silurian hills and runs up into the mouths of the deep ravines which score their flanks. At the upper end of the drain between Bess Mount and Glebe House bedded gravel composed of Silurian rocks rests on tough red boulder-clay. Farther down towards the Newton Ards road the gravel occupies the whole section, and is not so coarse.

The lower parts of the alluvial tracts betwen Dundonald and Ballyoran consist of a grey or yellow clay, which is often stony. In their upper parts the material becomes sandy or even gravelly, and forms flat cones at the mouths of the ravines.

Gravel, partly heaped up in a low ridge, caps the hill half a mile west of Ballybeen House, and a few isolated patches of sand or gravel occur as far west as Rockfield.

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[1] "Observations on the neighbourhood of Belfast, with a description of the cuttings on the Belfast and County Down Railway," by James MacAdam. *Jour. Geol. Soc. Dublin*, vol. iv. (1851), p. 250.

In the Ballyoran quarry about twenty-five feet of rather sandy red boulder-clay not containing many stones rests on red Triassic sandstone. The boulder-clay is seen to be of a purplish colour near its base, and it contains one or two lenticles of red sand. At the western end gravel and sand four feet thick lie on and to some extent interdigitate with the boulder-clay.[1]

In the cutting north-west of Dundonald Railway Station gravel rests on the dolerite, and in the neighbouring quarry, where the dolerite is worked for paving setts, a bed of boulder-clay underlies the gravel at the western end. Four hundred yards to the south-east of the station, boulder-clay caps a small mound chiefly formed of sand.

Beyond Henryville the inner valley of the Comber River within the broad Dundonald depression becomes well-marked. The alluvium is flanked on either side by a gravel terrace banked against the boulder-clay slopes. The terraces point to the passage down the valley of a large stream of water, probably in late-glacial times. The edge of the ice for a time during its retreat may have stood across the valley at Henryville, whence a large body of water may have escaped down the valley. It is also possible that at a later period a considerable stream escaping across the col east of Knock from a lake held up in the Lagan valley flowed down this valley, but there are no marked gravel terraces above Henryville.

Sand extends up the floor of the small lateral valley at Solitude, and a thick deposit of the same material stretches up the sides of the tributary stream which flows down from Ballyrussell on the opposite side of the valley. A large sand-pit, on the farm near the point where this lateral valley enters the main one, exposes thirty feet of false-bedded sharp sand and fine gravel with partings of fine red and loamy sand. Shell-fragments are plentiful in this pit as compared with the other pits in the neighbourhood. *Turritella terebra* is the most abundant species. *Trophon clathratus* and var. *Gunneri*, *Astarte sulcata* and fragments of other bivalves were also obtained; and with longer search the list could no doubt be extended.

A covering of reddish boulder-clay of variable thickness spreads over the hills to the west, but throughout Ballyhanwood and beyond as far west as Braniel Hill there are no drumlins until the watershed on the south is reached. The Silurian grits and slates appear at the surface in many places, presenting the characteristic knobs of ice-worn rock.

A hundred yards east of the Ballyoran sandstone quarry, mentioned above, decomposing dolerite is seen in the road cutting, and in the fields to the north and to the south the soil is a brown clay derived from the rotten dolerite. In a drain at the west side of Rockfield demesne the boulder-clay is more than eighteen feet thick and of a bright red colour. Red sandstone is touched at several points in the bed of the streams on the west as far down as the bridge below the upper Corn Mills. Red boulder-clay is spread

[1] This section along with that of an adjacent quarry is described by Miss S. M. Thompson (Madame Christen) in *Proc. Belfast Nat. Field Club* for 1893–94, p. 119, who mentions that no shells were found in it and only one species of foraminifera—*Bolivia dilatata*, Rss. Among the boulders, the Ailsa Craig rock is recorded.

as a thick covering over the hill-slopes to the south-east, but eastwards on the higher ground occupied by the dolerite the boulder-clay is largely derived from that rock, and becomes brown in colour.

Throughout the townland of Ballymagreehan, and to the south and to the east as far as the escarpment of Scrabo Hill, the boulder-clay is formed into drumlins, one of which is cut into in the sandstone quarry at the road-fork above the word "Ballymagreehan" on the map.. The section shows about forty feet of red and purplish boulder-clay, containing large boulders near its base and resting on Triassic sandstone the upper surface of which is smoothed and striated from N. 25° W. to S. 25° E. The hollows between the drumlins are occupied by alluvium, and are often artificially drained. In one of these old marsh deposits the remains of an Irish elk was found about thirty years ago.[1]

An irregular ridge of dolerite stretches from Rockfield to Ballyalton. Though the knobs of rock are often distinctly ice-rounded, striæ were only found to be preserved at one locality, marked on the map. The grooves trended from N. 55° W. to S. 55° E.

To the north of this ridge, in the townland of Greengraves, drumlins of boulder-clay, with their intervening alluvial hollows, again appear. The boulder-clay is sometimes thin, as white Triassic sandstone is reached at the bottom of some of the deeper drains. North of the old Belfast and Newton Ards road the dolerite appears at the surface again, and behind the farmhouse west of the trigonometrical station "Δ 306" it was found to be striated from N. 35° W. to S. 35° E. From this point a belt of rocky ground marked by outcrops of dolerite curves round through Ballyrogan to the north-west shoulder of Scrabo Hill.

In the north-west corner of the sandstone quarry south-west of Ballycullen National School more than twelve feet of hard reddish-brown boulder-clay overlies the rock. It contains large boulders of Silurian rocks, Triassic sandstone, and dolerite, and numerous small pebbles, chiefly of Silurian and Triassic rocks. The dolerite boulders have sometimes decomposed, leaving patches of 'white trap' in the clay. The water issuing from the base of the sandstone in this quarry is carried off by a drainage tunnel under the dolerite.

The boulder-clay runs up the slopes of Scrabo Hill, but on the southern and western flanks its upper limit is hidden beneath the hill-wash and screes from the dolerite cliffs above. On the top of the hill, knobs of rock having ice-worn surfaces and covered by a scanty vegetation are separated by grassy hollows in which the brown clayey soil, largely derived from the decomposed dolerite, occasionally covers a little boulder-clay. The cutting in the road up to the Londonderry Monument shows six feet of yellow boulder-clay containing striated pebbles of Silurian rocks, and also Triassic sandstone and flint. A little further up, at the side of the track, striæ on the dolerite may be observed running from N. 55° W. to S. 55° E.

Thick red boulder-clay overlies the red sandstones in the railway cuttings east of Scrabo Hill, and extends over the hill-slopes to the

[1] "Guide to Belfast and the adjacent country," by Members of the Belfast Nat. Field Club; *Belfast*, 1874.

north-west. The red sandstone is occasionally seen in the stream-courses, and the presence of a red sandy soil in other places indicates that the boulder-clay is locally very thin. In the stream-sections 600 yards W.N.W. of the Bleach Works the red sandstone is overlain by twenty feet of red boulder-clay, which contains many pebbles of Silurian rocks, but very few of basalt. The lower part of the boulder-clay is intensely red, and contains large angular blocks of red sandstone.

The extensive flat at the head of Strangford Lough has over most of its area a thin clayey soil overlying fine sand. Below the sand there is an estuarine clay with shells, but no section in the clay was open at the time the ground was mapped.[1] The flat is bounded inland by a steep slope or cliff, which is continuous with that at the back of the Raised Beach along the shores of the Lough. Below Scrabo Hill a slight terrace of sand, and at Newton Ards a gravel slope, doubtlessly represent beach-deposits equivalent to the estuarine clay.

The town of Newton Ards, with the exception of the higher parts from the railway station down to East Street, and of the lowest part situated on the estuarine flat, is built on gravel, which extends in a thick sheet from the east end of the town westwards as far as the Bleach Works, to the north and to the south of which it becomes moundy. In a plantation on the north of the Belfast road a pit opened in one of these mounds reveals ten feet of shingly gravel resting on loamy sand more than four feet thick. The whole section is much disturbed and traversed by small faults.

The gravel-sheet runs up in tongues into the mouths of the valleys and appears to wrap round the base of three hillocks of boulder-clay which lie between the railway and the Bleach Works. Some small pits excavated in the gravel at the west end of the town show that it is well bedded, and composed of water-worn slivers of Silurian slate.

Numerous wells sunk to a depth of twelve to twenty feet into this gravel are scattered through Newton Ards, and at present afford the chief water-supply of the town.

At the east end of the town a pit in Queen Street exposes coarse pebbly gravel, four feet thick, resting on fine gravel, which consists of rounded flaky bits of slate. The line of junction between the two gravels is well-marked, and the lower band contains a sharp sand and is strongly current-bedded. A larger pit 100 yards to the west has much the same arrangement, but the materials are finer. Four to five feet of gravel, not so coarse as in the last pit, rests on fine gravel, sand and loam, in which the bedding generally dips to the south. In the upper gravel, pebbles of Ailsa Craig eurite up to seven inches long and several pebbles of porphyrite were noted.

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[1] In "A Report on the Estuarine Clays of the North-east of Ireland", *Proc. Roy. Irish Academy*, 3rd ser., vol. ii., (1892) p. 238, Mr. Praeger mentions that two samples of sandy clay, one obtained from about high-water mark near the sluice-gates on the Greyabbey-road and the other from the eastern shore of the Lough a mile below this place, were found to be rich "in small shells, some of which, like *Montacuta bidentata, M. ferruginosa, Cæcum glabrum, Jeffreysia opalina, Rissoa albella* have not been taken in a recent state in the lough; the last-named is present in the clay in the greatest abundance . . . . .. Foraminifera were not abundant." Forty-four species of shells are recorded from this clay by Mr. Praeger.

The lower gravel corresponds in character and in the height of its surface with the gravel-sheet to the west. The upper gravel, which contains a larger proportion of far-travelled rocks, forms a delta-shaped mass running up the valley to the north. Beyond its apex there are isolated gravel mounds, and it was most probably formed by water coming from this direction.

At the railway station purplish boulder-clay, over twenty feet thick and full of striated Silurian boulders, rests on red Triassic sandstone. In the next cutting to the east the boulder-clay rests on the Silurian slates.

The hills east of Newton Ards present the same features as the Silurian hills elsewhere. The boulder-clay is formed into drumlins, the axes of which commonly trend about N.E.—S.W. The intervening ground is occupied by bare rock and pockets of drift, or by rock with a thin covering of boulder-clay. Striæ were observed trending from N. 60° E. to S. 60° W. and from N. 60° E. to S. 50° W., directions approximately parallel to the axes of the drumlins. The boulder-clay is often of a bluer colour than that found further to the west, and the proportion of stones other than Silurian is very small.

The drainage is much obstructed, there being numerous hollows filled with alluvium or peat. The removal of the peat down to the water-level has, in the case of the large patch cut by the eastern margin of the map, revealed a gravel terrace passing downward and outward into sand and silt, over which the peat lies.

Nearer Strangford Lough the boulder-clay becomes purplish, and there is no marked orientation of the drumlins. The road along the shore of the Lough lies on the terrace of the Raised Beach, which is backed in most places by a very steep grassy bank, the foot of which is between twenty and twenty-five feet above O.D. line. The terrace is covered by a deposit of clean rolled gravel, one to three feet thick, which in several places is seen to rest on the boulder-clay, and in one place to lie on Triassic sandstone.

The bluff at the back of the terrace is composed of boulder-clay except for a stretch of half a mile south-east of the Lock House, where it is composed of gravel. The gravel extends for a short distance up the hill behind, and runs up into the mouth of a valley in the same manner as the Newton Ards gravel does. A section in a pit 600 yards south-east of the Lock House exposes coarse gravel passing down into finer gravel, six to nine feet thick, and resting on clean yellow sand with twisted reddish loamy bands. The sand is seen for about seven feet. The gravel is composed chiefly of Silurian rocks, but also contains basalt, flint, porphyrite, and granite.

H. B. M.

In the lower part of the Dundonald valley, north of Comber, stratified gravel, apparently of Glacial age, is extensively developed. This deposit forms a more or less level platform or upper floor to the boulder-clay depression in which it lies, and towards the north it shows a tendency to become moundy. The apparently moundy character of these valley-gravels just above Comber is due to the eroding action of the Comber River, which wanders in an irregular manner down the valley, leaving isolated patches of gravel surrounded by the later river-alluvium.

South of Comber the gravels form a delta-like fan on both sides of the river, but chiefly on the north, covering an area of some two square miles. This area is almost flat, and its continuity is broken only by some minor depressions filled with alluvium and some slight elevations of boulder-clay. In a nearly straight line from the point where the Newtown Ards road crosses the railway two of these isolated outcrops of boulder-clay occur, and might appear to constitute an upper boulder-clay in this district. A deep section at Haw Hill, however, shows that they are merely the tops of drumlins protruding up through the gravel-flat and of similar character to the rest of the boulder-clay of the district.

A section across the Comber valley shows that the gravel is banked up against rather steep-sided and continuous walls of boulder-clay forming the sides of the old valley.

Almost at the extreme south-east corner of the map there occurs another small area, similar to those already described and composed of stratified material, mainly gravel.

The Raised Beach on this side of Strangford Lough attains its maximum development on the coast-border two miles east of Comber. It consists of a low-lying tract of perfectly flat country, the inland boundary being a well-marked scarp some ten to fifteen feet high in places, carved out of the gravel fan already referred to, or of boulder-clay.

This Raised Beach is distinctly traceable along the shores of Strangford Lough southwards, but there rarely attains to anything more than a few yards in width on the average, with, however, a few unimportant exceptions, such as to the east and south-east of Ringneill Bridge. The same narrow strip of flat ground is also traceable round the islands of Strangford Lough.

The material composing the Raised Beach is usually a rather fine sand or gravel, both, comparatively speaking, devoid of shell-fragments as compared with the corresponding beaches around the Dublin area, this being accounted for probably by the land-locked nature of Strangford Lough. The following section is seen about 100 yards due south of Ringneill Quay adjoining the Causeway connecting Reagh Island to the mainland:—

	Ft. In.
Sand, ...	1 6
Gravel without shells, ...	3 0
Gravel with abundant shell fragments, *Ostrea*, *Littorina*, *Mytilus*, and *Patella*.	1 0
Gravel without shells, ...	1 6
Greyish black estuarine mud with remains of sea weed,	0 6
Red boulder clay, ...	at base

This is practically the only section in which shell-remains occurred in any quantity; the estuarine mud also is on a higher level than that now forming in the Lough, though possibly the Causeway has affected this deposit here, as similar ones have undoubtedly done in other localities, notably at Rough Island.

The raised-beach material rests on the red boulder-clay, and varies much in thickness; in fact in many cases boulder-clay is at the surface, and forms the feature which it has been necessary to map as "Raised Beach," though typical raised-beach material is practically absent. In some places the Raised Beach with a storm-beach piled on top has linked together what were originally separate islands or islets in Strangford Lough. The most typical example occurs on Reagh Island, just outside the limits of the present map. Here a saddle-shaped storm-beach has been piled up at the northern end of the island; and in some gravel pits in the neighbourhood and in the cultivated land adjoining large numbers of rude flint flakes and cores may be picked up.

The foreshore of Strangford Lough is composed of boulder-clay overlain by a thick deposit of estuarine alluvium or mud, locally termed sleech, of a dark grey colour. Around the islands this mud is not so thick as it is three or four miles due south of Newtown Ards, where it is accumulating so rapidly as to have submerged some of the islets of loose boulders in the neighbourhood of Rough Island, an effect largely brought about by the building of causeways to connect the islands with the mainland.

H. J. S.

6. The hilly ground south of the Dundonald Valley.

The ground south of the valley followed by the railway between Knock and Comber rises into an irregular series of low hills composed of Silurian and Ordovician slates, with numerous drumlins of boulder-clay which render the surface still more uneven. This character of country extends to the southern margin of the map for the whole distance betwen the Lagan valley at Lisburn and the shores of Strangford Lough near Ardmillan. The western portion of this district has been already described, and we shall now deal with the part which lies to the eastward of a north and south line drawn from Knock through Castlereagh to Monlough.

Boulder-Clay.—The chief drift deposit of this district is boulder-clay of a reddish-brown colour. It contains numerous glaciated erratics, mostly Silurian, but a few far-transported pebbles also occur, notably the Ailsa Craig riebeckite rock.

This boulder-clay is mainly developed in the northern portion of the district, occupying extensive areas and seldom broken through by rock-bosses. To the south, however, outcrops of Silurian rock are very abundant, and make known their presence even when thinly covered over with drift, by the marked ruggedness and unevenness of the surface, very different from the characteristic smooth and gently-rounded outlines of the areas covered by boulder-clay. Where well-developed, the boulder-clay forms elongated mounds or drumlins, and almost invariably forms the high ground, the rock, with few exceptions, occurring in the valleys and low ground. Generally speaking, the drumlins are most plentifully developed on the Silurian area, though not exclusively confined to it. Usually their longer axes run parallel with the direction of the ice-striæ in the neighbourhood.

Many of the drumlins are crowned by pre-historic "forts" of circular shape, and very frequently the farm-houses are placed in similar situations. In the latter instances deep wells have been sunk from sixty to ninety feet in places below the summit of the drumlin, and water is very generally obtained. The bottoms of these wells occasionally run below the level of the surrounding more or less flat ground from which the drumlins rise up, and even at the depths mentioned rock is seldom encountered. This seems to show that if the irregular surface of the Silurian rock-floor has contributed to the formation of the drumlins, the latter are not at any rate disposed symmetrically over cores of rock, as has indeed been already suggested by Mr. Traill in the Survey Memoir to accompany Sheet 49, page 22.

The stony contents of the boulder-clay are modified to some extent, but not very greatly, by the character of the underlying formation. In the district lying north-east of the Comber river a rather larger proportion of Triassic sandstone pebbles is noticeable, derived from the rock *in situ* a few miles further north. Again south and south-east of Castle Espie the characteristic red limestone of that locality is frequently met with, especially on the islands, where blocks up to a cubic foot are not uncommon.

These islands lying off the shore about Ardmillan are composed of the typical red boulder-clay in the form of drumlins. Occasionally the islands are composed of several drumlins joined together by a raised- or storm-beach, the drumlins of boulder-clay being each and all orientated in the same direction, parallel to the ice-striæ on the rocks close by. This structure is well shown on Reagh Island, which is just outside the limits of the one-inch map, and is also distinctly noticeable on several of the islands in the immediate vicinity.

Sands and Gravels.—During the retreat and melting of the ice-sheet and the consequent floods much of the englacial and sub-glacial material was washed down the chief drainage-valleys and deposited in the form of terrace- and mound-gravels.

The latter form of deposit occurs in the present area chiefly in the rough and rocky ground to the south-west, and is usually rudely stratified, containing beds of red sand and gravel, in which latter flat rounded pebbles of Silurian slates and grits are abundant. The valley gravels, which are principally developed at Ballyalloly Lough and to the south and east of that locality, are generally found at the mouths of minor depressions, and are always closely associated with rock-outcrops. They usually occur in more or less isolated patches running in a north-easterly direction. The stratified drift of the main valley drained by the Comber River has already been described.

At Castle Espie the small tract which has been shown on the map as "sand and gravel," is composed of unstratified loamy sand with pebbles arranged just as in a boulder-clay, and it is only the absence of a clayey matrix which differentiates this material from boulder-clay. It is rather hard, owing apparently to calcareous percolation, and occurs in fine sections surrounding the old limestone quarries, which are at present difficult of access in most places owing to the quarry holes being full of water. The lower part of the section is probably more clayey, as it was formerly worked for making bricks and pottery. A note in the previous Survey Memoir on this district states that Liassic fossils were formerly obtained from this drift-material. The presence of these transported Liassic fossils, including *Gryphæa incurva,* and *Cardinia ovalis,* is also mentioned in a description of the section by Miss S. M. Thompson,[1] who likewise records the occurrence of glacial shells, including *Astarte sulcata* and *Leda pernula,* along with twelve species of foraminifera. This sandy drift is of a bright red colour, and is probably made up largely, if not entirely, of Triassic sandstone debris from a more northern or north-western locality.

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[1] *Proc. Belfast Nat. Field Club* for 1893–94, p. 118.

The erratics found in the boulder-clay and gravels are similar, and are largely of local origin, namely, Silurian slates and grits, white vein-quartz, Triassic sandstone, and Castle Espie limestone, the two last in localities south of their outcrops. Stones of foreign origin are also numerous, chief amongst which are pebbles of basalt, dolerite, chalk, flint, schist, and gneiss. One far-travelled erratic is found all over the district, namely, the Ailsa Craig riebeckite rock, and one boulder of this rock was observed on the roadside half a mile due north of Lisleen which measured 17 by 11 by 9 inches. The locality is about 350 feet above sea-level, and the boulder appears to be the largest of its kind hitherto observed in the district. Very large erratics of basalt or dolerite occur a little to the northwest of Ballyhaft Cottage, resting on Triassic sandstone. One, known as the "Butterlump," measures approximately 14 by 11 by 6 feet. Another close by is some two cubic yards in bulk. Both have probably been derived from the Scrabo outcrop.

Glacial Striæ.—In the northern portion of the district, striæ running nearly north-and-south were observed. To the west of Comber in two localities east-and-west striæ were seen. To the south-east good striæ running south-east were observed, the boulder-clay drumlins in the first and last cases corresponding accurately in direction of elongation with the direction of the striæ. Whatever may have been the cause of the east-and-west striæ, which are not very numerous, the transport of boulders clearly prove a direction of ice movement from the north-west.

The *Post-Glacial deposits* of the hilly interior consist of alluvium and peat. The former is confined chiefly to the river-valleys and to some minor depressions in the inland district. In the latter localities its greyish colour is in marked contrast with the prevailing red colour of the boulder-clay. The chief deposits of alluvium occur along the Comber river; south-west of Ballyalloly Lough; and on the Gransha river in the neighbourhood of Gransha Mills.

A very limited amount of bog-land occurs in this district, and the peat has been for the most part cut away.

The results of post-glacial erosion is in this district very clearly shown in the case of the Gransha River, which in its tortuous course, flowing first south, then east, and then north, has cut for itself three or four deep channels or gorges in the solid rock before reaching the Comber River, of which it is a tributary. The three principal gorges are cut at Gransha Mills; near the road quarter of a mile south-west of Gransha Close; and at about one-third of a mile north-west of Barn Hill at the Corn and Flax Mills. The drainage-system of this region is complicated, and many small streamlets wander about among knobs of rock, often cutting deep gorges for themselves, as in the case of Gransha River.

H. J. S.

The country east and west of Ballygowan presents the same features as the above-described Silurian ground farther north. The boulder-clay forms smooth rounded mounds and ridges, generally between 50 and 100 feet high, lying on an irregular surface of the Silurian rocks, which in the low ground between the drumlins present an uneven surface studded with rock-knobs. Here the boulder-clay occurs in pockets tending to smooth over and level up the irregular rock-features. There is no fixed orientation of the axes of drumlins observable in this tract, but a N.N.W. to S.S.E. direction is not uncommon.

The outcrop of rock on the top or high up on the flanks of one or two of the ridges shows that at any rate some of them possess a core of solid rock.

The boulder-clay is a hard reddish-brown clay, in which the majority of the boulders have been derived from Silurian rocks. Other stones consisted of vein-quartz, basalt, flint, and (?) Arran granite. Locally, small pebbles of slate about half an inch long become very numerous, and give the boulder-clay a gravelly appearance. Striated rock-surfaces are exposed in the quarries two-thirds of a mile north-north-east of Ballygowan, and as might have been expected from the highly irregular nature of the surface, the striæ run in various directions. The scratches, however, on several surfaces, including both horizontal and vertical ones, trend from N. 20° W. to S. 20° E., and from the ragged south ends of the rock-knobs it is evident that the ice moved from N.N.W. to S.S.E.

Several depressions surrounded partly by drift and partly by rock are occupied by small loughs; and peaty and alluvial hollows, marking the site of former loughs, are dotted over the ground. The large bog two-thirds of a mile north-west of Ballygowan has a distinct gravel-terrace running along its western edge. As a rule all the peat that it is possible to cut has been artificially removed from the bogs.

H. B. M.

PART III.

CHAPTER VIII.—ECONOMIC GEOLOGY.

The following notes on the economic mineral products of the district, in so far as they relate to the 'solid' rocks, are compiled, with some additions, from previously-printed information. The notes on Water-supply, Soils, &c., are original.

Metalliferous Ores.

No mines are at present being worked within the area of the map, but a lead-bearing lode was formerly mined on an extensive scale in the Silurian rocks at Conlig, 1½ miles N. of Newtown Ards. Trials have also been made in the "Interbasaltic Beds" at Lyles Hill, in the north-west corner of the map, for iron-ore and aluminous ore or 'bauxite' (see Fig. 3, p. 40); but as previously mentioned the Ballypalady workings, from which a large quantity of iron-ore was extracted, lie a little beyond the northern margin of the map.

Conlig (or Whitespots) Lead-mines.—The following is the description of these mines given in a previous memoir[1] :—

"The lode which has been worked under this name . . . . has been proved to extend for the distance of over a mile in a general northerly direction; in its southern portion the lode runs N. 15° W. for about 500 yards, and then trends more to the N., having throughout the remainder of its course a bearing of about N. 3° W. This mine was abandoned in 1865, so that at the time the district was under examination, it was impossible from the state of the workings to make a personal inspection of the lode; the following details, however, were gleaned from persons who had either been engaged in the working of the mine, or were on the spot when the mining operations were being carried out.

"From their account it would appear that the lode hades to the west at the rate of about one foot ten inches in the fathom, and coincides along its entire length with a dyke of dark-green diorite [dolerite ?], usually appearing along its walls, while the gangue of the lode is a fine angular breccia of Silurian rock, in a pale-gray felspathic matrix, through which there are strings of heavy spar, containing crystals of galena and minute quantities of copper pyrites, and peacock ore; some of these lead-bearing veins attaining a thickness of about ten feet."

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[1] *Mem. Geol. Survey* on Sheets 37, 38, and part of 29 (1871), p. 43

Mr. G. H. Kinahan ("*Economic Geology of Ireland,*" p. 16) refers to this mine as being on "a peculiar lode, a highly metalliferous whinstone dyke, so rich with lead that it could be profitably worked as an ore." Dr. S. Haughton also described the peculiarity of the lode,[1] referring particularly to "the asbestiform streaked appearance of the dark-green crystals forming the walls of the lode," and gave two analyses of this asbestiform mineral, from which he concluded that it had the composition of a hydrated aluminous hornblende.[2]

Judging from the material on the spoil-heaps, the dyke referred to in the above descriptions as forming part of the lode is one of the Tertiary basalt-dykes which are so prevalent in the district. The occasional association of metalliferous deposits with dyke-rocks of this period was noticed by the writer in surveying the Isle of Man,[3] and the conclusion was drawn that parts, if not the whole, of the valuable contents of such lodes must have been concentrated into their present position not earlier than the intrusion of the dykes—*i.e.*, during Tertiary times.

After lying idle since 1865 the mines were reopened and worked for a few years between 1881 and 1887, but are now again deserted.

Other smaller Lodes.—In the previous Memoir (on Sheet 37, &c., p. 23) mention is made of "a thin seam of galena" which was found on the coast at Swinely Point; and Griffith[4] and Kinahan[5] state that lead-ore has been found at Ballyleidy, near Crawfordsburn, in the same neighbourhood. It may be the same vein of galena which is referred to by Mr. J. Anderson as having been found at Carnalea.[6]

Iron-ores.—The presence of small quantities of iron-ore and of hematite-staining in fissures and joints of the slate-rocks in the coast sections is also noted in a previous memoir (on Sheet 37, &c.). The limited patch of iron-ore and 'bauxite' associated with the Interbasaltic Beds at Lyles Hill has already been referred to and needs no further description (p. 40).

Gypsum.

This mineral occurs rather plentifully in irregular veins and horizontal lenticles in the Keuper marls. In the brickyards on the western side of Belfast, where these marls are extensively dug, a limited quantity of this substance is raised, but remains as a waste-product on the spoil-banks.

[1] "Account of the Gangue of Conlig Lead Mine" (abstract); *Journ. Geol. Soc., Dublin,* vol. v. (1852), p. 203.

[2] Dr. Haughton's account, with these analyses, was reproduced in the "Memoir on Sheet 37, &c." p. 44.

[3] See *Mem. Geol. Survey,* "Geology of the Isle of Man," pp. 488-491.

[4] *Journ. Geol. Soc. Dublin,* vol. ix., p. 144.

[5] "Economic Geology," p. 16.

[6] *Proc. Belfast Nat. Hist. and Phil. Soc.* for 1871-72, p. 48.

Rock Salt.

Salt is not known to occur in the Keuper marls within the present map, though pseudomorphs of this mineral are abundant on the thin sandy bands interstratified with the marls. The well-known salt-mines of Duncrue, near Carrickfergus, where beds of rock-salt up to 39 feet in thickness are worked,[1] lies about four miles beyond the northern margin of the map.

Peat.

The places where peat occurs are mentioned in the foregoing local details in Part II. of this memoir. They are all of limited extent and unimportant, occurring principally on the high ground of the basaltic upland and in small boggy basins among the Silurian hills. In several tracts the peat has been almost entirely removed; where still available it is dug and used locally for fuel.

Building Materials, &c.[2]

Ordovician and Silurian.—The slate-rocks are used locally on a small scale for dry walling, and the intercalated grit-bands are quarried somewhat extensively in several parts of the district for road-material. At Ballygowan there are large quarries in dark fine-grained Silurian grits, which are dressed into paving setts, and are reported to answer this purpose satisfactorily. These setts are much used in Belfast.

Carboniferous Limestone.—The small patch of red (stained) Carboniferous limestone on the shore of Strangford Lough, at Castle Espie, was formerly quarried on a large scale for burning into lime, but the works have been in abeyance for some years past, and the quarries are now flooded (see p. 14). Some beds of this rock present a handsome appearance when polished, being of pleasant colour and dappled with markings, owing to the numerous fossils.

Permian.—It has been stated that Magnesian Limestone was obtained from the small outcrop on the shore at Cultra for use as a dressed stone in the old castle at Carrickfergus,[3] and also that the rock was at one time exported to Glasgow for the manufacture of sulphate of magnesia.[4] But the bed is so thin and occurs in so restricted an area (p. 16-18), that it seems impossible that much stone can have been removed.

Triassic Sandstone.—The material most extensively worked for building-stone within the limits of the map is the red and

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[1] See *Mem. Geol. Survey* on Sheets 21, 28 & 29, p. 10.
[2] On this subject, Mr. W. Gray's paper on "The Building Stones of Belfast and the Counties adjoining" (*The Irish Builder*, vol. xi., 1869, pp. 99–102) will be found to contain much useful information. Though written over 30 years ago this article includes an account of most of the quarries still worked around Belfast. See also G. H. Kinahan's "Economic Geology of Ireland," pp. 171, 252. 468.
[3] W. Gray, *op. cit.*
[4] G. H. Kinahan, "Economic Geology," p. 172.

white Triassic sandstone which underlies the dolerite of Scrabo Hill and the neighbourhood of Dundonald. These localities supply a useful "freestone," which at Scrabo Hill has been quarried on a large scale for a long period, so that nearly the whole of the eastern face of the hill is scarped by the workings (see Plate III., p. 20). The sandstone is variable in colour and quality, but when carefully selected gives good results and has been used in many of the larger buildings of Belfast and elsewhere, as well as for common domestic architecture in Newtown Ards and other places in the vicinity of the quarries. Owing to the heavy capping of decomposed dolerite, and to the manner in which the sandstone is cut by intrusive sills and dykes, as well as to its irregular bedding, there is a considerable proportion of waste in most of the workings, but blocks of large size and homogeneous structure are obtained from some of the massive beds, and the rock is comparatively soft and easily dressed. At present the sandstone quarries of Scrabo Hill alone are being worked, those near Dundonald having been abandoned.

Where the Triassic sandstones are seen at the surface on the western side of Belfast, they are too soft to be used as building-stone, and are dug in places for sand. The firmer texture of the sandstones of Scrabo Hill and Dundonald may possibly be due to the indurating effect of the doleritic intrusions (see p. 44). It has however been suggested, as mentioned on p. 20, that the Scrabo and Dundonald sandstones represent a higher horizon of the Triassic series than the softer beds of Belfast.

Triassic Marls.—The use of these marls for brick-making has already been noted (p. 21). Further details respecting this industry will be found in a subsequent paragraph.

Chalk.—This hard splintery white limestone was formerly quarried on a large scale in the escarpment under Cave Hill and brought down by tramway to Belfast for shipment; but these quarries are no longer worked. There are also extensive workings, some of which are still in operation, under Carnmoney Hill; at Whitewell; under Black Hill; in the slopes south of Collin Glen; and at other places along the escarpment, where the rock has been obtained for lime-burning and other purposes. It has occasionally been used as a building stone, but is difficult to dress and not very satisfactory.

Basalt.—Where hard and unweathered this rock affords an excellent road-material, and is utilised for this purpose throughout the district. It is also used for rubble-masonry, and is occasionally roughly squared and dressed. The intrusive dolerite at Dundonald has been quarried for shaped blocks and for paving setts.

On the upland, where the basalt is often deeply weathered, the decomposed rock is sometimes dug as a substitute for gravel, or where of a gritty texture, for sand.

Boulder Clay.—Bricks are the chief building material of Belfast, and these are almost all made locally from the glacial clays, from the Keuper marls, or from a mixture of both. The sections in several of these brickyards have been described in foregoing pages (pp. 67-73), and it will be unnecessary to repeat the details. The yards on the eastern side of the Lagan are worked entirely in the Glacial deposits, the material being partly boulder-clay and partly the stoneless stratified warp-clay (p. 72, 73). Boulder-clay is also worked, or has been worked, in several places between the Lagan and the Blackstaff; but in all the yards west of the Blackstaff, and also in those on the north and north-western side of Belfast, the Keuper marls afford most of the raw material. The larger yards are fitted with powerful machinery for mixing the clay and for moulding the bricks, which are generally burnt in 'continuous' kilns. The aggregate output is very large, and after supplying the requirements of the rapidly-expanding city, provides a heavy surplus for transport to other parts of Ireland, principally to the neighbouring towns in Ulster and to places on the east coast as far south as Dublin. The best red bricks are made from the Glacial clays; and in some of the yards large quantities of terra-cotta ornamental mouldings, tiles, chimney-pots, drain-pipes, &c., of excellent quality, are prepared from these clays. The Keuper marls produce a strong yellowish-red brick of less regular colour. The coal for burning the bricks is all imported.

When clayey ground is laid out for building-sites, rough bricks are also still occasionally made, on a small scale, by hand and burnt on the spot in 'stacks.' This process was in operation during the recent survey in the Ravenhill neighbourhood, and was at one time very general.

Brickyards are also worked in the Glacial clays at Bangor, Lisburn, and other places. The drift overlying the Carboniferous Limestone at Castle Espie was formerly utilised for the same purpose.

Sand and Gravel.—The Glacial sands ('Malone Sands,' see p. 50) on the south and east of Belfast have been dug on an extensive scale in numerous localities, particularly at Neill's Hill (Fig. 9, p. 75); Ballyhackamore; Annadale; Lagan vale; and in many places on the ridge between the Lagan and the Blackstaff. The material is used both as a moulding sand and for building purposes. Being of fine and somewhat loamy texture it is better adapted for the former purpose than for the latter.

The soft Triassic sandstone, from which the Glacial sands have been mainly derived, is of similar character, and has been dug for the same purposes in a few small excavations at its outcrop on the western side of the city.

In the Glacial gravels and sand of the moundy ground around Dundonald, and at the mouths of the valleys at Comber and Newtown Ards, many pits have been opened for local supply; and, indeed, wherever these deposits are shown on the map, especially in isolated patches, it will generally be found that they have been laid under contribution for building sand and for gravel.

The eskers of the Lisburn district have, in a similar manner, been largely excavated, the coarse material being broken up for roads and the finer serving for paths, &c.

House Sites, &c.

The position of the low-lying central portion of Belfast, including the principal streets and public buildings, on the soft estuarine clays (locally known as 'sleech'), and the consequent necessity for preparing foundations of wooden piles for the heavier buildings, have already been noticed.

The piles used are generally from 20 to 40 feet in length, according to the locality and the character of the intended superstructure. On these piles a foundation of concrete is spread, on which the building is erected.

Another difficulty caused by the low level of this part of the city is in the discharge of flood-waters in times of heavy rain. This difficulty arises mainly in regard to drainage of the Blackstaff depression, into which the flood-waters are sometimes carried by the rapid streams from the escarpment more swiftly than they can be discharged to the Lough by the impeded channel at Belfast, with the result that parts of the city contiguous to the stream-way are flooded to a depth of a foot or two above the roadways, to the great inconvenience and loss of the citizens.

A flood of this kind took place early in September, 1902, while the survey was in progress; and it was noticed that in the narrow part of the Blackstaff valley east of Broadway, the flood-waters spread exactly to the limit of the alluvial flat.

The thickly populated poorer parts of the city lie partly upon the margin of the low tract of estuarine clay and partly upon the contiguous slopes of stiff boulder-clay. Outside these are placed the residential suburbs, and it is noteworthy that either by accident or design these have tended to stretch out farthest along the sandy ground. The western suburbs are on boulder-clay thinly covering Keuper marl, but in this quarter the stiff retentive character of the subsoil is in some degree compensated by the greater elevation and good natural drainage.

The southern suburbs on both sides of the Lagan stand mainly on the 'Malone Sands,' above which however, here and there, small patches of boulder-clay occur. The eastern and north-eastern suburbs stretch out to Knock and towards Holywood on a platform of the same sands, again interspersed with some boulder clay.

Of the smaller towns, Lisburn is underlain partly by Glacial sand and gravel and partly by boulder-clay; and the same description will serve for Bangor and Comber, while Newtown Ards is mainly on gravel.

Water-supply.

The municipal water-supply of Belfast is obtained entirely from country outside the limits of the present map, though the service-reservoirs lie within the map, on the western outskirts of the city. The principal sources at present are from reservoirs at Stonyford, near the head of a westward-flowing stream on the Basaltic upland, and at Woodburn, on the slope of the escarpment eight miles north of Belfast; but works are approaching completion by which a more plenteous supply will be drawn from the valley of the Kilkeel river in the Mourne Mountains, forty miles distant from Belfast.

Large quantities of water are obtained for manufacturing purposes from the numerous private wells sunk into the Triassic sandstone, and this water is generally of excellent quality. The yield of the wells is variable, but cases are reported where it reaches 25,000 gallons per hour. The details of the sections in some of these wells, with notes as to yield and character of supply, will be found in Appendix II., p. 145.

The manufacture of ærated waters, for export as well as for home consumption, has become a local industry of great importance and is based largely on the suitability of the well-waters for this purpose.

It is somewhat remarkable that the numerous basaltic dykes by which the sandstone is traversed (see details of borings) should apparently have so little effect in impeding the passage of water through the rock. The varying depth at which the water-bearing sandstone is reached beneath the superficial deposits is illustrated by Fig. 12, p. 85.

The public supply for Lisburn is obtained from a reservoir on a small stream flowing from the basalt escarpment north-west of the town.

Bangor is supplied from a reservoir on the Silurian rocks near Conlig; Holywood, from a reservoir in the glen south of the town; and Helen's Bay, from a reservoir on the Silurian ground one mile S. of Clandeboye.

Along the escarpment the base of the Cretaceous rocks throws out many small springs, and the streams thus formed are utilised as they flow over the slopes of Triassic marl. In the Lagan valley, water for domestic purposes can generally be obtained from wells in the stratified Glacial drift; and throughout the district springs are freely given out where these beds are eroded down to the clayey base on which they usually rest. In the slate-country east of the Lagan the rubbly boulder-clay is frequently pervious, and a limited supply of water is often obtainable from the slaty rubble at its base.

G. W. L.

Agricultural Geology.

There is great diversity in the agricultural character of the land included within the map, owing in part to the wide range of variation in the soils and in an even greater degree to the wide differences in physical conformation and altitude.

In the subjoined "Notes on the Soils," Mr. J. R. Kilroe gives the results of his examination into the composition and properties of typical examples of the various kinds of soil which occur in the south-western part of the sheet, ranging from the basaltic upland across the Lagan valley to the Silurian hills on the east. These soils may be taken as representative for the corresponding districts in other parts of the map. As an introduction to these notes, a brief sketch of the agricultural characters of the whole area covered by the map may be found useful.

In the west, much of the high-lying hill-country along the border of the basaltic upland is uncultivated heathery moorland or partially reclaimed rough grazing-land; but as the ground gradually descends in the direction of Lough Neagh, the proportion of cultivated ground rapidly increases. The soil in this tract, where not derived directly from decomposed basalt, is formed from boulder-clay in which basalt is the preponderating component, with many patches of peaty land and clayey alluvial wash or stony rain-wash wherever the natural drainage is imperfect. It is noteworthy that while the decomposed basalt itself forms a friable loamy 'warm' soil, the boulder-clay derived from it (with a slight admixture of chalk and other extraneous material) usually makes a stiff retentive 'cold' soil which needs careful draining, the local detritus having apparently been kneaded and 'puddled' by the glaciation. The main crops in this tract are oats, barley, potatoes, turnips, and other roots, with a large proportion of rotation meadow and grazing land.

The long slopes leading up from the hollow of Belfast Lough and the Lagan valley to the foot of the chalk and basalt escarpment show nearly everywhere a stiff red clay-soil, either underlain directly by Triassic marl, or, more frequently, by a covering of boulder-clay derived from the marl. In spite of its high gradient, this land is often rushy and wet, and is mainly under grass.

Similar clay-lands extend also into the valley of the Lagan, but are here subordinate to the light well-drained sandy loams formed from the sands and gravels of the stratified drift-series.

As Mr. Kilroe points out, this warm easily-tilled valley-land, adjacent to a ready market for table-vegetables, is well adapted for market-gardening and largely utilized for the purpose.

Similar conditions prevail in the western part of the Dundonald valley. Between Dundonald and Comber the area of light land is more constricted, but on the other hand the boulder-clay becomes looser and less impervious through the admixture of slate and sandstone rubble. This kind of boulder-clay also extends in thick drumlins over the valley-slopes on both sides of the hollow, and spreads over all the lower part of the adjacent slate-country, obscuring the original rock-features.

Between the Dundonald valley and the northern coast, the altitude of the ground is in places sufficiently great to have some retarding effect upon agriculture, especially as the highest ground consists of the slaty Silurian rocks with very little drift; and there are some patches of waste land in this quarter. But except on these ridges, the ground is well cultivated, not only on the drumlins of boulder-clay but also in places where the soil is thin and rubbly and immediately underlain by slate-rock. Owing to the uneven character of the surface there are many wet hollows with alluvial wash, which require to be thoroughly drained before they can be tilled.

South of the Dundonald valley, although the physical features and geological conditions are the same, the average elevation is lower, and excepting in a few swampy hollows, there is no waste land. The soil is often thin and stony, but has been improved by the liberal application of refuse-manure, obtained cheaply from Belfast, and much enterprise is shown in agricultural methods. Along with the usual corn and root crops, parts of this area produce large quantities of green vegetables, not only for the supply of Belfast but also for export to England.

G. W. L.

Notes on the Soils of Lisburn District.

The many varieties of drifts, to which may be added those of local rock-detritus, in the area lying to the north and east of Lisburn, have been described in the foregoing portion of this memoir; and it is almost needless to say, such diversity of superficial covering gives rise to a corresponding diversity amongst the soils and subsoils. A table of areas is here given, drawn from the six-inch Survey maps, presenting, in somewhat greater detail than that given on p. 94, the areas occupied by the different kinds of deposits; and it may be necessary to say that the areas represented by "rock" on the published map, not only comprise small patches of drifts, as already stated, but, to a very large proportionate extent, the rocky portions are covered, besides, with local detritus, which is both capable of cultivation, and of carrying a coat of perennial herbage in all seasons except those of excessive drought.

TABLE of Areas (in acres) under Drifts, Rock and Local Detritus, and Peat :—

County.	Six-inch. Sheet	Boulder-clay.	Sands and Gravels.	Old Riv. Alluvium.	Recent Alluvium.	Rock and Loc. Det.	Moory and Peat.	Total Areas.	Remarks.
Antrim,	64	7,954	2,009	135	466	1,058	27	11,649	
" .	65	81	49	5	55	—	—	190	Corner of Malone.
" .	68	207	585	—	81	—	—	873	
Down, . .	8	71	442	27	89	—	—	629	S. E. corner.
" .	9	6,305	2,017	164	524	2,366	24	11,400	
" . .	14	105	188	—	27	—	—	320	Parts along north margins.
" . . .	15	1,120	63	16	78	623	40	1,940	
Totals. . .		15,843	5,353	347	1,320	4,047	91	27,001	

In describing the soils and subsoils in an economic point of view, the sources from which they have been derived, as judged by their stony contents, must necessarily come into view in estimating comparative fertility. Fertility is no doubt also dependent upon other circumstances, to be afterwards pointed out; but the comparative endowment of soils with the leading elements of plant food demands full consideration. It is acknowledged that soils derived from basic igneous rocks, such as basalt, possess a high degree of natural fertility, which Elie de Beaumont ascribed, and others now ascribe, to the presence of phosphates, probably also of lime. Soils of this character cover a large portion of this area. Besides these are some derived to a large extent from the Triassic marl, which in itself is rich in calcareous material; while others consist of *débris* of the Silurian grits and slates, which probably contain much potash, though in forms not easily soluble. A table of soils and subsoils has been prepared showing the chief stony contents of each sample. The samples, usually from one to two pounds in weight, were taken, with a 3-inch earth auger—with a boring-rod 1½ inches in diameter, where depths greater than 2 feet 6 inches required to be sampled; and the samples were treated in the manner afterwards described on p. 134. The fine matter is that which passed through a 2-millimetres round-holed sieve; and a ¼-inch square meshed sieve, long in use at Rothamsted, was used for the separation of stones from the gravel—those over ¼ inch admitting of easy determination. Stones larger than a walnut were rejected. In the cases of samples containing very few stones the presence and comparative abundance are represented by crosses—a percentage proportion in this case would be misleading and useless. The soils described are average samples throughout the depths stated in Column iv. The subsoil samples were taken at about the depths mentioned in the same column.

TABLE of Soils and Subsoils, showing their Localities, Nature, Depths, and the Petrological character of their contents:

ABBREVIATIONS:—S. = soil; Ss. = subsoil; c. = clay; s. = sand, sandy; g. = gravel, gravelly; st. = stony; l. = loamy; *c.* = coarse; *f.* = fine; *g.* = grey; *r.* = red; *b.* = brown; *l.* = light-coloured; *d.* = dark-coloured.

No.	Locality.	Description.	Depth of Sample (inches).	Percentages in Samples of: Fine matter.	Gravel.	Stones.	Presence, comparative abundance, and per cent. of different kinds of stones—weights in column VII., in each case, being 100: Basalt.	Chalk.	Flint and Quartz.	Grit and Sandstone.	Slate.	Other Kinds.
1	⅔ m. N by W. from △ 820 White Mountain.	*b.* tenacious S.	7	97·8	1	1·2	××	×	×	–	–	×
2		*r.b.* do. Ss	18	73	1·9	25	89	×	×	–	–	×
3	Aghalislone, ⅓ m. N.W. of Old Park,	stiff *b.* S.	7	90·9	1·5	7·5	81	×	15	–	–	×
4	Do., do., do., .	do. *r. b.* Ss.	15	93·3	1·1	5·6	××	–	×	–	–	×
5	300 yds. N. by E. of Beanstown, .	*r. b.* c. S.	10	88·8	4	7·2	80	×	6	–	–	×
6	Do., do., do., .	stiff *r. b* Ss.	15	919·	1·6	6·4	85	×	×	–	–	×
7	Beside road-cutting, Derryaghy, .	*r. b.* c. S.	10	93·8	1·9	4·3	77·3	–	×	×	–	–
8	Do., do., do., .	*r.* c. Ss.	18	93·7	·6	5·7	88·8	–	×	6	–	–
9	Magheraleve Cross-roads, . .	*r. b.* g. S.	9	–	–	–	–	–	–	–	–	–
10	Do., do., . .	*r.* s. g. Ss.	18	90·6	3·9	5·5	64	–	23	8	–	×
11	Ballymacoss, 1½ m. N.W. of Lisburn,	*r. b. g.* s. S.	9	81·4	4	14·6	93	×	×	×	×	×
12	Do., do., do., .	*r.* s. c. Ss.	18	76·1	8·7	15·2	93·6	×	×	×	×	×
13	Hill-top, N. side Lisburn Park, .	*b.* g. c. S.	9	86·3	3·3	10·4	50	–	××	43	×	×
14	Do., do., do., .	*r. b.* g. c. Ss.	18	87	3	10	92	×	3	2	×	×
15	Ballycarn hill-top, S. of New Grove,	*b. g.* st. l. S.	9	66·7	9·3	24	2	12	×	81	4	×
16	Do., do., do., .	*r. g.* c. Ss.	18	62·4	11·3	26·3	3·6	–	×	–	1·8	×
17	½ m. E. of Ballylessan, . . .	*b.* st. l. S.	8	66	6·7	27·3	29·2	–	×	59·3	7·1	×
18	Do., do., do., .	*l. b.* st. Ss.	18	74·2	4·6	21·2	3·7	–	2	92·1	1·8	–
19	Opposite Nat. School, Mealough, .	*b.* st. l. S.	9	70·2	5·6	24·2	–	–	×	95	3	×
20	Do., do., do., .	*r. b.* st. Ss.	20	79·9	5·9	14·2	–	–	×	92·1	6·7	–
21	S. of Reservoir (Belfast W. W.). .	*r.* st. c. Ss.	60	51	18·2	30·8	74·2	–	–	10·6	13·8	–
22	⅚ m. S. E. of Drumbo Village, .	d. r. st. c.	>72	61·4	12·8	25·7	–	×	×	80·7	19·3	×
23	Taughmonagh, ⅛ m. N. W. of Malone House.	*r.* c. Ss.	24	100	–	–	–	–	–	–	–	–
24	¼ m. W. by S. of New Grove, . .	*r. b.* s. c. S.	8	96	1·4	2·6	×	–	–	×	×	×
25	Do., do., do., .	*r.* c. Ss.	18	96·5	1·5	2	–	–	××	×	×	–
26	Esker near W. margin of Sheet, .	*r.* s. deep Ss.	–	–	–	–	72·5	5·8	10·5	3·4	1·2	6·4
27	Do., do., do., .	*r.* c. deeper.	–	81·7	4·5	13·8	94·8	×	3·8	×	×	×
28	Longstone. W. end of Lisburn, .	*d. b.* s. S.	12	92·8	3·6	3·6	×	–	×	×	–	×××*
29	Do., do., do., .	*r. b.* s. S.	24	94·5	2·5	2·9	×	–	×	×	–	××†
30	Castle Gardens, do., .	*r. b.* s. S.	18	88·2	4·9	6·8	40	×	6	24	×	×××‡
31	Do., do., do., .	*r.* s. Ss.	30	85	6·2	8·7	45	–	10	37·5	5	×
32	Sandymount, ⅓ m. E. of Lambeg, .	*b. r.* s. S.	11	100	–	–	–	–	–	–	–	–
33	Do., do., do., .	*r.* s. Ss.	24	100	–	–	–	–	–	–	–	–
34	Kilroosty, ¼ m. S. of last point, .	*r.* c. Ss.	36	88·9	1·8	9·2	84	–	4	6	6	–
35	Ballycarn hill-slope S. of New Grove.	*b. r.* s. S.	7	95·3	1·3	3·4	–	–	×	××	×	×
36	Do. do., do., .	*r.* s. Ss.	18	97	1	2	×	–	×	×	×	–
37	⅓ m. S. E. of Bridge End, . .	*g.* s. l. Ss.	18	100	–	–	–	–	–	–	–	–

* This sample contains 82 per cent. of cinders.
† " " 11 per cent. "
‡ " " 24 per cent. "

It will be perceived from the above table, especially by comparing it with that given in the memoir of the Dublin District of last year, that neither the boulder-clays nor the sands and gravels of the Belfast area stand in the same category as soil producers, with the limestone and granitic boulder-clays described in that memoir. The soils covering the plateau north-west of the escarpment and stretching along the escarpment-foot might be expected naturally to be endowed with phosphate and lime-yielding minerals. Basaltic detritus is, however, much slower in disintegrating and dissolving than that derived from limestone: the lime-silicates and phosphates contained in the soils, therefore, though ultimately so beneficial, do not readily meet the needs of vegetation. The Silurian rocks yield compound potassic silicates; with which, in consequence, the boulder-clays and soils covering the higher grounds east of the valley may be expected to be stocked. As in the case of basaltic detritus, however, the potash-bearing minerals yield slowly to solvents, so that soils after the Silurian rocks, are not richly endowed with available supplies of potash, and yield good crops only with "full manuring." They possess qualities which render them suitable to tillage, as will hereafter be shown. Of the sands and gravelly boulder-clays in the valley the same may be said; though in some cases basaltic gravels and boulder-clay, and marly layers in the sands, are to some extent present (see for example No. 34); and no doubt these contribute towards the fertility of the valley-soils. The marl and marly boulder-clays are decalcified to a depth of 18 inches or more, from the surface, but are so dense that capillary action is too feeble to minister much of the abundant store of carbonate of lime beneath, either as food to plants or as an ameliorative to the heavy retentive soil which forms the surface layer.

Having thus briefly reviewed the circumstances of these soils, as regards their chemical components, a detailed description of them will now be given from the point of view of texture, upon which their physical properties—so important as regards fertility—largely depends. It is indeed probable that differences of fertility amongst the soils of this area are better to be explained by diversity of physical conditions,[1] than by differences in degree and character of chemical endowment.

It does not fall within the province of a geological examination of soils to deal with their "condition" as technically known to agriculturists, which, dependent as it is upon methods

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[1] Professor Warington recognises the importance of this view of soils—"the overwhelming importance" as he writes ("Physical Properties of Soils," p. xiv)—which will be acknowledged in comparing soils equally endowed with available plant food. There is no doubt, however, that abundance of favourable chemical substances in soils is also a matter of considerable moment in determining comparative fertility. Hence, in many English Agricultural Colleges, and in the prosecution of soil research in France and Belgium, the chemical examination of soils takes a leading place; and nobody will question the extent of benefit which Ireland owes to its wide distribution of limestone detritus.

of treatment, and amounts of organic matter present, varies from farm to farm, perhaps from field to field of the same farm, and from year to year. Even a chemical estimation of the organic matter would scarcely give a correct view of *condition*. In this description, therefore, it must suffice to present the proportions in which gravel, sand, and fine earth intermingle, which, indeed, has long been recognized to form the basis of texture or physical condition.

The ordinary proportions of sand and clay in the different loams and clay soils, might suffice for general comparisons. For absolute comparisons, however, it would be necessary and alone scientific to grade the components after the manner practised, say, in the American Soil Bureau;[1] or after the somewhat less detailed plan adopted by Dr. Keilhack on the Prussian Survey.[2] In these methods much of the material denominated "clay" in Schübler's original plan for distinguishing agricultural sands, loams, clays, &c., is known to consist of silts, and very fine sand, rather than all of hydrated silicate of alumina, or *clay* in the true chemical sense. "Sand," too, is of different values in affording facility for percolation, according to the sizes of the particles; as are also the various mixtures of coarse and fine sands. Prof. Whitney has five grades of gravel and sand between 5 millimetres diameter and ·1 mm.; and three grades of silt from ·1 mm. to ·005 mm.; while under the term clay he arranges all particles below ·005 mm., the smallest being reckoned as ·0001 mm. in diameter. The separations of clay in this strict sense from silts, and even of silts from the sands, are extremely tedious processes; and however interesting and economically useful, would be impracticable in the limited time which ordinary Geological Survey work leaves for special soil investigation. The separations, therefore, which it has been found possible to achieve have been applied to the sands contained in the fine matter mentioned in Col. v. of the foregoing table, the percentages of four[3] grades from 2 mm. to ·1 mm. having been calculated; those grades below ·1 mm. diameter are necessarily grouped together. In order to achieve even so much, with so great a variety of soils and subsoils, an apparatus has been devised[4] combining the principle of Whitney's centrifugal method,[5] originally suggested by Hopkins,[6] with that proposed by

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[1] Report No. 64.

[2] *Einführung in das Verständniss der geologisch-agronomischen Specialkarten*, 1901, p. 27.

[3] A fifth grade between ·1 mm. and ·05 mm. was attempted, but for lack of time necessary for wet siftings it did not prove satisfactory.

[4] Described in detail by the writer in a paper read before the Royal Dublin Society, 19th January, 1904.

[5] Report 64, *Division of Soils, U.S. Agricultural Department*, pp. 174, *et. seq.*

[6] Bulletin 56, *Division of Chemistry, U.S. Agricultural Department*, 1898, p. 67.

Bennigsen[1] for rapid estimations by volumetric measurements. By means of the apparatus mentioned the sands and coarse silts are expeditiously separated from the finer silts and clays, after the samples have been prepared in the usual way by boiling and shaking, so as to loosen and detach clay particles from the larger grains in the mixture. Having obtained the sands thus freed and separated from clay and fine silts, and dried, they are easily graded by means of sieves. The results of the separations and gradings are set forth in the following table :—

TABLE showing Percentages of Sand of various grades in fine matter of previous Table, Samples correspondingly numbered in both Tables :—

No.	Sand.				Silt and Clay.	No.	Sand.				Silt and Clay.
	mm mm. 2—1.	mm. mm 1—·5.	mm. mm. ·5—·25.	mm. mm. ·25—·1.	Less than mm. ·1		mm. mm 2—1.	mm. mm. 1—·5.	mm. mm ·5—·25.	mm. mm. ·25—·1.	Less than mm. ·1
1	2·49	14·17	15·90	22·75	44·68	19	7·50	7·92	12·60	14·87	57·10
2	3·33	8·11	20·36	17·27	50·92	20	8·32	12·41	13·05	19·35	46·86
3	3·22	9·62	17·74	14·87	54·54	21	4·26	7·07	10·38	12·38	65·43
4	1·20	4·36	15·87	31·18	44·39	22	11·41	10·87	10·40	9·90	57·50
5	4·25	13·84	17·60	22·98	41·36	23	0·00	3·99	46·60	13·64	35·73
6	3·00	18·25	18·32	19·20	41·47	24	2·00	2·96	5·35	22·22	67·46
7	·74	4·88	15·34	29·32	50·69	25	·97	1·46	4·05	17·60	76·41
8	·90	7·88	13·49	19·85	57·84	27	4·60	7·56	8·60	17·55	61·65
9	2·54	3·68	12·20	21·46	60·11	28	3·03	5·54	22·40	31·72	37·31
10	2·98	6·72	14·82	31·46	44·74	29	2·08	4·22	18·98	44·76	29·98
11	4·10	13·25	17·82	20·22	44·60	30	5·18	8·20	15·67	18·60	52·35
12	10·14	14·75	13·27	20·00	41·83	31	10·85	15·25	25·05	17·90	30·95
13	6·51	12·92	19·07	11·77	49·71	32	1·90	2·30	29·00	36·25	30·60
14	6·58	4·85	7·66	15·32	65·58	33	·56	1·16	44·72	29·55	23·99
15	7·22	11·10	11·82	16·88	53·06	34	2·03	4·07	10·42	18·04	65·42
16	7·57	7·62	10·12	14·62	60·05	35	1·61	2·60	13·40	35·22	47·16
17	10·85	9·62	9·87	15·07	54·57	36	·57	1·62	9·40	38·45	49·95
18	6·58	11·06	13·87	13·55	54·92	37	·28	·99	16·70	52·44	29·77

Numbers 1 to 4.—The boulder-clay derived from the basalt covering the plateau, and to a large extent clothing the escarpment, consists of much weathered *débris*—clay with roundish stones and comparatively little coarse sand and gravel. It accordingly forms a retentive subsoil, and shallow clay soils. As a consequence, this land usually manifests much need of thorough drainage and liming. Where these necessities are attended to, the fair quality of the soils appears, though they are less suited to tillage than pasture. The usually beneficent character of basalt-derived soils is to be seen where only locally

[1] Principles and Practice of Agricultural Analysis, *Wiley: Soils*, vol. i., 1894, p. 195.

formed detritus covers the rock; for there the soils and subsoils are open and the percolation consequently free. For this reason the detrital patches along the escarpment, often no more than 12 to 18 inches in depth, are chosen for tillage, rather than the deeper clays.

The basaltic soils covering the escarpment in the vicinity of, and lower down than the chalk outcrop, show a measure of modification owing to natural irrigation with waters exuding from the limestone, and perhaps to an intermingling of limestone fragments with other materials of the boulder-clay. The soils covering the steeper slopes near the foot of the escarpment, are in certain places highly retentive, and seem to have been deposited as rain wash from the upper portion of the slopes. The very small proportion of stones and gravel in soil No. 1 is due to such a cause, and to a large proportion of decayed organic matter. The usual herbage borne by wet soils is here very prominent—coarse grasses and rushes, *Ranunculus*, *Pedicularis palustris*, &c., and little clover.

Nos. 5 to 8.—The band of boulder-clay stretching along the escarpment foot from Beanstown to Poleglass, covering the Triassic marl, and part of the Triassic sandstone, also yields retentive soils not very different from those covering the plateau. Marl mingles freely with basalt-derived detritus in the matrix, imparting a more distinctly reddish colour; but the marly component is almost totally decalcified, both in the soils and in the subsoils. At Derryaghy, however, the deeper subsoil shows the presence of calcareous matter.

The great spread of marly boulder-clay stretching from Collin Glen eastward towards Malone, yields remarkably retentive soils. The decalcification of this deposit has already been alluded to, as well as the non-effectiveness of the supply of calcareous matter in the subsoil on account of weak capillary action.

Nos. 9 to 18.—The gravelly clays occurring mostly in drumlins, along the middle of the valley, have already been described. They contain a considerable proportion of basalt pebbles, which not only contributes towards the fertility of these clays, but, with the finer gravel, produce a fair degree of percolation. To such causes the soils covering these boulder-clays owe a higher degree of natural fertility than belongs to other soils in this area. Exceptionally good land is to be seen near Conway House, which is probably to be attributed to the absorptive (and retentive) capacity of the soils for fertilizing substances, here liberally applied either directly, or through rich stuffs which are fed to grazing stock.

Nos. 19 to 22.—The soils covering the Silurian high grounds are characteristically stony loams. Possessed of a fine clayey matrix they retain available plant food well; containing a large proportion of small stones and gravel, they admit of being easily laboured, and afford the necessary conditions for free percolation; and the surface being strikingly uneven, it presents favourable circumstances for drainage, and in many cases for irrigation. Their natural deficiency in plant food has already been referred to; yet with generous treatment these soils form land of moderately good value, and may remain out under pasture for many years, as the areas lying to the east of Ballylessan shows, as well as that at Sheep Walk, near Ballydollagan.

Nos. 23 to 25.—A variety of soils clothes the areas mapped as clays along the valley; these clays are, on the one hand, distinguishable from the boulder-clays, the soils and subsoils of which are above described; and, on the other hand, either graduate into or contain seams of sand. The consequence of these latter features of the warp-clay deposits, is that the soils and subsoils may be either peculiarly strong retentive clay loams, or loams in which a good proportion of sand intermingles. The former class is exemplified in the pasture land west and south-east of Lambeg Church; while adjoining both, areas necessarily also mapped as clays show soils which are more or less sandy, and are under tillage. The large proportion of fine sand found in the red clay at Taughmonagh (No. 23), illustrates the character of the soil as well as the subsoil at that point; it is dry pasture land clothed with good grass and clover. The soil and subsoil of the clay band S.W. of New Grove (Nos. 24 and 25) contain a much smaller proportion of sand; and, in the herbage borne, *Ranunculus* is prevalent.

Nos. 26 to 37.—The Lisburn and Malone sands are admirably adapted to the early cultivation requisite to market gardening, being dry and warm, and easily tilled. Much of the sand area is consequently appropriated to this use, for the supply of Belfast markets. Needless to say, these sands require constant manuring, or to be kept in rotation cropping. It is surprising to what a depth organic matter descends, as judged by the dark brown colour imparted to the bright red sand of the subsoil. In certain places, as in some gardens at Lisburn, the original red colour is not discernible for a depth of 2 feet or 2 feet 6 inches, which illustrates how readily manure loses its strength in such soils.

Notwithstanding the usual liability of the sands to lose strength and vegetation, one sometimes notices that a good coat of grass is borne, especially in moist seasons, by some of the sandy soils, which have been years under pasture. This is easily accounted for where, as at Knockmore, in the south-western corner of the present sheet, the sand lies flat, and the water-table is no more than 2 feet 6 inches from the surface. Capillary action is strong in the fine sand of the locality; and rushes and other plants, indicative of wet soils, flourish in certain parts, where the water-table is but 2 feet downward. Near Kilroosty Lough, east of Hilden, another cause of abundant perennial herbage, even where the sands form hummocky ground, as at Sandymount, is suggested by the existence of layers of clay in the sand (compare Nos. 32 to 34, boulder-clay in this case). Such layers would intercept percolating waters and prevent or delay their disappearance downward.

The season of 1902 having been wet was particularly suited to the soils of the sand area. It is, no doubt, to this reason must be attributed the luxuriant growth of grass, which was borne by the loose shingly and gravelly deposit noticeable at the exit from the deep glen, immediately to the north of the Court, in Hillhall, and by similar gravelly deposits elsewhere bordering the Silurian high grounds north-eastward. At the point mentioned the layer of sandy vegetable mould, capping the gravel, is no more than two or three inches in thickness.

The alluvial soils of the area do not demand extended notice; sometimes they are gravelly, and even in parts shingly, particularly the older alluvial deposits along the tributary streams. The wider alluvial flats near the Lagan are sandy, bearing a good proportion of organic matter. The deposit east of Moss Side, though at its north-western end presenting a layer of clay over sand, and possibly laid down upon warp-clay, is for the most part sandy, particularly the subsoil (see No. 37). In the uppermost layer a large proportion of vegetable matter mingles with sand.

J. R. K.

APPENDIX I.

PETROLOGY AND MINERALOGY.

Petrographical Notes on the Igneous Rocks of the Belfast District.

The igneous rocks occurring in the Belfast district are chiefly of a basic type, usually *basalts* or *dolerites*. These basic rocks occur (*a*), in massive sheets constituting the Upper and Lower Tertiary lavas of the Antrim plateau; (*b*), as dykes intrusive in the sedimentary series of the district from Ordovician to Chalk, and again in the "lower basalts"; (*c*), in the form of massive sills in the Trias at Scrabo Hill; and (*d*), as a volcanic neck or plug at Carnmoney, and probably also in the recently observed mass breaking through the Ordovician rocks near Ballymoney, two miles east of Holywood (see p. 44).

Just outside the north-western limits of the map, a second type of igneous rock occurs, viz., the *rhyolite* of Templepatrick, which is regarded as intermediate in age between the periods of the Upper and the Lower basalts of Antrim[1].

The third and last type, which is of intermediate composition, is represented by only one dyke within the limits of the map, viz., that at the cross roads a little north-west of Tullynakill Church, 4½ miles E. by N. of Ballygowan. The rock belongs to the lamprophyre group, a type elsewhere (Ards Peninsula) abundantly developed. They occur typically as narrow dyke rocks intruded along the bedding planes of the uptilted Silurian sediments, and are only exceptionally seen crossing the strike of these rocks. Two types have been recognised up to the present, viz., *camptonites* and *kersantites*; such varieties also occur as *augite-camptonites* and *kersantites*, and others, such as *hornblende-kersantites* and *biotite-camptonites*. It is at present doubtful if true *vogesites* or *minettes* occur in Co. Down. A short account of these rocks was published in the "Summary of Progress" of the Geological Survey for 1899 (p. 181), and a more detailed account was prepared by the writer for the British Association Guide (1902) to the Belfast district, and was incorporated in the general description of the local geology published therein. The age of these dykes is believed to be Devonian.

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[1] A. M'Henry. "On the age of the Trachytic Rocks of Antrim." *Geol. Mag. dec.* iv. *Vol.* ii. (1895), p 260.

The Basic Rocks.

The 'Lower Basalt' type, as developed within the present area, is typically an amygdaloidal *olivine-basalt*, which occasionally becomes coarse enough in structure to be called an *olivine-dolerite*. It is usually devoid of that columnar structure so perfectly developed at the 'Giant's Causeway,' but on weathering down shows the characteristic spheroidal structure ('onion-structure') of basic rocks. The amygdaloidal character of the lower sheets, though characteristic, is occasionally absent or only sparingly developed, as, for instance, at the Black Quarry, Squire's Hill. In this quarry there are, or were, until recently, exposed in the basalt a number of cylindrical 'pipes' of some considerable length (over 12 feet), which traversed the basalt at several points. These 'pipes' were generally about 7 inches in diameter (one was 14 inches by 9 inches), ran in a straight or nearly straight line practically east and west, and dipped at various angles from 5° to 80°, and had numerous small branches penetrating the rock in various directions. They were hollow except for a lining of zeolitic material about ⅛ inch thick, the rock for a distance of some 3 inches around being altered to an earthy red colour and crowded with amygdales. Beyond this zone the rock was unaltered, and of the normal type of black compact basalt of the Antrim plateau. The two varieties shaded gradually into one another[1]. That these 'pipes' had acted as channels for the conveyance of heated waters carrying zeolites in solution was obvious, but their origin remained for a time a matter of doubt. The discovery however (by Mr. M'Lean, of Belfast, who first drew the writer's attention to the 'pipes'), at a subsequent period, of fossil wood, highly altered, in the basalt of the same quarry, suggests what is probably the true explanation, namely, that the pipes are the casts of trees overwhelmed by the lava and carried along in it in all kinds of positions. The side channels, observed running from the main 'pipe,' would on this hypothesis be the branches of the tree, whose trunk is now represented by the larger or main pipe.

This suggestion would help to explain the very different dips which were observed in the pipes, and which would probably not have been the case were they the result of a system of underground circulation. From the observed orientation of these 'fossil trees,' nearly east and west, and from the direction of the branch-channels, a flow of the basalt from west to east might be inferred for this locality; but without a knowledge of the contour of the buried chalk-floor, nothing very definite can be stated as to the focus or foci of the eruption.

The amygdales usually consist of zeolites, less often of chalcedony or of secondary calcite (replacing the zeolites), and not infrequently the mineral apophyllite,[2] rather nice crystals of which, of a pale water-blue colour, are fairly abundant in the area just mentioned. The zeolite present is most frequently

[1] *Irish Naturalist*, Oct., 1897. Proceedings Dublin Microscopical Club, p 277.
[2] See Mineral Index to district, p. 144.

chabazite; less often analcite occurs, and rarely stilbite and natrolite.

The following is a description of a microscopical slide of the rock forming the lower basalt sheets :—

[I. 880].[1] From lower basalt sheets near Carnmoney Hill. Under the microscope, the rock is seen to consist of a finely crystalline ground, composed of plagioclase and augite, with some scattered magnetite crystals rather oxidised, and with a little interstitial glass. The rock is porphyritic, the phenocrysts being olivine, occurring as more or less idiomorphic crystals a little over 1 m.m. in longer diameter. These are fairly fresh, but show signs of alteration on their edges and along the cracks which traverse the crystals. Rather small altered olivines are fairly abundant in the ground also. The phenocrysts usually occur in glomero-porphyritic groups. The plagioclase gives high symmetrical extinction angles, and is evidently labradorite; the augite is of the usual pale-coloured basaltic variety, and quite fresh, like the plagioclase. No ophitic structure is noticeable in the rock, which may be termed a *porphyritic olivine-basalt.*

The Upper Basalt is represented on the map only in one small area, at Lyles Hill, where it rests on a bed of lithomarge or bole, which separates it from the 'lower basalt.' Petrographically the rock belonging to this horizon is similar to that just described above, but the upper lavas are typically non-amygdaloidal, and frequently show a well-developed columnar structure.

THE DYKES AND SILLS.

These occur, rather numerously developed, all over the district, and particularly in the Trias. They have in general a N.W. and S.E. trend, though there are many exceptions; and they belong to two distinct periods of intrusion, probably contemporaneous with the upper and lower basalts of the plateau. A rude horizontal columnar structure is frequently noticeable in the vertical dykes, as in the Cave Hill quarry, where the effects of contact metamorphism on the chalk may also be observed. Not infrequently a tachylytic selvage is developed on the edge of the dyke where the material was chilled suddenly in contact with the surrounding cooler rocks and solidified as a glass. The dykes are usually basalts or dolerites with olivine, the latter mineral being occasionally rather plentifully developed, as at White House. The following description of two of these dykes may be taken as representative of their general characteristics :—

[I. 916.] Dyke in Bunter Sandstone, N.E. of Glen House, ½ m. N.W. of White Abbey, Co. Antrim.

A brownish grey finely crystalline rock, having a slightly altered appearance in the hand-specimen. In section, it consists mainly of fresh plagioclase laths, with a lesser amount of rather altered augite in the form of small crystals. The presence of olivine can only be inferred from the sparse occurrence of highly altered material with the outlines characteristic of that mineral. There is besides a considerable amount of interstitial matter representing altered glass, and also a number of round vesicles filled in with a similar substance and with secondary calcite. Ophitic structure is not conspicuously developed, but is just noticeable here and there. Secondary iron ores, derived from original magnetite, are also fairly abundant. This rock is an *altered olivine-basalt.*

[1] The number in square brackets is the Register Number of the slide in the Survey collection of sliced rocks at the Dublin Office.

[I. 1984.] Dyke near Ballyhaft Cottage, S.E. of Newtown-Ards. This is a fresh dark greenish-black rock, finely crystalline in texture. In section it is seen to be much coarser in texture than the rock described above, and contains little or no glass. It consists of fresh lath-shaped plagioclases (labradorites) and a slightly coloured augite in comparatively large crystals, ophitically intergrown with the plagioclase. Magnetite is present in small amount, and pseudomorphs, in greenish chloritic or serpentinous material and calcite, after olivine, are noticeable here and there. There are a few odd vesicles filled in with secondary chlorite and calcite, replacing what was no doubt originally a residual glass. This rock is an *ophitic olivine-dolerite.*

The next variety of the basic rocks occurs as sills at Scrabo Hill and Dundonald. A slide [I. 1334] of the rock from the former locality is, in general, similar to that just described [I. 1984], except that olivine is practically absent in the case of the present slide, though it may occur in other parts of the mass. Ophitic structure is well developed, and the rock is typically non-amygdaloidal.

THE CARNMONEY 'NECK.'

The volcanic plug or neck at Carnmoney is of special interest, and has formed the basis of a considerable amount of geological literature. This has chiefly centred about the so-called 'hullite,' which Hardman first described[1] in 1878.

The rock at Carnmoney neck is a rather vesicular dolerite without olivine, but with a good deal of magnetite, and might perhaps be more correctly termed a basaltic andesite or aphanite[2]. It has consolidated in the vent with a radial horizontal columnar structure. A good deal of chalcedony occurs throughout the mass, and this material occasionally fills up the vesicles, but most usually the latter are lined with a velvet-black glassy substance, sometimes showing a botryoidal or stalactitic structure on a minute scale. When this area was originally surveyed by the late G. V. du Noyer, he noted on the field-maps that the rock contained "cellular cavities lined with pitchstone." Hardman assumed that Du Noyer regarded the material as *acid*[3] in composition, an assumption which does not appear to have been justifiable on the above statement alone; and it seems just as reasonable to assume that Du Noyer regarded it as a *basic* glass (tachylyte, "the 'pitchstone' and 'obsidian' of older authors"), which the 'hullite,' as a matter of fact, has been now proved to be. In 1878, Hardman published the paper just referred to, in which he argued that 'hullite' was a distinct mineral species "allied to the chlorite group." In 1885, A. Lacroix[4] examined the Carnmoney rock, and showed that the translucent brown substance ('hullite') contained magnetite, calcite, and crystals

[1] "On Hullite—A hitherto undescribed mineral; A hydrous silicate of peculiar composition; from Carnmoney Hill, Co. Antrim, with Analysis, by E. T. Hardman; with notes on the Microscopical appearances by Prof. Hull." *Proc. Royal Irish Acad.*, Ser. II., vol. III. (1878), pp. 161-167.

[2] "Hullite" by Prof. G. A. J. Cole, *Proc, Belfast Naturalists' Field Club*, 1894, 95, p 222.

[3] *loc. cit.*, p. 162.

[4] "Sur le kirwanite et le hullite," *Bulletin Soc. Min. de France, tome* viii., (1884), p. 432.

of plagioclase, identical with those which occur in the main mass of the rock. He concluded that 'hullite' "is related to the gummy products to which the decomposition of olivine gives rise." Professor Cole, however, pointed out[1] that this explanation did not get over the difficulty that the 'hullite' frequently occurred as an interstitial substance in the groundmass of the rock, and then, in the course of an interesting *résumé* of the subject, demonstrated clearly that the substance in question is almost certainly a hydrated residual glass (a hydrated tachylyte), the final product of the consolidation of the rock.

Independently and simultaneously, a like conclusion was arrived at by Professor Sollas, in the course of an examination of a somewhat similar rock in the County Galway[2].

[I. 1680 and C. 76.] From Carnmoney 'Neck'. Under the microscope, the rock is a fairly coarsely crystalline *dolerite*, containing much magnetite in the form of opaque black and unaltered crystals. The chief constituents are pale brownish augites and fresh plagioclase laths (labradorite) intergrown ophitically with one another. There occurs also here and there in the sections a more compact or finely crystalline material of similar composition, but with a large proportion of glass. It is chiefly in this part that the so-called 'hullite' occurs as a brownish or greenish brown translucent substance, somewhat like palagonite in appearance, and more or less completely filling irregularly-shaped vesicles in the rock. The central greenish (chloritic) part is usually almost isotropic, and is surrounded by a zone of yellowish brown material, with a fibrous structure, and a radial arrangement of the component material.

Rhyolite.

The Templepatrick rhyolite, since it occurs just outside the map, will only be briefly described here. The rock is pale-pinkish, purple, or white in colour, and is usually compact and devoid of conspicuous phenocrysts, as in the case of the Tardree rhyolite. It frequently shows a well-marked banding, due to flow-structure, and this banding is often considerably crumpled and contorted. In section the rock is seen to be considerably altered (devitrified), showing little trace of its original glassy character, beyond the flow-structure just noted. The ground is crypto-crystalline in appearance, and contains minute orthoclase laths, and also very tiny rods of a greenish brown mineral (? an amphibole). Traces of an agglomerate-lava structure are occasionally noticeable.

Lamprophyre.

The single dyke of this class of igneous rocks, which occurs near Tullynakill Church, is very much decomposed, but its similarity in the hand-specimen to the common type on the Ards Peninsula, and its extreme toughness under the hammer, leave no doubt as to its nature. The rock is probably a *camptonite*, in which the original hornblende is almost entirely replaced by chloritic material.

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[1] *loc. jam cit.*, p. 224.

[2] Sollas and M'Henry—"On a Volcanic neck of Tertiary age in the county of Galway." *Trans. Roy. I. Acad.*, Vol. xxx., Part xix. (1896), p. 733, *et. seq.*, and *Nature*, June 27th, 1895 (abstract) p. 215.

Minerals.

The following is a list of the minerals which have been recorded as occurring within the limits of the 1-inch map of the Belfast district. The list does not pretend to be an exhaustive one, either as to the number of mineral species recorded, or as to the number of localities where any one species named has been found, but it is made as complete as the limited amount of information at present available renders possible:—

Analcite.—In amygdaloidal cavities of the lower basalt sheets at Squire's Hill, Cave Hill, &c.
Anhydrite.—In New Red Sandstone, near Belfast. Exact locality not recorded.
Apophyllite.—In cavities in the basalt of Squire's Hill, &c.
Aragonite.—In basalt of Cave Hill quarries.
Barytes.—Conlig lead mines, near Newtownards.
Bauxite (?).—Lyle's Hill, Templepatrick.
Blende.—Conlig lead mines.
Calcite.—Abundant everywhere; some good crystals in cavities of the lower Basalts. Black Quarry, Squire's Hill.
Celestine.—At Conlig lead mines, near Newtown Ards.
Chabazite.—In cavities of the lower basalt, Squire's Hill, &c.
Chalcedony.—In veins in the Carnmoney rock.
Copper Pyrites.—At Conlig lead mines.
Dolomite.—Massive (in Permian beds) on shore at Holywood.
Galena.—At Conlig lead mines, at Swinely Point, and at Ballyleidy.
Glauconite.—In the 'Greensand' of Cave Hill, Collin Glen, &c.
Gypsum.—Plentiful in veins in the Keuper Marls.
Halite.—As pseudomorphs in the Keuper Marls, west of Belfast.
Hematite.—As pisolitic iron ore, at Lyle's Hill.
Heulandite.—In cavities in the basalt of Black Mountain.
Lithomarge.—At Lyle's Hill, Templepatrick.
Magnetite.—Rather abundant in the local basalt, especially at Carnmoney.
Natrolite.—In amygdales of the Lower Basalt.
Olivine.—An essential constituent of much of the local basalt; occurs in 'nests' in the basalt at White House.
Pyrites.—In Silurian slates (as concretions), &c.
Pyromorphite.—At Conlig lead mines; rather good crystals, sometimes green in colour.
Quartz.—As common rock-constituent and in seggregation veins; good crystals line the cavities in the chalcedony of Carnmoney neck.
Stilbite.—Rare in the amygdaloidal cavities of the basalt of Cave Hill.

In addition to the foregoing, two essential constituents of the basalt lavas may be also included, namely, augite and labradorite, which occur as microscopic crystals. An examination by Dr. Hume of the 'insoluble residues' left after solution in hydrochloric acid of some of the Cretaceous rocks of the district (see p. 33), showed the presence of the following minerals:—

Glauconitic Sands.—Glauconite, quartz, muscovite, biotite, rutile, zircon, and (rarely) tourmaline, iron pyrites, garnet, and kyanite.
Yellow Sandstone.—Quartz, muscovite, tourmaline, rutile, and zircon.

It is probable that an examination of other sedimentary rocks in the district would also yield detrital minerals of other species not recorded in the foregoing account.

H. J. S.

APPENDIX II.

DEEP WELL-SECTIONS AT BELFAST.

[*Words, etc., in square brackets have been added to the original records.*—G.W.L.]

Boring at the Belfast Municipal Electric Power Station, East Bridge-street.—Communicated by the Engineer-in-Charge.

			Feet.
	Rough formation	[? made ground],	2
	Hard and soft concrete	[? made ground],	4
	Dry sleech clay	[Estuarine Clay],	16
	Heavy close gravel	[? Post-glacial],	14
[Glacial]	Hard sand and gravel		4
[Glacial]	Heavy clay,		3
[Glacial]	Fine close gravel, shell, and stone,		8
[Glacial]	Red clay with stone,		6
[Triassic Sandstone]	Hard gritty sandstone, with blue stone under [Triassic Sandstone with ? Basalt dyke].		7
[Triassic Sandstone]	Red sandstone [described as "red gritty sandstone," "hard red sandstone," "coarse-grained red and white sandstone," "fine close sandstone," &c.]		85
[Triassic Sandstone]	Hard dyke-rock	[Basalt dyke],	3
[Triassic Sandstone]	Fine red sandstone,		114
[Triassic Sandstone]	Do., with clay-marl,		19
[Triassic Sandstone]	Red sandstone,		160
[Lower Marls]	Tough clay and sand,		3½
[Lower Marls]	Red clay and hard stiff marl,		39½
[Permian ?]	Hard red sandstone with layers of magnesia,		18
[Permian ?]	do., with clay-marl, see p. 18,		30
[Permian ?]	do., showing more clay,		18
	Depth of Boring,		554

Notes (from original record).—The diameter of the bore-hole was 10 inches to a depth of 68 feet, and 8 inches thence to the end. The boring was done mainly by the rotary and drill system. A test discharge of the yield of water made at a depth of 350 feet was found to represent 2,200 gallons per hour; another test at 448½ feet averaged 2,700 gallons per hour; and a final test at bottom of boring showed 6,500 gallons per hour with an air-pressure of 112 lbs. per square inch.

Boring at Pure Ice Co.'s premises, Great Victoria-street.—From a record in the Geological Survey Office, Dublin.

		Ft.	In.
[Post-Glacial and Glacial]	Surface soil,	5	0
	Sleech,	4	0
	Blue clay,	39	0
	Fine red sand,	6	0
	Blue clay,	3	0
	Red sand,	10	0
	Sand and gravel,	1	3
[Trias, with Dykes]	Soft red sandstone,	7	9
	Red sandstone,	10	0
	Sand and gravel,	1	3
	Red sand,	17	9
	Sand and gravel,	1	0
	Soft red sandstone,	4	0
	Basalt [probably a nearly vertical dyke],	39	0
	Sandstone,	80	0
	Basalt [dyke, see above]	33	6
	Marl (blue),	5	0
	Sandstone,	162	1
		429	7

Water was found at depths of 365, 402, 415, and 425 feet from surface. "A large supply of good water."[1]

Boring at the premises of the Vulcanite Co., Ltd., Laganvale,[2] Belfast (about one mile S. of Ormeau Bridge).—Communicated by Mr. J. St. J. Phillips, Architect, Belfast.

		Ft.	In
	Surface clay . [Boulder-clay],	70	0
[Trias and ? Permian]	Red marl,	200	2
	Limestone [? gypsum],	0	10
	Marl,	1	4
	Sandstone,	16	0
	Flakes sandstone,	10	6
	Sandstone,	43	0
	Broken,	4	6
	Extra or very hard sandstone,	5	6
	[Basalt dyke] Very hard whinstone,	2	6
	[Basalt dyke] Soft whinstone,	1	0
	[Basalt dyke] Very hard whinstone,	1	0
	Sandstone,	64	6
	Very hard quartz [conglomerate of rounded quartz pebbles].	4	2
	Total depth,	425	0

[1] R. Young, *see ref. on p.* 150.

[2] Through the courtesy of the Manager, Mr. H. R. Vaughan, of the Lagan Vale Brick Works, we were allowed to examine the cores from this boring and to take away specimens. See pp. 21 and 71 for notes on this section

Boring at Corporation Baths, Templemore-avenue, Belfast.[1]

		Feet.
[Glacial],	Sand,	10
	Boulder-clay,	40
[Trias, with dykes],	Red sandstone,	50
	White sandstone,	15
	Black stone, very hard [Basalt dyke],	37
	Red sandstone,	26
	Black stone, very hard [Basalt dyke],	78
	Brown stone,	40
	Red sandstone,	38
	Total depth,	334

[*Note.*—The boring was six inches in diameter; with a small pump it yields 2,000 gallons per hour, but more could be obtained. The water is hard and contains magnesia. The dykes which were penetrated appear to have had a low hade so that the boring was carried along them for some depth.]

Boring at Messrs. Sinclair's Bacon-curing Warehouses, Tomb-street, Belfast. Made in 1903.

		Ft.	In.
	Made ground,	5	0
[Estuarine clay],	Sleech	23	0
[Peat-bed],	Sleech and moss,	1	0
	Moss,	1	0
[? Post-Glacial],	Sand and gravel	6	6
[Glacial],	Sandy Marl [Boulder-clay],	51	10
	Sandy Marl with gravel,	13	8
	Marl [Boulder-clay],	36	6
	Whinstone boulder,	0	6
	Red sandy marl,	0	6
[Triassic sandstone with basalt dykes]	Red sandstone,	20	6
	Whinstone,	1	0
	Conglomerate,	4	0
	Red sandstone,	127	0
	White sandstone, coarse,	1	0
	Red sandstone,	32	0
	Conglomerate,	17	0
	Whinstone,	3	6
	Red sandstone,	62	9
	Red sandstone, with marly bands,	68	0
	Red sandstone, marly,	117	10½
	Hard grey sandstone,	3	6
	Hard grey sandstone, cuttery,	29	6
	Hard grey sandstone with marl beds,	4	8
	Hard grey sandstone,	14	7½
	Total depth,	654	5

[Information regarding the upper 176 feet of this boring was obtained on the premises while the work was in progress. Details as to the portion below that depth have been supplied by Messrs. J. Henderson and Son, Well Engineers, Glasgow, by whom the boring was made. In the upper part of the Trias the rock-cores showed a red slightly mottled sandstone with a few grey streaks, much cross-bedded, with thin marl partings and well defined "clay-galls." The first bed of "conglomerate" of the record consisted of rounded bits of basalt, and probably represented the breaking up of the "whinstone" dyke under the boring operations.—G.W.L.]

[1] Details supplied by the Superintendent of the Baths.

Boring at Messrs. Inglis & Co.'s premises, Eliza-street, Belfast. Made (in 1903) and communicated by Messrs. J. Henderson & Sons, Ltd., Well Engineers, Glasgow.

		Ft.	In.
[Made ground],	Forced material; brick, stone, lime,	2	6
[Estuarine clay],	Fine brown clay,	21	0
[Glacial deposits],	Brown clay and whinstone boulders,	1	6
	Red sand,	3	0
	Sand and gravel,	3	6
	Sand,	0	6
	Whinstone boulder,	0	9
[Triassic sandstone],	Broken rock,	0	11
	Red sandstone,	224	4
	Red fakey [shaly] sandstone,	14	0
[Lower Marls],	Red fakes [shale], tough,	28	0
	Total depth,	300	0

Well-section at Messrs. Swanston & Bones' Works, King-street.

From "The Post-tertiary foraminifera of the North-east of Ireland," by J. Wright. *Proc. Belfast Nat. Field Club*, Appendix, 1879–1880, p. 152–153.

	Feet.
Estuarine clay of the usual yellowish gray colour,	6
Estuarine clay of brownish colour and with offensive smell,	22
Fine sand,	24
Boulder-clay; clay very fine and foraminifera very rare,	50
Boulder-clay; of the usual character and foraminifera plentiful,	100
	202
[on Triassic Sandstone; total depth about 235 ft.[1]]	

Well at Messrs. W. A. Ross & Sons' Aerated Water Factory, Victoria-square, Belfast.—Communicated by Messrs. Ross & Son.

	Feet.
Rubble,	5
Silt and shells [Estuarine clay],	21
Peat-marsh, inflammable gas found here; matrix of leaves, nuts, stones, and gravel, apparently bed of a river [Peat bed].	7
Stiff red clay [Boulder-clay],	37
Gravel,	8
Red freestone [Triassic sandstone],	146
Fine gravel,	2
	226
Another well on the same premises was sunk to a depth of 420 feet in the sandstone.	

[1] From information supplied by Mr. W. Swanston.

Well at Messrs. Cantrell & Cochrane's Aerated Water Factory, Victoria-square, Belfast.—Communicated by Messrs. Cantrell & Cochrane.

	Feet.
Silt with shells [Estuarine Clay], Peat, gas, &c. [Peat-bed], Gravel, } [Post-Glacial], . .	38
Clay, Rock, Sand, Gravel, } [Glacial drift: detailed thickness not stated],	40
Red freestone [Triassic Sandstone], ...	38
	116
In another well on the same premises the sandstone was pierced to a depth of 399 feet.	

Wells at Messrs. A. Crawford & Sons' Starch Works, Mill-street, Belfast.—Communicated by Messrs. A. Crawford and Sons.

	Feet.
At N.W. side of works:—	
Clay [Glacial], ...	25
Sandstone [Triassic], ...	150
At S.W. side:—	
Sleech with shells [Alluvium], ...	12
Sandstone, ...	300

Well at Messrs. James Neill Co.'s, Ltd., Flour Mills, College-place, Belfast.—Communicated by Messrs. Neill.

	Feet.
Sleech, clay, &c. [Post-Glacial and Glacial], . . (about)	110
Sandstone [Triassic], ...	305
A good supply obtained, and water rises to within 17 feet of surface.	

Well at The Rosebank Weaving Company's Factory, Rosebank, Crumlin-road.

	Feet.
Clay [Boulder-Clay and Triassic Marl], ...	300
Sandstone [Triassic], ...	310
A good supply (up to 12,000 gallons per hour proved), and water rises to within 45 feet of surface.	

Boring at the Tramway Co.'s Stables, Knock, near Belfast. Made (in 1900) and communicated by Messrs. J. Henderson & Son, Ltd., Well Engineers, Glasgow.

		Ft.	In.
[Glacial drift, 161 feet],	Well: sand and gravel,	41	0
	Sand and gravel,	22	0
	Rough gravel,	3	0
	Fine sand,	2	0
	Sandy clay,	12	0
	Sandy clay and stones,	27	6
	Mud and sand,	6	6
	Mud and stones,	6	0
	Clay and stones,	41	0
[Triassic sandstone, with bands of marl and conglomerate and with basalt dykes—236 feet 8 inches],	Whinstone, soft,	1	0
	Whinstone,	6	3
	Fakey sandstone,	13	0
	Dark fakes [sandy shale],	17	0
	Red marl with very hard sandstone ribs.	5	0
	Red marl,	11	0
	Red marl, very hard ribs,	7	0
	Red marl, very hard,	3	0
	Red marl,	8	0
	Red marl, extra hard,	5	0
	Whinstone, hard,	7	7
	Light red sandstone,	16	6
	Red sandstone,	85	9
	Volcanic ash,	0	5
	Red whinstone,	1	7
	Volcanic ash,	1	6
	Red whinstone, extra hard,	3	3
	Red conglomerate; very hard balls,	1	4
	Red whinstone, hard	1	2
	Red conglomerate; very hard balls,	14	1
	Red conglomerate,	21	9
	Red conglomerate with strongly marked veins of white spar.	5	6
	Total depth,	397	8

The data given in the remainder of this Appendix are, unless otherwise stated, reproduced from Mr. R. Young's paper, "Notes on some Recent Deep Borings for Water in Belfast," *Proc. Belf. Nat. Hist. and Phil. Soc.*, 1897-98, pp. 80-83 :—

Boring on the Bloomfield Estate, about 200 yards from Beersbridge-road, at a place now covered by Bread-street.

A six-inch bore was carried through 308 feet sandstone, 7 feet hard rock, and 39 feet soft rock; total depth 354 feet. Water rose 8 feet above surface, but was found unsuitable for raising steam.

Boring at the Irish Distillery, Conn's Water.

A six-inch bore, 460 feet through sandstone, and a four-inch bore for 65 feet further; in all 525 feet: only a trifling quantity of water, moderately hard and fresh. The last cores brought out gave strong indications of the Triassic sandstone being pierced where it thins out upon the Carboniferous series.

Boring at Avoniel Distillery, Albert Bridge-road, close to the Conn's Water—a six-inch boring.

	Feet.
Sandstone, ...	275
Coralline limestone [?], ...	4
Sandstone, ...	63
Total depth, ...	342
Chapman's air-pump lifts 25,000 gallons per [? hour] and quality is excellent.	

Boring at North of Ireland Chemical Co.'s premises, 56, Bond-street, off Macauley-street.

Four-inch bore through sandstone, 512 feet. 8,740 gallons per hour are being pumped.

Boring at Messrs. J. J. M'Connell's Distillery, off Ravenhill-road, close to the right bank of the Lagan; surface, 14 feet above O.D.

A six-inch bore through Bunter sandstone with thin veins of marl and gypsum, to 352 feet.

23,000 gallons of water raised per hour by Chapman's air-pump.

Analyses shows the water to be soft and good.

[For the following additional information respecting this boring, and for the two next borings, we are indebted to C. H. Brett, Esq., to whom the particulars had been sent by the contractors, Messrs. W. J. Campbell and Son:—"The Triassic Sandstone was reached at a depth of 16 feet and was overlaid directly by the boulder-clay. The usual bed of black-gravel which overlies the Trias about Belfast was absent. The well was so placed as to be altogether away from the strike of the dolerite dyke which came into the old well."]

Well at Messrs. W. J. Campbell & Son's premises, Ravenhill-road. (See last paragraph.)

Sandstone reached at a depth of about 35 feet, being overlaid by black gravel and boulder-clay.

Well at Messrs. Miller's Jam Factory, Ravenhill-avenue.[1]

Sandstone reached at about 60 feet.

Two borings at Messrs Millen & Rankin's, 50, Macauley-street.

One, a 4-inch bore in sandstone, 350 feet. A large supply of water of good quality obtained.

Boring at Mr. J. Fulton's Factory, Ormeau-avenue, at crossing of Apsley-street.

Four-inch bore through sand, sleech and sandstone, 420 feet. A good supply of water obtained.

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[1] Messrs. Campbell remark respecting the three last sections, that taking high-water mark as a datum, the depth to the sandstone would stand roughly as follows:—At M'Connell's, 12 feet; at Campbell's, 30 feet; at Miller's, 8 feet.

Boring at Messrs. Murphy & Stevenson's Factory, Ormeau-avenue, at crossing of Linenhall-street.

Four-inch bore through sand, sleech, and sandstone, 400 feet. An excellent supply of water.

Boring at the Public Baths, Ormeau-avenue, at crossing of Maryville-street—a six-inch bore.

	Feet.
Sleech and sand	90
Triassic sandstone.	310
Total depth,	400

The water on analysis proved to be pure and soft.

Boring at Messrs. Grattan & Co's premises, 68, Great Victoria-street.

Six-inch bore in sandstone to 252 feet. A large yield of pure water.

Boring at Brookfield Linen Co.'s Factory, Courtrai-street.

Four-inch bore in sandstone to 400 feet. Yield, 6,000 gallons of water per hour.

Boring at Sir D. Dixon's Saw Mills, Whitla-street.

Six-inch bore in sandstone; at 200 feet water brackish; at 320 feet, water fresh; at 400 feet, salt rock.

Boring at Belfast Union Workhouse—six-inch bore.

	Feet.
Soil and sand,	40
Sandstone,	480

Yield of water, almost 14,500 gallons per hour; quality excellent.

Well at Police-square, Belfast.[1]

	Feet.
"Silt" [Estuarine Clay],	33
Gravel charged with water, and containing a quantity of organic debris.	7
Very tenacious clay, "a thick deposit" [Boulder-clay],	—

The gravel gave off an inflammable gas (marsh gas).[2]

[1] Praeger, "Estuarine Clays." *Proc. R. I. A.*, 3rd ser., vol. ii. (1892) p. 237.
[2] Prof. T. Andrews. *Proc. Belfast Nat. Hist. and Phil. Soc.*, 1873-74, p. 93.

APPENDIX III.

List of Memoirs and Papers referring to the Geology of the Belfast District.

1790.

Mills, A.—Some Account of the Strata and Volcanic Appearances in the North of Ireland and Western Islands of Scotland. *Phil. Trans. Roy. Soc.*, vol. LXXX., pp. 73-100.

1803.

Richardson [Rev.] W.—Accounts of the Whynn Dykes in the neighbourhood of the Giant's Causeway, Ballycastle, and Belfast. *Trans. Roy. Irish Acad.*, vol. IX., pp. 21-43.

1808.

Richardson [Rev.] W.—A Letter on the Alterations that have taken place in the Structure of Rocks on the Surface of the Basaltic Country in the Counties of Derry and Antrim. *Phil. Trans. Roy. Soc.*, vol. XCVIII., pp. 187-222.

1816.

Berger, J. F. and [Rev.] W. Conybeare.—On the Geological features of the North-eastern counties of Ireland. *Trans. Geol. Soc. London*, vol. III., pp. 121-195. Abstract in *Portlock's Geology of Londonderry.*

Berger, J. F.—On the Dykes of the North of Ireland. *Trans. Geol. Soc. Lond.*, ser. 1, vol. III., pp. 223-232.

1817.

Buckland [Rev.] W.—Description of the Paramoudra; a singular fossil body that is found in the Chalk of the North of Ireland. With some general observations upon flints in chalk, tending to illustrate the history of their formation. *Trans. Geol. Soc. Lond.*, ser. 1, vol. IV., pp. 413-423.

1833.

Bryce, J.—On the Evidences of Diluvial Action in the North of Ireland. *Journ. Geol. Soc. Dublin*, vol. I., pp. 34-41.

Portlock, J. E.—On the study of Geological Phenomena in Ireland. *Journ. Geol. Soc. Dublin*, vol. I., pp. 11-15.

1837.

Bryce, J.—On the Magnesian Limestone and associated beds which occur at Hollywood, in the County of Down. *Journ. Geol. Soc. Dublin*, vol. I., p. 175.

Griffith [Sir] R.—Annual Address to the Geological Society of Dublin, 1836. *Journ. Geol. Soc. Dublin*, vol. I., pp. 146-149.

1838.

Apjohn, J.—Analysis of Irish Dolomites. *Journ. Geol. Soc. Dublin*, vol. I., pp. 379-380.

1843.

Bryce, J. and G. C. Hyndman.—Notice of an elevated Deposit of Marine Shells of the Newer Pliocene Epoch, lately discovered near Belfast. *Appendix to Portlock's "Geology of Londonderry, &c.,"* pp. 738-740.

Griffith [Sir] R.—On the Lower portion of the Carboniferous Limestone Series of Ireland. *Rep. Brit. Assoc.*, 1843, pp. 45-46.

Portlock, J. E.—Report on the Geology of the County of Londonderry, 8vo., Dublin, 1843.

1845.

Bryce, J.—Notice of a Tertiary Deposit lately discovered in the neighbourhood of Belfast. *Phil. Mag.*, 3rd ser., vol XXVI., pp. 433-436.

Wilkinson, G.—Practical Geology and Ancient Architecture of Ireland [Belfast building materials.] *London*, 1845.

1848.

MACADAM, J.—On the Cuttings of the Belfast and Ballymena Railway. *Journ. Geol. Soc. Dublin*, vol. IV., pp. 36–41.

1850.

MACADAM, J.—Observations on the Neighbourhood of Belfast, with a description of the Cuttings on the Belfast and County Down Railway. *Journ. Geol. Soc. Dublin*, vol. IV., pp. 250–265.

—— ——Supplementary Observations on the Neighbourhood of Belfast. *Journ. Geol. Soc. Dublin*, vol. IV., pp. 265–268.

1852.

BRYCE, J.—On the Geological Structure of Counties Down and Antrim. *Rep. Brit. Assoc.*, 1852, p. 42, trans.

GRIFFITH, RICHARD.—Notices of the Geology of Ireland. *Rep. Brit. Assoc.*, 1852, pp. 47, 48.

HAUGHTON, [REV.] S.—Account of the Gangue of Conlig Lead Mine (abstract). *Journ. Geol. Soc. Dublin*, vol. V., p. 203.

KING, W.—On the Permian Fossils of Cultra. *Rep. Brit. Assoc.*, 1852, p. 53.

MACADAM, J.—On the Fossiliferous Beds of the Counties of Antrim and Down. *Rep. Brit. Assoc.*, 1852, p. 53, trans.

1853.

GRAINGER [REV. CANON] J.—Catalogue of the Shells found in the Alluvial Deposits of Belfast. *Rep. Brit, Assoc.*, 1852, Transactions of the Sections, pp. 43–46. and pp. 74–75.

1856.

KELLY, J.—On localities of fossils of the Carboniferous Limestone of Ireland. *Journ. Geol. Soc. Dublin*, vol. VII. pt. 1, pp. 23 and 34–38.

1857.

KELLY, J.—On the Subdivision of the Carboniferous Formation of Ireland, *Journ. Geol. Soc. Dublin*, vol. VII., pp. 229, 239.

KING W.—On the occurrence of Permian Magnesian Limestone at Tullyconnel. *Journ. Geol. Soc. Dublin*, vol. VII., p. 67.

1858–1860.

HYNDMAN, G. C.—[First] Report of the Proceedings of the Belfast Dredging Committee. *Rep. Brit. Assoc.*, 1857, pp. 220–237. [Post-glacial fossils.]

1859.

GRAINGER, [REV. CANON] J.—Catalogue of the Shells found in the Alluvial Deposits of Belfast. *Nat. Hist. Review*, vol. VI., pp. 135–151.

—— —— On the Shells found in the Post-tertiary Deposits of Belfast. [A paper read before Dublin University Zool. and Bot. Assoc., 17th Dec., 1858.] *Nat. Hist. Review*, vol. VI., pp. 135–151.

1862.

GRIFFITH [SIR] R.—The Localities of the Irish Carboniferous Fossils, arranged according to the Stratigraphical Sub-divisions of the Carboniferous System adopted in the Geological Map of Ireland, with the Irish Mining Localities as appended to the Synoptical Table of Fossils, engraved on the Margin of that Map, and as originally compiled for the Use of the General Valuation of Ireland. *Journ. Geol. Soc. Dublin*, vol. IX., pp. 21–155.

1862–1869.

JEFFREYS, J. G.—British Conchology. Five vols., 8vo., *London*. [Turbot Bank glacial fossils, I., xciv.–xcviii. Vols. II–V. contain numerous references to Irish fossils, chiefly from Stewart's, Hyndman's, and Grainger's papers.]

1863.

TATE, R.—On the Liassic Strata of the neighbourhood of Belfast. *Quar. Journ. Geol. Soc.*, vol. XX., pp. 103–114; also *Geologist* for 1863, p. 444.

1864.

BELFAST NATURALISTS' FIELD CLUB.—On the Geology of Collin Glen. *Geol. Mag.*, vol. I., p. 187.

TATE, R.—On the correlation of the Cretaceous formations of the north-east of Ireland. *Quart. Journ. Geol. Soc.*, vol. XXI., pp. 15–44; abstract in *Geol. Mag.*, vol. I., p. 287.

1867.

CLOSE [REV.] M. H.—On the General Glaciation of Ireland. *Journ. Roy. Geol. Soc. of Ireland*, vol. I., pp. 207–242.

TATE, R.—On the Lower Lias of the north-east of Ireland. *Quart. Journ. Geol. Soc.*, vol. XXIII., pp. 297–314; abstract in *Geol. Mag.*, vol. IV., p. 329, and *Phil. Mag.*, 4th ser., vol. XXXIV., p. 321.

—— —— On the Fossiliferous Development of the Zone of *Ammonites Angulatus*, Schloth, in Great Britain. *Quart. Journ. Geol. Soc.*, vol. XXIII., 305–314. Abstract in *Geol. Mag.*, vol. IV., p. 329.

YOUNG, R.—The recent Elevation of the Land in the Vicinity of Belfast [abstract]. *Fourth Ann. Report Belfast Nat. F. C.*, pp. 20–22.

1868.

BELFAST NATURALISTS' FIELD CLUB.—A short account of the geology of part of Antrim. *Geol. Mag.*, vol. I., pp. 215, 216.

GRAY, W.—Glacial Markings recently observed around Belfast [abstract]. *Fifth Annual Report Belfast Nat. F. C.*, p. 34.

HARTE, W.—The Chalk of Antrim. *Geol. Mag.*, vol. V., pp. 438–439.

JUKES, J. B.—The Chalk of Antrim. *Geol. Mag.*, vol. V., pp. 345–347.

SMITH, D.—Outlines of the Rocks of Antrim. 8vo, *Belfast.*

1869.

BAILY, W. H.—Notice of Plant remains from beds interstratified with the Basalt of the County of Antrim. *Quart. Journ. Geol. Soc.*, vol. XXV., pp. 162, 357–362; also *Geol. Mag.*, vol. VI., pt. LVII., *Phil. Mag.*, ser. 4, vol. XXXVIII., pp. 241, 242.

GEOLOGICAL SURVEY.—Maps. Sheet 37. Newtown Ards. Part of the County of Down (Horiz. Sect., 24). Revised 1898.

—— —— Maps. Sheet 29. Carrickfergus. Parts of Antrim and Down (Horiz. Sects. 24, 29). Revised, 1883 and 1898.

GRAY, W.—The Building Stones of Belfast and the Counties adjoining. *The Irish Builder*, vol. XI., pp. 99–102.

KELLY, J.—On the Geology of the County of Antrim with Parts of the adjacent Counties. *Proc. Roy. Irish Acad.*, ser. 1, vol. X., pp. 235–327.

TATE, R. and J. S. HOLDEN.—On the Iron-ores associated with the Basalts of the north-east of Ireland. *Quart. Journ. Geol. Soc.*, vol. XXVI., pp. 151–165; abstract in *Geol. Mag.*, vol. VII. pp. 85, 86, and *Phil. Mag.*, vol. XL.

1870.

GEOLOGICAL SURVEY.—Maps. Sheet 36. Belfast. (Horiz. Sects. 22, 23, 31.) Revised 1876, 1901.

TATE, R.—A list of the Irish Liassic Fossils with notes on the new and critical species. *Proc. Belfast Nat. F. C.*, *Appendix* I. (1870), pp. 3–24.

1871.

DU NOYER, G. V.—On the flint flakes of Antrim and Down. *Journ. Roy. Geol. Soc. Ireland*, vol. II., pp. 169–171.

GEOLOGICAL SURVEY.—Explanation of Sheet 36 by Edward Hull, J. L. Warren, W. B. Leonard, and W. H. Baily, p. 28, &c.

—— —— Explanation of Sheets 37, 38, and part of 29, by Edward Hull, J. L. Warren, W. B. Leonard, and W. H. Baily.

STEWART, S. A.—A list of the Fossils of the Estuarine Clays of the Counties of Down and Antrim. *Proc. Belfast Nat. F. C.*, *Appendix* II. (1871), pp. 27–40.

—— —— The latest Fluctuations of the sea-level on our own coast [abstract]. *Eighth Ann. Report of Belfast Nat. F. C.*, pp. 55–57.

WRIGHT, J.—A list of the Irish Liassic Foraminifera. *Proc. Belfast Nat. F. C.*, *Appendix* II. (1871), pp. 25, 26.

YOUNG, R.—The Boulder Clay of the Belfast District. [Abstract.] *Eighth Ann. Report Belfast Nat. F. C.* (1870–1871), pp. 32–35.

1872.

GRAY, W.—An Inquiry into the possibility and probability of the Occurrence of Coal in the neighbourhood of Belfast [abstract.] *Ninth Ann. Report of Belfast Nat. F. C.* (1871-72), pp. 26-32.

HARDMAN, E. T.—List of Papers published on the Geology of the North of Ireland and adjoining Districts. Published for the use of the Geological Survey of Ireland, 8vo, 32 pp. *Dublin*, 1872.

WRIGHT, J.—Geology of Cultra, co. Down. *Ninth Ann. Report of Belfast Nat. F. C.* (1871-72), pp. 33-37.

1873.

ANDERSON, J.—On the Geological Formations of the County Down. *Proc. Belfast Nat. Hist. and Phil. Soc.* for 1871-'72, pp. 41-49.

BELL, A.—The Palæontology of the Post-glacial Drifts of Ireland. *Geol. Mag.*, vol. X., pp. 447-453.

GEOLOGICAL SURVEY.—Horizontal Sections. Sheet 22. Section from Annalong, County Down, to Lough Neagh. (Maps 36, 48, 60, 61.)

HULL, E.—On the Permian Breccias and Boulder-beds of Armagh. *Quart. Journ. Geol. Soc.*, vol. XXIX., pp. 402-405.

YOUNG, R.—Some Remarks on the recent Changes of coast Level at Ballyholme Bay, Co. Down. *Proc. Belfast Nat. Hist. and Phil. Soc.* for 1871-'72, pp. 39-41.

1874.

ANDREWS, T.—On the Composition of an Inflammable Gas Issuing from below the Silt-Bed of Belfast. *Proc. Belfast Nat. Hist. and Phil. Soc.* for 1873-'74, pp. 93, 94.

ANON. (MEMBERS OF THE *Belfast Naturalists' Field Club*).—Guide to Belfast and the adjacent Counties. 8vo, *Belfast*.

BAILY, W. H.—Sketch of the Geology of Belfast and the Neighbourhood. *Hardwicke's Science Gossip* for 1874, pp. 169, 170.

BRADY, G. S., H. W. CROSSKEY, and D. ROBERTSON.—Monograph of the Post-tertiary Entomostraca of Scotland, including species from England and Ireland. *Monogr. Palæont. Soc.*, vol. XXVIII. [List of species from Woodburn boulder clay, Portrush raised beach, and Belfast estuarine clay.]

GEOLOGICAL SURVEY.—Horizontal Sections. Sheet 23. Section 1. Across the Mourne Mountains and Slieve Croob to Lough Neagh (continued). (Maps 36, 60, and 61.)

—— —— Horizontal Sections. Sheet 24. Section 2. From Killinchy across Scrabo Hill to the sea at Cultra, Co. Down. (Maps 29, 37.)

—— —— Maps. Sheet 28. Antrim. Part of the County of Antrim (Horiz. Sects. 29, 31).

HULL, E.—The Volcanic District of the North-east of Ireland. Presidential Address, Section C. *Rep. Brit. Assoc.* for 1874, pp. 67-73.

RUDLER, F. W.—The Geology of Belfast. *Academy*, vol. VI., pp. 184-186.

1875.

GRAINGER [REV. CANON] J.—On the Fossils of the Post-tertiary Deposits of Ireland. *Rep. Brit. Assoc.*, 1874, Transactions of the Sections, pp. 73-76.

SWANSTON, W.—Graptolites, with special reference to those found in Co. Down. [Abstract.] *Proc. Belfast Nat. F. C.* (1874-'75), ser. 2, vol. I., pp. 115-117.

WRIGHT, J.—A list of the Cretaceous Microzoa of the North of Ireland. *Proc. Belfast Nat. F. C. Appendix* III. (1875), pp. 73-99.

YOUNG, R.—The water-bearing Rocks between Moira and Lurgan. *Proc. Belfast Nat. Hist. and Phil. Soc.* for 1874-'75, pp. 33, 34.

1876.

BARROIS, C.—Recherches sur le Terrain Crétacé Superieur de l'Angleterre et de l'Irlande. *Mém. Soc. Géol. du Nord*, Lille.

GEOLOGICAL SURVEY.—Explanation of Sheets 21, 28, and 29, by Edward Hull and W. H. Baily, pp. 39-40, &c.

HARDMAN, E. T.—Fossiliferous Pliocene Clays overlying Basalt, near the Shore of Lough Neagh. *Geol. Mag.*, dec. 2, vol. III., p. 556.

1877.

GAULT, W.—Observations on the Geology of the Black Mountain with special reference to the Cretaceous Rocks. *Proc. Belfast Nat. F. C.* (1876–'77), ser. 2, vol. I., pp. 251–262.

GEOLOGICAL SURVEY.—Explanation of Sheet 35, by E. T. Hardman and W. H. Baily.

SWANSTON, W., and C. LAPWORTH.—Correlation of the Silurian Rocks of the County Down. *Proc. Belfast Nat. F. C.*, Appendix IV. (1876–'77), pp. 107–147.

WRIGHT, J.—Recent Foraminifera of Down and Antrim. *Proc. Belfast Nat. F. C., Appendix* IV. (1876–'77), pp. 101–106.

YOUNG, R.—A volcanic ash deposit at the Cave Hill Quarries. *Proc. Belfast Nat. Hist. and Phil. Soc.* for 1876–'77, pp. 51, 52.

1878.

HARDMAN, E. T.—On Hullite. A hitherto undescribed mineral; A hydrous silicate of peculiar composition; from Carnmoney Hill, Co. Antrim, with Analysis. Notes on the Microscopical appearances by Prof. Hull. *Proc. Roy. Irish Acad.*, ser. 2, vol. III., pp. 161–167.

KINAHAN, G. H.—Geology of Ireland. 8vo., *London.*

WRIGHT, J.—Foraminifera, Recent and Fossil. *Proc. Belfast Nat. Hist. and Phil. Soc.*, for 1877–'78, pp. 22–28.

YOUNG, R.—Presidential Address. *Proc. Belfast Nat. Hist. and Phil. Soc.* for 1877–'78, pp. 1–21.

1879.

GAULT, W.—On the mode of occurrence and probable origin of the Hullite and other siliceous minerals found on the volcanic neck at Carnmoney and elsewhere in Co. Antrim [abstract]. *Proc. Belfast Nat. F. C.* (1878–'79), ser. 2, vol. I., pp. 353–357.

READE, T. MELLARD.—Notes on the Scenery and Geology of Ireland. *Proc. Liverpool Geol. Soc.*, vol. IV., pt. i, pp. 64–89.

SWANSTON, W.—On the supposed Pliocene Clays overlying Basalt, near the shore of Lough Neagh. *Geol. Mag.*, dec. 2, vol. VI., pp. 62–65, also abstract in *Proc. Belfast Nat. F. C.* (1878–'79), ser. 2, vol. I., pp. 348–350.

1880.

BAILY, W. H.—Report of the Committee, consisting of Professor W. C. Williamson and Mr. W. H. Baily, appointed for the purpose of collecting and reporting on the Tertiary (Miocene) Flora, &c., of the Basalt of the North of Ireland. *Rep. Brit. Assoc.* 1880, p. 107.

1881.

STEWART, S A.—The Mollusca of the Boulder-clay of the North-east of Ireland. *Proc. Belfast Nat. F. C., Appendix* V. (1879–80), pp. 165–176.

WRIGHT, J.—Post-tertiary Foraminifera of the North of Ireland. *Proc. Belfast Nat. F. C.* (1879–'80), ser. 2, vol. I., pp. 428, 429 [abstract]; and *Proc. Belfast Nat. F. C.* ser. 2, vol. I., *Appendix* for 1879–80, pp. 149–163.

1882.

HUGHES, W.—Geological Notes on Ireland. 130 pp. 12mo. 4th ed. *Dublin.*

STEWART, S. A.—The Boulder Clay of the north-east of Ireland [abstract.] *Proc. Belfast Nat. F. C.* (1880–'81), ser. 2, vol II., pp. 51–53.

YOUNG R.—Presidential Address [Ref. to supposed reptilian foot-prints in sandstone at Scrabo.] *Proc. Belfast Nat. F. C.* (1881–'82) ser. 2, vol. II. p. 117.

——— ——— [Wrought logs in boulder-clay near Belfast]. *Journ. Roy. Hist. and Arch. Assoc. of Ireland* (4), vol. V. ii., pp. 307, 308.

1884.

GARDNER, J. STARKIE—The age of the basalts of the north-east Atlantic. *Proc. Belfast Nat. F. C.* (1883–'84), ser. 2, vol. II., pp. 255–285.

1884 and 1885.

GARDNER, J. STARKIE.—The Lower Eocene Plant-beds of the Basaltic formation of Ulster. *Quart. Journ. Geol. Soc.*, vol. XLI., pp. 82, 83, and *Monogr. Palæont. Soc.*, vol. XXXVIII.

1885.

Lacroix, M. A.—Sur le kirwanite et le hullite. *Bulletin Soc. Min. de France*, tome VIII., p. 432.

Swanston, W.—The origin and history of the Lignite and Silicified Wood of Lough Neagh. [Ref. to Ballypalladyl]. *Proc. Belfast Nat. F. C.* (1884–'85), ser. 2, vol II., pp. 354–363.

1886.

Swanston, W.—An Important Local Geological Discovery [*Mosasaurus gracilis*, Owen, from Chalk of Whitewell]. *Proc. Belfast Nat. Hist. and Phil. Soc.* for 1885–86, pp. 18, 19.

1887.

Grainger [Rev. Canon] J.—A Question concerning the Antrim Gravels [abstract]. *Proc. Belfast Nat. Hist. and Phil. Soc.* for 1886–87, p. 39.

Kinahan, G. H.—Oldhamia. *Sci. Proc. Roy. Dublin Soc.* vol. V., p. 340, and *Journ. Roy. Geol. Soc. Ireland*, vol. VII., pp. 166–170.

Praeger, R. L.—On the Estuarine Clays at the new Alexandra Dock, Belfast. *Proc. Belfast Nat. F. C.*, ser. 2, vol. II., Appendix 2 (1886–87) pp. 29–52.

1887–1889.

Kinahan G. H.—Economic Geology of Ireland, pp. 16, 171, 252, 468, &c. *Journ. Roy. Geol. Soc. Ireland*, n.s., vol. VIII., parts 1–3.

1888.

Gardner, J. S.—On the traps and basalts of the Isle of Mull, and their relation to those of Antrim. *Proc. Belfast Nat. F. C.* (1887–'88), ser. 2, vol. III., pp. 50–52.

1888–1890.

Kilroe, J. R.—Directions of Ice Flow in the North of Ireland, as determined by the Observations of the Geological Survey. *Q. J. G. S.*, vol. XLIV., pp. 827–833; and *Sci. Proc. R. D. S.*, n.s., vol. VI., pp. 259–262.

1890.

Praeger, R. L.—Report of a Committee of Investigation on the Gravels and associated Beds of the Curran, at Larne. *Proc. Belfast Nat. F. C.*, ser. 2, vol. III. (1889–'90), pp. 198–209.

——— ——— A contribution to the Post-tertiary Fauna of Ulster. *Proc. Belfast Nat. F. C.* (1889–'90), ser. 2, vol. III., pp. 215–218.

Young, R.—Some Notes on the Upper Boulder Clay near Belfast. [abstract.] *Proc. Belfast Nat. Hist. and Phil. Soc.* for 1889–90, p. 57.

1891.

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1892..

Praeger, R. L.—On the Skull of an Irish Elk found at Belfast. *Proc. Belfast Nat. F. C.* (1891–'92), ser. 2, vol. III., pp. 416, 417.

——— ——— Report on the Estuarine Clays of the North-east of Ireland. *Proc. Roy. Irish Acad.* (3), vol. II., pp. 212-289.

——— ——— The Irish Post-glacial Estuarine Deposits. *Irish Naturalist*, vol I., pp. 138–141.

Young, R.—Notes on the Geology of the Excavations for the Main Drainage Works [Belfast]. [abstract.] *Proc. Belfast Nat. Hist. and Phil. Soc.* for 1890–91, p. 89.

1893.

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1894.

ANDREWS, [MISS] M. K.—Dykes in Antrim and Down. *Irish Naturalist*, vol. III., p. 93.

PEILE, W.—Notes and Analyses of Irish Ores and Bauxite from the Crommelin Mines, Co. Antrim. *Trans. Manchester Geol. Soc.*, vol. XXII., p. 522.

READE, T. MELLARD.—Excursion to Belfast. *Proc. Liverpool Geol. Soc.*, vol. VII., p. 226.

STEWART, S. A.—[Fossil fish in Lower Limestone Shale.] *Irish Naturalist*, vol. III., p. 204.

THOMPSON [MISS] S. M.—Report of the Geological Committee for 1893–94. *Proc. Belfast Nat. F. C.*, ser. 2, vol. IV., pp. 114–127.

WILLIAMS, C. H.—Practical Notes on the Mining of Iron Ores, Bauxite, &c., of Co. Antrim. *Trans. Manchester Geol. Soc.*, vol. XXII., p. 518.

YOUNG, R. M.—On a Recent Find of Irish Elk Bones, &c., in Belfast. *Proc. Belfast Nat. Hist and Phil. Soc.* for 1893–94, pp. 76–78; and *Irish Naturalist*, vol. III., pp. 81, 82.

1895.

BELFAST NATURALISTS' FIELD CLUB.—Boulders at Holywood and Whitehouse, in *Report on Erratic Blocks. Rep. British Assoc.*, p. 436.

COLE, G. A. J.—Scenery and Geology in Co. Antrim. Pp. 1–19. 8vo., *Belfast.*

——— The Volcano of Tardree. *Geol. Mag.*, dec. 4., vol. II., p. 303.

HERRIES, R. S.—Long Excursion to Belfast, the coast of Antrim, and the Mourne Mountains. *Proc. Geol. Assoc.*, vol XIV., p. 200.

HOSKINS, A. P.—On a Sample of Glauconite. *Proc. Belfast Nat. F. C.* (1894–'95), ser. 2, vol. IV., pp. 195–203.

KENDALL, P. F.—Erratic Blocks of England, Wales, and Ireland. Twenty-third Report of the Committee. [Report from Belfast Nat. F. C. on N. of Ireland Erratics.] *Rep. Brit. Assoc.*, 1895, p. 435.

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