

Memoirs of the Geological Survey.

EXPLANATORY MEMOIR

TO ACCOMPANY

SHEET 47 OF THE MAPS

OF THE

GEOLOGICAL SURVEY OF IRELAND,

INCLUDING THE

COUNTRY AROUND ARMAGH,

BY

F. W. EGAN, B.A., F.R.G.S.I.

WITH

PALÆONTOLOGICAL NOTES BY W. H. BAILY, F.G.S., &c.

(ACTING PALÆONTOLOGIST.)

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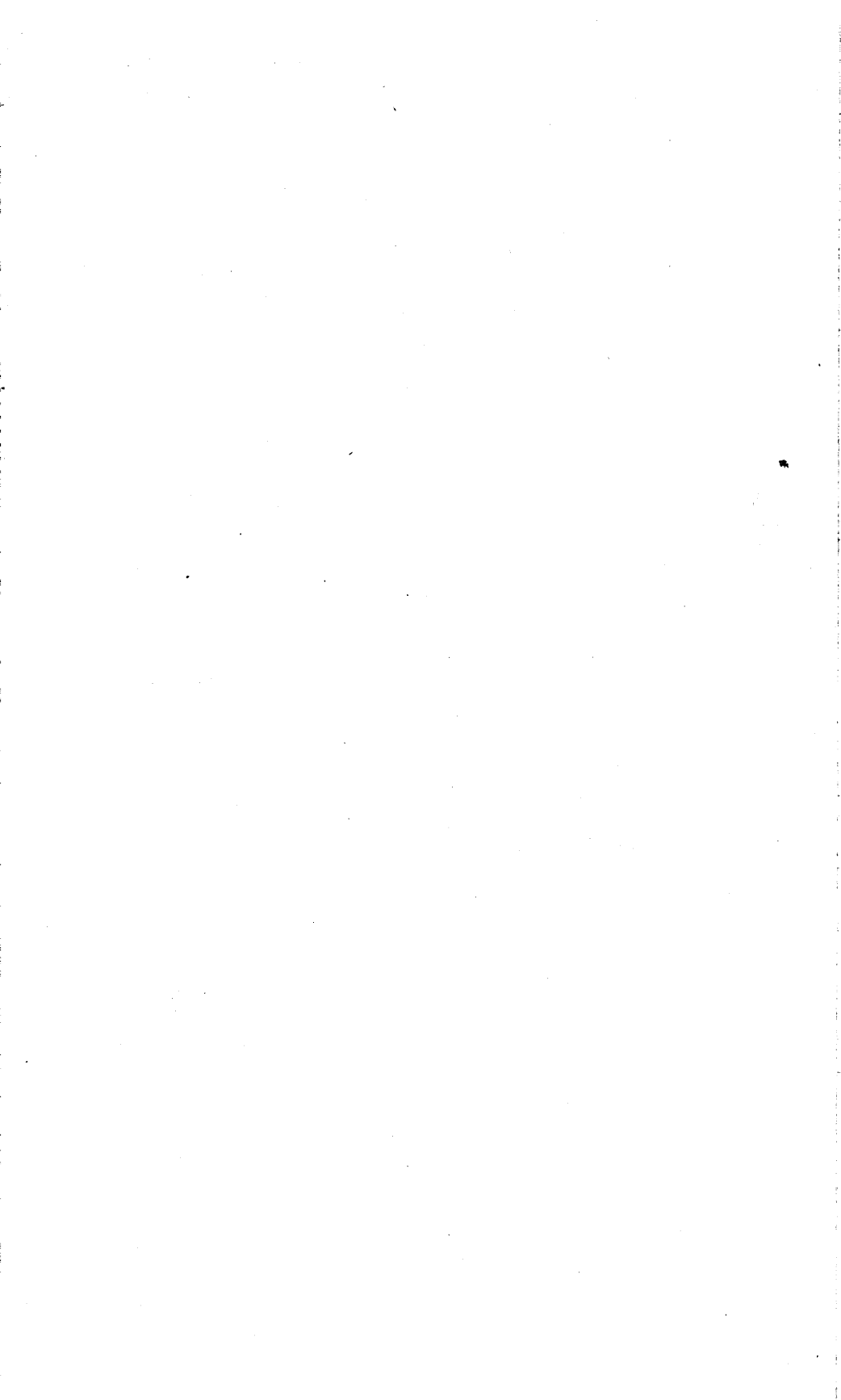
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The observations made in the course of the Geological Survey are entered, in the first instance, on the Maps of the Ordnance Townland Survey, which are on the scale of six inches to the mile. By means of marks, writing, and colours, the nature, extent,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

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

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

Condensed memoirs on particular districts will also eventually appear.

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

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P R E F A C E.

THE whole of Sheet 47 has been carefully surveyed by Mr. Egan, and inspected by myself on several occasions during 1871 and the following year. Some special interest attaches to the Geology of the country around the city of Armagh; as it is the locality from which were obtained a considerable number of typespecimens of fossil fishes originally collected by the late Admiral Jones, and described by Professor Agassiz in his great work *Recherches sur les Poissons Fossils*. A fresh amount of interest in the district will now be felt by geologists from the discovery of Lower Permian breccias and boulder beds, described for the first time in these pages.

EDWARD HULL.

Geological Survey Office, Dublin,
10th July, 1873.

EXPLANATORY MEMOIR

TO ACCOMPANY

SHEET 47

OF THE

GEOLOGICAL SURVEY OF IRELAND.

GENERAL DESCRIPTION.

THE district included within the limits of Sheet 47 lies chiefly in the county of Armagh; but at the N.W. corner there are about thirteen square miles belonging to Tyrone, and along the eastern margin there is a narrow portion of the county Down.

The principal places in the Sheet are—the city of Armagh; the towns of Portadown, Tanderagee, Markethill, and Rich Hill; with the villages of Loughgall, Blackwatertown, Killylea, Hamilton's Bawn, Pointzpass, and Acton, all in Armagh; Gilford and Scarva in Down; and Moy, Clonfeacle, and Benburb in Tyrone.

1. *Form of the Ground.*

There are no great elevations in the district, the highest being that on which stands the Vicar's Carn, four miles S.E. from Armagh, marked 819 feet, or about 200 feet above the lowest adjacent tracts. Several other elevations, from 500 to 700 feet above the sea, occur in the vicinity, and the general surface of the country around here is at a higher level than elsewhere in the Sheet. The less elevated area occupying the remainder is also in general hilly; being covered with mounds of drift, for the most part of an irregularly rounded form, and separated by small streams and alluvial flats, which traverse the country in many directions; among which, however, the northerly and southerly are most prevalent.

Bogs and alluvial flats of greater extent also exist, especially in the northern half of the Sheet, the drift being disposed among them in the form of smooth isolated mounds, which, in most cases, range in height from 120 to 160 feet above the sea; and 50 to 80, and occasionally 100, above the adjoining low levels. The principal flats are those connected with the Blackwater, Callan, and Tall rivers; those of the river Bann, near the eastern margin of the Sheet, being also extensive.

The limestone district stretching to the W. and N.E. of Armagh presents a uniformly undulating surface with drift hills chiefly 200 to 300 feet above the sea.

The fall in the surface from S. to N. which is most rapid near the centre, and almost limited to the southern half of the district, gradually diminishes, and at the east and west there is very little change of level.

The drainage is effected by a few main river courses, and many smaller streams, flowing northwards towards Lough Neagh, into which all the waters are discharged.

The river Bann enters the Sheet near Gilford at a level of 70 feet. Flowing north-westerly by Portadown, it leaves it again at two miles to the north of that town, after a fall of about 25 feet in nine and a half miles. One mile south of Portadown the Bann is joined by the Cushier river, which enters the Sheet at the southern margin at a level of about 200 feet. It flows north-easterly by Tanderagee, and coming close to the Newry Canal W. of Gilford, the two continue parallel till they join the Bann. The river Callan, crossing the southern margin four miles S.S.E. from Armagh, at a level of 230 feet, flows half a mile W. of that city, continues with a sinuous course northward, passing one mile W. of Loughgall, and thence north-westerly till it joins the Blackwater a little to the N.E. of Moy. The Blackwater, which is the largest river, enters at two miles W. of Benburb, at a level of 101 feet, and flowing by that village and Blackwatertown and Moy, passes out of the Sheet one mile N.E. of Moy, after a fall of about 50 feet. The Ulster Canal, which connects Lough Erne with Lough Neagh, passes at short distances from, and with a course generally parallel to, the Blackwater, which it joins at the N. of Charlemont. The excavations along its southern bank, where it comes close to the river near Benburb, afford the finest sections of the Carboniferous limestone in this part of the country.

The Tall and Ballybay rivers are of inferior size. The former, rising N.E. of the Vicar's Carn, flows into the Callan to the N. of Charlemont, after a very devious course; the latter, known by different names in its short length, flows into the Bann at Portadown.

The principal watershed, which separates the drainage areas of the Blackwater and Bann, the two rivers that finally convey all the drainage to Lough Neagh, enters the Sheet at the southern margin between lat. $6^{\circ} 34'$ and $6^{\circ} 35'$; and passing northwards in a direction generally parallel to the course of the Tall river, by Hamilton's Bawn, it crosses the Ulster railway near Sturgeon's Hill, then passes N.E. by Ballintaggart house and Hanna Vale, beyond which it is lost among the alluvial flats which are connected, more or less directly, with both rivers.

The less important watershed between the Blackwater and the Callan enters at the southern margin between lat. $6^{\circ} 43'$ and $6^{\circ} 44'$, and crossing the Armagh and Monaghan road near Fairview, it continues northward by Navan Fort, then west of Drumsill House, and enters the extensive bog to the W. of Grange Blundel, beyond which it ceases to be traceable.

2. Formations or Groups of Rocks entering into the Structure of this District.

AQUEOUS ROCKS.

Name.	Colour on Map.
Recent; Bog, Alluvium, or other superficial covering,	Chalons brown and Gamboge.
Post Pliocene. Drift Deposits,	Engraved dots.
Tertiary Clays, Miocene,	Sepia.
Triassic, { f ⁵ Lower Keuper Sandstone,	Venetian Red.
{ f ³ Bunter Sandstone,	Do. Lighter.
Lower Permian. e Breccia, &c.,	Burnt Roman Ochre and Gamboge.
Lower Carboniferous, { d ^{2''} Upper Limestone,	Dark Prussian blue.
{ d ^{2'} Calp or middle division,	Indigo dotted.
{ d ² Lower Limestone,	Light Prussian blue.
{ d ² Sandstones in and below do.	Same with wash of Indian ink and yellow dots.
Lower Silurian. b Caradoc or Bala Beds,	Pale Purple.

IGNEOUS ROCKS.

B. Basalt and Dolerite,	Crimson lake.
B., Do. (intrusive)	Do. Darker.
F. Felstone,	Orange Chrome and Carmine.

Lower Silurian Rocks.—These beds, occupying about two-fifths of the area of the Sheet, may be generally described as consisting of gray grits and darker shales interstratified, one or other of these classes of rock predominating for short distances. The beds have a prevailing south-easterly dip, with occasional variations, however, arising from contortions. The grits appear sometimes, but not very frequently, in massive beds. They are for the most part light coloured, but a few examples of very dark grits occur. The shales, which are in general splintery and fissile, and in some cases slaty, are in a few localities more massive. They sometimes exhibit various shades of gray or green, in delicate stripes caused by lamination. Dark shales containing iron pyrites occur in the south-east of the Sheet.

Carboniferous Sandstone.—Sandstones and conglomerates belonging to the Carboniferous Series are found below the limestone, resting on the older Silurian rocks. The sandstones present considerable variety, both of colour and texture. They are often of a light greenish-gray colour, very fine grained, and striped or mottled irregularly with red and purplish stains. Others are of a more uniform and darker colour with various shades of red and brown. Greenish and reddish gray sandy shales, often hard and delicately laminated, and in some places containing indistinct plant remains, are associated with the sandstones.

In addition to the above sandstones, dark purplish and reddish

brown softer grits are common. They are often marked with light greenish blotches, and in some beds this becomes the prevailing colour. These grits frequently pass into a fine brecciated conglomerate, consisting of pebbles of hard grit, in most cases of a purplish colour, and green and red shales, with a few of white quartz, imbedded in the finer gritty mass. This latter is seen in its coarser parts to be made up to a great extent of grains of quartz and flaky particles of the above-named green and red shales. The binding material is for the most part calcareous, as is the case also in some of the harder and more fine-grained sandstones, but in neither is this universal. Sandstones of a purer and more siliceous nature are occasionally to be met with, and also thin beds of brecciated limestone. Beds of hard impure arenaceous limestone, with a few of conglomerate, occur at the top of the sandstone series near Armagh.*

Lower Limestone.—This division of the Carboniferous Series consists here chiefly of light gray crystalline limestones, sometimes possessing a slight bluish tinge, and in certain localities assuming deeper brown and reddish shades. The beds are in most places separated by thin layers of dark gray shale. The limestone is in general highly fossiliferous, many of the beds containing large bunches of coral, crinoidal fragments, shells, and, especially towards the base, fish remains.† Cherty bands are occasionally met with. The thicker beds of limestone supply very good building stone, which has been extensively quarried in some parts. In the neighbourhood of Armagh some of the lower beds have been worked and polished for marble. These furnish a close-grained rock, which, being of a pinkish or purplish brown and gray colour, beautifully spotted and clouded with various tints of yellow and brown, and susceptible of a high polish, is well adapted for ornamental work. Some of these beds are flaggy, and have been used in the streets of Armagh. The limestone is in many localities burned for lime, of an excellent quality, which is principally used for agricultural purposes. A blueish limestone at Benburb is said to produce lime possessing hydraulic properties. This was used in the bridges over the Ulster canal. Occasional beds of yellowish and light reddish siliceous sandstone occur in various parts of the district, interstratified with the limestone, and these have in some places been quarried for building.

Calp.—The Calp, or middle division of the Carboniferous Limestone, is represented in this district by a series of beds consisting of sandstones, blue shales, and earthy limestones, which are exposed along the canal south-west of Benburb. A few very thin

* Beds of sandstone underlying the lower limestone are mentioned in Portlock's Report, &c., as having been noticed in a memoir relating to the county Londonderry, published in 1814 by Rev. G. V. Sampson.

† Many of the finest typical specimens of fish remains from the Carboniferous limestone have been procured from these beds. A list, contributed by Captain Jones, is given in Lieutenant-Colonel Portlock's Report, &c. Further on, notice is taken of the identity in mineral type of the same beds with those at Derryloran and Desertcreat in Tyrone, and Desertmartin in Londonderry. This is confirmed by fossil evidence, the most characteristic fish remains, *Psammodus* and *Cochliodus*, being common to all. Other comparative details are also given.

seams of coal have also been met with in these beds. The shales are highly fossiliferous, and the sandstones, which predominate, contain fine impressions of plant remains, and not unfrequently those of shells.*

Upper Limestone.—A small thickness of light gray fossiliferous and somewhat arenaceous limestone exposed in the same section, immediately above the sandstones, &c., just mentioned, is referred to this group.

Lower Permian Beds.

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

Resting on the Lower Carboniferous Limestone at the old marble quarries S.E. of Armagh, are certain beds of breccia, and conglomerate, which when first seen by myself in the early part of 1872, I referred with little hesitation to the Lower Permian Formation.† This opinion was confirmed by Professor Ramsay, F.R.S., in a subsequent visit.‡ On seeing them they reminded me at once of the Permian Breccias of Worcestershire and Salop, with which I had long been familiar; and Professor Ramsay pronounced the lower portion of the section to be apparently the equivalent of the "brockram" of the vale of the Eden; a formation of limestone breccia, resting often, like the beds of Armagh, on the Carboniferous Limestone of that district.

From Geological position, the Armagh breccias can only be referable either to the Permian or New Red Sandstone formations, as they rest on the Carboniferous Limestone, but it is exceedingly improbable that they belong to the New Red Sandstone, as they are altogether different in mineral character from any of the beds of that formation as it is developed along the valley of the Lagan, or to the northward of Armagh itself; where it consists of soft, bright red, and mottled sandstone—destitute of conglomerates or brecciated beds.

On the other hand, nothing can be closer than the resemblance of these beds to the Lower Permian strata of Worcester, Salop, and Staffordshire; the upper portion consisting of an old Palæozoic boulder bed, being in all probability the equivalent of the Permian boulder beds of the west of England, which Professor Ramsay has referred, for their formation, to the agency of floating ice.

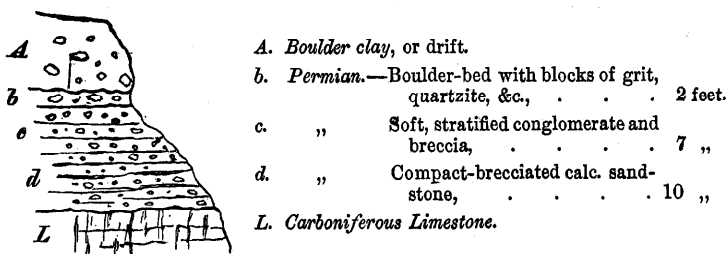
The beds are exposed in two quarries, west of Armagh, of which the following are sections.

* This series of beds, and the limestone, &c., immediately above and below them, are referred to and illustrated in section in Portlock's Report, &c. They are here described by Mr. (Sir R.) Griffith as belonging to the lower of two distinct sections into which the strata, extending from the lower portion of the mountain limestone to the upper portion of the coal, are divided. This section consists of a succession of strata of sandstone, limestone, and shale, with thin beds of coal; and the upper section, including numerous and thick beds of coal, with black shale, sandstone, and argillaceous ironstone, he considers as belonging to the true coal series.

† The *Rothe-todte-liege*nde of German Geologists.

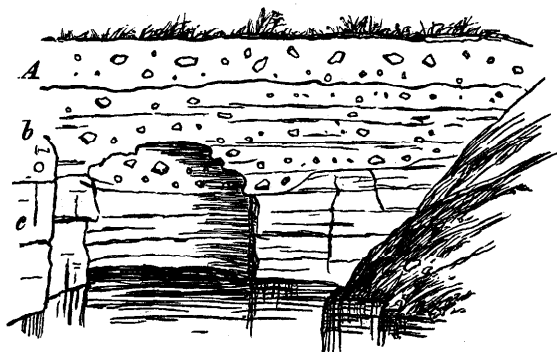
‡ In October 1872.

Fig. 1. Section of Permian beds, near Armagh.



The second section is shown in a quarry partially filled with water. The bottom of the quarry reaches the marble beds here formerly worked, which lie at the base of the Permian beds.

Fig. 2. Section in another quarry near No. 1.



A. Drift Boulder clay b. Permian boulder-beds. c. Permian breccia.

At the top of the section we have the boulder clay of the Drift period, resting on Permian boulder beds; the division between the two deposits being clearly discernible all along the face of the section, notwithstanding their similarity as regards composition. Below the boulder beds are consolidated reddish breccias of limestone pebbles in a red calcareous sandy paste. The upper surface of this breccia has in some places been eroded (see fig. 2,) but in other places there is a clear passage upward from the "brockram" into the boulder bed of the Permian formation.

The pebbles and stones of the boulder bed sometimes reach two feet in diameter, and consist of hard greenish and purple grits, probably of Lower Silurian age; vein quartz, slate, Carboniferous limestone, diorite, &c., some of which have probably been transported from the region lying twenty or thirty miles to the north-west of this locality. Considering the large size of these boulders, it is difficult to conceive that they could have been car-

ried to their present positions by any other agency than that of floating ice.*

Section in the banks of the Blackwater.—Another locality where strata referable to the same formation occur in this district is along the banks of the Blackwater near Benburb. These are described by Mr. Egan further on, and it will suffice here to observe, that in this locality they rest on the Upper Limestone instead of the Lower, as in the case of the Armagh deposits, and consist chiefly of purple sandstones and marls, with one or two beds of compact and brecciated limestone, probably derivative.

From the position in both of these localities of the Permian beds in relation to those of Carboniferous age it will be apparent that these latter had undergone a vast amount of denudation before the Permian beds were deposited upon them. We cannot assume this at less than several thousand feet of strata as it includes the whole of the coal-measures, the millstone grit, the Yoredale beds, and part of the limestone itself.†

E. H.

TRIASSIC BEDS.

Upper Mottled Sandstone. (Bunter.)—The Triassic strata, which occupy a considerable area in the north and west of the Sheet, are not exposed in many places. The bright red sandstones met with in the river Blackwater, to the west of Benburb, and those reached in the sinking of wells in various localities, appear all to belong to the Bunter series, and have accordingly been so mapped.

Lower Keuper Sandstone.—A few beds of hard red shale and light reddish gray sandstone in the river Callan, two miles north of Armagh, are supposed to belong to this division.

Basalt.—The basalt, which extends over a large area of this district, forms part of the great sheet that overspreads the county Antrim. The rock is well exposed, both naturally and otherwise, in several places, and is best seen in the cuttings of the Ulster, and the Newry and Armagh railways. The latter passes through a small basaltic area, distinct and separated by a narrow interval from the larger sheet to the north-east, with which, however, it was no doubt originally connected.

The basalt often exhibits a bedded structure, consequent on the occurrence of successive flows of the original molten mass. It is at other times more massive, and in the latter case especially it is often uniformly divided by nearly vertical joints, which give it a columnar structure. In general it is hard and finely crystalline, and of a dark gray colour, weathering with a tendency to the

* It is to this agency that Professor Ramsay has attributed the transportation of the boulders in the Permian beds of the west of England.—*Quart. Journ. Geol. Soc.* Vol. **xi.**, p. 185.

† A paper on the Armagh Permian Beds was communicated by the writer to the Geological Society of London, at the meeting of the 30th April, 1873, which will be published in the Journal of the Society.

globular structure, which is sometimes so far developed as to reduce the rock to a mass of concentric spheroids imbedded in a brownish gray sand. In some places it is very amygdaloidal, containing cavities filled with zeolites and carbonates, and in this case it disintegrates rapidly.

Intrusive Rocks.—Intrusive dykes of igneous origin are found occasionally crossing the Carboniferous and Lower Silurian strata. They consist principally of basalt, the rest being composed of felstone in different varieties. The former have the same general north-westerly bearings that prevail among the basaltic dykes of this region.

Tertiary Clays.—The boundary of these deposits, which extend a short way into the sheet, is obscurely defined, and has been drawn so as to include that portion of the extensive bogs and flats lying to the east of Moy, in which variously coloured clays exist below the surface, more or less mixed with sand. Among these pipe-clay occurs in some localities. The mounds which rise up from these flats are composed, so far as can be learned from the shallow cuttings near the surface, of brown and sometimes variegated clayey, and sandy materials, containing a few boulders, with occasional layers of gravel and pure sand. The purer clays, which are of a light brown colour, are sometimes calcareous.

3. *Relations between the External Form of the Ground and its Internal Structure.*

The low ground occupied by the New Red Sandstone in this Sheet lies at the south-western boundary of the great basin which extending over parts of the counties of Antrim, Tyrone, and Londonderry, contains the Triassic and Cretaceous strata, covered by basalt.

From what can be observed of the Lower Silurian, Carboniferous, Permian, and Triassic formations, as they occur in this Sheet, it may be inferred that the Lower Silurian rocks were subjected to great disturbances, which crumpled them, and produced flexures more or less rapid, ranging for the most part along E.N.E., and W.S.W. axes. They have subsequently been subjected to a great amount of denudation, which produced the present worn condition and truncated appearance of the beds at the surface.

The Carboniferous strata were deposited over the Lower Silurian, and afterwards, at intervals, the newer formations above named.

With the exception of the most elevated ground, which, as already stated, lies near the south of the Sheet, the almost universally undulating character of the surface is due to accumulations of drift, so that there is not observed the variety of configuration which accompanies different rock formations in districts where they are close to the surface. Low lying rocky patches occur, but they are of small extent. Of these the most worthy of observation is at the south-west of Armagh, where the Carboniferous limestone comes to the surface, presenting on a small scale the cavernous and scarped features which often characterize that formation.

4. MICROSCOPIC NOTES.

On the Microscopic Structure of the Basalt of Ballyleny, near Armagh.

This is a medium-grained basalt or dolerite, and would come under the head of "anamesite" amongst German petrographers. It belongs to the Tertiary period, being a portion of the great sheet of Miocene basaltic lava of the north-east of Ireland.

When a thin slice is viewed under the microscope with a low power (25 diameters), it is seen to consist of the usual net work of long colourless prisms of triclinic felspar (Labradorite) imbedded in a sub-crystalline augitic base of a pale brown colour. There are also numerous large grains of magnetite, or titanoferrite, perfectly opaque; and patches of a leek green mineral, together with a considerable infusion of a greenish pigment amongst the other minerals. This green mineral is probably chlorite.

A few grains, of ill-defined form, of a light brownish mottled or granular-looking mineral may be considered, with every probability, as being formed of olivine.

With polarized light the felspar prisms show the parallel bands of prismatic colour, and fine hair-like lines parallel to the longer axes, which are characteristic of the triclinic felspars. The augitic base exhibits rich bronze, green, pink, and other shades, but the chlorite and olivine have scarcely any refractive powers; particularly the former.

Olivine.—Seen with a very high power (450 to 750 diams.) the brownish granular patches which I suspect to be olivine exhibit a peculiar stellate structure, multitudes of centres radiating out in all directions. This is a structure of olivine which has been determined by Dr. Zirkel, and is figured and described by him from a specimen of the basalt of Moss in Norway.* I have very little doubt, therefore, of the correctness of the determination. The absence, however, of crystalline form precludes absolute certainty.

Chlorite.—The chlorite is here, as probably in all cases, a secondary mineral, due to percolation of water through the rock. It frequently discolours the felspar, and less commonly the augite, and forms several dense patches becoming translucent outwards.

With a high power the structure is well brought out; and it is seen how the mineral has insinuated itself amongst the primary constituents of the rock—in wavy hands or layers, deposited over each other in succession, and giving at once the impression of deposition from the flow of water.

On the whole, the specimen from Ballyleny seems a fair sample of the basalts or dolerites of the north-east of Ireland, so far as I have had opportunities of examining them under the microscope.

EDWARD HULL.

* Untersuchungen über die Mikroskopische. Zusammensetzung der Basaltgesteine. Taf. II.

5. PALÆONTOLOGICAL REMARKS.

LOCALITIES from which FOSSILS were collected.

No. of Locality.	Quarter Sheet of 6-inch Map.	Townland.	Situation, Geological formation, and Sheet of 1-inch Map.
County of ARMAGH.			
1	7/4	Carrickaness, . . .	At Blackstokes-bridge mills, on south bank of River Blackwater, a little south of Benburb; Carboniferous sandstone.
2	7/4	Do., . . .	South side of River Blackwater, half a mile south-west of Benburb; Carboniferous sandstone.
3	7/4	Do., . . .	Near the Seventh Lock, Ulster Canal, half a mile south-west of Benburb; Carboniferous sandstone.
4	7/4	Do., . . .	A little east of Booth's mills, three-quarters of a mile south-west of Benburb; Carboniferous sandstone.
5	7/4	Do., . . .	East of preceding locality, half a mile south-west of Benburb; gray shale.
6	7/4	Do., . . .	Quarry at Blackstokes-bridge mill, south side of River Blackwater, a little south-west of Benburb; gray shale.
7	7/4	Do., . . .	South side of Ulster Canal, a little north of Carrickaness House, quarter of a mile south of Benburb; Carb. limestone.
8	7/4	Maydown, . . .	A little east of preceding locality, and west of Third Lock, Ulster Canal; Carboniferous limestone.
9	7/4	Tullymore Etra,* . .	On south bank of Ulster Canal, south-east of Booth's mills, one mile south-west of Benburb; Carboniferous shale, and limestone breccia.
10	8/3	Tullygoonigan, . . .	Three-quarters of a mile east of road from Armagh to Moy, a little north of Callan river, three miles north of Armagh; Carboniferous limestone.
11	8/4	Ardrea, . . .	At Retreat Lunatic Asylum, a little north of Ulster Railway, three miles north-east of Armagh; Carboniferous shales.
12	8/4	Lisshffield, . . .	A little north of Fruit Hill, one mile north-west of Rich Hill Station, Ulster Railway; Carboniferous limestone.
13	8/4	Ballygasey, . . .	A little south of Ballygasey Cottage, two and a half miles south-west of Loughgall Village; Carboniferous limestone.
14	8/4	Do., . . .	Quarter of a mile north of Ballygasey Cottage, half a mile west of Loughgall village; Carboniferous limestone.
15	8/4	Greenan, . . .	One mile south-west of Loughgall Village, three and a half miles north-east of Armagh; Carboniferous limestone.
16	8/4	Carganamiuck, . . .	Three-quarters of a mile south-west of Grange Blundel, three miles north of Armagh; Carboniferous limestone.
17	9/3	Castleraw, . . .	One mile east of Loughgall, on north side of road to Portadown; Carboniferous limestone.
18	9/3	Annahugh, . . .	Three-quarters of a mile east of preceding locality, on north side of road to Portadown; Carboniferous limestone.

*Mr. Hull considers the beds in locality No. 9 to be of Permian age, and the fossils found in them to be derivative from the Carboniferous limestone.

LOCALITIES from which FOSSILS were collected.

No. of Locality.	Quarter Sheet of 6-inch Map.	Townland.	Situation, Geological formation, and Sheet of 1-inch Map.
19	9/3	Money,	A little west of Kilmore, two miles north of Rich Hill; Carboniferous limestone.
20	9/3	Mullaletragh, . . .	About a quarter of a mile south of Kilmore; Carboniferous limestone.
21	11/4	Annaghananny, . . .	West side of Ulster Railway, half a mile west of Killylea; Carboniferous shale and limestone.
22	11/4	Cavanapole,	Half a mile north of Fellows Hall, one mile south-west of Killylea; Carboniferous limestone.
23	12/1	Drumcarn,	Half a mile south-east of Drumshill House, one mile north of Armagh; Carboniferous limestone.
24	12/1	Carrickaloughran, . .	Half a mile north of Ulster Railway, one and a half miles north-west of Armagh; Carboniferous limestone.
25	12/1	Lisadian,	At National School, two and a half miles west of Armagh; Carboniferous limestone.
26	12/2	Tullyard,	Half a mile west of Wilson's bridge, Ulster Railway, one and a half miles north of Armagh; Carboniferous limestone.
27	12/2	Do.,	A little south-west of Wilson's bridge, one and a half miles north-east of Armagh; Carboniferous limestone.
28	12/2	Cabragh,	In grounds of Glebe House, about two miles north of Armagh; Carboniferous limestone.
29	12/2	Drummanmore, . . .	East side of road to Loughgall, north of Wilson's bridge, about one and a half miles north-east of Armagh; Carboniferous limestone.
30	12/2	Drummanbeg,	West of Drummanbeg Lake, about two miles north-east of Armagh; Carboniferous limestone.
31	12/2	Drumogher,	On road a little north of Castle Dillon, two and a half miles north-east of Armagh; Carboniferous sandstone.
32	12/3	Drumarg or Downs, . .	South side of road from Ballynahone bridge to Armagh, half a mile south-west of Armagh; Carboniferous limestone.
33	12/3	Do.,	"Marble" quarry, south of Green Park, three-quarters of a mile south of Armagh; Carboniferous limestone.
34	12/3	Aghamoat,	"Marble" quarry a little south-east of preceding locality three-quarters of a mile south of Armagh; Carboniferous limestone.
35	12/3	Do.,	About a quarter of a mile north-east of Red Barn, one mile south of Armagh; Carboniferous limestone.
36	12/3	Do.,	A little east of preceding locality, about one mile south of Armagh; Carboniferous limestone.
37	12/3	Ballyheridan,	A little north-east of Red Barn, one mile south of Armagh; Carboniferous limestone.
38	12/3	Do.,	A little south-west of preceding locality, one mile south of Armagh; Carboniferous limestone.
39	12/3	Farmacaffly,	A little north-east of Red Barn, about one and a quarter miles south of Armagh; Carboniferous limestone.

LOCALITIES from which FOSSILS were collected.—*continued.*

No. of Locality.	Quarter Sheet of 6-inch Map.	Townland.	Situation, Geological formation, and Sheet of 1-inch Map.
40	12/3	Kennedies, . . .	Near Milford mills, one mile and a quarter south-west of Armagh; Carboniferous limestone.
41	12/3	Legarhill, . . .	On branch road a little north of Ballycrummy House, three-quarters of a mile west of Armagh; Carboniferous limestone.
42	12/3	Navan, . . .	Navan quarry, one and a half miles west of Armagh; Carboniferous limestone.
		County of TYRONE.	
43	61/4	Tobermessen, . . .	A little east of Clonfeacle rectory, west side of road to Moy; Carboniferous limestone.

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

The numbers opposite each species refer to the places at which they were collected, and the mark × placed before them denotes their comparative abundance.

LOWER CARBONIFEROUS SANDSTONE AND SHALE.

PLANTÆ.

	Localities.
Sagenaria,?	1.
Plant fragments,	1, 2, 3, 4, 5, 8, 9, 11.
Fucoids?	9.

CARBONIFEROUS LIMESTONE, SANDSTONE, AND SHALE.

ACTINOZOA: Corals.

Alveolites depressa,	7, 8, 15, 33, 37, 41.
Chætetes tumidus,	5, 8, 25.
Cyathophyllum ceratites,	8, 14, 22, × 28, 29, 30, 32, 37.
" turbinatum,	25.
Favosites incrustans,	5.
Lithodendron affinis,	8, 9, 15, 18, × 25, 28, × × 29, × 33, 35, 41, 42, 43.
" irregularis,	8, 22.
" junceum,	8, 18, 28, 30.
Lithostrotion striatum,	17, 18, 20, × × 29, 30, 35, 37, 38, 39, 42.
Zaphrentis cylindrica,	× 7, 8.
" or Cyathophyllum, species indeterminate,	4, 9.

MOLLUSCA: Polyzoa.

Ceriodora rhombifera,	5, 8, 43.
Fenestella antiqua,	× × 5, 8, 21, 26.
" formosa?	5.
" frutex,	5.
" membranacea,	8, 26, 27, 29, 37, 41, 42.
Glauconome pluma,	5.
" pulcherrima,	5, 6.
Ptylopora pluma,	8.

Brachiopoda.

	Localities.
<i>Athyris ambigua</i> ,	8, 9, 27, 28, 36, 43.
" <i>planosulcata</i> ,	5, 8, 10, 12, $\times \times$ 13, $\times \times \times$ 18, 19, 20, 21, 22, 25, 26, 27, 29, $\times \times \times$ 30, 31, 36, 38, 39, 41, 42, ? 43.
" <i>sp. indet.</i> ,	14, 23.
<i>Chonetes comoides</i> ,	14.
" <i>Hardrensis</i> ,	$\times \times$ 5.
<i>Discina nitida</i> ,	5.
<i>Orthis Michelini</i> ,	5.
" <i>resupinata</i> ,	9, 12, 42.
<i>Productus aculeatus</i> ,	29.
" <i>fimbriatus</i> ,	5, 27, 29, 37, 41.
" <i>giganteus</i> ,	5, $\times$ 7, 8, 10, $\times \times$ 14, 15, 16, 17, $\times \times$ 18, 19, $\times$ 20, $\times \times$ 21, 22, $\times \times$ 23, $\times$ 25, 26, 29, 30, $\times \times$ 31, 32, 33, $\times \times$ 34, $\times$ 36, $\times$ 38, 40.
" <i>punctatus</i> ,	5, 6, 8, 9, 12, 17, 21, 22, 25, 26, 28, 29, 36, 38, 41, 42.
" <i>scabriculus</i> ,	8, 41.
" <i>semireticulatus</i> ,	5, 8, 12, 15, 17, 19, 21, 22, 25, 26, 27, 28, 29, 37, 41, 42, 43.
<i>Rhynchonella pleurodon</i> ,	5, 12, 17, 18, $\times \times$ 20, 21, 22, 26, 31, 38, 41.
" <i>pugnus</i> ,	22.
<i>Spirifera bisulcata</i> ?	9, 39.
" <i>glabra</i> ,	12, 14, 21.
" <i>laminosa</i> ,	5.
" <i>lineata</i> ,	21, 26, 29, 43.
" <i>striata</i> ,	5, 8, 9, 12, ? 25, 26, 29, 35, 42, 43.
<i>Spiriferina cristata</i> ,	$\times \times$ 5, ? 8, 12.
<i>Streptorhynchus crenistria</i> ,	8, 12, 14, 21, 29, 38, 42.
<i>Terebratulula hastata</i> ,	36.

Lamellibranchiata.

<i>Aviculopecten granosus</i> ,	? 5, ? 8, $\times$ 21.
" <i>interstitialis</i> ,	$\times \times$ 21.
" <i>megalotus</i> ,	8.
" <i>Sowerbii</i> ,	5, 6, 8, 21.
" <i>sp. indet.</i> ,	5, 28, 33, 38, 39.
<i>Axinus axiniformis</i> ?	3.
" <i>deltoides</i> ,	3.
" <i>sp. indet.</i> ,	5.
<i>Modiola Macadami</i> ,	3, 6, 11, 21.
" <i>subparallela</i> ?	8.
<i>Myacites Omaliana</i> ,	40.
<i>Pinna fiabelliformis</i> ,	36.
<i>Sanguinolites plicatus</i> ,	16, 38, 42.
" <i>transversus</i> ,	38.
" <i>sp. indet.</i> ,	3.
Other Bivalve shells indeterminate,	4, 30.

Gasteropoda.

<i>Euomphalus crotalocrinus</i> ,	29, 36, 38 ? 39.
" <i>Dionysii</i> ,	12, 36.
" <i>tabulatus</i> ,	38.
" <i>sp. indet.</i> ,	13.
<i>Loxonema sp. indet.</i> ,	27, 30, 34.
<i>Macrocheilus biserialis</i> (Turbo <i>Phil.</i>)	8.
" <i>sp. indet.</i> ,	8, 29.
<i>Natica plicistria</i> ,	8, 36, 38, 43.
Other univalve shells indeterminate,	30.

Nucleobranchiata (Heteropoda).

<i>Bellerophon apertus</i> ,	29, 38.
" <i>recticostatus</i> ,	18, 20, 27, 30, $\times \times$ 36, $\times \times$ 38, 39 41.
" <i>sp. indet.</i> ,	10, 14.

Cephalopoda

	Localities.
<i>Cyrtoceras Gesneri</i> ,	6.
<i>Nautilus dorsalis</i> ,	16, 18.
<i>Orthoceras</i> , sp. indet,	6, 20, 36.

ANNULOSA: *Echinodermata*. Crinoidea.

<i>Actinocrinus lævis</i> ,	5.
" sp. indet,	27, 38, 40, 42.
<i>Cyathocrinus</i> ,	27, 32, 34, 35, 37.
<i>Platycrinus lævis</i> ,	5.
<i>Poteriocrinus crassus</i> ,	8.
Crinoid fragments,	× × 5, 6, 8, 9, 17, 19, × × × 27, 29, 32, 33, × × × 34, 36, × × × 37 × × 39, × × × 42, 43.

Echinoidea.

<i>Archæocidaris Urii</i> ,	5, 6, 27.
<i>Palæchinus</i> , sp. indet,	33.

CRUSTACEA: *Ostracoda*.

<i>Bairdia elongata</i> ?	5.
" subcylindrica?	10.
<i>Leperditia Okeni</i> (<i>Cypris subrectus Porth.</i>),	5, 6, 8, × × × 11, × 21, 29.
" sp. indet,	37.

Trilobita.

<i>Phillipsia Derbiensis</i> ,	15, 22, 38, 42.
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VERTEBRATA: *Pisces*. Cestraciontidae.

<i>Cladodus mirabilis</i> ,	39.
<i>Cladodus striatus</i> ,	39, 42.
<i>Cochliodus contortus</i>	35, 42.
<i>Ctenacanthus tenuistriatus</i> (defence spine),	26.
<i>Ctenopetalus serratus</i> ,	27.
<i>Deltoptychius acutus</i> ,	39.
<i>Helodus didymus</i> , or <i>gibberulus</i> ,*	39.
" <i>lævissimus</i> ,	39.
" sp. indet,	42.
<i>Petalodus lævissimus</i> ,	42.
<i>Pæcilodus Jonesii</i> ,	17, 39.
<i>Psammodus porosus</i> ,	39, 42.
" <i>rugosus</i> ,	38, 39.
<i>Psephodus magnus</i> ,	35, 36, 38, × × 39.
<i>Streblodus Colei</i> ,	39.
" <i>oblongus</i> ,	39.

In the preparation of this list of species more than 800 fossils were examined and named; the largest proportion of them were collected by Mr. Edward Leeson, and the remainder by Mr. Alexander M'Henry, of the Geological Survey. Not having had an opportunity of visiting the district myself, the results are derived from the examination of the specimens only.

* Probably identical species.

Plant remains were collected at locality 1, in sandstone, some of them being coarsely ribbed stems measuring over an inch in diameter, and resembling *Sagenaria* of the Lowest Carboniferous and Upper Old Red Sandstone strata. Those from localities 2, 3, and 4, also in sandstone, were fragmentary, some being marked with fine longitudinal striæ; at locality 11, plant remains occur in shales apparently of the lower limestone, with *Modiola Macadami* and *Leperditia Okeni*. Plant fragments were also found at locality 8 in gray limestone, associated with many Carboniferous species, such as are usually observed at the lower portion of the Carboniferous series. Plant remains, including fucoid-like impressions, were also obtained from red shales at locality 9. Belonging to the Actinozoa, *Chaetetes tumidus*, a prevalent fossil of the lower limestone shale occurs at localities 5 and 8, at the latter place being associated with the small turbinated coral, *Cyathophyllum ceratites*. At locality 7, large and fine specimens of *Zaphrentis cylindrica* were collected from what is probably lower limestone shale.

The other corals consist of species which form aggregate groups of corallites, and usually occur throughout the mass of beds composing the Carboniferous Limestone, the most frequent being *Lithostrotion striatum*, (basaltiformis) and *Lithodendron affinis*.

Amongst the lowest group of Mollusca, the Polyzoa, *Cerriopora rhombifera* and *Fenestella antiqua*, characteristic fossils of the Lower Limestone Shale, occur with others of the same class at several localities, especially 5 and 8.

The most frequent of the species of Brachiopod shells from the Carboniferous Limestone of this district is *Productus giganteus*, found at 24, and *Athyris planosulcata*, at 22 localities, the latter shell being abundant and of all ages at localities 18 and 30. *Productus semireticulatus*, *punctatus* and *Rhynchonella pleurodon* are also widely distributed; *Terebratula hastata*, so common in the Carboniferous Limestone of the south of Ireland, was found here only at one locality.

The ordinary Bivalves, Lamellibranchiata, include *Modiola Macadami*, a species notably characteristic of the Lowest Carboniferous, it occurs in sandstone at locality 3, and in shales at localities 6, 11, and 21.

A rare Univalve, *Macrocheilus biserialis* (Turbo, Phillips), was collected at locality 8; the large species of Euomphalus, *E. crotalocrinus*, appears to be the prevalent form of this genus of Turbinoid shells in the limestone of this district. A Heteropod shell, *Bellerophon recticostatus*, Portl, is of frequent occurrence, especially in the pink or reddish limestone, a little south of Armagh, at localities 36 and 38.

The remains of Cephalopod Mollusca in this collection are very few; the entire absence of Goniatites as well as of the great variety of Orthoceratites, so prevalent in the Carboniferous Limestone of the south, is remarkable.

Crinoids appear to be rare, except in a disjointed condition; the limestone at some of the localities, especially 27, 34, 37, and 42, is very full of Crinoidal fragments. Detached plates and spines of *Archæocidaris Urvii* were collected at localities 5, 6, and 21, all apparently in Lower Limestone Shale.

The bivalved Entomostracan included in our list is referred by Messrs. Jones and Kirkby* to *Leperditia Okeni* Münster sp. variety (Cypris) *subrecta*, Portlock.† This small crustacean has, according to these

* Annals and Magazine of Natural History, May, 1865, and June, 1866.

† Geological Report of Londonderry, Tyrone, &c., p. 316, pl. 24, figs. 13 b and (Cypris Scotoburdigalensis) 18 c.

authors, a wide geographical range, "being found in Russia, Nova Scotia, Germany, and Belgium, and in the Upper and Lower Carboniferous strata throughout the British Isles." In the district we are now describing it has been collected from six localities, all, with one exception, in shales, which from the associated fossils would appear to indicate Lower Carboniferous strata; it is especially abundant at localities 11 and 20.

Only one species of Trilobite was observed, *Phillipsia Derbiensis*, collected at four several localities.

The pink or reddish limestone especially to the south of Armagh, some occurring in places described as "marble quarries," has long been celebrated for the abundance of fish remains obtained from it. They are for the most part palatal teeth and defence spines of fish allied to sharks and rays, of which the "Port Jackson shark," *Cestracion Phillipi*, is a recent example. They are included by Professor Owen in the order Plagiostomi, family Cestraciontidae.* Fifteen species enumerated in the preceding list were obtained from seven localities by Mr. E. Leeson; this does not give anything like the number of the various forms recorded from Armagh, which amount to upwards of ninety; a revision of the species is however necessary, when it will most probably be found that their number can be reduced considerably.

Most of the original specimens, many of which were collected by the late Admiral Jones, who contributed a list of them to the late General Portlock,† were described by Professor Agassiz, several being figured in his fine work on fossil fishes.‡ Revised lists of the species have still later been published in the table appended to Messrs. Morris and Roberts' article "On the Carboniferous Limestone of Oretton and Farlow, Clee Hills, Shropshire,"§ and in the catalogues of "Type Specimens of Fossil Fishes," in the collections of Sir P. Egerton and the Earl of Enniskillen.||

Fish remains corresponding in general character to those of Armagh are found in the lower beds of the Carboniferous Limestone near Bristol, and also in the basal beds of the Limestone at Farlow, in Shropshire, before referred to; many of the species at these three widely distant places being identical.

WILLIAM HELLIER BAILY.

June 13th, 1873.

DETAILED DESCRIPTION.

5. Position and Lie of the Rocks.

For convenience of description the whole area of this Sheet may be divided into the *Tanderagee, Armagh, Benburb, and Portadown Districts*.

TANDERAGEE DISTRICT.—*Lower Silurian Rocks*.—These strata appear in a few small bosses to the south of Pointzpass, in the form of blue splintery shales, which sometimes exhibit a delicate oblique lamination, and beds of fine-grained grit. The dips vary from S.E. to E. 20° S., at 15°–35°.

Dark shales, sometimes abounding in iron pyrites, occur below those

* Palæontology, p. 106, &c.

† Report on Londonderry, &c., p. 460, &c.

‡ Recherches sur les Poissons Fossiles, par L. Agassiz, 1833–4.

§ Quarterly Journal, Geological Society, May, 1862.

|| Geological Magazine, September and December, Vol. VI., 1869.

just mentioned. They are occasionally exposed along the road which proceeds westward from Pointzpass. Where it passes through a natural ravine at half a mile north-west of M'Court's Lake, they appear in contorted beds, together with a few beds of gray and greenish grit; and nearly a mile further west there are dark, splintery shales, containing soft carbonaceous nodules, with a wavy south-easterly dip at 30° to 80° , and among them are beds of lighter coloured fissile flags.

In the low-lying patches to the west of the village of Acton, beds of bluish grit alternate with shales and slates. The dips are very variable, but there is a prevailing south-easterly direction, the angle ranging from 10° to 40° .

Splintery shales, with occasional beds of grit, are well exposed up the slopes of a ravine three-quarters of a mile west of Acton. They are covered in some parts by 8 or 10 feet of drift. The dips here are also variable, mostly pointing, however, south to south-east at 20° to 60° . Many of these shales are of an olive-green colour, and some are very ferruginous. These shales weather into nodules of a rusty-brown colour on the surface, and greenish in the interior.

North-westerly dips prevail along the river Cusher, to the east and for a mile south-west of Tanderagee, and in the small rocky spaces lying a little south of east of that town. The prevailing direction is N. 20° W., sometimes becoming almost horizontal, but chiefly ranging from 20° to 40° , and occasionally amounting to 75° . These, with the few exceptional south-easterly dips, occur among bluish grits in beds of various thickness, interstratified with blue flaggy shales.*

Blue and gray shales with very dark coarse grits occur in the river at the south-east of the ruins of Clare Castle. They dip S. 40° E. at 20° – 40° .

In a railway cutting at the south of Drummiller Lough, on the Banbridge and Scarva railway, tough gray grits with layers of shale, and thick beds of friable shale, are exposed beneath a thick covering of drift. They have an easterly dip at 20° to 50° , with a wavy strike generally parallel to the railway, and at the south end of the cutting change to S. 30° E. 50° , where they are disturbed by a small fault bearing E. 30° S.

At Hunter's Close there are dips to N. 20° W. at 40° – 80° among gray grits and greenish shales, this being about the southern commencement of the prevailing north-westerly dips, which reach to near Gilford, and which have just been noticed as existing in the vicinity of Tanderagee. Half a mile south-east of the former town, in the curve of the river Bann, fine grained grits, with thin, delicately laminated compact flags, dip N. 30° W. at 30° , being laid bare from beneath 40 or 50 feet of drift which here forms the banks of the river.

Shales are exposed to a small extent at the western edge of the river Bann at Gilford Bridge, dipping S. 10° E. at 10° , and on its eastern bank, close to the junction of the basalt, there are massive purplish grits and green and reddish shales, dipping S. 30° E. at 55° .

Ice striæ were observed on a smoothly worn surface of massive grit, from which several feet of drift had been recently removed, in a quarry south of the road, two-thirds of a mile from Gilford, towards Tanderagee; and others within about the same distance of the latter town, in a cutting through which the road passes, where grits and shales dip

* It is probable that the changes of angle of dip here and elsewhere mentioned are due both to contortion and inversion of the strata, which are sometimes folded back on themselves.—E. H.

N. 10° W. at 50°-70°, below ten feet of drift. These striae vary in direction from S. 25° E. to S. 35° E.

In the country extending westward from Gilford to the basaltic district, the Silurian rocks are almost entirely concealed by a deep covering of drift deposits. Shales were met with, ten feet below the surface, in excavating for a foundation at Laurel Vale.

Gray fine-grained grits appear in thick beds, together with shales dipping S.E. at 70°, at several places along the stream which flows eastward through the Duke of Manchester's demesne, nearly a mile west of Tanderagee; and along the same stream, at the west of the demesne, hard bluish grits alternate with thin beds of dark shale, dipping E. 10° S. to E. at 70°. These rocks are crossed by a dyke of felstone, which shall be noticed among the intrusive igneous rocks (see page 47).

South-west from Tanderagee we pass over a wide area in which the rock is quite concealed below drift deposits, for three miles from the locality just named, and at the east of the Glebe House we meet with blue shales and beds of grit, in places a good deal contorted, with, however, an average south-westerly dip, at 50° to 70°. These beds are crossed by a dyke of felstone (see page 48).

Small exposures of the Silurian rocks are found in the hollows along the streams to the north and north-west of Markethill. They have nearly all south-easterly dips at high angles; but there are a few variations, at much lower angles, to the west. Thick beds of fine-grained grit predominate, separated by flaggy layers of shale.

Ice striae bearing S. 40° E. were observed in the angle formed by the road and railway to the south-west of Gosford Castle, the surface of the rock being protected by one foot deep of drift. Faint striae bearing E. 40° S. occur half a mile due west of this; and 200 yards east of the latter the surface is striated below three feet of drift, the direction being S. 35° W. The rock here consists of tough bluish grits with layers of rotten shale.

Wavy beds of blue flags and dark shales occur close to the basalt in a stream south-west of Gosford Castle, inside the demesne.

At the north-east of Waugh's cross-roads there are dark delicately laminated shales and coarse grits, with beds composed of fragments of both these rocks in the form of a coarse breccia.

In the rocky space south-west of Markethill, there are many exposures at the surface, of thick beds of grit alternating with thinner beds of flags, the latter being sometimes shaly. Some of the grits are very coarse and siliceous. These strata present varying directions and amounts of dip, from south-east to north-west.

The cuttings of the Newry and Armagh railway north of Markethill afford several small sections through the Silurian rocks. In one of these, where the road from Hamilton's Bawn to Markethill crosses, there are exposed contorted beds of fissile micaceous schists and bluish grits and shales, cut by a dyke of vesicular trap (see page 48). At the north end of the cutting the rock is covered by fifteen feet of drift deposits.

A smaller cutting north of this contains pale bluish fine-grained calcareous grits and layers of rotten shale, with wavy south-easterly dips at 20° to 40°, and these beds are covered by eighteen feet of drift.

The denuded areas lying to the south of Hamilton's Bawn contain many surface exposures of massive grits, with layers of shale. The grits occasionally contain large grains of quartz, which remain adhering to the weathered surface. The dips are S. 20°-40° E. at 40°-50°. These

rocks are to some extent quarried for the use of roads, and in one quarry at the west of the road faint glacial striae occur, bearing S. 15° W. Here also numerous strings of carbonate of lime traverse the rocks with some degree of regularity from north to south.

Thin alternating beds of grit and dark blue shale, the latter weathering greenish, occur in a quarry close to the road, a little north-west of Hamilton's Bawn station. Some of the joints are thinly coated with carbonate of lime, and there are a few strings of white quartz. In the north part of the quarry there is a regular series of joints or cracks, filled with a rusty-brown powdery substance. These strike about E. 30° N., inclining northerly at 20°–45°. The beds dip S.E. 45°.

In the portion of this division which lies westward of Rich Hill, the Silurian strata have steady dips of about 30° east of south, at 20° to 30°. In a quarry one-third of a mile south-west of the town, there are thin beds of fine-grained bluish grit, evenly parted by shales, with layers of shale rudely cleaved. Dip S. 15° E. 25°. The cleavage dips in the same direction at lower angles, or 5° to 15°. The joints are crusted with carbonate of lime, and the beds traversed by quartz strings.

Grits, sometimes coarse and containing flaky fragments of dark shale, occur to the west of Rich Hill, with layers of shale. These also contain veins of quartz and carbonate of lime.

Half a mile north-west from Loney's Town, fine grained dark bluish grits appear dipping S. 10° E. 30, quite close to the junction with the carboniferous sandstone.

Basalt.—Basalt appears at the surface in a few places among the lower lying portions of the district at the east of Pointzpass, forming, no doubt, a disconnected portion or outlier of that which occurs more extensively to the north and west. It is seen in small masses at the surface, 300 yards north-east of Prospect Cottage. The rock is dark, and very finely crystalline, breaking with a rough uneven fracture, and contains a few vesicular cavities filled apparently with white carbonate of lime. It weathers to a rusty brown colour. Basalt again appears at a house on the roadside, 700 yards south-east of Prospect Cottage; and has been quarried at the southern extremity of the patch here assigned to the formation.

The basaltic area about Markethill was in all probability connected originally with the very extensive sheet stretching away to the north. Good sections are laid bare in the railway cutting at the south of Markethill, where it is covered by several feet of boulder-clay, overlying the clayey material which results from disintegration of the basalt. The passage of the solid rock into this condition is clearly marked, the joints becoming gradually obliterated, and disappearing *in situ*. These latter are disposed with considerable regularity, in some places exhibiting a columnar structure, in which the planes of separation are highly inclined to the horizon, giving the rock a stratified appearance when viewed from a short distance. There is, besides, a bedded structure throughout, apparently marking the planes of flow. These are in some cases horizontal, but generally inclined at low angles, the direction of dip being chiefly towards the east. In many places the basalt here weathers into concentric nodules, and it is also in great part reduced to a light brown sandy mass, full of zeolites, which can be easily picked out in rude almond-like shapes. The joints and cracks, as well as many of the smaller vesicular cavities, are lined or filled with carbonate of lime. In some places where water flows out through fissures in the rock, the surface is thinly coated with a hard whitish substance, changing sometimes to light green; in others the coating material is a brownish red

glossy brittle mineral, so soft as to be easily scratched by the nail, and having a soapy feel (*steatite*?). They both fuse readily, the former to a white, and the latter to a green, porous glass.

Where the surface of the basalt below the drift has remained undecomposed, it is occasionally smoothed and polished. Striae bearing S. 25° E. were found at the south end of the cutting.

Basalt appears at the surface in the space between the above cutting and Markethill, and again in a stream at the pound. Close to the same stream, at one-third of a mile east of the town, it forms a small hillock, and it was found in a weathered condition in a well at the road-side, south-east of Gosford demesne.

The basalt is exposed for nearly half a mile continuously in a large stream which flows in a southerly direction through Gosford demesne, to the south and west of the castle. It is of a dark gray colour, is cut up by many joints, for the most part nearly vertical, and has the same bedded structure as already noticed. The joints here also are coated with a whitish mineral, which sometimes appears on the outer surface in small rhombohedral crystals. It fuses easily to an opaque very white porous glass. This basalt affects the magnet slightly.

Grains of olivine were detected in the basalt from a quarry inside the demesne, to the north-east of the castle, and also in a quarry to the north of it, a little outside the walls.

The basalt in the area to the east of Rich Hill and Hamilton's Bawn is exposed in many places, especially towards the southern part. It is perhaps best seen in a quarry a little north-west of Ballynewry House, where it is very finely crystalline and vesicular, having the cavities filled with a dull blackish soft mineral.

A few bosses of basalt occur near the road which passes eastward by Marlacoo House, and it is found in the streams and hollows as far north as Kilnaharry House, beyond which it is more completely covered by drift.

The junction of the basalt with the Lower Silurian rocks crosses a stream at the east of the road, a little more than a mile east of Hamilton's Bawn. The latter are shales dipping S. 10° E at 20°, and the two descriptions of rock are seen within a few feet of each other in the sides of the stream.

The basalt, as seen in a large patch in the surface of a hill flanked by drift, a little north-east from the last named spot, contains cavities full of zeolites and, perhaps more frequently, the dull blackish mineral above alluded to, which fuses with difficulty to a green glassy bead.

At the south of Rockvale basalt occurs weathering spheroidally, and regularly jointed so as to resemble a dip of 70° S.W.

Where the wide stream passes under the road at the north of Aghory House, a cascade, about ten feet wide and fifteen feet high, is formed by basalt. The stream thence flows northward between steeply sloping banks of drift, partly up which the rock appears in spots, weathering to nearly spherical balls, and in many places vesicular.

A portion of the basalt appears nearly in contact with the carboniferous sandstones in a stream to the west of Belview, about half a mile north-east of Rich Hill; and in the flat land north-east of Belview it occurs weathering spheroidally to a light gray sandy mass.

Basalt appears in a small exposure at the surface, to the west of Derryhale, at the north of the road; and for some extent about here it exists at no great depth. It has also been reached in different places along the road passing southward by the east of Cornascreeb House.

Carboniferous Sandstone.—These beds appear, with fine conglomerates,

along the stream between Belview and the town of Rich Hill. They are exposed at various intervals for a length of about 200 yards, and have very low north-easterly dips, changing in some places more towards the north.

The highest beds exposed consist of coarse brown siliceous sandstone, passing into a fine brecciated conglomerate at top. Below this is a soft coarse grit, of pinkish colour, variegated with green, and consisting chiefly of quartz grains and particles of light coloured shale, bound with a calcareous cement. Under this are red sandstones and sandy shales, overlying a bed of hard cherty limestone.

Reddish brown sandy shales, fissile and micaceous, occur in a stream south-west of Rich Hill station, close to the Lower Silurian boundary. These are overlaid by light green and reddish fine sandstones interstratified with soft purplish shales.

The same beds appear with others in the stream east of Hockley Lodge. They dip N. 20°–40° W. at angles ranging from 15° to 50°, but in most cases about 20°. They are but obscurely exposed in the bed of the small stream, at intervals within a space of about 100 yards in length, and appear in the following order. Commencing at the lowest, a few degrees north of east of Hockley Lodge, there is first a fine reddish sandy conglomerate, containing flat pebbles of green shale. Next in order were observed green and purplish friable shales, with some of a white marly nature, the latter being seen in a well at the east of the stream. These dip N. 20° W., at 40°. About seventy yards to the north appear flaggy beds of brownish and greenish shale, delicately laminated, and very fine light brown sandstone. Dip N. 20° W. 23°. Next are greenish and purplish gray soft grits and fine sandy conglomerate, and over these a few irregularly alternating beds of light gray shales and impure limestone, with soft greenish grits.

The appearance of these beds here, with their north-westerly dips, and of the Lower Silurian beds a short distance to the north-west, must be explained by the existence of a fault between them, the position of which is more fully established further on (page 30).

Flaggy beds of brown earthy sandstone occur in a stream at the north of the railway, quarter of a mile east of Rich Hill station. Below them are purplish coarse sandstones, becoming finely conglomeritic; and dark brown and reddish flaggy sandstones were observed in the next railway cutting eastward, slightly exposed on both sides, at the level of the railway. All these have north-westerly dips.

ARMAGH DISTRICT.—*Lower Silurian Rocks.*—But little remains to be said of these strata, which have been almost fully described in the preceding details. They appear in drains, and in some places at the surface, to the south of Hockley Lodge, and here they dip S.W. at 40° to 70°, the difference between the dips here and those a short distance to the east, where the directions are easterly and south-easterly, being probably due to an intervening fault, which has also brought the carboniferous and Silurian strata abruptly into contact for a length of a mile in a direction due north and south.

Silurian grits occur in a deep drain at the west side of the road nearly half a mile south of L. Gall, close to the junction with the carboniferous sandstones.

The Silurian rocks are well exposed in the railway cutting at the south of Castle Dillon demesne, below about 15 feet of drift deposits. They consist of dark gray shales, and some beds of hard close grained grit, both in many cases slightly calcareous and penetrated by strings of carbonate of lime. They also contain often a little iron pyrites. The dips are

variable, but in general have a southerly direction at low angles. At the east of the bridge there are friable shales interstratified with grit beds, some of which latter are of a very light colour and highly calcareous. Striae were observed on the smoothly rounded surfaces of the rock, about 100 yards from the west end of the cutting. Their direction varies between S. and S. 10° W.

At Armagh the junction of the Silurian and carboniferous strata, which is in many places obscure, is determined with tolerable accuracy, from the sinking of deep wells, &c. The former are exposed almost continuously for three-quarters of a mile along the stream which flows through Dobbin's Valley, from the reservoir to the workhouse, and consist of grits and shales with dips varying in direction between S.E. and S.W., at 20° to 40°. Some of the grits are micaceous.

South-west of Lowry's Lough the dips point in a south-westerly direction, as indicated in the map, but through the remainder of the Sheet to the south the usual south-easterly dips prevail.

Thick grit beds with bands and layers of shale occur in the rocky spots in the high ground east of the Vicar's Carn, the average dip being S.E. at 40°. Coarse quartz grains sometimes stand out in thin bands on the surface of the grits, many of which weather brown. These rocks often occur in small bosses which retain obscure traces of ice-rounding on their north-west side. The same is observed in the denuded space south of Outlack House.

The Silurian rocks of this part of the district, besides appearing in many patches and bosses along the small streams and hollows, are more extensively exposed along the beds of the Butter Water and the Callan river, but more especially in the latter. In each case, as well as to the north-east of the Vicar's Carn, they are crossed by a basalt dyke. These are noticed among the intrusive rocks.

Where the Butter Water flows south and west of Ennislare House, pale grits are exposed along its course, with beds of fissile shale, the grits weathering brown. Some of these assume the character of a fine conglomerate, in which pebbles of quartz, shale, and hard grit are distinguished. The dips west of the road are S. 40° E. 20°, changing to a wavy north-westerly direction at the east side, at 40° to 60°.

Blue shales and grits form the bed of the River Callan in many places south of the junction with the carboniferous rocks, sometimes appearing from beneath many feet of drift. The finer grits are often micaceous. The south-easterly dips are very constant, the average being about S. 20° E., at 30° to 60°. At the north of Roughan House and occasionally to the south of this, however, they become nearly due west for a short space.

The Silurian boundary to the west of the river Callan, that is, for a distance of nearly five miles, can be only approximately defined, owing to the prevalence of the drift deposits. There is a small boss composed of Silurian grits at the side of the stream, south-west of Aghavilly House, where a pit is said to have been opened some years since in search of coal, but, as has always been the case among the Lower Silurian strata, without success.

The next place westward, where these rocks were observed, is where the road leading to Brookly House leaves the Armagh and Monaghan road. They are fine blueish grits containing black shaly particles, and dipping south-westerly at 20°. They are here slightly exposed in the bed of the stream.

Further west they are not at all seen near the junction, but one mile south-west of the last-named place the road passes through a hollow

space in which are exposed dark shales and gray grits, a good deal broken up and cracked, dipping variously towards the north-west and south-east at 20° to 40°.

Lower Carboniferous Sandstone.—The beds belonging to this division are best exposed in section at the north side of the Ulster railway, close to the summer-house in the grounds belonging to Retreat, three miles north-east of Armagh. Here they dip N. W. at 35°.

Besides those seen in this section, they occur along the stream south of the railway, and also further on along the path leading north-west from the summer-house. In these places the dips are chiefly W. 20°—30° N., at angles of 20° to 50°.

The junction is drawn through a point where three townlands meet, at the south of the house. Here part of the bank of the stream had been torn or washed away, so as to expose two thin beds of dark gray cherty limestone resting nearly horizontally on soft purplish and greenish grit, below which, and apparently forming part of the same bed, is a harder grit, evidently of Lower Silurian age.

A little farther down the stream, opposite the end of the building, there is a red fine brecciated conglomerate, calcareous, containing pebbles of light green shale and purple grits and shale, and overlaid by fine grained red earthy sandstones, dipping W. 10° S. at 5° to 10°. These appear for a length of fifteen yards along the stream.

Thirty-five yards from the end of the house, Silurian grits again occur, for a distance of a few yards, a little above which they again appear in the form of a greenish micaceous flaggy bed nearly in contact with an overlying bed of cherty limestone similar to that already noticed at the junction. Another limestone bed appears above this, and is immediately succeeded by a soft red fine sandy breccia or coarse grit, which, with a coarser brecciated conglomerate, and the finer breccia repeated, occupy a distance of about six yards. This red brecciated conglomerate is highly calcareous, consisting of flat pebbles of green and red shale, with more angular fragments of quartz and hard purplish grit, bound by a crystalline calcareous cement. The dip here is W. 10° S. 60°.

A little east of the tunnel under the railway the soft red grit or fine breccia appears again for two yards, and a few yards beyond the western end it occurs in various more or less earthy forms for a length of nineteen yards, dipping about W. 10° N. at 30°.

The section at the summer-house is as follows, in ascending order :—

	Ft.	In.
Impure light greenish limestone, variegated purple,	2	6
Dark purplish brown friable shales, and clayey débris,	4	0
Various sandstones, more or less earthy, and generally calcareous, with layers of shale,	13	0
Friable and fissile arenaceous shales, some containing plant remains; with layers of sandstone, and occasional bands of limestone, 3 to 10 inches thick,	11	0
Fissile arenaceous shales with plant remains, sometimes obliquely laminated,	17	0
Alternating beds of shale and sandstone, with thin bands of light brown tough limestone,	12	0
	59	6

The above are exposed for a depth of about 8 feet, and covered by 3 or 4 feet of drift. Some of the succeeding beds, and apparently those which rest on those just described, occur in section for a thickness of several feet close to the stream, west of the summer-house. They consist of sandy shales and fine whitish marly sandstones, some of the latter

containing cavities lined with closely packed yellowish crystals of carbonate of lime.

These sandstones and shales, so far as they are exposed, represent approximately a thickness of 500 feet.

At the west of the angle formed by two roads, north of Fruit Hill, there appear in a small quarry thin beds of hard, finely-granular, arenaceous limestone with carboniferous fossils. It is of a light gray colour, striated and mottled purple and greenish, and becomes conglomeritic by the appearance of small pebbles of quartz. Fragments of reddish calcareous conglomerate, which were observed lying about, were said to have been quarried from thin beds in the same place. They contain pebbles of quartz, Silurian shale, and of the above limestone. The dip is north-easterly, at 10° to 15° .

Two hundred yards N.N.E. of the last, light brown close-grained calcareous sandstone occurs in a well, and a little more than the same distance N.E. of this, coarse calcareous sandstones, of greenish and reddish shades of gray, occur in a drain. These pass into a fine conglomerate.

A little further north, along the stream, a bed of compact purplish limestone was observed, dipping N.E. 15° , and, still higher up, gray shaly limestone flags with a few coral remains, appearing to pass into a shaly conglomerate. Above these—most of which were noticed with difficulty, and by close searching—there are better exposed beds of compact blue limestone and gray shale, containing a few corals and shells, and dipping N. 40° E. at 20° . These last have been included in the sandstone series, as they are overlaid a little further north by beds of sandstone and gray sandy shale, exposed in a well at the north side, and a drain at the south side of the road. All present north-easterly dips, thus confirming the existence of a north and south fault, already noticed (p. 27), and here bringing the sandstones against the carboniferous limestone, the beds of which, in the immediate vicinity eastward, dip N. 15° W. at 25° .

At the north of Castle Dillon Lake, hard light brown fine sandstone is slightly exposed at the north side of the road, below six feet of drift clay—also a softer, dark, brownish-red sandstone, with a layer of soft sandy marl. These beds dip obscurely westward, or a little south of west, at 10° to 40° . They contain a few fossil impressions—(*Productus semi-reticulatus*, &c.)

A series of beds of sandstone, conglomerate, and occasionally limestone, occurs, with some interruptions, along the bed of a stream which flows under the road from Armagh to Portadown, at Killuney Bridge, about a mile from the former place. It extends over a distance of about 520 yards, and represents nearly the whole thickness of these lowest carboniferous strata.

Commencing at the junction with the Silurian rocks, 430 yards south-east of Killuney Bridge, we there meet with a fine conglomerate resting on a coarse breccia of fragments of grits and shale bound together with white carbonate of lime, and this rests on gritty and micaceous Silurian flags. These latter lie nearly horizontal at the point in the bed of the stream where the different rocks were seen in contact. Eleven yards further to the south-east, they dip about S. 10° E. at 10° to 20° .

For about fifty-five yards from the junction, down the stream, its bed is formed nearly continuously of coarse soft grits, and fine brownish-red brecciated conglomerates, the latter containing pebbles of hard grit and shale, all embedded in a coarsely gritty calcareous mass. In a few places the conglomerate becomes coarser, with pebbles as large as an egg. A little way from the junction the dip is N. 30° W. 20° .

A short distance further down the stream, and for a length of thirty yards or thereabouts, there are hard, dark brown, earthy sandstones, fine-grained, and occasionally containing beds of fine conglomerate and coarser sandstone. In one place a thin bed of light greenish, mottled marl, separates the beds of fine sandstone from an overlying fine conglomerate, which latter passes upwards gradually into fine hard sandstone.

There is a nearly continuous exposure of sandstones and shales along the bed and in the banks of this stream where it flows at the foot of an orchard. The sandstones predominate, and vary greatly in texture, colour, &c. The shales occasionally contain indistinct plant remains, and are generally finely laminated. Two very thin layers of hard arenaceous limestone were also observed. Dip W. 40° N. 20° to 40°.

A little west of the orchard there is a section in the bank of the stream, ascending as follows :—

	Ft.	In.
Greenish-gray calcareous sandstone,	0	10
Harder ditto, changing to purplish,	0	2½
Greenish friable marly shale, somewhat arenaceous,	0	6
Compact light gray pseudo-brecciated limestone, roughly distinguishable into four thin beds,	0	11
Light gray arenaceous limestone, obscurely laminated, and stained with purple spots,	0	7
Ditto, more distinctly laminated, and striped purple in the same direction,	0	8
Dull greenish-gray soft shales,	0	8
Dark gray, soft, fine calcareous sandstone, tinged pink,	0	2
Hard green friable shale,	0	3
Light greenish-gray marly sandstone, striped in the direction of laminae, with shades of red and green, and stained with purple spots,	2	0

Dip N.W. 30°.

Between the above section and Killuney Bridge, coarse greenish grits, sometimes variegated purple, with beds of fine conglomerate, appear at intervals along the bed of the stream. Close to the bridge there is a calcareous conglomerate of greenish-gray or purple colour, containing pebbles of coarse grit, and finer siliceous sandstone, quartz, and shale.

The beds at the west of the road at Killuney Bridge are well seen in section, and due west of Killuney House they come to the surface, with a strike of N. 35° E. They consist of hard calcareous close-grained sandstone or arenaceous limestone, thinly bedded, with layers of hard fine conglomerate.

A section at the side of the lane close at hand may be described as follows :—At top a bed of coarse conglomerate, 1 foot thick, containing pebbles of quartz, gray grits, and green shales, and overlying a series of thin beds, averaging 3 inches in thickness, of hard compact arenaceous limestone, of light gray colour, often inclining to purple. These are separated by thinner partings (about ½-inch) of very fine grained calcareous light gray sandstone, and occasionally conglomeritic. Near the bottom of this section, which is about 10 feet thick, there is a thin bed of calcareous conglomerate. Dip W. 30° N. 30°.

Just above these beds there are similar limestones and sandstones, with, however, more frequent layers of conglomerate. These are exposed in a section 9 feet deep at the rear of the house nearest to the road. They are crossed by a small fault bearing N. 25° W.

Sandstones and fine conglomerates occur at intervals in the stream which flows at the rear of the workhouse at Armagh (Ballynahone river). At a short distance from the south of the road, and not many yards from the junction with Lower Silurian, there occur among them two beds of light coloured compact limestone. The dip is N.W. at 20° to 40°.

About 100 yards north of the road there are thin beds of light gray compact limestone, generally arenaceous. Over these are dark gray shales with plant remains, and a few corals. The boundary of the sandstones has been drawn here, the limestones predominating throughout the remainder of this section northward. The dip here is W. 40° N. 25°.

Lower Limestone.—We may conveniently commence the description of this division by continuing the section along the Ballynahone river, from the point of junction above noticed at the north-east of Armagh.

A little more than 100 yards north of the junction there are thin beds of compact limestone, with a few small shells and scattered crystals of calc-spar. Some beds are of a light bluish and others a brownish colour. Dip N. 40° W. 25°.

A short distance further down the stream there are thin beds of dark shale with plant and coral remains, and a few beds of compact limestone. Next appears very compact limestone, and above it, for a few feet along the stream, thin beds of very hard light gray siliceous sandstone, with layers of soft gray shale.

Next in order appear dark gray calcareous shales with plants and corals, and some beds of dark compact limestone.

The remainder of the exposed beds consist of limestone, in most cases less compact than the preceding, and in this respect, as well as in exhibiting various light tints of blue, yellowish, and brown, they more nearly resemble the general character of the series, as seen in this Sheet. Throughout the beds last described, the north-westerly dips continue at about 20°, but in the uppermost they become lower and somewhat wavy.

The lower limestone is exposed in very many places throughout the district extending north-east of Armagh by Loughgall and Kilmore, and in many it has been quarried.

The lowest beds in which fossils are abundant occur at the south-west of Annaclare House, one mile and a half north-east of the city, where they dip N. 20° W. at 15° to 20°. The rock is light gray, sometimes pinkish, and in thin beds, occasionally alternating with darker earthy limestone. Both contain coral and shell remains.

Above the limestone just mentioned, and slightly exposed in a stream at the north side of the railway, three-quarters of a mile W.S.W. of Annaclare House, is a thick bed of brown and reddish sandstone, with small flakes of mica. This may be the same which has been quarried for building at the east side of the Ulster railway, a little over a mile to the N.N.E. In the latter place the prevailing reddish brown colour is seen to be the result of weathering, the interior being rather of a light gray, sometimes tinted green. In its more weathered condition parts of it abound in small cavities full of ferruginous powder; and the rock, which in places is coarse and gritty, is often striped with various shades of brown to light green. No reliable dip could be obtained, the quarry being permanently filled with water; but there is an obscurely bedded structure dipping north-westerly, at 30°.* The same sandstone is said to have been met with at the east of Kelter's Bridge, 170 feet below the surface, in an ineffectual search for coal.

A little above this sandstone, exposed in a small quarry at the north side of the road, and west of the railway, there is a light yellowish fossiliferous limestone, arenaceous to a high degree. It dips N.W. at 35°.

* The Protestant cathedral at Armagh was partly rebuilt with stone from this quarry, and some of the columns of the new Roman Catholic cathedral were obtained here. This sandstone has also been used extensively for scythe-stones.

Limestone has been burned in large quantity at a quarry west of Drumman Lake, where some of the beds, which dip N.W. 20°, contain, in their weathered portions, unusually perfect specimens of fossils, especially *Rhynchonella*, with coralline and crinoidal fragments, *Producti*, &c. The bedding is in some parts obliterated, in others it is from one to three feet thick. The rock is covered by ten feet of drift. Average price of the lime, 1s. per barrel. Westward from the quarry just noticed, the dips change to the west, and over the low lying space through which the Ulster railway passes, a little way north-east of its junction with the Newry line, the direction lies in most cases a few degrees south of west, the amount being 20° to 25°. This prevails to near Drumsill House, where it is probably interrupted by a fault which bears a little east of north, as shown on the map. (See page 45).

About the bend of the road, north of Wilson's Bridge, the limestone is a good deal quarried, principally for burning. The beds, which here dip W. 20° S. at 25° to 40°, range chiefly from one to three feet thick throughout this locality, and are parted by gray and purple shales. They generally contain numerous fossils. The rock is for the most part crystalline, of a light gray colour, and frequently tinted with shades of bluish and yellowish brown.

Four hundred yards south of Grange Church, the beds, which dip W. 10° N. at 20°, present very uneven surfaces, with bunches of coral, six to nine inches in diameter, projecting from them.

Very finely crystalline limestone, nearly white, occurs in a quarry half a mile E.S.E. from Drumsill House, at the west of the river Callan. Dip W. 25° S. 15°.

The limestone comes up in patches at the surface on the hill at the south side of the Callan, S.S.W. of Grange Blundel. It occurs in regular beds, with uneven surfaces, and dipping steadily W. 20° N. 20°. The rock is light gray, sometimes variegated or mottled with purple, &c. The beds below these are better seen, in section, in a quarry half a mile to the north-east. They are light blue, two to three feet thick, and alternating with thin beds of light gray marl. Among them are a few beds of softer earthy limestone abounding in *Producti*.

The limestone crossed by a basalt dyke, at the west side of the road from Armagh to Loughgall, weathers in part with a finely brecciated appearance, as is best seen in the uppermost beds exposed in a ridge immediately south of this, and east of the road. Dip W. 25° N. 30°.

In a quarry at the west of the same road, and one mile and a quarter S.W. of Loughgall, fossils are abundant in thin beds of light brownish compact limestone, with layers of dark reddish sandy shale. Fish remains were found in the latter, and some of the former are, in parts, almost made up of small shells crushed up together. This was better seen a quarter of a mile due south of the quarry. The dips hereabouts are slightly disturbed, but retain their average north-westerly direction, which, as we proceed northwards along the line of strike, gradually recedes from the west.

At Ballygasey Cottage, S.W. of Loughgall, limestone is quarried and burnt. The upper beds here, for about ten feet, are softer than the lower, and of a yellowish brown colour. The latter are rather purplish, and variegated purple and yellowish. Dip N. 5°—15° W. 15°.

Half a mile west of Loughgall, at the west side of the road, dark chert occurs in small masses in compact bluish limestone, and about the limekiln at the east of the road the rock is finely granular and of a yellowish white colour, with wavy beds dipping N. 20° W. to W. 20° N. 25°.

Three hundred and fifty yards east of the road, more compact limestone, often tinted blue and purple, underlies the last-named beds.

At the east of Lough Gall, in Drumilly demesne, beds of light gray fossiliferous limestone, with partings of reddish shale, occur in a quarry at the east of the cottage, and come up to the surface between it and the lake, as also at the base and partly up the slope of the adjacent hill to the north-east. In the low ground at the other side of this hill they are well seen in different places in which they have been quarried for roads, &c. The dip average N. 30° W. at 15° to 20°.

At one mile and three-quarters from Loughgall, along the road to Portadown, and in the townland of Annahugh, the limestone beds are well exposed in a quarry, dipping W. 25° N. 35°. At the south side of the road they are crossed by a basalt dyke bearing N. 40° W. The upper beds are rather thinner than the lower, which latter sometimes measure four feet. The rock is generally compact, of a light bluish gray tint more or less variegated, and contains many shells and large bunches of coral. The surfaces of some beds are very uneven, but there is some degree of regularity, so as to resemble large rude ripple-marks. The most constant direction of the joints is about E. 30° N.

The patch of sandstone about one mile and a half east of Loughgall represents a thick bed or series of beds interstratified with the limestone, which latter appears in the stream 470 yards west of Flush Bridge. The sandstone was quarried in two places, but is not now exposed *in situ*. It is said to have furnished stone for building the old church of Kilmore. The fragments lying about are of a light reddish colour, striped with different shades, and contain minute flakes of mica.

There are several quarries in the limestone west and south-west of Kilmore. The north-westerly dips are very constant, the only exception noticed being near the railway, north-west of Bell's Bridge, where there is a dip to S.E. at 3° to 15°.

Quite close to the railway, at the S.W. of this, there is a brownish red and purple micaceous sandstone laid bare in a small quarry, and south-west of Bunton's Bridge thin beds of limestone dip N. 20° W. 15°. They appear to be here cut off by a fault bearing about N. 30° W., along which they, together with the underlying sandstones, have come into contact with the Lower Silurian rocks for a distance of a mile.

The evidence bearing upon this fault, as well as upon that which occurs a short distance to the west, though rather scanty, is yet sufficient to establish their positions with tolerable correctness.

The most important limestone quarries in the district, and the most instructive, lie westward of Armagh. About a mile S.S.W. of the city, to the N.W. of Red Barn, a large quarry, from which a great amount of lime is supplied, and which has also furnished a considerable quantity of building stone, contains beds of various thickness, from one to five feet, the upper ones including the thickest. Many of them present uneven surfaces. The dips vary between N. and N. 25° W., at 5° to 15°. The rock is mostly of a light colour, and either slightly yellowish or inclining to pink. In the lower beds it is somewhat clouded with purple stains, and is in general more highly crystalline than in the upper. Large bunches of *Lithostrotion* occur, especially in the thicker beds near the top. One of these measured almost four feet in diameter. Other corals, with crinoid stems and shells, are common; and from these beds fine specimens of fish remains have been obtained. A somewhat rare fossil, *Archæocidaris Urii*, occurs on the weathered faces of joints (see page 20). These beds are crossed by a narrow basalt dyke, to be noticed hereafter.

The better qualities of the Armagh marble were obtained from the beds which come next above those just described. These are exposed in a quarried face, showing in one place the following section, commencing at the top :—

	Thickness. Ft. In.
Compact light-coloured limestone, variegated bluish and purple, somewhat used for "marble" flagging. Beds 1 to 3 feet thick,	10 0
Tough compact limestone, of greenish and purple colour, with partings of soft flaky shale. Beds 1 to 8 inches thick. Decrepitates in the kiln,	3 0
Bed almost entirely made up of fragments of shells closely pressed together (<i>producti</i>),	1 0
Bed of pale crystalline limestone (white marble),	3 0
Thin beds of somewhat similar limestone, with shales,	3 0
Bed of very finely crystalline limestone, purplish brown, variegated with green, &c., and containing a few <i>producti</i> : known as "shell marble," from which many of the flags in Armagh were procured,	1 0
Bed of softer red limestone,	0 9
Bed of marble, of purplish brown colour, in places mottled so as to resemble the marking on a thrush's breast, hence called "thrush-breast marble,"*	4 0

The above, together with the variegated beds below them, and especially those in an old quarry 600 yards east of Red Barn, appear to have supplied the best flags. Many were also obtained from the Navan quarry, west of Armagh, to be noticed further on.

In the beds exposed in the section just described, the dips range between N. and N. 25° E. at 10° to 20°, and in the immediate vicinity northward of this they are for the most part at low angles, and dipping eastward under the Permian strata.

The sections along the exposed faces at the south and south-west of the sheep-walk show beds of light-coloured limestone, more or less variegated with blue and purplish shades. The average thickness is from one foot to two feet six inches, reaching occasionally four feet. These beds are jointed very regularly, the average principal direction being N. 25° W., with shorter cross joints nearly at right angles. The dip is N. 10°–20° W., at 5° to 15°, changing, however, to N. 10° E. 15°, close to the road that goes southward by Red Barn. The beds are often separated by thinner bands of a more earthy nature, weathering to a soft mottled pseudo-breccia, and besides the distinct lines which divide the rock into separate thick and thin beds, there is throughout all a system of surface cracks rudely parallel to the dip. Some of the joints are lined with light brown crystals of carbonate of lime, and in the quarries south-east of the sheep-walk there are very fine semi-transparent crystals of the same mineral, in the form known as *dog-tooth spar*.

Within the enclosure of the sheep-walk the limestone is penetrated by two caves, a few yards apart at their entrances. The more northerly is nine feet high and six feet wide at the mouth, the other a little less; and both gradually decrease in size. They proceed in north-easterly directions for many yards. That which lies to the north has been traced to a greater distance than the other.

At the north-west of the sheep-walk, striæ were observed in a quarry south of the road, as indicated on the map. This was on a rounded

* A good specimen of highly coloured marble from this locality may be seen in a well polished slab in the Cathedral at Armagh; and others in the small columns at the altar of the R. C. Cathedral. Ornamental chimney-pieces also have been worked of this stone, some of which possess considerable beauty. An example was seen in which variously coloured portions of the same bed were selected for different parts of the work, so as to appear as if they were formed of quite distinct varieties of marble.

surface of rock exposed on a level with the floor of the quarry. The boulder-clay drift, which originally covered it, is seen in section below the road fence, and there remains projecting from it, for a distance of about one foot, an unquarried portion of the limestone exposing a vertical face similarly marked. The striae on the horizontal surface bear S. 35° E. Dip N. 5°.

Close to this there are bands of light-brown chert contained in the limestone, which latter is in some beds changed to a loose, apparently brecciated mass. Some of the thicker beds disintegrate with an irregularly nodular and concretionary form, as represented in the sketch. This heterogeneous disintegration is observed only in the variegated beds.

Fig. 3.—Showing disintegrated cherty limestone.



The uppermost part of the limestone which is exposed in this locality, or that which has its outcrop at the junction with the Permian strata, is a hard, finely granular rock of a pale pinkish colour, in some parts finely mottled with purplish brown spots. It is known as "pale marble," and has been quarried at the edge of the road, 450 yards south of Green Park. It is exposed at a short distance west of the quarry, where it comes to the surface, and the overlying Permian breccia is seen close at hand under the wall of the sheep-walk.

Limestone appears in the bed of the river Callan, in a few places south of Millford mills, dipping N. to N. 20° W., at 10 to 25°. Close to the junction with the Lower Silurian there is a mass of brownish limestone among soft sandstone and fine conglomerate, all very obscurely exposed. These are included among the carboniferous sandstones.

Due west of Linen Hill House, thin beds of compact light-coloured limestone, with purple and green mottling, occur in the river.

East of Millford mills there are, in the bank of the river, some beds of soft variegated marl among beds of limestone; and north-east of the mills there is a quarry exposing limestone of a more or less earthy nature, some beds containing many fossils, among which *Productus giganteus* is a very prevalent description.

A large quarry at the east of the ancient entrenchment called Navan Fort, which lies one mile and a half west of Armagh, has supplied a great quantity of stone for building and burning. The beds range principally from six inches to two feet in thickness. The general colour of the stone is a light gray, but some of the beds, especially towards the bottom of the quarry, which is sixty feet below the surface, are variegated brown and purple; and from these many of the street flags for Armagh were procured. The beds are in most cases separated by thin partings of reddish shaly material called "scroof." They weather to a

rubbly form for about six feet from the surface of the ground. A few feet of clayey *débris*, with occasional basalt and diorite boulders, cover the rock. The dips are N. 20° W. 10° to 20° at the east and west of the quarry, changing to N. 5° E. 6° towards the middle. The usual sub-crystalline texture prevails, with occasional examples of a more earthy form; and at the bottom there are said to be two "flinty beds" beyond which the rock is not quarried. This hard quality in the stone arises from the presence of closely crystalline masses of coral (*Lithostrotion*), which is also found in some of the upper beds. The thickest beds reach about three feet six inches, but in working these split into thinner portions. The surfaces are here, as elsewhere, uneven. Many shells are found in these beds, with fish remains, the latter being said to occur most abundantly in the upper and lighter-coloured portion. This limestone dresses with a darker shade than that from the south of Armagh, where even the deepest colours work out white under the action of the chisel. The difference is perceptible in the new building for the Roman Catholic Cathedral at Armagh, which is constructed of stone from this quarry up to a certain level, the upper visible portion being from the other locality.

North of the Navan quarry the Ulster railway cuts through beds of limestone, with ice-striated surfaces, the direction of the striae being E. 35°-45° N. The beds, which dip N.W. 20°, are crossed by a dyke of basalt, ten feet wide, and are covered by twelve feet of drift.

In the small townland of Carrickaloughran, north-west of Armagh, there is a quarry exposing beds of compact, light brownish limestone, dipping in various directions at very low angles. They are traversed by four basalt dykes, in close proximity to which the limestone becomes altered in different degrees. In some cases it becomes harder and darker in colour, while in at least one place, at the most easterly dyke, it is changed to a light gray, loose, granular mass, which is sold for the purpose of scrubbing floors, &c.

A similarly modified condition of the limestone occurs in contact with the basalt dyke already alluded to in the large quarry south of the sheep-walk near Armagh; and at Lisadian, the limestone touching a basalt dyke is changed to a white soft mass of extremely fine grain.

In the last-named place the limestone is chiefly of a light brownish gray colour, inclining in some parts to yellow, and rather more coarsely crystalline than in most other parts of the Sheet. The dips vary from N. to N. 25° W. at 20° to 35°, with a gradual change, however, in the east of the large quarry, to N. 20° E. A little farther north, at the middle of the curve in the road, the beds are well exposed, rising up several feet on the east side, and crossed by regular joints, the principal of which strike about E. 40° S. These beds vary from six inches to three feet thick, and contain a few shells and crinoidal fragments. Dip, N. 20°.

About half a mile N.N.W. of Lisadian there was observed, in a small quarry, east of the stream which there flows northwards, compact brownish red hard limestone, similar to the coloured marbles south of Armagh; and a quarter mile south of the railway, along the same stream, finely clouded marble dips N. 20° E. at 35°, immediately south of which the dip changes to W. 30° N. 20°, among beds some of which contain very abundant large bunches of coral.

At the south side of the road from Armagh to Killylea, in the townland of Drumgar, a pit was opened many years since, in which, it is said, thin beds of coal were found among shales and impure limestone. The dip is described as being N.W. 20°.

There was a shaft sunk at a later period, about forty years ago, in Knockagraffy, the adjoining townland to the east, a section in which, according to information, showed 75 feet of drift over 2 feet of calcareous conglomerate (probably drift conglomerated, such as exists elsewhere in the Sheet, immediately over the rock); and below this, 17 feet of shales. The rock was then bored for a considerable depth, and was found to consist of shales, with occasional beds, a few inches thick, of what was pronounced to be coal. These were by one informant stated to number 4 or 5 in a depth of 220 feet bored.

The upper beds of shale were said to contain remains of leaves and nuts, which, however, crumbled away after a short exposure to the air. A block of black oak was also said to have been found in the drift 45 feet below the surface.

Various small exposures of limestone occur in the streams, &c., through the district extending 2 miles north, and 1 mile south, of Killylea. Some of these are indicated by dip arrows pointing on an average W. 30° N., the inclination ranging from 10° to 30°. It is in all cases of a light colour, sometimes bluish, and more or less crystalline, with crinoidal, coralline, and shell remains.

Coal is supposed by the residents in the locality to exist in a hollow three-quarters of a mile west of Derrydorrage House.

The limestone to the north of this is described in the details of the Benburb district.

Permian Beds.—These strata appear in section close to the junction with the carboniferous limestone, at the west side of the road, at a point 730 yards due S.W. of the Primate's Palace, near Armagh. They are exposed for a little more than 30 yards northwards, and consist of thin beds of brownish red highly calcareous breccia, or, more strictly, brecciated conglomerate, for the most part fine, the pebbles varying in size up to an inch in diameter. There are also, however, irregularly interstratified bands, from 2 to 18 inches thick, containing larger fragments of 3 to 6 inches diameter. The pebbles consist chiefly of the following:—Fine grained purplish earthy grits, the softer descriptions being in general slightly calcareous; similarly coloured hard shales, chiefly occurring in rounded flat pieces; quartzite; and hard fragments of the variously coloured underlying limestone. These are embedded in a brownish red calcareous paste containing grains of sand. The beds dip N. 30° E. at about 10°. This section shows 12 feet of the more solid rock, with 5 feet above it disintegrated to a softer earthy mass. The space occupying the angle between this and the adjacent road contains several partially filled quarry-holes, from which limestone was formerly procured; having been reached by removing the covering of breccia or drift. Sub-angular blocks of limestone, evidently belonging to the drift, lie in some of these hollows.

Another section, a little more than 40 yards in length, and 10 feet in greatest height, occurs at the west side of the road which leads by Red Barn. Here the bedding is generally obscure. There are also sometimes very thin partings of fine sandstone. The dip here is N. 25° E. 10°.

In a small quarried space, a short distance to the west of the above, the lowest beds of the formation are slightly exposed, and again at the adjacent angle of the sheep-walk a little way to the north-west. In both cases there were observed quite close to, though not actually in contact with, the limestone, which, in the former, is of a hard brecciated form, and in the latter is the "pale marble" already described. These bottom Permian beds consist of a hard red breccia composed of fragments of limestone compactly embedded in a fine sandy mass, which is highly

calcareous. They have been much used for flagging in Armagh, and are said to wear better than the limestone. Several houses also have been built from these and from the beds immediately over them.

At the angle of the two roads above alluded to, due west of the Palace Farm-yard, another section shows 9 feet deep, of which the upper half consists of the fine brecciated conglomerate above described, and the lower part contains beds which more nearly approach the character of the true harder breccia. Above all there is an obscurely defined layer, about 3 feet thick, containing large pebbles and small boulders of the rocks already enumerated. These form the loose boulder beds already described by Mr. Hull*. The thickness here of these breccias and conglomerates over the limestone is probably about 40 feet. They dip N. 25° E. at 8°.

The same beds are similarly exposed in another quarry site about 160 yards to the north-west, in a section 9 feet deep, covered by 6 feet of drift. The limestone is said to lie within 3 feet of the surface in this spot. The average dip is 10° N.E.

Beds of light coloured limestone occur in St. Bridget's Well, inside the Palace demesne, and a few yards south of it there is a small exposure obscurely showing similar beds dipping about 40° W. 15° N., and overlaid by hard sandy breccia. This may be taken as about the junction of the Permian and Carboniferous formations, which has accordingly been drawn through this point.

The Permian rocks were reached in a deep well at the rear of a house in Beresford Row, at the Mall, Armagh. They consist of beds of reddish brecciated conglomerate, with bands of fine-grained red sandstone, some of which is micaceous, and among which also are occasional very thin partings of harder greenish white sandstone. These beds were found at 158 feet from the surface, and are described as being overlaid by 4 feet of Red Marl, and 154 feet of drift clay. Limestone was reached at 176 feet, which gives 18 feet for the thickness of the Permian beds. The dip is said to be a little south of west, at low angles. The pebbles, as seen in the *débris* from the well, resembled those in the upper beds south of Armagh, except that those of quartzite and limestone are here comparatively rare, the grits and shales predominating. In some of these beds also many of the well rounded pebbles were as large as an egg, which was not so frequently the case in the others. The red more brecciated beds, at least towards the bottom, are sometimes variegated or largely mottled with a light greenish gray colour, which in places becomes white, arising from the admixture of an earthy substance resembling pipe-clay. They are in some parts calcareous, but not generally so; and they occasionally contain cavities lined with semi-transparent crystals of carbonate of lime.

Brecciated conglomerates, similar to the Permian beds south of Armagh, and overlaid by a few feet of fine reddish-brown calcareous sandstone, were reached below 70 feet of drift, at 530 yards west of the R. C. cathedral at Armagh, and bored for about 60 feet deeper. They are said to have been also met with in a well at the bend of the road 400 yards west of this, and in this place to overlie the limestone for no great depth.

These beds were again opened up in a well at the west side of the

* See page 12.

road, opposite to the gate leading to the railway station, at 16 feet from the surface; and, finally, at the rear of the lunatic asylum, where they were sunk and bored for 96 feet, below 45 feet of drift. Thin beds of brown and brownish-red fine-grained sandstone and fine brecciated beds, generally similar to those above described, occur, dipping at various low angles in a south-easterly direction, along the stream which flows by the back avenue to the lunatic asylum. These are probably at the outcrop of those which were last mentioned.

The only Permian strata in the vicinity of Armagh remaining to be noticed occur at the bend of the river Callan, S.S.W. of Grange Blundel, and two and a half miles north of Armagh. Here there are thin beds of fine brecciated conglomerate, exactly similar to those south of Armagh. They were observed in three places, in one of which, at the base of the southern bank of the river, they dip N.W. at 10° . 150 yards east of this, on the north side, they appear in a section 10 feet high, dipping N. 20° W. 10° , while the underlying limestone is exposed at the opposite bank, dipping W. 30° N. 20° . The Permian beds are again slightly seen 150 yards farther to the east, close to the northern bank. All these brecciated conglomerates are highly calcareous when they occur, as here, in the immediate vicinity of the limestone.

Triassic. (Bunter Sandstone).—Bright red faintly striped fine-grained sandstone, closely resembling that which occurs in the valley of the Lagan and near Dungannon, was met with about 30 feet below the surface in a well at the angle of Dobbin-street and Ogle-street in Armagh, and quarried for several feet deeper, when the well fell in. Rock of similar character, so far as can be judged from the description given, was found in two wells at the gas-works, 16 feet below the surface. In the former case it was found to be very calcareous. These seem undoubtedly to belong to the Bunter series.

BENBURB DISTRICT.—*Lower Limestone.*—These beds are exposed along the Ulster Canal at the south of Benburb, almost continuously westward from their junction with the Bunter sandstone to the overlying calp. Of this distance about 320 yards occur in one section at the south of the canal, commencing 30 yards west of the third lock, and going along the direction of the dip for 200 yards.

The first appearance of the limestone is on the north side of the river Blackwater, 50 yards west of Benburb Bridge. Here it dips W. 10° S. at 45° , and continues to be seen till nearly opposite the commencement of the section above spoken of.

This section commences with a dip of W. 20° S. 20° , and for a little more than 100 yards exposes, for a depth of about 18 feet at most, an uninterrupted succession of beds, consisting of light gray sub-crystalline limestone, alternating with thinner beds of darker gray soft shale. The beds range in thickness principally from 1 inch to 2 feet. Thin irregular bands and lenticular masses of the limestone often occur in the shales. At 100 yards from the beginning of the section the dip is W. 20° S. 15° , and a few yards farther to the west the beds are slightly disturbed by a narrow fault bearing N. 20° W. Between this and the fourth lock of the canal, nearly 30 yards westward, there are other small dislocations with the same general strike. Some of the joints about here contain crystals of carbonate of lime (dog-tooth spar). Many of the beds abound in fossils. Half way between the fourth and fifth locks the beds, which about here are exposed for upwards of 30 feet high, dip at lower angles than elsewhere along this section, becoming almost horizontal for a short space, and soon again resume their dip of 20° W. 20° S.,

which is interrupted at the fifth lock by a narrow fault bearing N. 15° W. On the west side of this fault the dip is W. 20° N. 30°, and this continues to be the average dip to midway between the fifth and sixth locks, where the rock ceases in a quarry; dip W. 20° N. 35°. The beds here are thin, and are parted by shales. Some of these beds, especially near the fault, are of very compact rock, of a dull brownish colour, others a light blue, weathering light brown. They are evenly jointed just here, and contain a large quantity of dog-tooth spar, some crystals of which measure 1½ inch in length.

The limestone next appears at 20 yards west of the sixth lock, dipping W. 25° S. 25°. It is a compact bluish limestone, containing large bunches of *Lithostrotion*, and in some of the joints large crystals of spar. The rock is then exposed on both sides of the canal to Blackstones Bridge, becoming of a more earthy nature than lower down in the section. Corals and crinoid stems and shells are here abundant. Fish and plant remains were also found. These beds are exposed in a quarry on Shelling Hill, the space partly enclosed on the south side of the river by a sudden bend in its course. They are parted by dark shales, and dip W. 5° S. 20°. The purer rock is of a light blue colour. Some of these beds furnished hydraulic lime, used in the bridges of the Ulster Canal.

The ruins of Benburb Castle stand on a short cliff about 40 feet high, the face of which, striking N. 25° W. for the greater part of its length, exposes beds of light gray limestone dipping N.W. at 15°, but somewhat waving at the northern part.

At the north-western part of the bend of the river, on the county Tyrone side, there are thick beds of compact brownish and purplish-gray limestone, and these are taken as the uppermost beds of the lower limestone, the earthy limestone and shales of the calp being seen immediately above them in a quarried face at the back of the adjacent corn mill.

Going northwards from Benburb, the first appearance of the lower limestone is at the east of the Glebe House, which lies south-west of Ninewells Bridge. It is a compact light gray rock, with numerous fossils, and is but slightly exposed, showing an obscure north-westerly dip.

It is next found in the stream to the south-west of Gorestown House, at the junction with the New Red Sandstone, the beds of the two formations appearing within 4 feet of each other. The limestone is compact and fossiliferous, of a brownish colour, and sometimes bluish in the same bed. It has a dip of 20° E. 30° S.

In a quarry 500 yards south of Brookland House there are beds of compact light coloured limestone, with a few of a more shaly character, and occasionally soft rotten shales. One bed of the last named especially abounded in corals, some of the stems of which were broken out in large pieces. Dip W. 40° N. 15°, changing to W. 10° N. at the south of the quarry. The joints are lined with white crystals of carbonate of lime. This rock is quarried for burning and for the use of roads.

The beds above those just described are a little exposed in the stream along the south side of the road, a short distance west of the quarry, and are overlaid by beds of sandstone, almost white in the interior, but weathering light brown, and in places dark reddish-brown, with a dip of 15° W. 20° N. In quarrying this sandstone at the cluster of houses marked S.S.W. of Brookland House, a thin bed of coal is said to have been met with.

In the side of the stream just mentioned, at a point 60 to 70 yards

west of the Triassic boundary, there are beds of friable dark gray shale, not calcareous, and containing small ferruginous nodules of a brownish-gray colour, some of the surfaces of fracture of which are minutely spangled with yellow metallic crystals, which appear to be iron pyrites. These shales dip N. 45°–65° E. at 20°. Fragments resembling coal are said to have been picked out of them at one time.

Half a mile south-east of Culkeeran House, at the north side of the road, light brownish sandstone, of rather coarse grain, was at one time quarried, but is not now exposed. It is said to dip north-westerly, and it may be seen in the walls of a house a short distance south-east of this spot. Light coloured limestone is said also to have been quarried close to the New Red Sandstone, at a point due east of Brookland House, and to have a south-easterly dip.

From the occurrence of the two last-named rocks in close proximity at this point (the New Red Sandstone appearing in the stream where the arrow is shown), and from their being found together again south-west of Gorestown House, it is tolerably clear that the boundary has been shifted eastward, somewhat in the manner shown, by a fault, the existence of which is confirmed, and its course determined, by observations in the adjoining Sheet.

Calp.—As before casually stated, the lowest beds of the calp series appear in section behind the corn mill which stands close to the river at the S.W. of Benburb. At the bottom are seen several feet of gray and blue shales; above these, nine feet consisting in the lower part of thick beds of hard blue shale or shaly limestone, and in the upper of friable beds similar to those at the bottom. Over these are beds of compact bluish and brownish limestone, in thicknesses of one foot six inches to two feet six inches, all covered by several feet of drift clay. All are fossiliferous, and the shales abundantly so. Dip W. 5° S. 25°.

Between the corn mill and the house 140 yards to the west of it, there are dark blue friable shales, very fossiliferous, dipping W. 25°; and below these, in the bed of the river, are beds of blue earthy limestone. These same beds are well exposed in a large quarry at the south of the canal, called the "blue quarry," with a dip of 20° W. 5° S. to W. 10° N. They vary in thickness from about nine inches to three feet, and are composed chiefly of the earthy limestone, which is worked for gate piers, &c. The rock is unfit for burning, with the exception of two comparatively pure beds low down in the quarry. These are distinguished by their uneven surfaces, and are known as the "ball beds," from the ball-like protuberances that mark them. Some of the upper beds are said to have also afforded lime. Towards the top there are three thin layers of dark soft shale containing specimens of *Productus giganteus*, which occurs also occasionally in the purer beds, with other shells; and over all are thinly exposed the friable dark blue shales just now described as being highly fossiliferous. These beds are cut across by a dyke of basalt, four feet six inches wide, which forms the back of the quarry, and in contact with which the dark limestone in some parts is converted into a nearly white compact marble.

The shales appear for several yards westward of the dyke, along the southern bank of the canal, and contain many small nodules of a light brown colour, which appear to be clay-ironstone. These sometimes enclose fossil shells.

At a little over 130 yards west of where the dyke appears among the shales, we meet with brown rusty sandstones of various degrees of coarseness, containing plant remains. After an interval they come to the

surface in different spots on the sloping ground which rises up from the canal. It is here white in the interior, weathering brown for two or three inches, and is in some beds obliquely laminated. These also appear at the north side of the river, and in its bed, where, as well as among the strata next the canal, occasional thin bands of ironstone occur. Dip W. to W. 20° N. 20°.

About 150 yards east of the seventh lock there are small surface exposures of hard tough impure limestone, separated by layers of shale, and these again appear twenty yards further west, dipping W. 15° N. 30°.

Thirty yards back (east) of the seventh lock a three-inch bed of ironstone appears at the surface, and a few yards to the west of this, sandstone is well exposed, containing plant remains and shells (*Productus semireticulatus*). This continues along the canal for a short distance, with dips varying from west to a few degrees north of west, and in the upper beds south of west. The latter are principally very compact, hard, delicately laminated sandstones, of a light gray colour, in thin beds, with the surface weathered light brown; and the lower beds are softer and less compact, and of a rusty brown colour. Thin seams of coal (three or four inches) are said to have been met with among these sandstones in making the canal.

Forty yards west of the seventh lock a thin bed of hard fine-grained sandstone, with plant remains and shells, lies among beds of soft fissile sandstones and sandy shales. Dip W. 15°. These are taken as the uppermost exposed beds of the calp, the boundary between it and the upper limestone being about 160 yards farther west.

Upper Limestone.—The beds of this division are exposed for sixty yards along the bank of the canal, dipping W. 10° S. 15° to 20°, with slight variations. A short distance below them there is a three-inch bed of ironstone. On the north side of the river they also appear, dipping W. 15° N. 20°. This limestone is of a light gray colour, shaded blue in some parts. A few of the beds are tough and arenaceous, especially in the lower part, the rest being purer and more compact; and all are fossiliferous.

Immediately west of the limestone, and overlying it, thin beds of dark gray fossiliferous shale occur in the bed of the river, with the same general dip to the west.

Lower Permian Beds.—One hundred yards west of the limestone, as seen on the south of the canal, there are slight exposures of light purple sandstone, some of which passes to a hard fine breccia; and this is overlaid by thin bedded purple shales, all being calcareous. Dip W. 20° N. 15°. Forty-five yards back (eastward) there were observed blocks of purple sandstone of a darker shade, containing plant remains. The rock is probably *in situ* below, resting unconformably on the upper limestone. Similar fragments occur at the opposite side of the river. A little beyond the latter point, nearly opposite the old spade-mill, a fine brownish red brecciated conglomerate appears at the surface, and this was also slightly exposed immediately below the New Red Sandstone in the bed of the stream at the east of the spade-mill. It bears a close resemblance to the finer Permian beds south of Armagh, and has, together with the purple shales and sandstones, been here included in this formation. These, along with the calp and upper limestone, have been here thrown up along a fault as shown in the map. The appearance of the limestone and underlying sandstone in a quarry 350 yards south-west of the spade-mill, taken in connexion with the westerly dip of the Permian, necessitates this explanation.

Triassic. Bunter Sandstone.—Bright red fine-grained sandstone, in thin beds, is exposed in the river and the adjoining mill-race at the spade-mill, and to a considerable extent westward from this. It disappears at the weir half a mile N.W. of Booth's mills. The rock is in general finely striped with different shades, which mark the thin laminæ of which it is composed, and when broken along these it is seen to be finely micaceous. In the lower beds it is somewhat calcareous, and in an excavation for a new building at Booth's mills there were found, with the sandstone, thin layers of red marl. Dip W. 10° N. 20° . This is also about the average dip throughout. In the uppermost beds it dips W. 30° N. 10° – 15° .

At the south-west of Clonfeacle Glebe House (near Ninewells Bridge) soft earthy red sandstones occur in the side of a stream. They are in some parts divided by thin harder laminæ of a nearly white colour. Dip N.W. 30° . This is at the boundary of the Carboniferous limestone, from which the sandstone has been here denuded for a narrow space. At the other side of this neck of limestone, 430 yards E.N.E. of the Glebe House, fine red sandstone occurs in a drain, in thin flaggy beds which dip 70° S. 15° E.

At the junction, in a stream S.W. of Gorestown House, similar beds occur for a length of forty yards, dipping E. 30° S. 35° .

Half a mile N.E. of Gorestown House there is a small exposure of bright red sandstone in a stream at the north side of the road. Dip E. 30° N. 30° .

Fine-grained red micaceous sandstone occurs on the east bank of the river at Blackwatertown. It dips W. 15° N. to N. 30° W., at 15° to 30° . Similar beds appear a mile north of this, fifty yards east of the river, in Shanmullagh. A large quantity of it is said to have been quarried here for the oldest buildings in Blackwatertown. Here it dips N. 20° W. 20° .

Fine red sandstone is said to have been reached in a deep well close to the road from Blackwatertown to Loughgall, nearly a mile from the former; and fragments of the underlying rock occur in a drain at the north of the road, 400 yards east of this.

A short distance west of Bagnel's Bridge, at the northern edge of the alluvial flat, there are beds composed of fine sandstone, nearly white in the interior in some parts, in others light brown, but for the most part weathering red on the surface. It is calcareous and micaceous, and dips N. 10° E. 20° . This has been reached in two wells, near the road, at the south of Bagnel's Bridge; and in the stream at the west of Killylyn there are horizontal beds of red flaggy sandstone, calcareous and finely micaceous.

It has been found in a few places between Killylyn and Mullyloughan House; and at the east side of Benburb Bridge, at the foot of the steeply sloping ground north of the river, there are bright red striped sandstones, without any distinct bedding being apparent, the laminæ dipping south-westerly, with variations to south-east, at 18° to 30° . It is similarly exposed at a small plantation at the west bank of the canal, 400 yards S.S.E. of Benburb Bridge; and again due west of that, at the east of the river. In the last place the laminæ dip E. 20° N. 25° .

At the point where the stream turns eastward from the road, S.W. of Mullyloughan House, beds of sandstone dip, so far as they could be observed, S. 20° E., and at the side of the same stream, nearly due south of the same place, there is a section forty-five yards long, showing thin beds of fine sandstone, of a bright brick red colour, dipping N.E. 15° .

Six hundred yards N.N.E. of Bryer's Corner, red sandstone, micaceous

and very calcareous, occurs in the stream marked on the map, and comes near the surface over a small space just here. A section on a farm road, close to the stream, at the north of this, shows a dip of 20° E. 10° N.

The boundary to the west of Drumsill House is determined by the occurrence of sandstone in the small alluvial flat east of Bryer's Corner; and again in the stream 700 yards N.N.E. of this, where it is said to rest on limestone. In the latter place it is described as white in the interior, and weathering light brown, and in the former it is fine-grained, and of a red colour, as seen in an example used for flagging. Sandstone of a light brick red colour, finely laminated, and with a close grain, was reached at the south of Drumsill House below 32 feet of boulder drift, the lowest 12 of which were firmly cemented into a hard conglomerate, by carbonate of lime. This is said to dip S.E. at 20° . It was again reached in another well opposite the gate-lodge, at the west of the road, and 340 yards west of this the limestone appears in a stream, dipping N. 40° W. 30° .

A small exposure of very red close grained sandstone occurs in the side of a well at the west bank of the Callan, 400 yards S.E. of Bond's Mill Bridge. Dip N. 40° W. 8° .

Red sandstone occurs a little below the surface in the west part of Tirmacrannon, one mile and a half west of Loughgall; and 30 feet below the surface at a house in Causanagh, one mile north-west of the town; besides other places in the same townland. In the former place, and the adjoining townland of Kinnegoe, coals are supposed to exist, but no grounds for this supposition appear to be forthcoming. It is possible there may be a bed or beds of coal in the limestone below.

At three-quarters of a mile N.E. of Loughgall the New Red Sandstone and Carboniferous Limestone appear about 200 yards apart, the former being in a quarry at the west side of the road, with a dip of 15° N. 25° E. It is in part soft, and of a dark brick red colour, while in some beds it is much harder, and with a purplish tinge, striped with light brown. In this condition it contains flaky fragments of purple shale, and becomes in part very coarse. The rock here is covered with five feet of drift.

Ordinary red striped sandstone occurs a little below the surface at Hall's Turn, one mile north of the last-named spot; and last may be noticed a fine red micaceous sandstone at three-fourths of a mile N.E. of Hall's Turn, at the N. side of the stream between Tall Bridge and Redmond's Bridge. Here it is exposed in a small quarry, dipping N. 20° E. at 5° .

Lower Keuper Sandstone.—At a bend in the river Callan, south-east of the corn mill which lies north of Drumsill House, there are thin flaggy beds of hard red shale and light reddish gray calcareous sandstone. They probably belong to this upper division of the Triassic Series, and have been thrown down from east to west along a fault parallel to the course of the river, as shown on the map. These beds dip E. 20° N. 35° to 75° , the highest dips occurring in a well close to the east bank.

Basalt.—The best exposures of basalt occur in the cuttings of the railway leading westward from Portadown. The first appearance of this rock along the road from Armagh to Portadown occurs at Ballyleny, where it comes up to the surface in several places. It is seen also at the south side of the railway in a drain, east and west of the stone bridge, and in a road cutting 400 yards further east.

In a railway cutting between Drumard House and Sturgeon's Hill, the basalt forms rounded bosses covered by drift, the intervening spaces being filled by the latter for a depth of about 40 feet in places. Besides the

indication of glacial action afforded by the rounded surface of the rock, the hard smooth portions of it are striated. This was best seen at the south side, 80 yards east of the bridge, where the drift had been removed. The prevailing direction of the striae was E. 40° S., and in one place it was S. 30° E. The basalt is cut up by numerous joints, nearly vertical, and principally striking N. 10° to 30° E., with others at right angles to them or nearly so. Occasionally also an additional face appears, cutting off the angle, and the rock throughout has a distinctly columnar structure. There is also a less clearly marked bedded arrangement, with low dips varying in direction a little east and west of north. The basalt is of a dark colour, in general finely crystalline, but in some parts it is a dull dark compact mass in which no crystals are apparent. A great portion of it here is amygdaloidal, and decomposed. The fissures are often coated with zeolite, and sometimes with this mineral and carbonate of lime combined.

In several localities about here the basalt appears, either in the low bosses in the hollows, or merely surface exposures in the higher ground. Examples of the former occur at the south and west of Highway Gap, and of the latter at the west of Ballintaggart House.

In a railway cutting west of Clownagh House the basalt comes up to the surface, being covered in the deeper parts with a few feet of drift clay. It weathers a good deal in rudely globular flat masses. The columnar structure is here well seen, as also the nearly horizontal arrangement spoken of in the cutting noticed above.

The largest exposure of basalt yet unnoticed is in Ballyfodrin, nearly three miles from Portadown along the Dungannon railway. It is here quarried for building and for roads. It is of a finely crystalline form, and has not much regularity in the arrangement of the joints.

Basalt appears in a small exposure in the cutting at Stothard's Bridge, below 10 feet of drift, and also in the following places in this vicinity.—In the stream west of Fair View, at the edge of the sheet; at the west of the road, half a mile south of Scotch Street; at the edge of the flat south of Spring Lane; in the Tall Water, at the west of Redmond's Bridge, &c., and it has been quarried in a few places; the church of Tartaraghan, a little outside the Sheet, having been built of basalt from this locality. At the south of Spring Lane it weathers into small spherical balls, and in an old quarry a short distance to the north of Redmond's Bridge, it is amygdaloidal, and weathers away to a soft crumbling brownish gray mass.

In the vicinity of the road going N.W. from Portadown, basalt occurs as follows:—at the back of the Glebe House near Drumcree Cottage; close to the road at the south of Drumgoose Cottage; N.N.E. of Pearl Hill, near the main road, &c.

Eastward of Portadown the basalt is found at the north and south of Killycomain House, where it has been quarried for roads. It is very finely crystalline, and cut up with some regularity by numerous nearly vertical joints, which are often thinly coated with white carbonate.

Basalt occurs N.N.W. of M'Dowell's Bridge, in quarries situated between it and the main road to Lurgan; and it has been quarried near the road, a short distance N.E. of the same bridge; and again a quarter of a mile S.S.W. of the Cemetery, at the west side of the road.

North-west of Ballydougan House the basalt appears in several places at the surface, and presents a character different from that which occurs elsewhere in this Sheet. It is here porphyritic, consisting of a dark-gray compact base with many crystals of felspar, which often display a variety

of colour. These crystals are occasionally of a large size. The rock in weathering becomes abruptly of a light brown colour for a depth of sometimes half an inch or more, the light and dark shades being in some cases separated by a narrow stripe of white. The weathered exterior is also occasionally composed of a yellowish white cellular mass, and in parts a deep rusty brown. A patch occurs at the top of Shane's Hill, (marked 336 feet), and another 300 yards E.N.E. of it. The interior of the rock is best exposed in a quarry at the west of the road west of Shane's Hill; and there are bare patches next the alluvial flat. The surfaces are in some parts marked with a series of close rudely parallel lines, apparently the result of a laminated or thinly stratified structure, which marks the directions of the flow.*

Basalt of the more ordinary description was found 28 feet below the surface at Ballydougan House, and all through the remainder of the basaltic area. There is a small hill altogether composed of it along the stream, three-quarters of a mile N.E. of Moyallan; and a short distance south of this, at the east of the road from Gilford to Lurgan, it comes up close to the surface for some distance up the rising ground to the east. Here the rock is exposed in a quarry for a depth of 25 feet, the upper portion being decomposed to a depth of 2 to 5 feet. The jointing is in many directions, but there is a prevailing strike of about N. 20° to 30° W. At the east of the quarry these, combined with another system bearing nearly N. and S., and a third nearly horizontal, give an appearance of a regular series of steps 3 feet high. Some of the exposed faces of joints present irregularly curved surfaces, causing the rock sometimes to overhang, at others to recede above; and these contain fissures, many of which are fitted with zeolite. This mineral also occurs in vesicular cavities, some of which are of a much larger size than was elsewhere observed in this Sheet, reaching 3 inches in diameter, and, according to report, many more. The zeolite lining these cavities is a solid white mass, which exhibits well the radiated arrangement of its component crystals, the interior surface bristling over with these in the form of slender glassy prisms.

Basalt occurs in the stream a short distance north of Elmfield, and was reached in sinking for the foundations of that house, immediately south of which the Silurian rocks were found.

Intrusive Igneous Rocks.—In a small plantation at the N.W. of Drum-inargal House, near the south-east corner of the Sheet, a dyke of finely granular pinkish felstone strikes S.E. across Lower Silurian grits. It is apparently 12 or 14 feet wide. The rock is of a light colour, with particles of a darker greenish mineral having an obscure fibrous structure. There are also thinly disseminated minute crystals of iron pyrites.

At the boundary between Corlust and Mullanary, half way between Markethill and Acton, a basalt dyke, about 100 yards wide, strikes N.W. across beds of Silurian grit and shale, exposed in a low-lying denuded strip. The rock is dark gray and finely crystalline.

A mile west of Tanderagee, at the south of the road to Hamilton's Bawn, a dyke of light bluish-gray finely granular felstone, in places more compact, strikes with a curve in a N.N.W. direction obliquely across Silurian grits and shales. Width about 5 feet.

* A specimen of similar rock from Antrim, microscopically examined by Mr. Geikie, was found to consist of plagioclasic felspar (probably Labradorite), augite, and titaniferite.

Due east of the Glebe House, north of Gosford Castle, in a plantation at the east of the road, contorted beds of Silurian grit and shale are cut very obliquely by a felstone dyke, 1 foot wide, bearing S. 20° E. where best seen in a section 6 feet high, close to the road. It then bears E. 20° S., and appears about 65 yards away among Silurian flags. This rock is of a bluish-gray colour, weathering greenish-gray, and in places rusty-brown. It in some parts has a finely spherular structure, containing globular particles which in general vary from one-eighth to one-half of an inch in diameter. This occasionally changes abruptly to a close platy structure, which, wherever it appears, has a pretty constant direction, inclining or dipping N.E. 50°, while the inclination of the vein itself is W. 20° S. 75°.

A dyke of gray vesicular trap, two feet wide, cuts up through thin beds of schist in a railway cutting due west of the Glebe House mentioned in connexion with the last dyke. It is of a compact form, having the smaller cavities filled with iron oxide, and many lined with white quartz. Some of the larger cavities (one-half to three-quarters of an inch in greatest diameter) are lined with minute cubes of iron pyrites.

Quarter of a mile N.W. of The Flush, which is two miles west of Markethill, in a cutting on the road, hard blue grits and friable shales of the Lower Silurian formation are crossed by a dyke of coarse-grained vesicular basalt, weathering to nearly spherical balls. The cavities are filled with zeolite. It bears W. 30° N., and then appears to branch off in two directions, being seen on the north side of the road to overlie the grit beds, and on the south to cut through them with a width of three feet. Close to the same road, at the west side, one mile and a half to the N.W. of this, a basalt dyke appears at the surface. These two may probably form portions of the same vein.

At a point in the bed of the Butter Water, east of Lisnadill Church, and three miles S.S.E. of Armagh, there appears a dyke of hard crystalline basalt, nine feet wide, crossing flags and grit beds at right angles. It bears N. 20° W. for 100 feet, and then turns obliquely across the beds eastward, and disappears below the bank. The surface is divided by many joints, both in the direction of its course and at right angles to it, which cause it to wear into rudely globular masses under the action of the water.

A portion of a basalt dyke, eight feet wide, is similarly exposed in the bed of the river Callan at the southern margin of the sheet, crossing beds of grit and shale. This rock also contains zeolites.

A mile and a quarter west of Roughan House a small portion of intrusive basalt occurs in a quarry in the denuded area marked on the map, the remainder being occupied by grits and slates.

The large limestone quarry at the N.E. of Red Barn, S.S.W. of Armagh, is traversed by a basalt dyke a few feet wide, but its exact width was not ascertained. It appears in several places, with a slightly curved course, across the quarried ground; and a parallel thin vein occurs close to it at the east of the lane leading to the lime-kiln. The rock is dark and finely crystalline, containing in some parts distinct crystals of augite. It weathers globularly in some places, and in others it appears to pass without this structure into a light gray earthy mass. The weathered portion is sometimes full of small globular ferruginous particles. This basalt affects the magnet very sensibly, as is the case with all the intrusive basalt in the Sheet, to a greater or less degree. The dyke is here traceable for upwards of 200 yards.

A mile and a half west of Armagh the Ulster railway is crossed obliquely by a dyke of vesicular basalt, ten feet wide, and bearing W. 40° N., cutting across beds of limestone at right angles. This may be the continuation of the dyke last noticed, and it may also be the same which again appears at Lisadian, two and a half miles W.N.W. of Armagh, in a quarried space close to the north side of the road. Here it occurs for twelve feet high, its southern wall forming a side of the quarry, and bearing W. 20° N. The rock is finely crystalline, and weathers to irregular concentric spheroids, the uppermost five feet being converted to a soft and earthy mass. This dyke, the width of which was not ascertained, but which is of narrow dimensions, is clearly seen to cut across the limestone beds, which here dip N. 15° W. at 35° .

In Carrickaloughran, one mile and a half N.W. of Armagh, four distinct basalt dykes occur, bearing N. 30 to 40° W. The two widest are fifteen feet and nine feet respectively, and the latter is well seen in section for twelve feet high at one place, cutting clearly through nearly horizontal beds of limestone. Here the sub-columnar structure of the rock is well marked.

The basalt composing the dyke in the Blue Quarry, south-west of Benburb, is similar to those already noticed, being dark gray, and finely crystalline. It forms the western wall of the quarry, the limestone and shales dipping against it, and appears in section among the upper friable shales at the back of the canal, where its width is seen to be four feet six inches. Here it weathers into concentric spheroids. It is again found in the river, north of which it disappears below the drift. The direction of its course is N. 40° W.

The basalt dyke at the west side of the road, halfway between Armagh and Loughgall, is about twenty yards wide, and crosses the limestone beds at a very oblique angle, its course being almost along the line of strike. A section of it is seen at the field fence, and north of it some small exposures occur at the surface.

Nearly one mile and a quarter S.E. of Loughgall, a basalt dyke, three feet wide, bearing N. 30° W., crosses beds of limestone at right angles, and appears in one wall for a few yards.

At Annagh, between Loughgall and Portadown, the dyke which cuts through beds of limestone at the south of the road is said to be ten feet wide, and is exposed for fifty feet along its northern wall, which is in places coated with calcareous spar. It has a bearing of N. 40° W.

Tertiary Clays, &c.—In the boggy flat along the river Callan, at the east of Moy, a fine white sand exists below the turf; and a similar deposit is found in other places, in general more or less mixed with light-coloured clay. A whitish stiff clay, with little or no sand, also occurs, and to a small extent pure pipe-clay has been met with.

About the edge of the Sheet, N.W. of Tullyroan corner, a grayish white-clay underlies the turf. A purer white clay is reached a few feet below a less pure deposit covered by turf, at the south of the hill on which the Church stands. A little further south, and eastward of the Meeting-house, there is a light brownish and sometimes bluish-coloured clay, mixed with sand.

South-east of the Church, the sandy deposit below the turf contains small rounded gravel of quartz, sandstone, &c.; and at the west of the Church these materials are found stratified with fine brown and whitish sand.

Good pipe-clay is said to have been met with at thirty-feet below the surface, in sinking a well nearly 300 yards west of Ardress House.

At the northern base of the hill on which Carnagill is situated, frag-

ments of coal are reported to have been reached in an excavation twenty feet deep. These probably were portions of a bed of lignite, but there appears to be no further evidence of the occurrence here of lignite among the clays, such as is found more to the north, near Lough Neagh.

Besides the deposits above noticed, there are brownish clays with small boulders, forming the mounds which stand out from these flat areas. These, with their associated gravelly and sandy layers, are described under the head of drift.

6.—*Drift and other Superficial Deposits.*

The great body of the drift which lies so thickly over the district belongs to the boulder-clay formation. This consists of boulders and pebbles of the subjacent rocks, with some also from other localities, embedded in a gravelly clay, depending in its character very much on the nature of the rock below, from which it has been in great part derived by glacial abrasion. Many of the local fragments occur in angular blocks, and the rounded boulders are often polished and striated.

In several instances a small irregular mound, composed of stratified sand and gravel, is found lying against the base of a higher hill of boulder clay, and occasionally traces of it exist higher up the slope. The general arrangement of the layers, which are in some cases distorted, is most frequently found to point down in the same direction as the slope of the hill, but at somewhat lower angles. A well-marked feature in the mode of their occurrence is, that in the great majority of examples the mounds are situated at the southern sides of the boulder-clay hills, it may be a little east or west, the latter being somewhat the more prevalent; but they were never observed on those parts which are well exposed to the north. In a few cases they occur at the east or west side. These heaps of fine stratified materials, which appear always to rest on the boulder-clay, and do so certainly in some of the best marked examples, are probably remnants of the marine sands and gravels of the "Middle Drift," either left in their original positions, or else carried some distance and re-assorted. In one place small fragments of shells were found in the gravel by close searching.

There are examples, too, especially in the district west of Gilford, where small areas of the boulder-clay are covered by a few feet deep of stratified sand and gravel. The principal details are given a little farther on.

There are several cuttings along the railways in the boulder-clay, which sometimes serve well to show its character. On the Newry and Armagh line, in the basaltic district at the south margin of the Sheet, it is a brown clayey mass, with numerous round and sub-angular blocks of basalt, and occasional Silurian boulders, some of the latter being scratched and polished. In the Silurian ground to the north-west of this the basalt blocks decrease in number, and those of the Lower Silurian prevail, as seen in the cuttings S.E. and N.W. of Hamilton's Bawn.

Natural exposures along the streams in the hollows of the drift often afford good sections. About a mile west of Hamilton's Bawn, at the south of the Armagh road, one of these shows pebbles of diorite, gneiss, fine carboniferous conglomerate, chalk, &c., mixed up with the ordinary Silurian and basalt boulders.

Along the course of the Tall Water, N.W. of Hamilton's Bawn, the drift hills are in several places partly worn away by the current, exposing faces sometimes twenty feet high, or more. A little way south of the

railway one exposes ten feet, composed of layers of gravel, sand, and clay, covered by twelve feet of clayey drift.

One mile E.N.E. of Outlack House, which is three miles S.E. of Armagh, a deep cutting along the boundary between Carnavanaghan and Calone exposes a reddish brown clay, with boulders and pebbles of limestone, basalt, Silurian grits, &c., and numerous small chalk pebbles. It contains also small nodules composed of hard calcareous matter, of a light brownish colour, incrustated round pebbles of limestone or other rock. They vary from a very small size to three inches in diameter, so far as they were seen, and are for the most part of a regularly rounded form. Others are less so, and appear to be composed of two or more of these joined together. Similar incrustations occur in the deep banks of drift along the Carn Water, one mile and a half due south of this. They have evidently been formed since its deposition, by means of water charged with carbonate of lime.

The limestone drift is cut through for about fifty feet deep one mile east of the railway junction at Armagh, and consists of light reddish-coloured marly clay, with large more or less rounded blocks of local limestone, and large boulders of basalt and diorite. In another cutting at the junction, some of the limestone blocks were polished and scratched. Many examples similarly marked are found in a cutting at the south of Castle Dillon demesne, and among them blocks of the carboniferous conglomerate from the neighbourhood. The largest exposed blocks of limestone are about four feet diameter.

In a cutting S.S.E. of Castle Dillon Lake, about twenty-five feet deep, a short section of eight feet deep at the lower part exposes fine gravel and coarse sand stratified, the former chiefly Silurian pebbles, with some of chalk, basalt, flints, &c. At top the drift is clayey, and towards the southern end of the cutting the rock appears below ten feet of this.

As already noticed, the drift in the adjacent cutting to the north-west overlies glaciated rocks, and the same is true of that to the south-east, where striæ bearing E. 20° to 40° S. occur below twelve feet of boulder-clay.

At the bottom of a cutting N. of M'Broom's Hill, on the Ulster railway, below about thirty feet of clayey drift, there is a deposit of gravel and boulders of various rocks, as basalt, local limestone, red and yellow sandstones, round flints, &c.; and part of a bed of fine siliceous sand is exposed below the basalt drift at the west of Selshion Bridge, on the Portadown and Dungannon railway.

A great variety of rock fragments occurs in a drift cutting fifty feet deep at the west of the Armagh station. The clay is of a light reddish colour, and of a marly nature, full of boulders and pebbles, many of which consist of carboniferous sandstone. The largest boulders are limestone and basalt. As a general rule, the drift overlying the carboniferous rocks has more or less of this reddish colour, but it is especially the case in the sandstone districts; and in some of the cuttings on the Ulster railway it is remarkably stiff and marly, as for instance, to the east of Rich Hill station.

Boulders and pebbles of the harder carboniferous sandstones, such as are found near Benburb, abound in the drift to the west and north of Armagh. Syenite and basalt boulders are also numerous, and fragments of mica-schist are found in many places, at least at the surface.

These last, with many of the syenite and other pebbles, are probably remnants of the middle sand and gravel, the mica-schist being otherwise almost exclusively found in the exposures of these beds.

Chalk pebbles and flints are of frequent occurrence in some of the

railway cuttings N.W. of Portadown, especially about midway to the margin of the Sheet. They are also common in the drift at the south of Redmond's Bridge, and fragments of chalk, resembling local *débris*, were found in the banks of the Tall Water at a point in line between that bridge and Diamond Hill.*

The clays, sands, and gravels forming the mounds in the flat district east of Moy, are not exposed in any deep cuttings. On the south side of the small hill west of Tullyroan Corner, there is a pit six feet deep with variegated brown and white clay, and a little gravel through it, with a few small basalt boulders.

On the west side of the larger hill south of this was a shallow excavation containing light brown clay with gravel and boulders, over pure brown sand. Some of the fragments were of Silurian rocks; also sandstones, &c.

An excavation at the north of the church exposed stiff yellowish brown clay, somewhat calcareous; and shallow cuttings in the hills south-east of the church contain brown clay with small basalt and carboniferous sandstone boulders, &c.

At the centre of the low hill east of the meeting-house a well was sunk for, it is said, fifty-seven feet, through light coloured clay with a little sand and not many small boulders, and at forty-eight feet a thick branch of black oak met with, similar to that found in the bogs.

A well at the farm-house 700 yards S.W. of Ardress House is said to have passed through fourteen feet of dark clay and boulders, below which, for forty-one feet, it was lighter and varied in colour and tenacity. Fragments of wood resembling perfectly finished "noggin-staves" are said to have been found at the bottom.†

Six hundred yards E.N.E. of Roscory, white sand was reached in a well below twenty feet of light brown clay.

The stratified sand and gravel is well seen in a gravel pit at the south side of the hill marked 153 feet high, $4\frac{1}{2}$ miles east of Moy. It consists of irregular layers of sand, gravel, and sandy clay, with small boulders, &c., of basalt, syenite, sandstone, limestone, and other rocks; with round flints, chalk pebbles, occasional fragments of silicified wood, and many nodules of ironstone.

Seven hundred yards west of Ardress House, at the north side of the road, there is stratified sand and gravel with similar fragments, and many of bright red sandstone and mica-schist. There is here also a thin layer of fine hard ferruginous conglomerate.

At the northern edge of the Sheet, three-quarters of a mile west of the river Callan, there is a low esker-like mound, 100 yards long, with a S.E. bearing. It was once covered with turf, as was also a larger mound of the same composition to the N.W. of it. A section in a pit exposes stratified sand and coarse gravel, the latter being to a great extent formed of Silurian rock. A few pebbles of granite were observed, mica-schist, syenite, &c. Close to the bog-road there were seen to be eight feet of turf resting on fine light coloured earthy sand, with gravel and small

* Inferior bricks have been made in several places from the drift clay, in small quantities for private use; and sometimes more extensively for sale, especially at Portadown, where the stiff brown clay of the basalt drift is cleared from boulders and the largest pebbles for the purpose. They sell at about 21s. per thousand.

† Other instances occur of oak stumps, &c., being found in the drift; for example:—At the N.W. of Annaghmore station, just outside the Sheet; at Knockagraffy, three miles west of Armagh, forty-five feet below the surface, and in a railway cutting at the west of Armagh station. Fragments of apparently charred wood were found at thirty feet down in the drift at the N.W. of Aghavilly church, three miles S.W. of Armagh.

boulders of the same rocks scattered through it. The stratified sand and gravel is again exposed 200 yards south of the adjacent meeting-house.

Some of the best exposures of the middle sand and gravel occur in a small area embracing Loughgall, Rich Hill, and Castle Dillon. At the west side of the road, 500 yards N.N.E. of Retreat, a section several feet deep exposes layers of gravel and pure fine siliceous sand, with a few boulders of basalt and limestone. This deposit rests against the eastern side of a hill of boulder-clay, which is seen in various shallow cuttings higher up.

South-east of the above exposure, at the east side of the road, stratified sand and gravel has been removed from a large patch overlying boulder-clay drift, at the south-west of the summit. It remains still sufficiently exposed to discover its character. Gravel and small boulders of limestone, red and yellow sandstones, syenite, &c., with flint nodules, form the principal materials. 600 yards N.N.E. of this again a similar deposit extends with a shallow depth up the south-western slope of a boulder-clay hill; and another 450 yards W.S.W. of Fruit Hill.

At 400 yards south-east of Retreat, a pit 40 feet deep shows a section in stratified sand and gravel with a dip of 20° S.S.E. It occurs in the form of an irregular mound against the base of the hill on which the obelisk stands, at its S.S.W. side, and has been excavated as far down as the boulder-clay, that is, immediately below the present level of the surface. The sand varies in coarseness in separate layers, and is for the most part pure. The gravel is chiefly coarse and shingly, and contains occasional boulders of basalt, &c. The pebbles consist of Silurian grits and shales, sandstones and conglomerates similar to the basal beds of the carboniferous formation in the neighbourhood, limestone, mica-schist, syenite, and diorite, rarely chalk flints, and occasional fragments of white fossil wood. Small fragments of marine shells were picked out of the gravel.

At the west of Loney's Town, and three-quarters of a mile N.W. of Rich Hill, thirty feet deep of sand and gravel are exposed in a mass which flanks the S.S.W. part of a long *drumlin* of boulder-clay; and it appears in two other places between this and Rich Hill.

Westward of Armagh the stratified sands and gravels are exposed along the road to Benburb by Lisadian. Three-quarters of a mile east of Lisadian House there is a pit containing twelve to fifteen feet deep of this deposit over boulder-clay drift, heaped against the southern part of a hill composed of the latter. Fragments of white fossil wood, and nodules of iron-stone, were found here, similar to those found four miles and a half east of Moy.

At the S.W. of Carrickaloughran, where several parallel basalt dykes appear on the map, there is a low well-defined mound composed of stratified sand and gravel, at the eastern base of a boulder-clay hill. It is opened into a gravel pit, which exposes the layers for about ten feet deep dipping generally E. to S.E. at 15° to 80° . Some of these consist of pure sand resembling fine sea sand. The gravel is chiefly of limestone, with diorite, basalt, red and brown sandstones, mica-schist, flints, &c.

Three-quarters of a mile W.S.W. of Lisadian House, at the south side of the railway, twenty feet deep of sand and gravel are exposed, with boulders of many kinds, and nodules of flint and iron-stone. A few of the boulders were of granite. The railway cutting at the N.W. of this is in boulder-clay, and overlying it, higher up the hill on the north of the railway, the stratified sand and gravel occur. At the S.W. of the

summit of the hill, close to the lane, the sand is very fine, and resembles ordinary sea-sand.

Half a mile from Lisadian, at the east side of the road to Benburb, a large excavation exposes obscurely stratified sand and gravel, with shingle and numerous boulders. Flint and iron-stone nodules are frequent, and large flaggy fragments of new red sandstone are found, with round boulders of harder carboniferous sandstones.

One mile N.E. of Knappagh House, at the east side of the road to Benburb, layers of sand and gravel appear in section, dipping down the slope of the boulder-clay hill, but at a lower angle (about 25°). They appear for six feet in depth, overlaid by four or five feet of a mixture of sandy clay and shingle with small boulders. The lower part consists of thin layers of sand and gravel, the sand itself being finely marked by laminæ of different textures.

Large angular blocks of the local limestone lie scattered over part of the low rocky surface S.E. of Lisadian House, at the south side of the railway, the largest examples weighing about five to nine tons. A similar block was observed at a higher level close to this, at the north of the railway, partly embedded in the boulder-clay, just above where the latter is overlaid by a patch of stratified sand and gravel. One mile S.S.W. of this, at the edge of the alluvial strip west of White Cross, there are many large angular blocks of limestone with a few rounded boulders of basalt, scattered over a small area.

Three-quarters of a mile from Tanderagee, at the north side of the road to Hamilton's Bawn, a patch of sand and gravel overlying the boulder-clay extends N.W. for 300 yards, and is about half that in width. Near the northern extremity of it a section across it shows thin layers dipping evenly at about 30° in a south-westerly direction. This section is sixty yards long and ten feet deep. Silurian fragments prevail in the gravel, with basalt, limestone, syenite, granite, flint pebbles, &c.

At the north of Mullavilly House, at the angle of the roads west of Ballylisk Cottage, and 450 yards S.S.W. of the Glebe House, these deposits are also laid bare, occurring in small patches; and another occurs at the east of Ashtree Hill House, at the north of the road. Near Ballylisk Cottage it is only four feet deep over the boulder-clay, and this is stated to be an average depth met with in several small patches in the locality. S.S.W. of the Glebe House it is about ten feet deep, on the eastern slope of a hill of boulder-clay, and dips down evenly to the lower ground.

By far the greater portion of the flat tracts east of Moy are covered with turf, as are also many parts of the flats south-west of this, connected with the rivers Blackwater and Callan. In some parts of the former the bottom of the bog has not been reached. Trunks and branches of trees, especially oak, are numerous in most places, and three to four miles east of Moy branches of what appear to be alder and sally are common. In the large bog four miles north of Armagh a white sandy and clayey deposit has been reached in some parts; in others blue clay. The oak stumps here are not now very numerous, having been nearly exhausted for fire-wood, &c.

Extensive portions of the flats of the river Bann north and south of Portadown are covered with turf, which is both here and in the places already mentioned cut or baked in large quantities for fuel. North-west of Ballyworkan House it is said to be thirty feet deep still, and Brackagh bog, at the east of the same place, has been so much cut away as to leave only a few feet of a soft peaty deposit over the clay. This is spread out to dry somewhat, then cut into sods, and left to bake in the

sun. Trunks of oak are exceedingly numerous in this bottom part of the bog.

As a general rule it is not the portions of the alluvial flats nearest to the rivers that are covered with turf.

Very many of the smaller strips along the minor streams are altogether, or have been, so covered to a small depth, the lower part being composed of fine clay or silt, containing sometimes a few boulders of the harder descriptions of rock found in the drift.

A mile and a half north of Portadown the alluvial flat of the river Bann is composed of a fine brown clayey deposit with many boulders of basalt and syenite, and some of Silurian grits.

The river Callan in some parts flows at a depth of ten or twelve feet below the adjacent flat lands, as north of Drumsill House, where the latter are seen to be composed of a very fine light brown clay, with sometimes a little sand, compacted as if by considerable pressure. Farther south, at the north of the railway, two or three feet of similar material overlie fine gravel stratified with sand and clay.

Killylea bog, north of Killylea, contains a few feet of turf over clay full of fragments of the underlying limestone. This turf is baked, the upper portion being nearly all gone.

Outlack bog, west of Vicar's Carn, has been cut away for many feet from over gray clay, which becomes nearly white when dry. Many larch roots remain standing in the turf in some parts, and the same is observed in other places, as, for example, two miles east of Moy, where the clay has never been reached.

Shell marl was observed in several localities below the peat, viz. :— West of Moy, one and half mile due west of Gorestown House ; below two feet of turf at the east of Loughgall lake, and at the south of the road, half a mile W.N.W. of Fruit Hill ; in the alluvial flat connected with Drumman lake, two miles N.E. of Armagh ; in the peaty flat west of Navan Fort ; at the east of Brookly House, which is two and a half miles S.S.E. of Killylea, and at a mile S.W. of Brookly House ; at the N.W. of Maghery, between the last place and Armagh ; in the Palace demesne, half a mile south of Armagh ; half a mile east of Hamilton's Bawn, and at Black-bridge, to the N.E. of this.

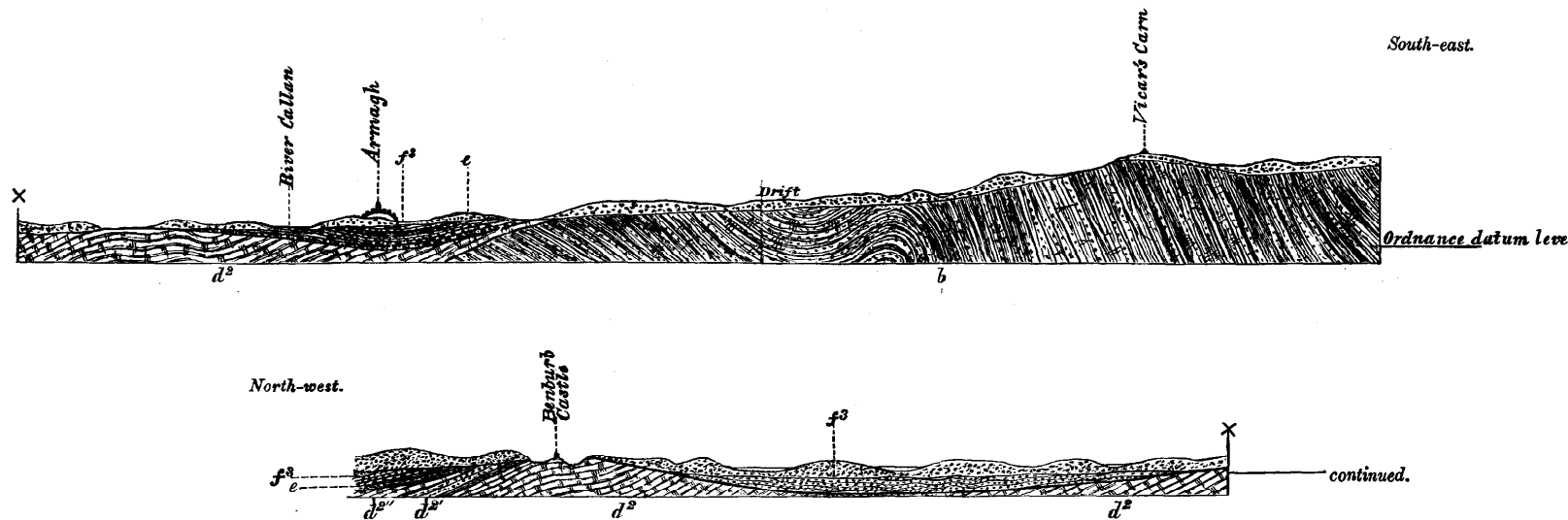
At the east of Hamilton's Bawn a large portion of a deer's skeleton is said to have been found resting on sand below four feet of marl. Portions of antlers were also found in different parts of the alluvial deposit of the Tall Water, at the east of Redmond's Bridge, and again one mile N.N.W. of Loughgall, at the N.W. of the Roman Catholic chapel. Remains of antlers and a large part of the skeleton (*Megaceros Hibernicus*) were found near Killylea ; and some of the former also in the marl near Brookly House.

The preserving property of the peat is shown by the discovery of crocks and firkins of butter in the bogs, as, for example, west of Tully-roan corner, and one-third of a mile west of the Callan, near the north margin of the Sheet, &c.

Bog iron ore was observed at one mile E.S.E. of Charlemont, in a drain where the old course of the Callan turns westward. The water in the bog drains is sometimes covered with a brown ferruginous scum, and this is occasionally the case in wells. An example of the latter occurs one mile from Armagh, at the south side of the road to Hamilton's Bawn, where the water is strongly tasted of iron. Another is two miles N.N.E. of Armagh, 760 yards N. of Wilson's-bridge, &c.

SECTIONS TO SHOW GENERAL STRUCTURE OF THE ARMAGH DISTRICT.

Fig. 4. Section from the south of Armagh through Vicar's Carn and Benburb Castle.



b. Lower Silurian Beds. d². Lower Carboniferous Limestone. d²'. Calp Series. d²'. Upper Carboniferous Limestone. e. Permian Beds. f³. Bunter Sandstone (Trias)

Horizontal scale—An inch to one mile. Vertical scale—Three inches to a mile.

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