DEPARTMENT OF AGRICULTURE AND TECHNICAL INSTRUCTION FOR IRELAND.

MEMOIRS OF THE GEOLOGICAL SURVEY OF IRELAND.

THE GEOLOGY OF THE COUNTRY AROUND LIMERICK.

BY

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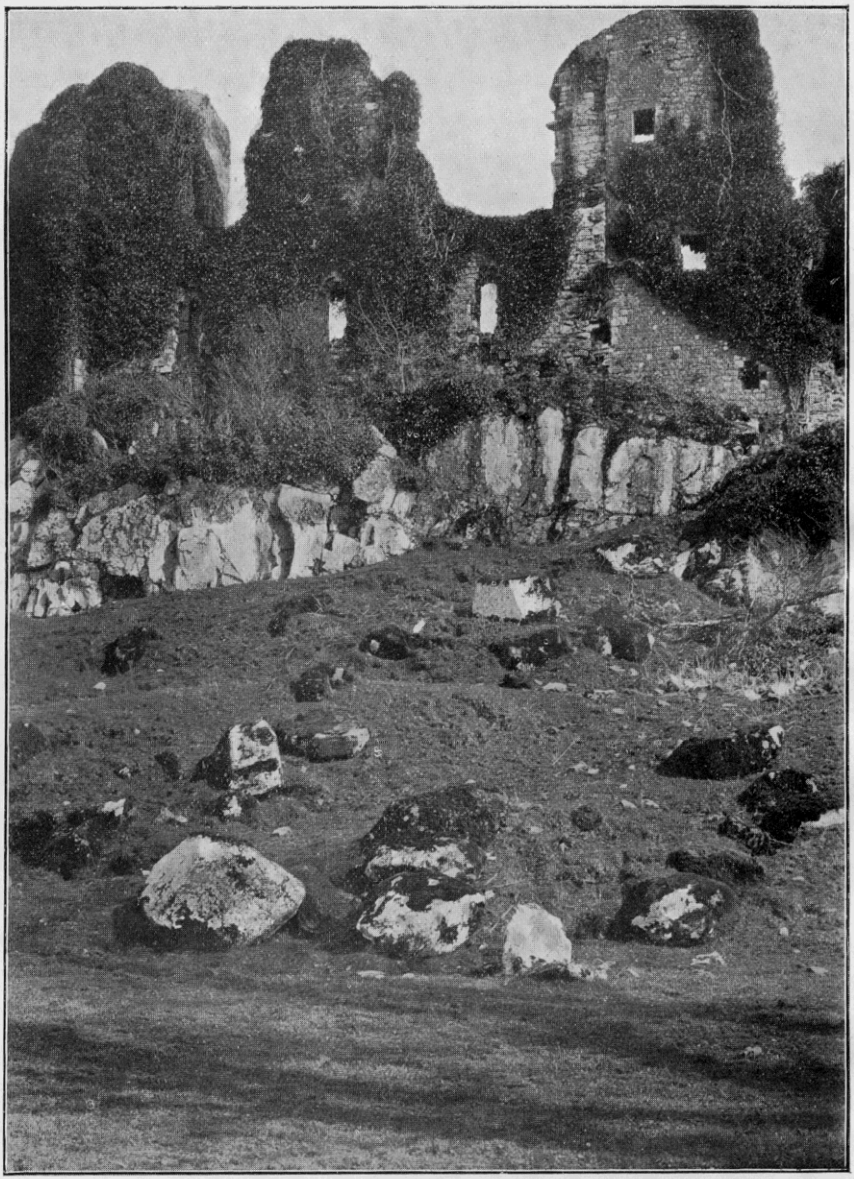

Frontispiece.

PLATE I.—Carrigogunnel Castle from the south, showing Ash-beds (on right) resting on Basalt (on left).

PREFACE.

This memoir has been prepared to accompany the new colour-printed map of the Limerick district. The boundaries of the map are shown in fig. 1, p. 1, and include the basin of the Shannon between Adare and Cratloe on the west and Caherconlish and Castleconnell on the east. This area includes nearly the whole of the previously published Sheet 143, and the western part of Sheet 144, of the geological map showing the rocks beneath the "drift."

The recent survey had for its object the mapping of the glacial drifts and other superficial deposits which were not included within the scope of the original survey. A general revision of the boundaries to be assigned to the rocks below such deposits was not attempted; but in certain cases, where fresh observation showed the need for an alteration of the line between the limestone and the igneous series, a new line was drawn upon the map. Mr. Kilroe, who has written the account of the "solid" geology of the area, believes that many of the lavas dealt with are intrusive in the masses that surround them; but this does not necessarily remove them from contemporaneity with the general volcanic action that characterised the Limerick district in Carboniferous times. A volcano of the explosive type may thus show, when dissected by denudation, beds of tuff and ash, cut by those parts of the lavas that never reached the surface.

Mr. G. W. Lamplugh, as District Geologist, controlled the work in the field, and has contributed a general account of the physical features and the superficial deposits, as well as details of the area personally surveyed by him. Mr. J. R. Kilroe has written on the Economic Geology and the Soils; and Mr. H. J. Seymour has added considerably to our knowledge of the igneous rocks, some of which may be quarried for road-metal. The plates illustrating the memoir are from negatives by Mr. H. J. Seymour. Among the friends who have helped forward the work of the geologists, special thanks are due to Dr. G. Fogarty, R.N., of Limerick.

On April 1st, 1905, after the main part of this memoir had been prepared, the work of the Geological Survey in Ireland was transferred to the charge of the Department of Agriculture and Technical Instruction in Dublin. The responsibility for the final revision and issue of the memoir, and of the map which it describes, has thus become shared between two public bodies. This fact, however, which marks a transition rather then a break of continuity, may be regarded as of pleasant augury, and as typical of the free intercommunication and interchange of ideas that will, it is hoped, always subsist between the Geological Surveys of Great Britain and of Ireland.

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PART I.—GENERAL DESCRIPTION.

CHAPTER I.—GENERAL ACCOUNT OF THE AREA AND ITS SUPERFICIAL DEPOSITS.

By G. W. Lamplugh, F.R.S.

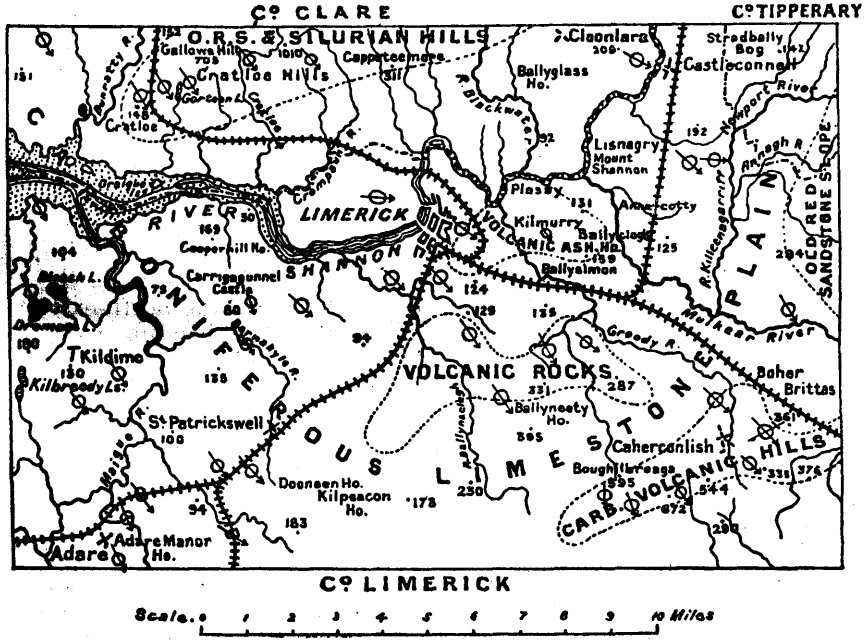
Area and Scope of the Drift Map.

In pursuance of the plan of mapping the superficial deposits in Ireland first around the chief centres of population, the survey of these deposits in the country around the city of Limerick was carried out during the field season of 1904 by Messrs. Lamplugh, Wilkinson, Kilroe, MacHenry, Seymour, and Wright, under the supervision of the first-mentioned officer.

As the city lies near the eastern margin of Sheet 143 of the Ordnance Survey one-inch map, it became necessary to arrange

FIG. 1.

INDEX TO LIMERICK SHEET



for the production of a special "Limerick District" sheet, to correspond to the special sheets of Belfast and Cork which have already been published. This map is of the same size as the ordinary one-inch sheets of the Ordnance Survey, covering 12 × 18 miles, and representing an area of 216 square miles. It comprises the eastern two-thirds of the Ordnance Sheet No. 143, along with the western third of Sheet No. 144.

The area covered by the map is shown on the accompanying index-map, Fig. 1, on which also the chief physical features of the district are roughly indicated.

In the previously-published maps of the Geological Survey for this district (Sheets 143 and 144), the solid rocks and alluvium alone were shown by distinctive colours, while the Glacial deposits were represented only by black stippling within diagrammatic boundaries, without any indication of the lithological character of the deposits. On the new map, not only are the boundaries of the superficial deposits everywhere traced out with as great detail as the scale of the map will allow, but they are also shown by separate colours according to their age and composition, the Glacial deposits being subdivided into 'Boulder-clay' and 'Sand and Gravel'; and the Post-Glacial deposits, into 'River-Gravel,' 'Peat,' and 'Alluvium and Intake,' (the Intake consisting mainly of estuarine alluvium).

A later chapter of this Memoir contains a detailed account of these superficial deposits under a topographical arrangement, wherein full descriptions of the local characters, exposures and other particulars are given by each officer for the district which he surveyed. The following brief summary of the results is intended to serve as an introduction to these descriptions.

Topographical and Physiographical Features of the District.

The dominant physiographical feature of the district is the great River Shannon, which enters the map on the north-east, flows south-westward for five miles, and then bending westward, takes a sinuous course across the map into its estuary. The river is affected by the tides up to about two miles above Limerick; but from above its westerly bend to the place where it enters the map near Castleconnell its current is swift, and broken in places into picturesque rapids by rocky ledges, so that continuous navigation is impossible. Communication between the more placid waters above and below this broken reach is carried on by means of a canal lying to the west of the river. In the upper part of its course this canal follows a pre-glacial hollow deeply filled with drift, but on joining the Blackwater River it leaves this hollow which, however, is continued southward to the Shannon at the great bend.

There are some interesting physiographical problems in association with the Shannon which will require the examination of a wider area before they can be satisfactorily elucidated. To judge from the evidence in the district recently surveyed, it would appear that the river has attained its present dimensions only since Glacial times. Although its present course between Killaloe and the intake of the canal at O'Brien's Bridge probably coincides with a pre-glacial valley, the river loses touch with this valley before reaching Castleconnell and has cut a new channel for itself across a hummocky lowland of Carboniferous Limestone and Glacial drift; and not until it reaches Limerick does the river permanently recover the pre-glacial hollow. Taking into consideration the powerful volume of the Shannon, the rapidity of its current below Castleconnell, and the readily erosible character of the rocks over which it flows, it is remarkable that the post-glacial trench cut by the river should be still so shallow and ill-defined, especially when we compare it with the deep gorges which have been cut since Glacial times by much smaller streams in adjacent parts of the country. As a rule we find that, above its tidal portion, the present river in moderate flood occupies the whole breadth of its trench, and that there is a remarkable absence of terraces of gravel or alluvium, or of any indication that the stream has materially deepened or widened its channel since settling into its present course. Nearly all the lobes of alluvium that occur along its banks may be recognized as deltaic deposits of the tributary streams or as the result of back-water floods in hollows contiguous to the river that were previously in existence. The fact that the river is strained of its coarser sediments in passing through the lakes in its middle reaches may explain some of the phenomena; but the evidence seems also to denote that its present course between Castleconnell and Limerick is essentially post-glacial, and moreover that, contrary to the general rule for Irish rivers, the stream has not been appreciably more powerful than at present since its establishment.

The Shannon receives several important tributaries in the district covered by the recent survey, including the Mulkear and its branches, draining from the mountainous ground along the border of Cos. Limerick and Tipperary; the Maigue, flowing northward across the limestone country and falling into the estuary near the western margin of our district; and the Bunratty, symmetrically opposite to the last, draining southward through the north-western part of the district in Co. Clare.

As indicated in the Index-map, Fig. 1, the irregularly undulating lowland underlain by Carboniferous Limestone occupies by far the greater part of the area. This lowland is generally drift-covered, but contains many low hills and hummocks of bare limestone which rise above the general level, especially to the westward of the Maigue and Bunratty rivers. Where the volcanic rocks associated with the Carboniferous Limestone

include massive members, as in the south-eastern part of the area, they rise above the plain in bold and sometimes craggy ridges, of which the most conspicuous example occurs in the neighbourhood of Caherconlish.

The highest ground within the map lies at its northern margin, in Co. Clare, which embraces the southern part of the hill-range formed by the sharp uplift of Old Red Sandstone and Silurian rocks. One of the summits in this district attains a height of about 1,000 feet. A similar uplift of the pre-Carboniferous strata forms mountainous ground immediately to the north-eastward of the district surveyed, but only the lower slopes of these hills are included in the present map.

The Glacial Drifts.

Although the main features of the surface-relief of the district were in existence before the Glacial Period, the great glaciation is responsible for most of the minor features; and it has also profoundly modified the drainage system of the lowlands, where it is now almost impossible to trace the pre-existing channels, owing to the depth and irregularity of the drift-covering. While most abundantly developed on the lower ground, the Glacial deposits are found overlying the solid rocks in every part of the district and at all elevations, except, perhaps, on the highest summits at the northern edge of the area, in Co. Clare, where the evidence at present forthcoming is inconclusive. Unstratified boulder-clay, which is recognised as the direct product of the ice-sheet, constitutes the most prevalent type of Glacial drift; but there are also many extensive masses of stratified drift, consisting of sand and gravel, which have evidently been assorted and deposited by water.

From the evidence afforded by the glacial scratchings on surfaces of rock and by the direction of transport of boulders and other material incorporated in the drift, it is clear that the ice by which the country was overwhelmed had a general movement from approximately north-west to south-east, though with many local deflections due to the irregularities of the ground. It is important to note that this direction is transverse to the Shannon, and is, moreover, not toward the western coast but trends somewhat inland.

Boulder-clay.—The boulder-clay is, as usual, made up chiefly from the waste of the subjacent rocks or of those lying a little to the northward of the place where the material is now found. Its composition therefore undergoes local modification according to its relation with the 'solid' geology. The two varieties most prevalent in the present map are derived respectively from the Carboniferous Limestone and from the Old Red Sandstone. The former is usually a dark bluish or greyish clay, hard, tenacious and full of well-scratched fragments of limestone, with a more or less scanty sprinkling of detritus

derived from other rocks, in most cases either from Old Red Sandstone or from the Volcanic series, according to the locality. Material of this kind overspreads most of the limestone-plain and the slopes bordering upon the Shannon.

The boulder-clay in which the Old Red Sandstone has supplied the principal component is, as we should expect, much redder in colour and more sandy in texture, though still often so firmly compact as to be impervious to the surface-water. It is very thickly banked along the southern slope of the hilly ridge in Co. Clare, and extends for some distance southward beyond the boundary of the parent rock, resting then upon limestone. Another mass of drift of this type occurs along the north-eastern margin of the map, enwrapping the slopes of Old Red Sandstone, and here, also, passing for some distance over the limestone country.

Both types of boulder-clay mould themselves to a large degree upon the 'solid' rock-features, but tend to smooth down the sharper contours by accumulating more thickly in the original hollows and on the lower slopes. Occasionally the boulder-clay builds up smooth lenticular hillocks or drumlins, this mode of occurrence being most frequent on low ground where there has been the greatest thickness of superincumbent ice, the best examples being seen along the northern margin of the Shannon estuary east and west of the Bunratty river. Drumlins are not, however, so numerous or so conspicuous in this district as in some of the more northerly parts of Ireland.

Boulders.—The breaking-up of the Carboniferous Limestone under glacial action is strikingly exemplified in many places where there are clear exposures showing the contact of boulder-clay with the solid rock (see pp. 46, 54, 64). So large and so numerous are the masses which have been displaced that it is sometimes difficult to decide from a small outcrop whether the limestone is in place or is part of a shifted block. From the wide development of the limestone-drift, boulders of this rock are more abundant than any other, except where the Old Red Sandstone drift prevails, when the majority of the boulders consists of sandstones, grits, and pebbly conglomerates derived from the latter formation.

Stray boulders of Old Red Sandstone are also not infrequent in the limestone-drift, and there is no part of the present area from which they are entirely absent. The Carboniferous Volcanic rocks likewise contributed their quota of boulders; and in several places, as noted in the subsequent detailed descriptions, the glacial deposits to the southward of the outcrops of these rocks have incorporated much detritus of this character in their mass. Trains of boulders from the harder portion of the Volcanic series afford good evidence as to the direction of ice-movement (p. 52).

Boulders of rocks entirely foreign to the district, though not absent, are of comparatively rare occurrence. The most notable are the blocks of granite recognizable as that which

occurs in place on the north side of Galway Bay. Boulders of this granite were found here and there at wide intervals over most of the low ground, except in the westerly part of the map. The majority noticed were lying loose at the surface or were in positions to which they had been artificially removed, but a few were seen in gravel-pits and had evidently been dug out of the gravels. In very few cases were these boulders found actually embedded in boulder-clay, though this may perhaps be explained by the rarity of adequate sections. A few instances of the occurrence of other igneous and metamorphic rocks almost certainly derived from the same distant region are recorded in the later detailed descriptions.

Glacial Striæ.—Reference has already been made to the evidence afforded by these glacial markings as to the direction of ice-movement. They are best seen on the hard surfaces of Old Red Sandstone on the lower part of the hill-slopes above Cratloe, where the ice seems to have grated with exceptional severity around the outstanding shoulder of the high land. They were also observed on the low ground in many places where the drift had been recently removed from surfaces of Carboniferous Limestone or Volcanic rocks; but they are soon obliterated by weathering where the limestone is exposed. The general south-easterly trend of the striæ is subject to considerable local modification determined by the shape of the ground, the tendency being for the markings to indicate a more easterly flow in the vicinity of steep ground lying athwart the ice-flow. The small Index map, Fig. 1, shows the approximate position and direction of many of these striæ.

Glacial Sand and Gravel.—Although the area covered by stratified glacial drift in the district is much smaller than that occupied by boulder-clay, the deposits of the former type might seem the more conspicuous on cursory examination, from the frequency with which they are piled up in steep mounds and ridges wholly or in great part composed of sand and gravel. On the limestone-plain, drift-features of this kind usually show little or no relation to the contours of the solid rocks, but tend to form broken chains of elongated mounds, sometimes giving place to sharper ridges of the esker-type, and sometimes expanding into broad low fans like deltas, with the whole system orientated in a definite direction, in the majority of cases not far removed from north-and-south. A bold chain of this kind runs southward from the northern margin of the map, approximately parallel to the Shannon, at a distance of from one to two miles east of the river; and another less conspicuous chain occurs west of the Shannon along the margin of the Blackwater valley. On the plain south-east of Limerick, the gravel mounds tend frequently to assume a well defined esker-shape, and seem to betoken a glacial river-system during the closing stages of the ice-age. At this period the waters escaping across the ice-sheet appear to have excavated channels for themselves in the waning mass and to have

accumulated large quantities of stream-borne detritus in these channels (p. 48), which was left in its present position on the final disappearance of the containing ice-sheet.

The gravels of this character usually show an arched arrangement of the bedding, roughly parallel to the slopes of the ridge; and they frequently also exhibit curious contortions and small faults due to disturbance of the mass after their deposition (pp. 54 and 66).

Another position in which we find an extensive development of stratified drift is in places along the margin of the high ground, fringing the slopes of the hills in irregular moundy terraces or spreading out from them in broad low-lying fans.

The former type is best seen in this district on the southern side of the Cratloe Hills (p. 40), and the latter in the neighbourhood of the Carboniferous volcanic ridge south of Caherconlish. In these places it is probable that the gravels have accumulated in hollows at the margin of the receding ice-sheet, perhaps partly in ice-dammed lakelets by which some of these hollows were temporarily filled. The higher portions of the hills are usually devoid of stratified drift; but the broader upland valleys sometimes contain local deposits of this character, as for example at Cappeteemore (p. 49).

The position and arrangement of the stratified drift in all the above instances is incompatible with the view formerly held that it was formed by marine agency; and we can only explain its features by supposing that it represents the material of the ice-sheet modified by fluvio-glacial action. No indigenous fossils of any kind have been found in the sands and gravels of this district.

Post-Glacial Deposits.

Old River-Gravels.—Owing to the relatively low level of the greater part of the district and the consequent sluggish courses of most of the streams, the fluviatile deposits are principally the finer sediments—silt, loam and clay—which form wide alluvial flats, and there is a notable scarcity of river-borne gravels such as are so commonly found in terraces bordering the drainage-channels of upland tracts. Near the north-eastern corner of the map, however, the Newport and Annagh rivers enter the district immediately after leaving their deep and steeply graded upland valleys; and both streams have thrown down masses of torrential gravel where their current is checked on reaching the lowland. These coarse gravels form high terraces fringing the valley of the first-mentioned stream between Newport and Ballymackeagh, and are spread in a broad delta bordering the Annagh River east of Mount Rivers. Narrow strips of similar material also occur along some of the small streams descending from the upland on the northern margin of the area, in Co. Clare.

Alluvium.—As mentioned above, the streams on the Carboniferous Limestone plain are frequently bordered by extensive flats of clayey or loamy alluvium. These flats are especially well-developed along the streams which fall into the Shannon where that river is affected by the rise and fall of the tides, as in the case of the Maigue, the Bunratty and the Crompaun. Under these conditions, the stream-alluvium merges gradually into the estuarine flats or corcasses of the Shannon which are protected from the high tides by artificial embankments; and the back-waters of the main river, as well as the arrested floods of its tributaries, have contributed their sediment to the flats. The Maigue itself is affected by the tide as far inland as Adare, seven miles above its junction with the Shannon; and the character of its alluvium, with that of the other streams mentioned above, suggests that there may have been a sinking of the land around the Shannon estuary during Post-Glacial times, by which the lower parts of the previously excavated valleys have been submerged and partly buried under alluvium.

The irregular hollows caused by the unequal deposition of drift on the lowland during the Glacial period constituted numerous shallow flood-basins on the disappearance of the ice-sheet, which when they lay adjacent to the course of the newly-established streams were periodically covered by the muddy flood-waters, and were thus gradually converted into wet alluvial flats which still require artificial drainage. But where the basins were not thus directly associated with the stream-drainage of the country they became shallow lakelets, which persisted until partly filled by the accumulation of marl from the decay of fresh-water shells and plants, and partly drained by the gradual wearing-down of their outlets, after which they formed peaty bogland. The little loughs at Dromore and Kilbreedy are examples of these hollows which still contain water; while between the Maigue and the Mulkear there are several small tracts of peat, overlying fresh-water shell-marl, which must originally have been the sites of similar loughs.

The wide flat of alluvial clay and silt which lies between the Newport and Annagh rivers above their junction at Annagh Bridge, and extends in long strips up the tributary valleys north of the Newport river, represents the finer sediment from the flood-waters of these streams after the coarse gravels had been thrown down as previously described. On reaching the plain these flood-waters were arrested and diverted southward, partly by barriers of glacial drift and partly by the great accumulation of peat in the Stradbally bog to the westward.

Peat.—The numerous small peat-bogs in the basins of the lowland south of the Shannon have already been referred to, and these have their counterpart also in a few places north of the river. The deepest and most extensive peat-bog within

the limits of the map, known as the Stradbally Bog, is, however, of somewhat different type. It covers an area of about 1,700 acres lying to the east of Castleconnell, and although its western margin approaches within about half a mile of the Shannon, its surface rises about 80 feet above the level of the river, and forms a smooth low plateau between the Shannon and one of its tributaries, the Newport river. The bog is partly held in on the north, west and south by moundy drift, mainly sand and gravel; but there are some low gaps through which the peat has spread toward the Shannon. On the east it ends off against the alluvial flats of the Newport and its tributaries, which lie slightly below its level (p. 86). The bog appears to have enveloped and buried an irregular surface of drift in a tract subject to occasional floods from the streams to the eastward.

All these lowland peats are extensively dug for fuel, and indeed, in several cases, the combustible material has been almost entirely removed from the basins. The Stradbally bog, however, still possesses large reserves, in spite of the inroads made around its margin.

In the hilly ground at the northern margin of the map, east of the Bunratty River, there are several small tracts of upland-peat, ranging up to 12 feet in thickness. These also are being rapidly cut away for fuel.

PART II.—DETAILED DESCRIPTION.

CHAPTER II.—SOLID GEOLOGY OF THE LIMERICK AREA.

By J. R. Kilroe.

Following the arrangement adopted in the Drift Memoirs of the Dublin, Belfast, and Cork areas, a description is here given of the solid foundation upon which the superficial deposits rest. The description, as in the other instances, is mainly based upon the information furnished in the original Survey memoirs—in this instance those issued in 1860, to accompany the published geological Sheets 143 and 144. Since the publication of these two memoirs, text-books and other works mentioned in the bibliography have appeared, in which references are made to the geology of this interesting region; and special attention is called to it in Sir A. Geikie's elaborate work, "Ancient Volcanoes of Great Britain." Aid has now been obtained from these works; and opportunity is here taken of acknowledging the kindness of Dr. Wheelton Hind, F.G.S., in placing information at the writer's disposal, prior to the publication of his paper on "The Beds which succeed the Carboniferous Limestone in the West of Ireland."

Certain facts, moreover, came under the notice of the geologists during the mapping of the superficial deposits, although the revision of the areas free from drift did not form part of the work entrusted to the Survey in 1904-5; and it was thought necessary to make two brief inspections of the entire area, preparatory to writing this portion of the present memoir. Amongst the additional facts observed were some which throw fresh light upon the history and relations of the rocks forming the igneous group, in consequence of which, and of certain observations bearing upon the nature of the sedimentary series, the writer believes that somewhat important alterations are required in the lines indicating the "solid geology" on the map. To attempt a revision would necessitate a re-survey of considerable areas; and the time at disposal did not admit of this, when the mapping of the drifts was of paramount importance. It was accordingly thought best to reproduce the boundaries, and for the most part the colouring, of the original map, while noting in this memoir the chief points as to which a change of view has taken place. Even this necessitates the incorporation of a large proportion of new material in the present memoir.

Systems and Series of Rocks entering into the Structure of the District.

SEDIMENTARY ROCKS.

CARBONIFEROUS, . .	d^4. Flagstone Series. d^3. Shale Series. $d^{2''}$.$d^{2'''}$. Upper and Middle Limestone. $d^{2'}$. Lower Limestone. d^1. Lower Limestone Shale.
OLD RED SANDSTONE. .	. c^3. Upper Old Red Sandstone.
UPPER SILURIAN. , .	. b^4. Llandovery beds.

IGNEOUS ROCKS.

Bs. VOLCANIC TUFF and ASH.

B. BASALT and DOLERITE.

F. TRACHYTIC ROCKS (Orthophyre type).

Sedimentary Rocks.

Upper Silurian, b^4.—The oldest group of rocks appearing in this area belongs to the lowest member of the Upper Silurian formation. The fossils collected at some four points, while many range from the Bala to the Ludlow series, indicate as a fauna a high zone in the Llandovery series. The beds, as generally described in the published Memoir accompanying the original one-inch Sheet 143, consist of "green, gray, highly calcareous shales and grits, interstratified with a few red beds and clay rocks. Some of the shales are cleaved into coarse slates, and were formerly quarried for roofing" purposes. "In the calcareous beds fossils are locally abundant." The grits are fine-grained, in some cases thick-bedded, hard and siliceous, suitable for road-metal; in others, flaggy and comparatively soft. The strata have been intensely affected by pre-Carboniferous compression, which produced the cleavage above-mentioned, and also gave rise to violent contortion here and there along nearly east and west axes, and a fractured condition in certain places.

The fractured grits, though quite fragmental, even as seen in hand-specimens, are re-cemented by siliceous infiltration so as to form compact solid masses, which sometimes stand out prominently above the present surface, whether of adjacent Silurian rock or the neighbouring Old Red Sandstone. A range of such hillocks, terminating westward in "Gallows hill," is to be seen east of Heathmount Lodge. It gives the name Gallows Hill to the mountain of which the hillocks in question form a part, and against which the nearly horizontal basal beds of the succeeding formation were deposited.

The highly contorted and fractured Silurian beds were subjected to extensive denudation prior to the deposition of Upper Old Red strata, their upturned truncated edges forming the floor upon which the latter were laid down.

The following list of fossils found within the limits of this special Limerick sheet is prepared from those given in the Survey Memoirs accompanying sheets 133 and 143. All were collected within the area of the six-inch Ordnance Sheets 52 and 53, County of Clare, at three points east and south-east of, and in proximity to, Troutstream Bridge, in the townland of Glennagross; and at a point one mile south-west of Trough Cottage in Ballycar South. All the forms named were found in Ballycar South, with the exception of those marked ‡.

List of Species of Upper* Silurian Fossils.

Plants.

‡ Fragments, showing reticulated structure.

Hydrozoa.

‡ Monograptus priodon.

Actinozoa.

Heliolites interstincta, *Linn.*
Favosites alveolaris, *Blainville* (= aspera *d'Orb.*)
Petraia elongata, *Phillips* × ×
„ Du Noyeri, *Baily*, n.s. ×
Cyathophyllum.

Echinodermata.

Crinoid stems.

Annelida.

Cornulites serpularius, *Schlotheim.*

Brachiopoda.

Meristella tumida? *Dalmann.*
Atrypa marginalis, „
„ reticularis, *Linnæus.*
Atrypa? n.sp.?†
Orthis elegantula, *Dalm.* ×
Rhynchonella Wilsoni, *Sowerby.*
Spirifer elevatus, *Dalm.* ×
Leptæna rhomboidalis, *Wahlenb.* ×
Strophomena euglypha, *His.* ×
„ funiculata, *M'Coy.*
„ (Orthothetes) pecten, *Linn.*

Lamellibranchiata.

‡ Cardiola interrupta, *Broderip.*

Gasteropoda.

Euomphalus funatus, *Sow.* ×
„ lautus, *M'Coy.*
Murchisonia Lloydii, *Sow.*

Cephalopoda.

‡ Orthoceras elongato-cinctum, *Portl.*

The mark × indicates that the species is abundant.

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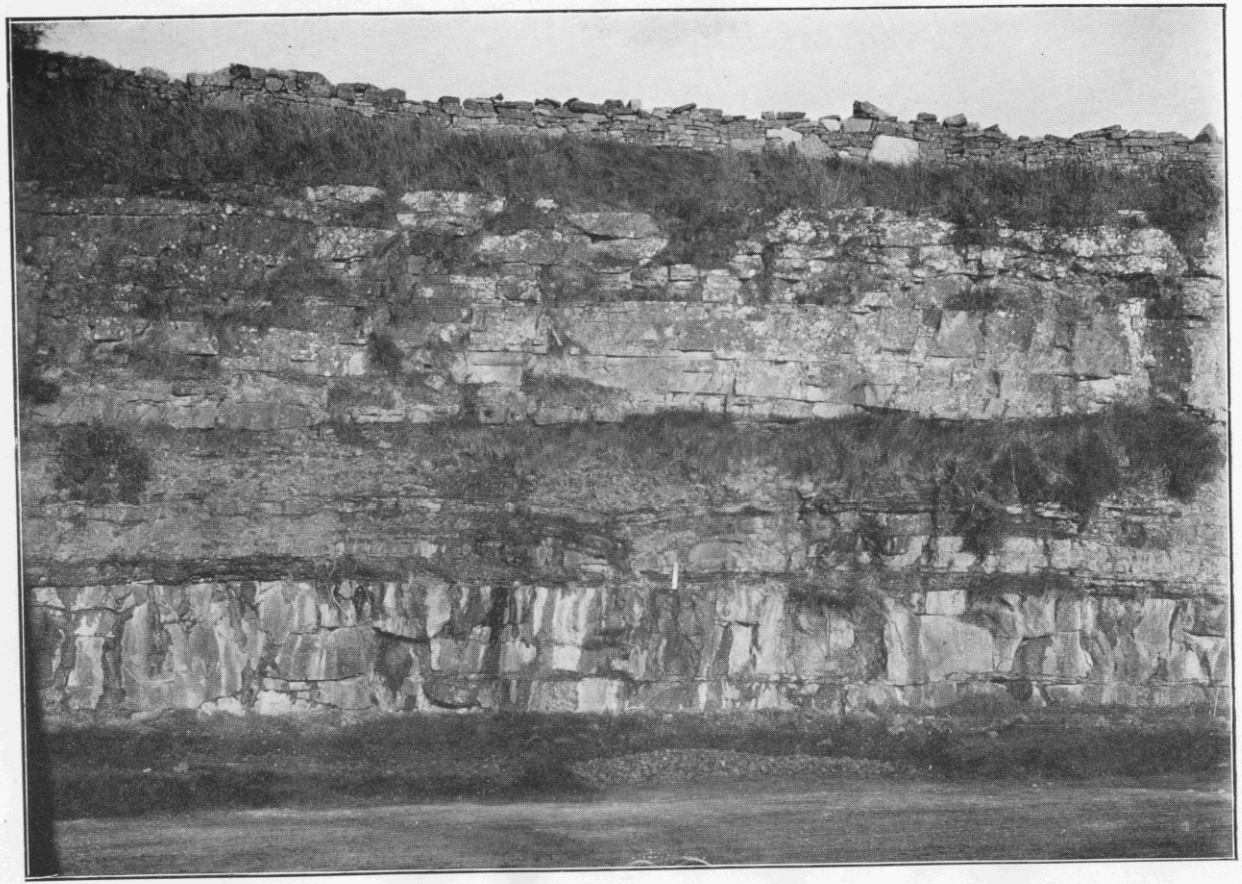
* Given in Memoir of Sheet 133 (published in 1862) as "Lower Silurian" forms. The rocks have since been relegated to the Upper Silurian, a return, indeed, to the classification adopted in the Memoir of Sheet 143 (published in 1860).

† Described and figured in Memoir 133, pp. 14, 15.



To face p. 13.

PLATE II.—Section on east side of road near railway-viaduct, one mile N.W. of Cratloe Railway-station, showing grits, sandstones, and shales of Old Red Sandstone age. The rule in centre of picture is one foot long.

UPPER OLD RED SANDSTONE, c^3.—The foot hills of the Slievefelim range, formed of Old Red Sandstone, just appear in the eastern part of the area (Pl. II.). The strata are visible in the townland of Cappanahanagh and in the low outlying hill of Knocknagorteeny. On the west side of the Shannon valley, the southern flanks of the Cratloe hills present a considerable area of Old Red strata, which are described as follows in the original memoir of Sheet 143, p. 6 :—

"The Upper Old Red Sandstone in this district is usually a coarse yellow quartzose grit, sometimes conglomeratic, and sometimes calcareous, and often having greenish sandy shale partings between the beds. The bottom beds are reddish, or yellow, ferruginous, quartzose grits or conglomerates; over these are coarse, sometimes flaggy, grits and conglomeratic grits, with a few red and purplish beds. The next beds in an ascending order are purplish red and yellow sandy shales, clay rock or indurated marls, and a few grits, in which there are nodules and lenticular calcareous patches (*cornstones*), which are sometimes nearly a pure limestone. Above these are quartzose grits, usually of a yellow colour, very quartzose, and sometimes calcareous, with, in places, greenish sandy shale partings. All the Old Red formation in this district seems to belong to the *Upper Old Red Sandstone*. On account of the great accumulation of drift on the southern face of the Cratloe range of hills, no exact estimate of the true thickness can be formed, but it cannot be more than 500 or 600 feet."

The junction of this with the Silurian formation is generally much obscured by local detritus; it may, however, be seen to fair advantage on Gallows Hill, on the west side of Glennagross, near Troutstream Bridge, and at Ballycar. Most of the massive pebbly grit beds are yellowish gray, frequently approaching white. Thus, at a point "due west of Cratloe cross-roads, at the boundary of the alluvial flat there is a very superior building-stone seen in an old quarry. It is a massive whitish-yellow grit, and dips nearly due west at 5°." Red is by no means the prevailing colour; green shale partings between the beds are frequently to be seen; and it is noted in the original memoir that "some of the grits have a spheroidal structure."

South of the Shannon, at and near Mellon Point, coarse yellow grits with red slate and grit and "green breccia" are exposed in a few places along the shore, some of the beds being calcareous. At Knocknagorteeny and Cappanahanagh, previously mentioned, red sandstone and blue and yellow flaggy grit—in parts conglomeratic—form the Old Red Sandstone hills in the eastern part of this area. There is no question that the rocks here described belong to the division of the Old Red which lies conformably below the Lower Carboniferous series, though clear evidence of conformity is not available within the limits of the present map. Fossil evidence as to their age is also wanting, though indefinite organic forms have been recorded on the six-inch field-maps near Mellon Point, and near Ringmoylan Quay, three miles to the westward.

CARBONIFEROUS.—*Lower Limestone Shale, d^1.*—This member of the Carboniferous system is almost wholly concealed by

drifts. The sequence upward from the Old Red Sandstone is to be observed at points beyond the sheet-margin; and inasmuch as it is chiefly upon the strength of such outside evidence that the band of shale, &c., is introduced, bounded by dotted lines, on the present map, the following account of the sequence may be given, taken from the memoir accompanying Sheet 143, p. 7 :—

"Between the Old Red Sandstone and the Lower Limestone Shale there is no regular boundary, since there are beds of yellow quartzose grit in places calcareous, which as we descend begin to alternate with red beds, while as we ascend they alternate with black shales. Even below the black shales the calcareous parts of these grits are generally fossiliferous, often abounding in bivalve shells, though the fossils are usually not perceptible, unless when the rocks are weathered. Above these are alternations of yellow quartzose grits and ribboned black and blue shales. Over these are grits, shales, and argillaceous fetid limestones. The next rocks in an ascending order are black and blue shales, very fossiliferous. These pass up into calcareous shales and highly argillaceous shaly limestones. The portion which may be assigned to the Lower Limestone Shale is about 50 feet in thickness."

The most important opening on the band is to be seen a little to the north-west of Mellon House, and is described in the following table (p. 19) :—

	Ft.	In.
6. Black shale, ...	4	0
5. Yellow sandy shale, . . . *on an average*,	1	6
4. Black argillaceous limestone	3	6
3. Shales and thin grits, ...	2	0
2. Blue argillaceous limestone, ...	0	6
1. Black and gray shales, ... *over*	4	0
	15	6

"No. 2 is a mass of bivalve shells, 'Modiola Macadami;' it weathers into a yellow-brown clay. No. 3 are calcareous to a greater or less degree. No. 4 is very fetid and seems to have shells in it. No. 5 is an irregular bed full of what seems to be the rootlets of plants; in some places it is only six inches thick, while in others it widens out to two feet. Part of it is affected by an oblique lamination when it can be split into flags. The upper portion contains more rootlets than the bottom of the bed, and, in the part exposed in the quarry, there are a few large calcareous nodules, which always occur in a thick part of the bed. In them are found the same shells as in bed No. 2. No. 6 is an ordinary black shale with calcareous nodules. The beds in this quarry dip S.S.W. at 10°."

On the north side of the Shannon dark blue limestone and shale are to be seen, in an opening on the band half a mile west by south of the old Friary site at "Cratloe Woods."

A corresponding thin band skirts the Old Red Sandstone on the east of the Shannon valley, also almost wholly concealed by drifts. The only good opening upon this band occurs in the Newport river-bed, a little to the south-west of Newport. The rock there consists of dark blue shaly limestone, arenaceous limestone, thin shale, and a few thin beds of grit.

About 150 yards north by west of Maddyboy House, white sandstone (associated with limestone) is to be seen in a small quarry adjacent to, and perhaps under, the igneous rock represented there, and occupying part of the area thus indicated. It may be that the Lower Limestone Shale band (with sandstone), which is so much concealed, should have been shown on the map as passing through the point in question. Arenaceous conditions, at all events, were present while the beds at Maddyboy were being deposited.

Lower Limestone, d^{2}.—In the western and southern portion of the area, this member of the Lower Carboniferous group consists of light gray, blue, and dark bluish gray limestone, usually massively bedded; the bedding, indeed, is not always easily distinguishable. The Lower Limestone is well exposed in the region around Kildimo, as well as at and east of Adare; while along the southern margin it is much concealed by drifts. For a general description of this portion of the Lower Limestone extracts are here given from the original memoir of Sheet 143, p. 7.

"The upper part of the Lower Limestone is generally full of an oblique coarse cleavage, which might easily be mistaken for bedding, the strike of which varies from E. 20° N., to E. 35° N. It is also much jointed, the principal joints running N. 20° W., and E. 20° N. . . . ."

"A red bed is generally found nearly immediately under the cherty beds that have been made the boundary between the Lower Limestone and the argillaceous beds of the Middle and Upper Limestones. The Lower Limestone is often magnesian, the magnesian limestone occurring in beds, parts of beds, or dykes; it is seldom a true dolomite. When magnesian it is of a yellowish gray or brown colour, the weathered portions having a sandy aspect. The dykes generally run between the principal joints, and therefore N. 20° W., and E. 20° N."

Purple beds* are to be met with in Clorhane, two and a half miles north of Adare.

It was noted by the original surveyors that chert occurs in the Lower Limestone at Shanaclogh House and at Rockstown House, south by west and south by east of Limerick, respectively, in both cases near the margin of the sheet.

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* A footnote in the original Memoir referring to such unusually coloured beds is here reproduced :—

"These variegated red and purple beds are sometimes quarried for marble, and they have been extensively used in the building of Adare Manor, the seat of the Earl of Dunraven. The colouring matter seems to be derived from iron in some form or other, as in that part of the Manor that is longest built, some of these limestones have become marked with iron stains. From this it would appear that they are better adapted for internal ornamental purposes than for use where exposed to the atmosphere. The colour may itself be due also to atmospheric influence, as sometimes in the same quarry, and seemingly in the same bed, the limestone is red or purple near the surface of the ground, and when followed down is of the ordinary gray colour. My attention was first directed to this latter fact by George Fosberry, Esq., and the Rev. H. H. Jones, of Adare.—G. H. K."

In the eastern portion of the area this member of the group is visible only in a few isolated places, the limestone being for the most part concealed by drifts and other recent deposits. To the south of Castleconnell the limestone is gray and in parts magnesian. Along the Mulkear River, from Annacotty eastward, the same kind of rock, frequently magnesian, is to be observed at several points, passing downward into dark blue shaly limestone, with some chert; and ultimately into similar limestone with shale at Abington. Here the rock can be well seen in a large quarry south-west of the bridge, where it has been found to be traversed by a barytes lode. Gray massive limestone forms the hill overlooking Inch St. Lawrence on the west; similar rock has been extensively quarried in Stone Park, little more than a mile south of Ballyneety, and again appears in Ballinagarde demesne, where it passes beneath cherty limestone, which is supposed on account of this circumstance to belong to the next higher members of the group.*

North of the Shannon, gray limestone, in parts magnesian, forms the portion of the Lower Limestone which is not concealed by drifts.

Summarizing the characters assumed by the Lower Limestone throughout the area comprised in this special Limerick sheet, we may speak of it as consisting in the lower portions of earthy limestone, in parts shaly, passing up into blue and gray limestone, much purer in quality than the lower strata, containing some chert, and being in certain places dolomitic, notably south of Newtown Hall, near Carrigogunnel, and 1¼ miles south of Ballyneety. This agrees with the general description of this member of the Carboniferous system given in the memoir to Sheet 143, and based upon data drawn from the region extending westward to Askeaton. The characters are therefore uniform over a wide area, and indicate deposition in a region little if at all disturbed, wherein the waters became more and more cleared of muddy sediments, remarkably little impurity remaining when the highest massive beds of the member were being formed. Following this, the conditions underwent a striking change, as will be pointed out.

Middle and Upper Limestone $d^{2''}$, $d^{2'''}$.—A subdivision of the entire limestone group into upper and lower members would suffice for this area; it is well known that the three-fold division recognizable in other parts of Ireland cannot be maintained throughout the Limerick region. It may, however, here be mentioned that, notwithstanding the peculiarity of the region, as compared with other parts, portions of the upper series are sufficiently shaly to be quite comparable with the "Calp" of Dublin and Sligo. The original descriptions of this upper series are adopted from the memoirs, slightly

* Regarding the limestone of Ballinagarde, see p. 18.

modified, and subject to remarks which will afterwards be offered. Referring to the western part of the present sheet, the memoir of 143 proceeds (p. 8) :—

"The Middle and Upper Limestones are undistinguishable in this district. The limestones above those just described are full of layers and nodules of chert. These cherty beds vary in thickness from 20 to 50 feet. Over them the limestones are argillaceous, fetid, granular, and thin-bedded, with shale partings between the beds. They are occasionally cleaved into a coarse slate, and sometimes the beds are so thin as to form good flags." The limestone "is often magnesian, sometimes a true dolomite. Immediately west of Limerick it has an oolitic structure, and is magnesian to a greater or less degree. When magnesian it is of a yellowish brown or whitish gray colour. . . . . The partings between the beds are black shales and yellow clay; some of the black shales have all the appearance of coal smuts."

In the eastern portion of the district, described in the memoir of Sheet 144, p. 8, after mentioning that the set of cherty beds is well developed in the counties of Limerick and Clare, the writer states that their occurrence and position in this area are taken as determining the boundary between the Upper and Lower Limestones. The description proceeds :—

"These cherty beds are generally about forty feet thick, though in one place they have the unusual thickness of 150 feet. Large contemporaneous masses of igneous origin frequently come in just above them. Over these cherty beds, or where present, over the igneous rocks, are dark blue, sometimes black, fetid, argillaceous limestones, that generally have thin shale partings between the beds; these are in some places succeeded, as we ascend, by another group of igneous rocks, and these again by blue compact limestone. This limestone is usually in beds, that range from a foot to three feet in thickness. Near the top of it there are sometimes beds of shale. It is also magnesian in places. The Upper and Middle Limestones, including the associated trappean rocks, are calculated to be about 2,000 feet thick."

In the foregoing descriptions of the limestone extending south-westward from and lying to the south-east of Limerick, the prominent development of chert has been taken as characterising the incoming of the upper series, which includes the Middle and Upper Limestones; and, viewing the two portions of the present district conjointly, the band is recognised to vary in thickness from 20 feet in the west to 150 feet in the east. The latter estimate is taken from the succession of chert beds which is to be seen on the northern slope of Foxcover Hill. It should be remembered that cherty beds occur below this zone, as previously mentioned; and that in another case, to quote from the memoir to Sheet 143, p. 21, we read :—

"To the S. of the alluvial flat which lies to the W. of Rockview, there are dark blue, nearly black limestones, which may belong to the Upper Limestone, but have been allowed to remain in the Lower, as they might be part of the lower portion of that sub-group."

It may also be stated that, to the south-west of St. Patrickswell, black calcareous slate (cleaved shale) may be followed along the Croom Railway, towards the south margin within

a short distance of the Lower Limestone boundary—the beds dipping at a very low angle—without encountering any marked development of cherty beds, or indications of their presence if partially concealed. A few thin seams of cherty limestone in a highly crushed calcareous shale were noticed there, but these seemed of exceptional and minor occurrence. Neither is the abundance of chert a characteristic of the gray limestone noted at the base of the upper series near Meelick House, north of the Shannon, while on the other hand it is to be found in beds of limestone on the southern outskirts of Limerick, well within the limits of, and therefore probably at a high level in the upper series.

Not only is the chert not of constant prominent occurrence along the divisional zone between the Upper and Lower Limestone series, but it is acknowledged to be "sometimes difficult to draw a satisfactory line of division."* It seems doubtful, therefore, if the areas of limestone indicated at Ballinagarde, six miles south-by-east of Limerick, truly belong to the Upper (or Middle) division. For here, though cherty beds seem to overlie gray massive limestone near Glen View (where there may be a slight dislocation of the strata), the same gray series followed southward, represented as Lower Limestone, dips away from the tract of cherty beds along a brow which rises up on the east from Ballinagarde House. The occurrence of chert in the Lower Limestone at Shanaclogh House and at Rockstown House has already been mentioned (p. 15); and the indefiniteness of the line of division between the two members of the group may account for the insertion of a band of Middle Limestone on the map, eastward of Caherconlish, and westward from Cahernarry, beneath the volcanic ash,* whereby the lowest beds of the latter are made to appear at different horizons, within a limited area.

Massive light gray beds of Lower Limestone are to be seen along the railway line, for a short distance from Adare, on the east side of the Maigue River. Thence onward towards Limerick, for about half a mile east of St. Patrickswell, the beds are in strong contrast to the former type; and the change in character is almost as sudden as it is striking. The rock is now usually dark gray, nearly black, fetid and thin-bedded or flaggy, characteristically argillaceous, with shale-partings frequently between the beds. Some of the beds, and in certain places all, become quite shaly upon weathering. In other places, variations in character, due probably to the conditions of deposition of the strata, are striking, as are also the different degrees in which the alternating beds have yielded to cleavage. Where the cleavage runs obliquely to the dip and strike, a highly argillaceous bed may be observed to be much affected by it, while the less earthy beds above and below scarcely exhibit the structure, as may be seen in a quarry beside the railway in Kilgobbin.

* As pointed out by Sir A. Geikie, "Ancient Volcanoes," Vol. II., p. 43.

Though some of the limestone at Limerick and extending from the city south-westward toward St. Patrickswell, is earthy, yet a well-recognizable difference prevails between these beds and those immediately around St. Patrickswell and south-westward towards Adare; and if this difference prevailed throughout the area, the three-fold division of the limestone group could be maintained in this as in other areas. It does not prevail, however; for about Clarina, between Mongret and Carrigogunnel, no evidence for an important earthy series is to be seen. Indeed, the limestone in this part of the region is remarkably free from argillaceous matter. It is of interest, too, as has recently been observed, that the limestone near Clarina, which is usually granular, shows striking instances of false bedding, which testify to the existence of alternating currents of some strength in the area while deposition proceeded.

No marked extension of argillaceous conditions is presented in the strata which form the lowest portion of the upper series around the margin of the tract now in question—eastward toward Castleconnell and southwards thence by Annacotty. At Carrigparson small quarries have been opened upon rapidly weathering limestone; three being in the areas represented on the original map as ash. One of these shows argillaceous beds, and two show rottenstone, on weathering, in which the residue probably consists in large part of ashy matter.

From what has been set forth above regarding the lithological differences noticeable in the rocks of this higher member of the limestone group, it seems obvious that corresponding differences of an interesting character prevailed in the conditions of contemporaneous deposition. There is little doubt that the sudden change, and diversity in character and contents, in the higher series, was accompanied, if not caused, by the commencement and continuance for a time of volcanic activity in the region.

Shale Series (or Yoredale Beds) d^3, *and Flagstone Series (or Millstone Grit)* d^4.—In the south-east corner of the present sheet occur two series of beds which were originally regarded as Coal Measures, represented as such on the map of the district published in 1860, and so described in the memoir accompanying this map (Sheet 144). The lithological characters of the group are given in the following description taken from the memoir, p. 24 :—

"These rocks only require a brief notice. In the road that runs N. and S. through Ballybrood the beds are well exposed. On the N. are olive and black shales; over these, are flags and flaggy grits, which are succeeded by alternations of grits, shales, fire-clay, clunch, and (as reported) coal (?)* The Measures are calculated to be between eleven and thirteen hundred feet thick.

* Coal is said to have been proved here; but when the district was examined it could not be found; and in subsequent inquiries, no positive proofs that it ever was found could be obtained.

"A mile E. of Ballybrood, there are good flags. A little to the S. of the flags, near Clover Ville, there is a remarkable quarry of gray grits which exhibit spheroidal concretions in places. Some of these spheroids are slightly calcareous, while others are soft sand full of thin veins and oxide of iron; usually they are not removed by the quarryman, and now stand up in large grotesque rounded masses, giving a most peculiar aspect to the quarry. Nearly all the Coal Measure rocks that are exposed in this district dip S. at angles varying from 5° to 45°."

The group was afterwards subdivided into the two series above named, as shown on the edition of the Sheet issued in 1874. They correspond in stratigraphical position and approximately in age with the subdivisions that have been correlated elsewhere in Ireland with the English Yoredale Shale and Millstone Grit respectively. Dr. Wheelton Hind has recently described, as the Pendleside Series and Millstone Grit, beds in West Clare and West Limerick which closely correspond in lithological character with those now in question to the south of Ballybrood; and it is unfortunate that a somewhat exhaustive search in the latter beds failed to bring to light any fossils by means of which full zonal identity could be established.

Igneous Rocks.

Within the limits of the present sheet occur three large areas of igneous rocks, mainly of volcanic origin, and some seven smaller outlying areas, all within easy reach of the city of Limerick. Viewed in association with similar rocks which appear throughout an area extending some twenty miles to the south-eastward, they render this region peculiarly interesting to the geologist, a region which Sir A. Geikie describes as "one of the most varied and complete, of all the Carboniferous volcanic districts of Britain." The largest area—that in the vicinity of Caherconlish—is the northern part of a volcanic basin the rim of which extends in an almost continuous zone, first eastward beyond the sheet margin, to Pallas Grean, thence south-westward to Herbertstown, and from there north-westward by Lough Gur towards Shehan's Cross, in the southern portion of the present sheet. Of the other two larger areas, one adjoins the city of Limerick, from which it extends eastward almost to Annacotty; the other also stretches eastward in an irregular lenticular area from Lemonfield House to Carrigparson. By far the largest proportion of the rock in these areas consists of volcanic ash, which is also found in some of the smaller outlying areas; and in a well-boring in the city a bed of ash 80 feet thick was reached at a depth of 92½ feet below the surface (see p. 22).

Volcanic phenomena manifested themselves in areas bordering the present sheet, in Upper Old Red Sandstone times*; and, after a period of quiescence, they appeared in the Limerick region, first in a minor way during the deposition of the Lower

* Ancient Volcanoes of Great Britain, vol. ii., p. 41.

Limestone beds, and then establishing themselves in force approximately at the incoming of the Middle Limestone. To the movements that were probably attendant upon or preceded the volcanic eruptions, may be due the local undulations of the sea-floor, or abrupt alteration and diversity of conditions of deposition, which have already been pointed out as having existed at this epoch (p. 19). Then volcanic action declined and seems to have disappeared—from the present area at least*—before all, or perhaps any of the Upper Limestone (*i.e.*, $d^{2'''}$—as distinguished from Middle Limestone, $d^{2''}$) was laid down.

FRAGMENTAL IGNEOUS ROCKS.—Associated with the volcanic ashes are *andesites*, *porphyrites* and *basalts*, which will be referred to later on. The general account of the rocks as given by the original writers, under the supervision of Prof. J. Beete Jukes, F.R.S., will be followed; and, inasmuch as the volcanic ashes assume such importance, and were earliest to appear in this locality, they will first be described (p. 8, Mem. 143, and p. 9, Mem. 144). Additions are enclosed in square brackets :—

"The *Ashes* are of a blue, green, [red], or purplish colour, and vary from a coarse breccia or conglomerate to fine trappean grits. The latter are often porphyritic or amygdaloidal, especially when of a purplish colour. When blue the ash is highly calcareous, sometimes nearly a limestone, and it might sometimes be called an Ashy Limestone or Limestone Ash. Green, however, is the prevailing colour for most of these rocks. In these ashes are fragments of grit, slate, limestone, [chert], trap, and ash, the pieces of limestone being most abundant, and some of them of considerable size, their diameter being over 8 inches. Beds of limestone and ash are often found alternating with each other in the district. Fossils, chiefly encrinite stems, are sometimes seen in the mass of the ash, and are abundant in the embedded limestone fragments. . . . [Some of the ashes] are a good firm stone, while others disintegrate when exposed to atmospheric influence. In the green ashes a spheroidal concretionary structure is of common occurrence, while the red are usually of a shaly nature, and the purple are hard and compact, often being good building stones."

According to Sir A. Geikie† the tuffs around Limerick "are distinguished by a scarcity of andesitic debris, by their persistent dull greenish-grey colour, and more particularly by the abundance of minute lapilli and larger fragments of an epidote-green, finely vesicular, easily sectile basic pumice. These tuffs," Sir Archibald adds, "are in evident relation with the more basic lavas that accompany them"; and again, "I have

*Sir A. Geikie describes as "an intrusive mass like a sill or dyke" a basic rock which penetrates the Millstone Grit, south of Ballybrood. It is therefore later than the volcanic rocks above described. How far the igneous tract south of Dromkeen affords evidence for the continuance of volcanic activity throughout the Upper Limestone period is not here discussed. The portion of this tract which reaches to the boundary of the Yoredale beds may, like the basic mass above described, also be intrusive.

†Op. cit., p. 44.

noticed fragments of fine, dark, flinty felsite, grit and other rocks. The stones are for the most part small, but vary up to blocks occasionally a foot in diameter."

Lisnagry Ash.—Evidence for the earliest appearance of volcanic phenomena* in this district is to be met with in the vicinity of Lisnagry, two miles south-by-east of Castleconnell. In a quarry three-quarters of a mile east-by-south of the Lisnagry railway station, nearly horizontal beds of limestone are seen to be overlain conformably by fine, well-bedded volcanic ash. This ash, becoming coarser upward, forms the hill of Knockbrack (269 feet), which stands 140 feet higher than the adjoining ground, so that the series of ash beds may be about 130 feet in thickness, at least. A view of this interesting section is here shown (fig. 2). The coarser part of

FIG. 2.

Sketch in Drominboy Quarry, Knockbrack, showing volcanic ash resting conformably upon limestone. The dotted layer immediately above the limestone is compact fine ash, which is overlain by a layer of similar ash showing spheroidal weathering. This in turn is overlain by ten to twelve feet of ash, parts showing stratification, parts spheroidal, and parts rude vertical (? columnar) structure. [From a photograph by Dr. G. Fogarty, R.N.]

the ash may be seen in a quarry on the south-west side of the hill, by the margin of a cut-away bog, 400 yards south-westward of this quarry, and at other points in the vicinity.

Limerick and Newcastle Ash Area.—The main series of tuffs at Limerick is preceded by alternations of beds of fine ash and limestone, as may be seen beside the railway on the road between Limerick and Annacotty, where the succession has been graphically described by Sir A. Geikie.† The suc-

* The ash met with at 92½ feet in depth in the Limerick well-boring may correspond in age with the Lisnagry series of ash-beds.

† Op. cit., pp. 44, 45.

cession is also set forth in a section near Limerick, a quarter of a mile west of the last-mentioned point, and thus described in the memoir of Sheet 143 (p. 29) :—

"Where the Ennis and Limerick Railway crosses the mail-coach road, ... limestones and ashes were seen in a quarry, on the N. side of which the following beds were noted."

		Ft.	In
7.	Green shaly ash,	0	6
6.	Dark blue limestone,	0	6
5.	Green shaly ash,	0	9
4.	Dark blue ashy limestone,	0	7
3.	Green shaly ash,	0	5
2.	Dark blue limestone,	2	8
1.	Ash, *over*	2	0
		7	5

A still more interesting section was seen when the ground was originally surveyed, but is now in large part concealed; it is described as follows, and it is worth noting that, unlike the cases previously alluded to, coarse ash of considerable thickness seems to form the initial layer of the series.

South of the city, in the railway-cutting to the W. of the bridge which crosses the railway at the old terminus, this excellent section has been seen, including limestone under, over, and interstratified with the ashes :—

Section in the railway-cutting, and in the quarry at the S. of the Artillery barracks.

		Ft.	In.
14.	Dark bluish gray limestone, with shaly partings,	7	0
13.	Fine green calcareous ash,	1	6
12.	Dark blue crystalline limestone,	1	9
11.	Fine green calcareous ash,	0	9
10.	Very compact fine ash, porcelain-like,	0	3
9.	Highly ferruginous crystalline limestone,	3	0
8.	Very fine ash,	0	3
7.	Green flaggy ash, in fine and coarse layers,	2	6
6.	Fine ash,	0	6
5.	Dark blue limestone, ferruginous and magnesian, *about*	8	0
4.	Shaly, ferruginous, dark blue limestone,	2	0
3.	Bedded ash, made up of alternations of fine shaly flaggy and calcareous beds. One of the latter, seven inches thick, is nearly a pure limestone. All the rest, except one reddish purple shale three inches thick, are of a greenish colour,	5	6
2.	Green brecciated ash, *over*	25	0
1.	Dark blue limestone with layers of calcspar, to the bottom of quarry,	10	0
		68	0

An attractive section of the fragmental beds in this Limerick area is laid open in a quarry at Newcastle, two and a half miles east of Limerick, where alternations of fine and coarse ash are displayed in remarkable regularity. The details of this section

will be given later on (p. 39); but here it may be mentioned that rounded pebbles are arranged in distinct layers, embedded in a matrix of finer ashy matter, and alternating with massive layers of ordinary angular ash.

Kilpeacon, Cahernarry, and Carrigparson Area.—The area south of Limerick is, unfortunately, much obscured by drifts, and almost the only good sections of ash to be seen are in the townlands of Ballysheedy, Drombanny, and Cahernarry. In the first-mentioned locality the description of the ash is as follows—taken from the memoir of Sheet 143 (p. 32) :—

"At Ballysheedy House there are purple ashes in coarse and fine layers; they generally dip N. at about 5°. The ash is nowhere else seen where it can be said without doubt to be *in situ*: but angular blocks, which seem not far removed from their natural beds, are found scattered over the space marked as ash. The ashes that are found in this district contain fragments and pebbles of limestone, grit, slate, trap, amygdaloid, and ash, the limestone usually being the most abundant."

Similar ash is to be seen at many points in Drombanny, it being coarse and angular on the slope of the high ground near the great alluvial flat. To the south-east of this point, near Knockea R.C. Chapel, occur beds which have been described as "green ashes, with a spheroidal concretionary structure." An interesting question arises out of the character of these beds, and others in the same volcanic area, 600 yards eastward of Cahernarry Church, shown in the west corner of the small map on page 26, which the present writer regards as truly conglomeratic in origin. (See p. 38).

The lowest beds of this great fragmental series have been observed at Carrigmartin quarry, in Cahernarry townland, and are thus described as they occur in section in the original memoir (p. 31) :—

	Ft.	In.
5. Massive green ash, containing fragments of limestone, traps, regularly laminated, but weathering into large globular blocks, &c., . . . *over*	30	0
4. Very fine green ash, porcelain-looking, . . .	0	9
3. Compact blue, in places purplish limestone, full of cavities, filled with red clay and sand, the clay horizontally stratified, ...	8	0
2. Fine green brecciated ash, the top of the bed for about five inches being very fine and porcelain-like, .	4	3
1. Compact blue limestone to the bottom of the quarry,	5	0
	48	0

The Cahernarry ashes extend eastward into Carrigparson, and may pass beneath the drifts and alluvium, towards High Park, more directly than is represented by the dotted lines on the original map. These have been transferred to the drift map in accordance with the arrangement explained on a foregoing page. As has already been noted, small quarries to obtain limestone have recently been opened in parts of the area

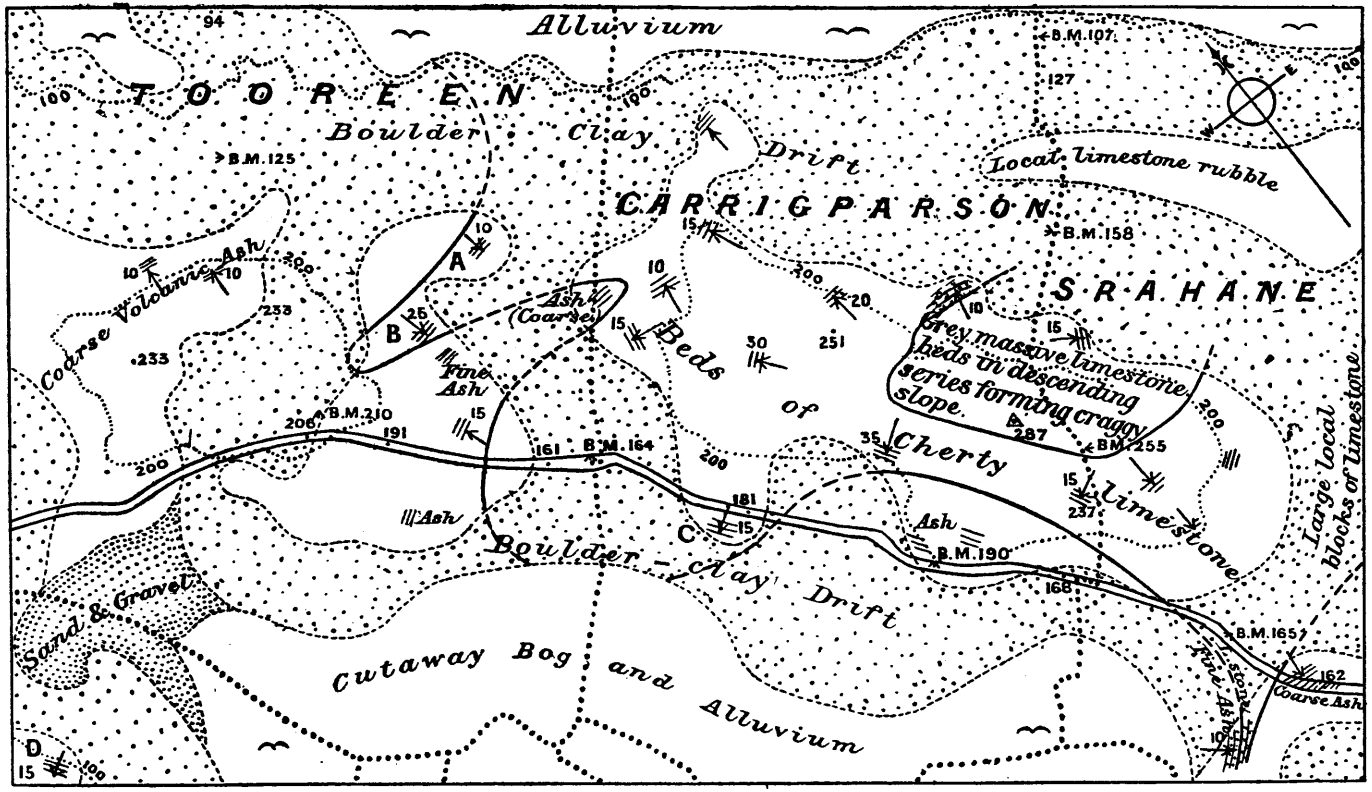
represented as ash on the original map; and limestone was also observed east of Carrigparson Hill, where ash had previously been shown. The residue of the limestone, after weathering, is in places ashy, which may account for some of it having been included in the volcanic series. A *descending* series of limestone beds without chert forms the eastern craggy slope of Carrigparson Hill, and the whole should therefore be included in the Lower Limestone. The ash boundary, moreover, runs further to the south than it does on the published map, at the right-angled junction of the road to High Park with the main road through Carrigparson. A map is here given (fig. 3), representing the rock-exposures as they are at present to be seen, and the boundaries which seem required by the facts of the case, as now revealed. It will be noticed how interestingly the limestone and ash dovetail into each other, as they have already been recognized to do in the neighbouring locality of Carrigmartin.

Boughilbreaga and Caherconlish Area.—The ash in this area forms a strip extending eastward by Caherconlish, representing in this locality the great igneous basin which stretches southward, as previously sketched, and forms Carrigawattin, Boughilbreaga (or Ludden More), Knockroe, and Fox Cover hills. The rocks consist of a set of alternating ashes, lavas, and at least one important intrusive sill, dipping southward, and are very well exposed. The ashes, as in the previously described areas, are green and purple, usually made up of angular fragments, chiefly of basic lavas, and at a few points diverging from their normal character in containing well-rounded debris (see p. 38).

The basin, the rim of which thus crops out along this tract, must have extended far northward beyond its present limits, to coalesce probably with the large neighbouring areas previously described. The rocks of these areas occupy approximately the same general horizon in the Carboniferous system, and are now severed from each other by a stretch of Lower Limestone exposed by denudation. All probably once lay concealed beneath Upper Limestone and the overlying Shale and Grit series, which now occupy the centre of the igneous basin. Sir A. Geikie mentions Knockdirk and some other bosses along the southern margin of the basin as centres of eruption; and he believes that some of the basic masses of the present sheet may denote other such centres; but no distinct igneous core can be pointed out with confidence.

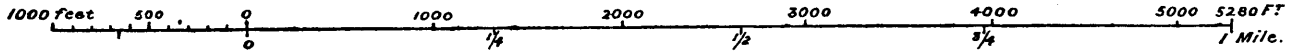
It is unfortunate that along the margins of the larger tracts above mentioned no sections have been exposed exhibiting the manner in which the deposition of igneous matter grew scanty and vanished, giving place to ordinary sedimentation and the formation of limestone, consequent upon the cessation of volcanic activity in the region.

FIG 3.



A *Dark grey earthy limestone, with fossils.* **B** *Dark blue thin-bedded limestone.*
C *Dark grey encrinital limestone.* **D** *Red Sandstone conglomerate & calcareous seam associated with ash.*

SCALE.



Carrigogunnel Area (Fig. 4).—This interesting igneous area "is situated four and a half miles to the west of the city of Limerick, and is an irregular tract about two and a half miles long with a general bearing of N. 15° E. The geological position of the trappean beds is at the junction of the Upper and Lower Limestone." The ash, as described in the memoir of Sheet 143, p. 26,

> ". . . . has either a red, purple, green or purplish green base, and embedded in it are pebbles of white, gray, and blue limestone, which are often fossiliferous, and yellow, purple, and gray grits and slates. It varies from a fine porcelain-looking ash to a coarse breccia or conglomerate, fine and coarse layers lying so close together that a hand specimen can be broken off, showing three or four different textures. A few encrinite stems were found in the base of this ash. This ash is about 150 feet thick."

At the Castle, eastward toward the Model Farm, and northward, the fragments in the tuff are coarse and angular, with pieces of vesicular lavas and the other rocks named above. The castle stands upon a detached portion of the ash—an outlier—which has escaped denudation; and another such outlying mass rests upon the basalt and about fifty yards to the south-west of the former (Frontispiece, Pl. I.).

An upward sequence from the angular ash to the limestone at Cooper Hill is almost traceable; one of the beds of the limestone, in a quarry outside the demesne wall, contains pebbles of igneous rock up to 3½ inches in diameter and well rounded; and between the limestone and the ash occurs a series of beds—well seen to the south of the quarry, near the roadside—of sandstone and conglomerate bands, the pebbles in which are well rounded and subangular; almost, if not all, consist of ashy materials. The change in character, bedding, and shape of the contents, from the ordinary fine and coarse angular

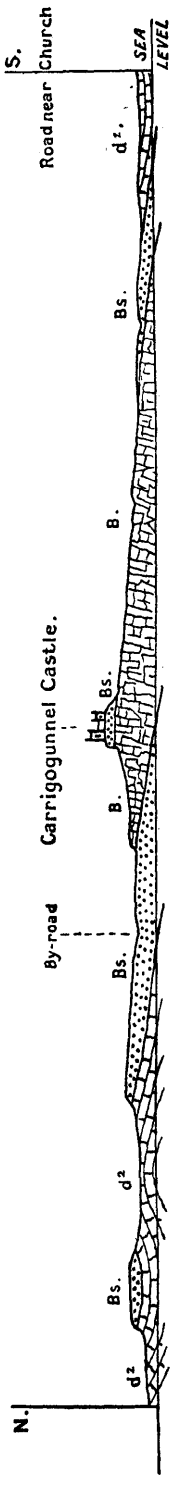


Fig. 4.

Section nearly N. and S. through Carrigogunnel, showing the relations between the limestone (d^1), ashes (Bs), and basalt (B).

ash or tuff which underlies the beds in question is very striking, though the change is gradual; and it is manifest that the conglomerate and sandstone series is introductory to the limestone series, which at its base contains the igneous pebbles; the former series, therefore, is taken to be indicative of littoral conditions, or at least to have been formed of volcanic products by attrition in shallow water of the period, about the time when disturbance in this region had almost if not entirely ceased. Similar beds of rolled material are to be seen bordering the limestone area and the igneous tract, a mile to the southward near the church; and fine conglomerate, three-quarters of a mile to the west of the last-mentioned point, near Corrig View. The ancient shore-region is approximately represented on the reduced tracing of the six-inch map given on p. 34. For reasons which must be given later (p. 33), the lines do not coincide with those on the original six-inch or one-inch map, though these have to some extent been utilized.

Other small areas of ash are to be seen, as near Meelick House and Gilloge Bridge north of the Shannon, and to the north of Jockey Hall, near St. Patrickswell, none of which demand special notice here.

MASSIVE IGNEOUS ROCKS.—It has been generally held that the basaltic layers of Carrigogunnel and Boughilbreaga are contemporaneous and "interbedded" with the tuffs of these localities. Preliminary to a presentation of the evidence which has led the present writer to a contrary opinion, it is appropriate to recall Sir Archibald Geikie's concluding references to this celebrated district* : —

"On comparing the maps of the Limerick basin with those of the Carboniferous districts of Scotland, the main difference will probably be acknowledged to be the absence of any recognizable sills in the Irish ground. That no sills actually occur, I am not prepared to affirm. Indeed some of the more acid rocks, both outside the basin and among the rocks of the older volcanic group, appeared to me during my traverses of the ground to have much of the character of sills. A more critical examination of the area would not improbably detect some truly intrusive sheets which have hitherto been mapped among the interstratified lavas. Some appear to exist among the surrounding Lower Limestones.

"An intrusive mass, like a sill or dyke, is represented on the Geological Survey Map as traversing the Coal Measures in the inner basin south of Ballybrood. But as the strata are on end along the southern margin [*i.e.*, of the basin], it may possibly be only a portion of the upper volcanic series which has been thrown into its present position by one or more faults."

That the circumstances may be clearly understood, however, the original descriptions of the rocks must be given; and attention is invited to statements bearing upon a discussion of the structure from the standpoint here adopted, by placing the words in italics.

The descriptions run thus (Memoir 144, p. 9; 143, p. 8, 32, &c.) :—

"The rocks called *Greenstone* and *Basalt* are often found so blended

* "Ancient Volcanoes of Great Britain, vol. ii., p. 48.

together that it is impossible to draw a line of demarcation between them. Other trap rocks occur which are in different places dark green, light green, light blue, dark blue, or reddish in colour, the last-named colour being often due to decomposition. Their texture is generally compact or fine-grained, with crystals of feldspar widely dispersed through the mass; other crystals are rare, and some even of those traps, which from their dark colour have been called Greenstone, seem almost entirely feldspathic. Some of these rocks pass imperceptibly into Porphyries and Amygdaloids, which have many varieties in the different localities in which they are met with."

". . . . When amygdaloidal and porphyritic, [the rocks] contain almond-shaped pieces and crystals of feldspar, calcspar, &c. . . . . On the weathered surface of the amygdaloids and porphyries will be seen empty cavities, but on breaking the rock these are found to be full of a white mineral, [while on going still deeper its place] is taken by pink, green, or red minerals—some of the cavities being filled with a substance marked like an agate. Specks of a greenish mineral are numerous in these traps; also veins and crystals of quartz." [Scoriaceous patches are also to be met with included in the traps.

Associated with the ashes at Cahernarry, Drumbanny, Roxborough, and Kilpeacon, are five masses of trap. The two at Cahernarry] are possibly parts of the same outburst, *with a mass of ash caught-up and dividing them.*

"The trap at Cahernarry is of a dark green or bluish colour, with white and greenish crystals widely dissiminated through the mass.

". . . . Amygdaloid is found in the mass on which the church stands, and good porphyry was noted due east of Cahernarry House."

In the same paragraph (Mem. 143, p. 32), it is added,

"*The trap just described appears to be intrusive, as the ashes are found dipping at it, away from it, and obliquely towards it*; but its exact relations are undeterminable, as there is no natural or artificial exposure of the junction of the rocks."

On the same page we read :—

"The Drombanny trap is similar to that just described, but here the trap seems to be contemporaneous, lying on part of the ash, and under the rest. All the ash to the N. of the trap dips away from it, and is of a purple colour, except one green bed before-mentioned, while the ash to the south is all of a green colour, and seems to dip under it. The ashes to the east seem to be horizontal, and may be under or over it. From this it is seen that this *may be* a bed of trap between two ashes. *If it is, it must die out, as it goes east.*

"At Kilpeacon Glebe the trap is well seen at the old church and in the fields to the E. of it. Much of it is amygdaloidal, but the trap seems to be similar to that before described."

A diagrammatic section across Knockroe is given in the Memoir of Sheet 144, p. 27, representing an alternating series of lavas and ashes; the existence of an important band of ash —the lowest layer of the series—is partly based upon evidence thus described :—

"The ash bed, No. 1, is first seen coming from the E. in a quarry in the townland of Stonepark (three-quarters of a mile to the N. of Shehan's cross-roads), where it is found to be interstratified with the limestone and to have a thick mass of that rock between it and the trap (*bed No.* 2). Through this mass of limestone runs a dyke of trap, near the angle in the parish boundary."

The "ash" here referred to is a much weathered layer of igneous rock—lava-flow, or sill?—interbedded with the limestone, and possibly connected with what the writer regards as a vertical dyke which traverses the limestone beneath the layer. Ash beds* of considerable thickness, with ashy sandstone and conglomerate, are, however, to be seen a quarter of a mile to the east of the quarry. It may also here be said that the massive basalt which is represented as an important east-and-west outcrop of a lava-flow north of Rock View, near the quarry, protrudes above the surface in a small ridge running north and south, which is more suggestive of a dyke than a lava-flow; and at a point 250 yards north-eastward from the ridge across an obscure hollow—also in the supposed lava-layer—the basalt is to be seen invading limestone. The main basalt mass represented as the extension of this same lava-flow—"Bed No. 2"—is next to be seen half a mile further east, in Boughilbreaga, the intervening ground, so far as the rock is to be seen, being formed of ash, with possibly some small dykes or sills of basalt.

The basalt mass is thus described :—

"On the west face of Boughilbreaga [the basalt] *is columnar*; to the east of Boughilbreaga, as before remarked, it rests, *to the exclusion of the ash (bed No. 1), on the limestone. The limestone is altered to about the depth of four feet. In this place the base of the trap is cut up by joints into angular fragments that are now cemented together by calcspar.** As this trap is followed eastward, *it thins, or, perhaps, dies out*, as it could nowhere be found on the road that runs south from Mount Saint Lawrence; *but there is a coarse breccia made up, seemingly, entirely of angular fragments of trap*, which is supposed to form a connexion between the part of the trap just described, and that which lies to the north of Knockroe (Mason). After this road is passed, the trap can be traced eastward to and through the wood that lies to the S.W. of Caherconlish House, immediately to the E. of which it is supposed to die out or amalgamate with the trap (*bed No. 4*)."

Sir A. Geikie gives a section of the Boughilbreaga volcanic escarpment (*op. cit.*, vol. II., p. 45), showing ash resting upon limestone, and overlain by two thick layers of basalt dipping southward, enclosing a thin interbedded seam of, and overlain by, ash, these features being thus described :—

"Besides the andesites there occur also, and, so far as I have observed, in larger number, sheets of true basalt. This rock is typically black, exceedingly close-grained in the central portion of each sheet, but becoming highly slaggy and vesicular along the upper and lower parts. . . . . These rocks form distinct escarpments along the northern rim of the basin as in the foregoing section east from Shehan's Cross-roads. From the summit of this ridge, which is about 600 feet above the sea, the eye looks northward over the plain, across which low outliers of the volcanic series are scattered, and southwards across the basin to the corresponding line of volcanic heights forming the southern rim."

A similar trap was remarked at Carrigogunnel.—*See Explanation of Sheet* 143.

Prof. Watts* describes the basalt of Boughilbreaga under the heading of "The Older Volcanic Series," thus:—"The earliest lava-flows, in the northern part of the area are close-grained basalts. . . . The base of the rock is in some cases still glassy, as in specimens from Boughilbreaga; . . . other examples are coarser grained." Mr. Watts proceeds:—"The lower basaltic lavas are succeeded by others of porphyrite, purple in colour, much decomposed. . . . Unfortunately, the only rock analysed could not be demonstrated to be a lava-flow . . . and was much like one of the intrusive porphyrites." The same writer also describes as olivine basalts an "Upper Volcanic Group," made to include the lavas of Cahernarry, Roxborough, and Meelick House. It will be remembered that the memoir to Sheet 143 describes the mass at Cahernarry as possibly intrusive.†

With regard to the dislocations of the Knockroe succession of ashes and other rocks, it is questionable whether those cutting transversely across the ridge are of such magnitude as represented on the map; it is indeed questionable if the faults are of such importance as to warrant their introduction. A point of interest seen on the east side of the gap in which the main fault is shown to lie, and near its northern end, is a remarkable instance of miniature pillow-structure, marking the top of a layer or lava-flow, wherein the spheroids, three or four inches in diameter, are huddled loosely together, beneath a succeeding lava-flow.

The series of massive rocks at Carrigogunnel is described in the original memoir in general terms as consisting of two compound beds of trappean ash, and an intervening bed of trap. The lower ash rests upon blue limestone, and the upper passes beneath limestone in the manner previously described. The trap was stated in the Memoir 143 to be either a diorite or a basalt. It is without doubt a basalt.

It was during the examination of the rocks in this small but extremely interesting area of Carrigogunnel that suspicions previously entertained as to the mode of occurrence of portions of the series of massive igneous rocks, and regarding the nature of some of the rocks previously considered to be volcanic ash, became verified, and to such a degree as to warrant more exhaustive inquiry in other localities, also comprised within the sheet.

A small outcrop of rock occurs south by west of Carrigogunnel, which is thus referred to in Memoir 143:—

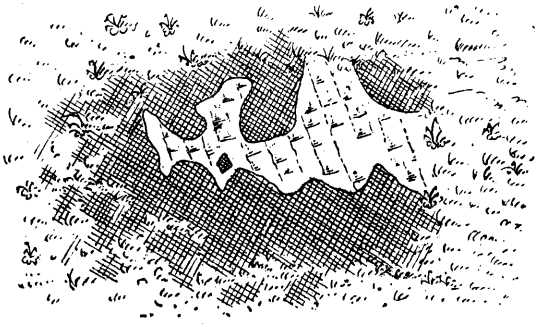
"There was only one actual junction of the ash and the overlying limestone seen, which is situated about a quarter of a mile to the N.N.E. of Meelick House (which lies about a mile and a quarter to the S.W. of Carrigogunnel), where the rock which rests upon the ash is a dark blue, nearly black argillaceous fetid limestone."

*"A Guide to the Collections of Rocks and Fossils," by A. M'Henry, M.R.I.A., and W. W. Watts, M.A., F.R.S.

† Mr. H. J. Seymour, however, who surveyed the drifts of this district, informs me that he regards the Cahernaharry and Drombanny basalts as lava-flows, and the local ash as underlying them.

The so-called "ash" in this description was seen to be a brecciated mass at the junction of the basalt, which is well exposed, and the limestone. The basalt has obviously invaded the limestone, which, as stated in the extract, overlies it. The manner of the invasion may be judged from a small sketch-plan made on the spot (Fig. 5).

FIG. 5.



Plan of exposure of limestone (structureless), 20 inches in length, invaded by fine-grained basalt, a fragment (or pipe) of which is included in the limestone, near Carrigogunnel.

Pieces of limestone of different sizes, and in large number, have become included in the basalt, quite detached from their parent mass; while fragments of basalt usually angular, and just as numerous as the others, are included in the limestone. The mass therefore is a confused mixture of fragments of both rocks embedded in a matrix either of basalt or limestone. A curious feature of the case noticed by Professor Cole, who visited this section with the writer, is that the microscopic organic remains in the limestone are recognizable and unaltered up to the junction of the basalt. The flow-lines in the volcanic rock are, moreover, in some blocks perpendicular to the surface of junction with the limestone, showing similarly that the basaltic mass had almost ceased to be viscid when the breccia was being formed. The brecciated mass, therefore, resembles "ash" in some points, but has an entirely different origin—it is a breccia of intrusion*; and the basalt, judging from its lie and aspect in the field, is a sill.

* The writer fortunately can speak from acquaintance with similar ash-like rocks on the south coast of Waterford, in Donegal, and elsewhere in Ireland. See Summary of Progress of the Survey for 1899, p. 80; and a Paper in the Quart. Jour. Geol. Soc. London, vol. lvii., p. 479, on "Intrusive Tuff-like Rocks in Ireland," by A. M'Henry, M.R.I.A., and J. R. Kilroe, from which part of the concluding paragraph (p. 489), is here borrowed. After more or less detailed reference to several other eruptive areas, the following is stated:—"It is certain that, whatever the origin of the masses we describe, their true character and disposition have been overlooked in Ireland. Judging from what we know of so-called 'contemporaneous igneous rocks' in the Lough Guitane district near Killarney, and their disposition in the field, as well as of some of those in the Limerick basin, we believe that more rigid examination of these areas would reveal the existence of masses younger—possibly much younger—than the surrounding sedimentary strata."

Proceeding north-eastward, a similar brecciated mass was observed beneath the Carrigogunnel trap, 300 yards south-west of the castle. Here, as in the preceding instance, limestone and basalt fragments lie embedded in alternative matrices; and as showing the degree of pressure under which the fragmental mass was formed, and the differential movement to which it was subjected, it may be noted that thin seams—attenuated sills—of basalt, formed during the first invasion of the limestone and solidified, have been twisted and bent in a striking manner, giving to the mass a gnarled appearance. This rock seems to have been noticed by the officers who originally mapped the ground; it is described as "trappean ash," equally with the true coarse volcanic ash which is to be seen just across a small alluvial flat adjoining. Before passing from the breccia below the trap, it may be mentioned that the mass of basalt, which is rudely columnar, forms a steep brow west of the castle, resting apparently upon limestone, and not upon ash, as the original description might lead us to suppose. Attention is specially called to the passages italicised in the following quotation from Memoir 143, p. 26:—

"Above the lower ash, as previously mentioned, lies the trap, which is usually very compact, but sometimes has vesicular *or scoriaceous patches in it.* It is generally of a dark blue colour, and becomes porphyritic and amygdaloidal at the top of the bed. The almond-shaped vesicles are now usually filled with calcspar. To the south of the castle, near the boundary of the upper ash, the trap is in angular fragments, that are now joined together by a calcareous cement; *it has a very brecciated appearance, and might easily be mistaken for an ash.** The bed is about 170 feet thick. Under the castle it is nearly horizontal, or diping at from 5° to 10° to S.S.E. To the S. and S.E. of the castle, a considerable quantity of the upper ash has been denuded away, exposing a large portion of the trap."

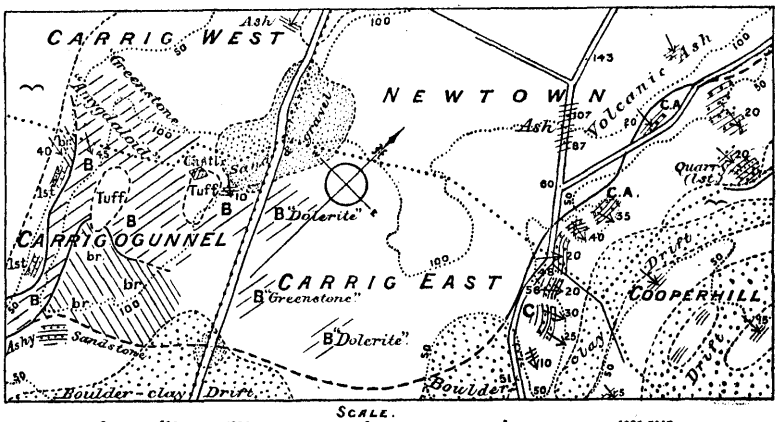
Referring to the brecciated rock mentioned in the text and footnote quoted above, the quantity of "calcareous cement," or matrix, binding the basalt fragments in the breccia, is remarkable. If the origin claimed in the original Memoir for the fragmental rock be admitted—and it can scarcely be questioned—and if, as will be put forward later on, the similarity between it and the rock at Boughilbreaga hold, there is little room to doubt that the "cement," though now for the most part white calcite, was originally limestone, just as is the matrix binding the basalt fragments in the breccias already discussed.

Here, then, we have, and partly on the strength of the evidence in the original memoir, a mass of basalt, showing rude columnar structure, interposed between two breccias of

* The writer of the original Memoir states "this peculiar form of trap was also remarked at Boughilbreaga (*see Explanation of Sheet* 144); but in that place it is at the bottom, while *here it is at the top of a flow.* I also remarked the same thing at the end of a dyke of felstone, in Bear Island, county Cork, *see Explanation of Sheets* 197 *and* 198. In Bear Island, the angular fragments did not seem to be cemented together."

intrusion, lying—not entirely upon ash, as might be expected in a volcanic series within narrow geographical limits—but in part upon ash, and, side by side with this, upon limestone, which passes under the ash. There seems only one conclusion from these data, which is, that the Carrigogunnel trap is a basalt sill of considerable dimensions, and not a lava-flow, as was originally supposed. A small map of the immediate area, prepared partly from the original observations and partly from those recently made, in so far as a brief examination would warrant a change in the mapping, is here shown (fig. 6).*

FIG. 6.



B. *Basalt or dolerite*—C.A. *Conglomeratic Ash*—C. *Conglomerate*—1st. *Limestone*.
br. *Intrusive breccia*.

It is with diffidence that one turns to a discussion of the great basic sheet, which forms so conspicuous a feature of the Caherconlish range, seeing that it has been hitherto consistently regarded as a great lava-flow, interposed between two series of ashes, and forming, so to speak, the backbone of the ridge, and of the whole volcanic group, alike.

The broken-up condition of the base of the basaltic sheet on the east side of Boughilbreaga is alluded to in the preceding foot-note from the original Memoir 143. The breccia is made up of pieces of basalt included in a paste, not exactly of calcite, but of limestone; as well as fragments of limestone and of fine calcareous ash, in a matrix of basalt; all confusedly mixed together, as in the breccia first described north of Meelick House, S. by W. of Carrigogunnel.† The detached pieces of fine ash exhibit beautifully its original bedding or lamination; and, along the margin of the pieces, the laminæ are invaded by smaller intrusions of the basalt. Furthermore, in following the base of the basalt northward, one finds it resting, first, upon coarse angular volcanic ash of considerable apparent thickness; then upon limestone for some fifty yards,

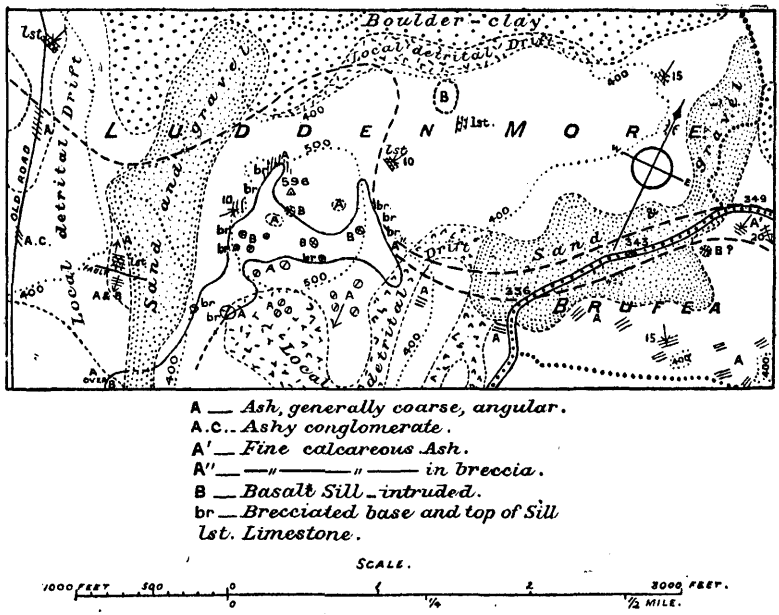
* On the origin and spelling of the name Carrigogunnel, see T. J. Westropp, Proc. R. I. Acad., vol. xxvi., sect. C. (1906), p. 144.

† *Cf.* Verschoyle, Trans. Geol. Soc. London, Ser. 2, vol. v. (1840), p. 167.

in which the bedding rolls considerably; then once more on the coarse ash. From this section alone the massive sheet may be regarded as intrusive. The limestone has been to some extent structurally affected by the intrusion.

The writer found a similar breccia at the base of the basalt, as well as included masses of ash in this rock, on the west side of the hill; and, in tracing the base-line northward, it was found to pass transgressively across the ends of strata of well-bedded ash at one point (see fig. 7), and finally to terminate

FIG. 7.



Geological map of Boughilbreaga (596 feet).

in a tongue laterally penetrating the ash, where the latter forms the north slope of the hill. Further examination of the hill, in the very limited time at his disposal, enabled the writer to trace the outline of the basalt and ash with a fair degree of accuracy; the result of which appears in the accompanying map.

Hence the writer believes that the basaltic sheet, so often mentioned as a lava-flow, will, by those who examine the ground most closely, be recognised to be a great intrusive sill —to which its columnar structure also points.

If, as is possible, the sills are of the period to which the great basic mass south of Ballybrood belongs, they would be more recent than the Millstone Grit—but how much more recent there is no evidence to show.

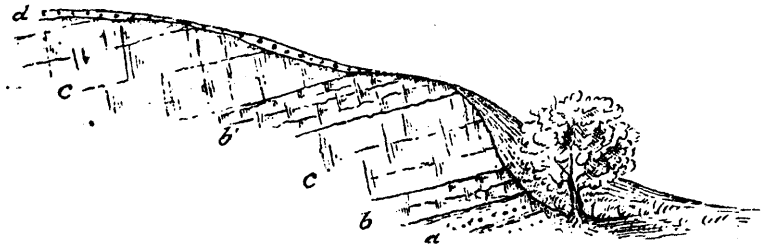
The small outcrop of basalt to the north of Boughilbreaga seems to be that of a minor sill; no ash is to be seen associated with it. Other small outcrops south-west of Shehan's Cross

may likewise be sills; in which case there would be no justification for representing them to be part of the Boughilbreaga "lava-flow" continued westward.

We may now refer briefly to two other small areas of rock, which are petrographically described on pp. 108–110, one at the old castle of Caherconlish, north of the village, and the other at Maddyboy, north of the Mulkear River. That near Caherconlish presents a striking section on the east side of the knoll which the igneous rock there forms (Pl. III.). It is seen to be columnar in structure, and seems to be continued southward, though in most part concealed, to the small stream where this runs eastward after flowing from the village. The stream separates the igneous rock from the limestone, and the latter seems to pass under the former—which confirms the surmise, engendered by its columnar structure at the castle, that this igneous mass is an intruded sill.

The somewhat similar type of rock at Maddyboy, called *Ivernite* by Prof. Watts,* seems also to be of intrusive origin, and is probably a sill or group of sills. In a somewhat obscure section, seen in an opening behind Maddyboy House, a succession of the following nature may be fairly made out.

FIG. 8.



Section of E. slope, Maddyboy hill, showing old quarry at back of Maddyboy House—with (*a*) white sandstone; (*b*) dark grey limestone; (*b'*) grey limestone with chert; (*c*) felsitic rock, "Ivernite," probably intrusive sills; (*d*) local detritus and drift.

The rock shows a rudely columnar structure in a large quarry beside the sharp bend of the Maddyboy road where it turns northward. Half a mile west of the road beside a by-road, near some cottages, an opening has been made upon the same rock; and as it probably extends westward thus far at least, beneath the drift, the area of the outcrop is considerably larger than is represented on the original map.

Probable Shallow-water and Land Deposition of certain Volcanic Products.

Before concluding this description of the grouping of the igneous rocks, reference may be made to the question raised by Jukes as to whether the ashes, &c., were subaërial or submarine. In the Memoir 143, p. 9, the matter is referred

* "A Guide to the Collection of Rocks and Fossils," p. 93.

To face p. 36.

PLATE III.—Quarry in columnar Felsite on hill due north of Caherconlish. The columns on right are some 15 feet in height.

to in the following words :—" In Limerick the old cones, if they ever existed, and whether they were submarine or subaërial, have, of course, been long ago destroyed and their materials strewed over the adjacent seas, making, perhaps, many of the thick deposits of the present trappean ashes and conglomerates. We may, perhaps, too, suppose that the eruptions were more entirely submarine, and doubt whether any cones were ever formed over the orifices." Spheroidal pebbles have been noted in several places in the ashes, the shapes of which, notwithstanding the above allusion to conglomerates, suggested in earlier days a concretionary origin, as previously noticed (p. 2[illegible]; and " the red ashes " are stated in Memoir 144 (p. 9) to be " usually of a shaly nature." Curiously enough, the rounded shape of the pebbles was not stated in any part of the original description to be due to attrition under moving water; nor was the red shaly ash, or ashy shale, attributed to sifting, oxidation, or re-arrangement of the finer green ash—with possible comminution of coarser ash —under more turbulent subaqueous conditions.

The view about to be presented is, however, in satisfactory accord with that held by the late Prof. Jukes. In the Memoir of Sheet 143, p. 9, he makes an interesting comparison between the volcanic rocks of Limerick and those of the islands of Torres Straits, with which he was familiar; and in his account of " the Igneous Rocks interstratified with the Carboniferous Limestones of the Basin of Limerick," published in the Report of the British Association, 1860, p. 84, we read : —" The trappean ash (or tuff) is the result of the mechanical erosion of the igneous rock, either during the time of its eruption, or immediately after, and before it was buried under other aqueous rocks. It consists of grains or fragments of trappean material, varying from the finest powder to a coarse conglomerate, with blocks several inches in diameter, and often contains large and small fragments of limestone, and sometimes of other matter.

" It is perfectly stratified, lying in regular beds, interstratified both with the limestone and with the trap, and blends almost insensibly, sometimes into the one and sometimes into the other rock."

The term " volcanic ash " is applied in the present memoir to beds of angular and mixed material, while the zones of round, water-worn material are regarded as true conglomerates.

The reader will recall (p. 27) the band of red sandstone and conglomerate which intervenes near Cooper Hill between the coarse ash (of the Carrigogunnel tract) below, and the limestone, containing rounded pebbles, above. This band must have been laid down in comparatively shallow water, to admit of the formation of beds of well-rounded pebbles, and the alternating arrangement of fine and coarse beds in the sandstone. It has been suggested that rounding might have taken place in the processes of eruption and deposition, without calling in the aid of subsequent attrition by waves or rapid cur-

rents; but if this be adequate cause, such pebbles should be of frequent occurrence scattered indiscriminately throughout the angular ashes; and it would not account for bands of rounded pebbles, interstratified regularly with those of ashy sandstone. Were such a series of beds as those now in question met with under ordinary circumstances of aqueous deposition, there would be no hesitation in ascribing their formation to attrition and sedimentation. The difference in the present case consists in the conglomerates and sandstone being formed of ashy materials. The simplest reading of such a band, however, is that it is of littoral origin.

Similar beds of ashy sandstone and conglomerate have been noted in the larger areas of ash, in the south-eastern portion of the district, thus:—at Drombanny, south of Limerick, already referred to; at a point east of Cahernarry Church, where a small section reveals an interesting series—calcareous ashy seams, red ashy sandstone with manifest false-bedding, and fine conglomerate; at Ludden More, east of Stone Park quarry (see map on p. 35); and in the townland of Dromkeen, the rock at which point is thus referred to in Memoir 144, p. 9:—"Two miles to the east of Boskill House, near the coach road, the ash dips south at 10°, and is a red coarse-bedded sandstone, very hard and compact, like some of the ashes to the north of Lough Gur." Fine conglomerate is also noticeable here.

It is worth noting, and has special interest because of its bearing upon the point under discussion, that at the four last points mentioned—Lough Gur apart—the sandstone and conglomerate occur at about the same stratigraphical level above the horizon at which the deposition of ash commenced in this region, though the points referred to are scattered throughout a tract seven miles in length. We must conclude that this is not a casual circumstance; it points rather to the existence of conditions favourable to the formation of sedimentary beds at some time during the accumulation of the volcanic ashes, when eruption was less pronounced, and when ordinary processes of attrition in tempest-tossed waters could assert themselves on materials ejected and lying on the floor of a sea not very profound, and probably shallow, in the area immediately concerned.

At the southern end of the gap crossing Knockroe ridge occurs the striking section already mentioned (p. 25), showing red sandy shale, fine red sandstone, which becomes coarser upward, and finally conglomeratic beds, forming a series eight to ten feet in thickness. The uppermost portion of the series at one point is a peculiarly coarse conglomerate, with well-rounded blocks up to ten inches in diameter, consisting of ash, red sandstone, and porphyrite, as if it had been formed at the base of a wave-washed cliff of the Carboniferous sea. This series of beds seems to mark an episode in the accumulation of the great series of ashes, like that previously dwelt upon, during a temporary decline or cessation of volcanic activity, though at an epoch somewhat later than

the former. The sandstone has been quarried for local building purposes, a little to the east of where the section referred to is exposed, beside the small road passing by the section.

In this connection, reference may now again be made to the beautiful rock in Newcastle quarry, east of Limerick, where seams of well-rounded pebbles emphasise the succession of beds in the great series of coarse and fine ashes there laid open. Not only are many of the pebbles well rounded, and the seams in sharp contrast with the angular ash above and below them, but the pebbles almost all consist of purple compact basic lava; while the matrix consists of grains and small angular fragments of chloritic pumice—this latter being full of minute amygdales of a purplish colour. The purple compact rock of the pebbles also shows, in some instances, chloritic alteration in parts; these parts also contain the same kind of purplish amygdales, which are so numerous in the pumice. Taking the above facts into consideration, conjointly with those previously reviewed, it cannot but be concluded that some other agency operated in rounding the fragments than the haphazard action attendant upon the processes of volcanic eruption. And though rounding should thus be accounted for, there must also have been a sifting of the fragments, bringing together those of the same shape, character, and approximate size, at successive stages of the accumulation. The more natural way of accounting for the circumstances is to attribute them to the action of waves operating on an exposed mass of basic lava, the results of attrition being then distributed over the neighbouring sea-floor, where ash was accumulating—volcanic accumulation and sedimentation predominating alternately.

The ash was, moreover, probably in part deposited upon land; and the evidence above given also shows that the shore-deposits were formed at different stages of the volcanic disturbance and eruption, viz., shortly after the great mass of the ashes commenced; in the middle of that period, as indicated at Newcastle and Knockroe; and at its close near Cooper Hill.

A great mass of limestone is surrounded by ash in the ground between Boughilbreaga and Stone Park; and as it protrudes well above the ash, and yet is obviously in its original position, particular inquiry was directed towards discovering its true mode of occurrence. On the south side of the mass it was proved to be severed from the ash by a fault. On the north side, however, the ash was found to be deposited upon and against a broken shelving surface of the limestone, as if the latter had been subjected to erosion about the time, or immediately before, it formed the platform upon which the ash accumulated. It is obvious that the conditions above postulated occur in many volcanic areas at the present day, notably on the shores of Pacific islands, where eruptive activity and oscillations of the earth's crust bring ashes, lavas, and contemporaneous beds of limestone into varied and interesting relations in the field.

CHAPTER III.—DETAILED DESCRIPTION OF THE SUPERFICIAL DEPOSITS.

Country for two miles north of the Shannon between the Bunratty and Crompaun Rivers,

Included in the Six-inch Sheet 62, Co. Clare.

By W. B. Wright.

This district comprises the lower slopes of the Cratloe Hills and the low-lying limestone country between the hills and the river. A large proportion of it is covered with thick drift, the area of most abundant deposition being south and east of Cratloe Wood. The thickness of this drift is due directly to its position with regard to the hills. The ice coming from the north-west and impinging on the western flanks of the hills appears, to a large extent, to have been fended off by them into the low ground in the neighbourhood of the Bunratty River. The area of low ice-pressure lying in the lee of the hills was necessarily one of abundant deposition, while their western flank, being exposed to the full impact of the ice, was, on the contrary, an area of erosion. Thus we find that the hill-slopes to the north of Cratloe have but little drift, and that lying in irregular patches and pockets, while large areas of smoothly planed and striated sandstone may be exposed by merely stripping off the turf.

To the south and west of Cratloe, however, there occurs in the low ground a condition of things intermediate between these marked phenomena of deposition and erosion. Here the drift is one locally thick, and is thrown up into a series of hog-backed mounds or drumlins, whose long axes are parallel to the direction of the striæ on the glaciated hill-side to the north-east.

A section through one of these drumlins can be seen on Quay Island, which is still exposed to the waves of the estuary. The island is bounded on the south and west by a cliff from 5-10 feet high composed of reddish boulder-clay with sandstone and much limestone. Large boulders of both sandstone and limestone may be seen on the shore, but the limestone blocks are both the largest and most abundant, ranging to a size of 9 ft. × 5 ft. × 3 ft. A section through a drumlin may also be seen at the beacon south-west of Cratloe Woods House.

By far the greater proportion of the material of the drift is derived from the Carboniferous Limestone and Old Red Sandstone, but there are also fragments of the Silurian rocks which come to the surface on the hills to the north. Boulders and

pebbles of granite, though not abundant, were also found at the following places :—

(1.) 150 yards S.W. of the ruins of Crughaun Church, half a mile N.W. of Cratloe Station.

(2.) In a boulder-clay section at the beacon ¼ m. S.W. of Cratloe Woods House.

(3.) Near the site of the "Friary" in the grounds of Cratloe Woods House, a three-foot boulder of granite, blasted in two.

(4.) On roadside 150 yards N.N.W. of Cratloe Station.

(5.) In gravel-pit on roadside about half a mile N.W. of Punchbowl—granite with large pink and smaller yellow felspars.

(6.) A quarter of a mile N. of Punchbowl Church.

The boulder-clay slopes in the eastern portion of the area are more or less dissected by the streams which flow southward across them. About three-quarters of a mile north by west from Punchbowl Church a small stream has made sections 15 feet deep in the boulder-clay, which is here a stiff brown clay with purple and yellow sandstone and grit pebbles, and light and dark blue limestone and shale. In places it is full of small stones. The drift at this point is, however, probably much deeper than these sections indicate. Another small gully about 500 yards east of this reaches a depth of 30 feet without exposing the rock.

About a quarter of a mile north of Punchbowl Church the stream on whose banks the first mentioned sections occur receives on its right a small tributary. Round about this confluence of present-day streams lies a group of small mounds of glacial gravel, such as commonly occur in such situations, and seem to indicate some connexion between the drainage of glacial and post-glacial times.

On the roadside 600 yards north-west of Punchbowl House is a pit showing the best section of glacial gravel in the district. It shows from 2 to 3 feet of coarse tumbled gravel resting on 15 feet of current-bedded sand and gravel. The sand at the top is very ferruginous, but lower down it becomes much cleaner, being of a yellowish white colour when damp, but bluish gray when dry. The gravel consists mostly of red, yellow and purple sandstones and grits, but also contains light and dark blue chert and felspathic grit. A pebble of granite with large pink and smaller yellow felspars was found in the pit. These gravels appear to be a continuation of the terrace described on p. 42, but this is not certain.

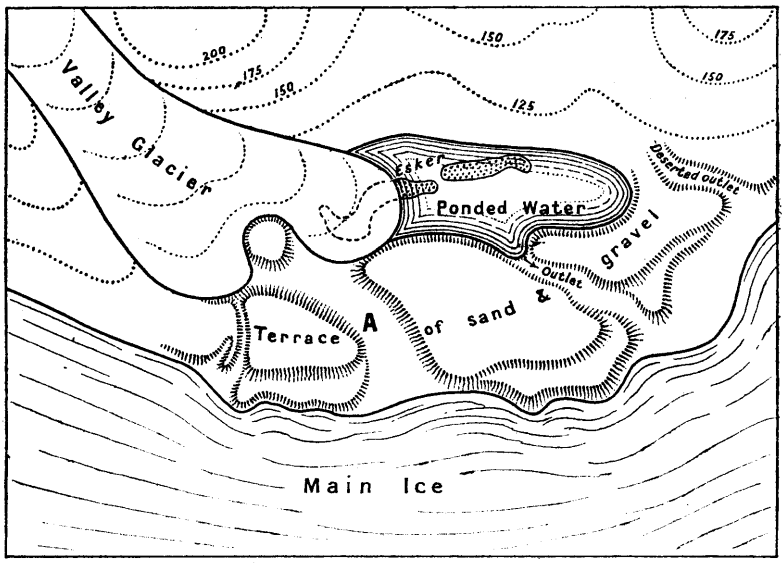
The road, which runs north-west from Punchbowl House, turns westward after half a mile, and soon crosses a small stream. By following this stream north some fairly fresh sections in the drift may be seen. At first the banks consist of

sand and gravel, in which small cliffs are cut to a depth of about 10 feet, but further on the boulder-clay is seen beneath the gravel, and at a distance of 400 yards north of the road is an excellent section showing the following beds :—

Gravel, ...	4 feet
Light loamy boulder-clay, sandy and stratified in places,	7 ,,
Tough clayey boulder-clay with Old Red and Silurian grits and sandstones and fragments of chert; bottom not reached, ...	15 ,,

On regaining the road and following the stream southward in the opposite direction, we find it deflected suddenly westward by a large mass of glacial gravel, along the north side of which it flows, to fall ultimately into the Cratloe River. The check caused by this deflection has resulted in a considerable widening of the alluvial flat of the stream, part of which is quite marshy. The gravel deposit is of a rather unusual nature (Fig. 9). Its northern slope, which forms the boundary

FIG. 9.



Gravel-Terraces north of Burtonhill House, about two miles east of Cratloe, showing conditions under which the drainage-channels were formed, and the esker preserved in the ponded water. The channel marked A in which the Cratloe River now flows was probably only initiated at this stage, and attained its present size subsequently.

of the alluvial flat, and which faces towards the hills, is remarkably steep, and at once gives the impression of the presence of ice on this side during its formation. On ascending the slope and passing south we find, moreover, that the gravel forms a strikingly flat-topped terrace or plateau about 300 yards wide, and that it is bounded on the south by steep sides just as on the north. The southern face, however, has a double slope

with an intervening terrace at a lower level. An examination of this plateau of gravel from end to end shows that it forms a rude crescent stretching obliquely across the valley of the Cratloe River, and, moreover, reveals the fact that it is trenched deeply in several places not only by the Cratloe River, but also in a minor degree by several overflow-channels, which are now dry. The peculiar form of the terrace and the occurrence of these drainage channels seem to show that the terrace was formed between the margin of the general ice sheet, which hugged the southern slope of the hills, and the front of a smaller lobe, which came over the hills and down the valley of the Cratloe River. The overflow-channels must have carried off, either at successive stages or simultaneously, the frontal waters of the smaller lobe. At their northern ends they are not cut much below the level of the top of the terrace, so that it is fairly evident that, on the further retreat of the smaller lobe, there must have been an area of slack water to the north of the ridge. To the existence of this slack water, and the consequent checking of the destructive action of the outwash from this lobe, must be attributed the preservation of a small linear esker, which lies in the hollow to the north of the terrace.

On passing north along the valley of the Cratloe River from the point where it cuts through the terrace-gravels, we find that it has thrown down a fan of gravel on a small alluvial flat which lies to the north of the western end of the gravel barrier. This fan seems to lie well within the valley-walls, which are cut in drift, and is therefore entirely post-glacial. Glacial gravels may be seen here and there exposed in the banks, and good sections of boulder-clay 15-30 feet deep occur about three-quarters of a mile to the north-west. The banks, however, are abundantly wooded, and in consequence a large number of the sections are much obscured.

The slopes from here west as far as Cratloe are largely composed of boulder-clay, with the usual small associated seams and mounds of gravel. The most remarkable of the latter is a small linear esker near where the northern or old Cratloe road enters the wood.

Passing along this road, one sees at the western extremity of the wood, and close to Cratloe school, a small steep-sided gully, which is cut in the Old Red Sandstone, and which can be traced up the hillside to Lough Gorteen. The amount of water which it carries off at present is small, but may have been formerly much greater.

The prevalent direction of the striæ on the hillside to the north of Cratloe is S. 30 E. Some of the exposed surfaces are many square yards in extent, and still larger glaciated areas probably lie hidden in places beneath a thin skin of turf. From this hillside a view may be obtained of the wide alluvial flat at the mouth of the Bunratty River, and of the hog-backed mounds of boulder-clay which rise out of it. Passing west of the railway we find on the lower slopes extensive

deposits of sand and gravel. Small pits have been opened in these in several places. In one place the upper portion of this gravel has a tumbled structure and more or less loamy matrix, and is rather suggestive of an overlying sandy boulder-clay. At Cratloe railway bridge (100 yards south of the school) a section in the road-cutting shows genuine boulder-clay overlying stratified sand and gravel. The section is—

Boulder-clay with large angular blocks of sandstone,	3-5 feet
Stratified gravel composed almost entirely of red and yellow sandstone with an occasional chert pebble; base not seen, ...	8 ,,

The lower or new road from Limerick to Bunratty passes, south of Cratloe, through an extensive alluvial flat, several portions of which were formerly occupied by lakelets which have been artificially drained. A portion at the westerly end of this alluvial flat is still very frequently under water.

East of Cratloe Woods House there is a large area of bare craggy limestone with pockets of drift in the hollows. The limestone hillocks here and near Punchbowl are penetrated by creeks of alluvial mud, which forms the great area of reclaimed land that borders the river along the whole northern shore of the estuary as far as surveyed.

Round several of the smaller islands in the estuary of the Shannon there are indications of former erosion and deposition at higher levels. On Graigue Island the foot of the overgrown boulder-clay cliff is two feet above the line of drifted reeds that indicate the highest recent tide. A deposit of gravelly estuarine mud, also overgrown with grass, stretches right up to the foot of the cliff. Little Quay Island, south of Bunratty, shows a good section of stratified estuarine mud now undergoing erosion at a level a couple of feet below its surface, and apparently never covered even by the highest spring tides. Observations of this kind, made in estuaries, are, however, of little value as indications of an oscillation of the general level of the sea. This is especially the case in places where reclamation of tidal areas has been carried on to such an extent as in the estuary of the Shannon.

Remainder of the country north of the Shannon, in County Clare,

Included in the Six-inch Sheet 63, *and parts of Sheets* 51, 52, 53, 54, *and* 61, *Co. Clare.*

By S. B. Wilkinson.

Drainage.—The country in this district is drained by a succession of little rivers and streams all running into the River Shannon. The principal of these is on the west, the Bunratty River, which, however, is tidal within the limits of this sheet. Following along the slopes of the hills towards the east, the next stream of any importance is the Cappateemore,

which, rising nearly at the 700-feet contour line O.D., has only about two and a half miles of its course to run before entering the alluvial flats of the Shannon Valley. Having a rapid flow in its upper reaches, it has eaten deeply into the superficial deposits of glacial gravels and boulder-clay. The Blackwater River rises to the north of the limits of the sheet, and flows southward past Blackwater Mills, and enters the Shannon parallel to the canal at Plassy Lock.

Glaciation.—The evidence collected in connexion with the glacial phenomena of this part of the district goes to prove that the ice-movement was most persistent from N. 25° W. to S. 25° E. Glacial striæ abound on the shoulder of the hills N. and N.E. of Cratloe railway-station and striæ were also noticed on the west side of the Bunratty Valley, bearing in the same direction. Numerous striæ have been observed further east, both east and west of the Cappateemore River, on the hard beds of the Old Red Sandstone. All the evidence goes to prove that the ice moved southward across this range of hills. The elongated drift-hills or drumlins also have their long axes bearing approximately N. and S., and the same arrangement is observable in the larger masses of boulder-clay and in the gravel-mounds and ridges. If more proof were needed as to the direction of the ice-movement, it is to be found in the fact that well-rounded boulders of porphyritic granite, recognised as similar to the Galway granite occurring miles away to the N.N.W., are found in the boulder-clay and glacial gravels of the district.

Moraines.—In the passage of the ice-sheet over the shoulder of the hill north of Cratloe Wood, angular masses of the country rock were brought down and deposited on the southern slopes in the form of small moraines. Further to the east, about half-way between Gallows Hill and the extreme north point of Cratloe Wood, a small lateral moraine is seen on the east side of a little peaty depression. Large angular blocks are arranged at intervals on the hillside like a broken wall, bearing exactly parallel to the striæ seen close by on the glaciated surface of the sandstone.

Boulder-clay.—To the west of the Bunratty River, most of the country appears to be bare of drift, with the exception of some hog-backed ridges of boulder-clay, which stand out conspicuously from the bare limestone, or from the alluvial flats. There are also some very small patches of drift occurring in the hollows in the limestone; but these are too unimportant to indicate on the map.

Of the drift-mounds a good example may be seen near Woodpark House, running in a somewhat sinuous course for about half a mile, with its long axis bearing almost north and south. At the northern extremity of this ridge a section discloses a yellow clay matrix charged with small boulders of limestone and a few of sandstone. At the southern extremity a pit has been opened which exposes good typical boulder-clay, having

a stiff clay matrix abundantly charged with well rounded boulders of limestone and sandstone, the scratches on the limestone boulders being particularly well preserved. At the bottom of the pit the solid limestone is clearly striated, the direction being N. 25° W. to S. 25° E.

About 200 yards east of the above-named locality the ground is hummocky for a short distance, and it is hard to determine whether this is occupied by the solid rock or by a thin coating of boulder-clay, owing to there being no section exposed. Three similar hog-backed ridges, having the same direction, occur at the northern margin of the sheet, only a very limited portion of each coming within the limits of the map. A large boulder of porphyritic granite was noticed in a wall situated on one of these drift-hills. Doubtless this boulder had been derived from the drift. At Firgrove House a similarly shaped mound of boulder-clay occurs, into which, at one place, a pit has been opened, which shows a bed of sharp sand, probably intercalated with the boulder-clay. A mass of limestone occurs in this mound, but whether it is in place, or is a mass that has been carried with the drift, is difficult to determine.

On the banks of that portion of the River Shannon situated between the mouth of the Bunratty River and Drummin Point, several promontories are formed by the characteristic hog-backed drift-hills known as drumlins, their axes bearing approximately north and south. At Drummin Point, in the shore-section, large angular masses of limestone are seen weathering out of a stiff clay matrix, which is also plentifully charged with well rounded and scratched boulders. This section discloses the fact that large masses of limestone have been carried along by the glacial movement, but were not sufficiently long in the mill to get worn down. Occasionally similar masses crop out from the surface of the grass-covered hill, and might at first sight be supposed to be in place.

Iniscronan Point is formed of a similarly shaped hill, and a little further south the shore-section is well seen at Tradree Point, where the shingle or storm-beach is composed of boulders and pebbles washed out of the boulder-clay. Limestone boulders predominate, but there are also boulders of red and purple sandstone. Similar hills occur at Illaunbeg Point and at Illaunmore Point. A further example of these hog-backed hills occurs some distance up the Bunratty River, near St. Michael's Well, a little to the north of Rossmanagher House. A small area of boulder-clay occurs on the flanks of the rising ground near the church of Bunratty West.

As the high ground of the Gallows Hill range is approached, sheets of typical boulder-clay are found banked against the flanks of the hills, in some instances running far up their slopes. Especially is this the case on the southern slopes, where deep banks of drift have accumulated under the shelter of the higher ground, but apparently get thinner as the low-lying lands of the Shannon Valley are reached.

North of Cratloe Station, on the Limerick and Ennis Railway, a belt of boulder-clay stretches in a northerly direction round the west and north-west flanks of Gallows Hill. Good sections of boulder-clay about ten feet deep may be seen in the railway-cutting immediately north of Brickhill Railway Bridge. Here the matrix is of stiff reddish clay, charged with well-rounded boulders and pebbles of Old Red Sandstone and limestone. Two large boulders of porphyritic granite, probably derived from the mass of granite in County Galway, were also noticed in this section. The presence of Galway granite boulders in this drift has been previously recorded in the original Survey Memoir for Sheet 143, p. 33.

A little further north a cutting through the drift discloses a deeper section, from fifteen to twenty feet, but no granite boulders were here noticed. Except at these two localities it is difficult to get a clear section, but from the contour of the country it is probable that there is a considerable depth of this superficial deposit banked against the rising ground.

Along the southern slopes of the Gallows Hill range deep deposits of boulder-clay are found extending as far up as the 700-feet contour line, immediately east of Gallows Hill. The small stream which drains this area, as its southward course is followed, is seen to cut deeply down into a mass of boulder-clay; the matrix is exceedingly stiff, red in colour, and abundantly charged with boulders of Old Red Sandstone, grits and conglomerate, and also a fair percentage of limestone. Some boulders of an igneous rock were also noticed, too much decomposed for identification, but apparently granitic, besides some fragments of other extraneous rocks.

The boulder-clay forms a poor soil, being so retentive that the water tends to collect in any hollow, rendering the land wet and cold, and often overgrown with rushes. In the old road south of Woodcock Hill rifle-ranges, which are now disused, very strong red boulder-clay appears. From this point eastwards the margin of the boulder-clay is very clearly defined, lying under the shelter of the high ground, which is covered with heather and good dry grass-land. Along this slope, wherever a section can be obtained, the boulder-clay exposed is made up principally from the waste of the Old Red Sandstone. The glacier which moved over the shoulder of the range of hills formed of Old Red Sandstone has left vast quantities of detrital material from this formation in its track. A very satisfactory section is laid bare in the banks of the Cappateemore stream. The drift is seen to begin at the head of the valley at Poundstream and Troutstream bridges at an altitude of very nearly 700 feet O.D. Following the stream down along its southern course, it is seen to cut deeply down into typical Old Red Sandstone boulder-clay, the red stiff matrix of which is freely charged with boulders of red sandstone, grit and conglomerate, with a few fragments of limestone and of Silurian slates. In places these sections reveal at least 50 feet of boulder-clay without exposing the base. The

boulder-clay in the little stream-sections on the eastern extension of the slope is of similar character to that above described; and drift of the same type is also exposed in deep sections along the River Blackwater. A marked difference in the composition and the colouring of the mass is observable when the ice has passed over a limestone area; the blocks of limestone are then more numerous, and the matrix is not so red, often assuming a blue or grey tint. The "Old Red" boulder-clay has, however, been spread beyond the limits of the formation from which it is derived, and extends for some distance over the margin of the Carboniferous Limestone. In the low ground just north of the margin of the present map a clear section of boulder-clay is exposed in the canal-cutting near Erina bridge, and the tract of land to the south-east of this appears to be a hollow filled in with this deposit.

East of Athlunkard Bridge there are several depressions in the contour of the country which are generally occupied by either peat or alluvium, but the higher ground separating these tracts is formed of low hills of boulder-clay and mounds and sheets of glacial gravel. On the banks of the River Shannon under Landscape House the river cuts through stiff boulder-clay, which is here about ten to twelve feet deep as seen in the bank, the matrix of the clay being yellowish and light grey in colour, and doubtless derived from the area of limestone to the north.

Glacial Sands and Gravels.—Closely connected with the boulder-clay are the glacial sands and gravels found in this district. The manner in which they occur is irregular; sometimes they appear in sheets or layers intercalated with the mass of boulder-clay, at other times as elongated ridges, and often in mounds. Sometimes they are made up of fine sharp yellow sand, and are quite devoid of any pebbles; in other instances sheets of fine stratified gravel appear intercalated with the sand. The pebbles and fragments of rock are similar to those found in the boulder-clay. These mounds, which often form bold prominent features, are probably due to depressions in the ice-sheet, which were filled up with sand and gravel, this material being left on the surface of the country by the melting of the ice.

North of Cratloe Station a ridge of gravel and sand occurs parallel to and touching the railway line, and extends southward into ground surveyed by Mr. Wright (see p. 40.)

A few hundred yards N.N.E. of Brickhill Railway Bridge there are two small lenticular masses of sand and gravel, which present a structure similar to that of the boulder-clay. The predominant pebbles are limestone, with some of sandstone and a few of granite, the matrix being a sharp sand.

At Cappateemore Bridge there are several bold hillocks formed of gravel and sand. An elongated mound to the west of the road is formed in a great measure of sharp yellow sand, becoming more gravelly at its northern end, and resting on a

To face p. 49.

PLATE IV.—View from top of Bunratty Castle, showing junction of Bunratty River with the Shannon. The higher portions of the islands in the Shannon consist of Boulder-clay. The foreground consists entirely of alluvial mud.

great sheet of boulder-clay. The river at this place has cut deeply through a thick mass of sand and gravel into the underlying boulder-clay. At the gravel pit opened in one of these mounds opposite the farmhouse of Cappateemore, the "esker-structure" is very clearly illustrated, the stratified layers of sand and gravel sloping away from the centre of the mound.

South of Cappateemore Bridge the river cuts somewhat deeply into the glacial deposits, and although the section is not very clear, it appears from the evidence obtained that the upper portion of the steep bank is formed of stratified sand and gravel, while underneath this is a bed of yellow boulder-clay with an increasing number of limestone boulders. The sand and gravel occur for some few hundred yards along the banks of the little glen. Similar occurrences of stratified drift are found round Ballycanan House, as many as five or six small isolated areas being of sufficient importance to show on the map.

Further to the north-east there are three well-defined sand and gravel mounds, the most southerly showing well-marked "esker-structure." The two more northern mounds, near Trough Castle, only just come into the limits of this map.

In the vicinity of Anngrove Bridge, on the road between Limerick and the little village of Cloonlara, several mounds of gravel and sand occur. These are probably the remains of an esker-chain which has been partially demolished by fluvio-glacial action. In the valley east of the Blackwater Mills, the old river course is well defined by a steep bank, and the valley itself is packed full with the gravels which have been swept down the hollow. It is probable that south of the River Blackwater there was an extension of the esker-chain, which has been broken down and spread out, forming low plateaus of sand and gravel between the tracts of peat and alluvium.

River Gravels.—The only well-marked occurrence of river gravel in this district is to be found in the bed of the Cappateemore stream. The torrent has cut deeply down through glacial sands and gravels and stiff boulder-clay, and must have been of considerably greater dimensions than it is now. South of the bridge it has left a well-defined terrace on each side of the river, in places twenty to thirty yards in breadth. The section in the river-banks shows two to three feet of alluvial rubble, closely packed, resting on a floor of boulder-clay. There is a greater percentage of well-scratched limestone boulders than is usual in the latter; but the overlying gravel is almost entirely composed of sandstone and grit.

Alluvium.—There are large tracts of alluvial land bordering on the banks of the River Shannon, of which the most important in this area are those occurring in the Bunratty Valley (Pl. IV.), in the townlands of Rossmanagher and Ballinphunta, and the area extending inland from the banks of the Shannon in the townlands of Clonmoney South and Bunratty West.

Both these flats have been reclaimed from the tidal waters of the Shannon by a system of high banks and deep dykes. If this had not been carried out, the lands would be flooded periodically, and would be useless for agricultural purposes. As it is at present, the hay-crop is abundant and the other portions afford rich pasturage for cattle. The soil near the banks of the rivers is soft ooze, so common to tidal rivers and estuaries, but a little distance in it has become more consolidated, owing to the system of drainage, and is a stiff bluish clay, and would probably make a fair brick if burnt.

There are numerous smaller areas of alluvium occurring along the margins of the Shannon and its small tributaries, which are all affected by the tide as far up the River Shannon as the weir marked on the map a little to the north of Athlunkard Bridge, and these tracts have been reclaimed from flooding at the period of spring-tides in the same manner as those lower down the river.

North of Plassy Bridge a considerable extent of alluvial flat is found fringing the margins of the River Shannon and running inland, and, although much of this ground is flooded during the overflow of the river during the winter rains, it is above the influence of spring tides. About one and a half miles further east up the river from Plassy Bridge a belt of alluvium rather more than half a mile wide stretches in a northerly direction from the banks of the Shannon for a distance of over three miles, to near Monasker Lock on the canal, where it terminates against the deep bed of boulder-clay that comes in from the north near Erina Bridge.

Peat.—Tracts of peat occur not only on the low ground, but also, in places, on the highest points in the district. In both instances the areas occupied by this growth of vegetable material are small, and are being rapidly consumed.

Of the peat on the higher ground, there is a small area immediately east of Gallows Hill, resting in a basin formed of boulder-clay. It is in much request for fuel by the peasants who live far up on the mountain-side. Unfortunately there is no great depth. North of Woodcock Hill a somewhat similar area occurs, but in this case it is of some considerable depth, as in the face of the "peat bank" as much as twelve feet is seen. It is resting in a rock-basin at almost the highest point of these hills, the contour line indicating 900 feet O.D. It extends down the little valley to the west. This "bog" supplies many of the inhabitants of the surrounding district with fuel. There are also innumerable little areas of hill-peat, too small to indicate on the map, and even these small accumulations are cut for fuel.

Of the tracts of peat to be found on the low-lying ground, the largest area occurs south of the Blackwater River, extending for some considerable distance south, resting in a basin formed partly of boulder-clay and partly of glacial gravel. This tract of peat ranges up to ten feet or more in depth, and

is much used for fuel. About a quarter of a mile to the west of the last area a small extent of peat occurs, which is being rapidly cut away. Another small area of peat occurs in the middle of the alluvial flat south of Cloonlara. There are many places in this district where at one time deep peat existed, but the constant cutting for fuel has exhausted the supply. After the removal, however, of the upper portion, the ground has been drained and tilled, and yields good crops.

The Western and South-western part of the Map, south of the Shannon.

Included in the Six-inch Sheets 4 *and* 12, *with the northern parts of Sheets* 21 *and* 22, *Co. Limerick.*

By A. McHenry.

The district for some miles on both sides of the River Maigue, from a little south of Adare on the south to the Shannon on the north, presents a gently undulating surface, with the exception of the prominent rocky knoll towards the north, on which the Castle of Carrigogunnel is built, and the craggy limestone ridge to the west of Kildimo. Outside the limits of the broad alluvial flats of the Maigue, the country is more or less overspread with drift-deposits, the deepest accumulations being towards the south in the neighbourhood of Adare. The same conditions prevail from Adare eastward along the southern margin of the map, where a strip, measuring 2¼ miles in breadth and 12 miles in length, is included in the following description.

Drainage.—The River Maigue and its tributary streams drain the whole western portion of the district, and extensive alluvial deposits have accumulated along the main river, especially toward its outlet into the Shannon, the river itself being tidal up to Adare. Farther eastward in the southern part of the map, the streams are all small, and in many cases the drainage is now carried off in deep artificial trenches.

Boulder-clay.—The boulder-clay is pretty generally spread over the whole country, the deepest deposits of it being towards the south. In hollows of the rock-surface in the north also, however, there is often a considerable thickness of boulder-clay. For instance, at the creamery close to Ferry Bridge, on the east side of the River Maigue, a well-sinking passed through sixteen feet of boulder-clay before the rock was reached. The railway-cuttings southward and westward from St. Patrickswell show similar material up to twelve feet in thickness at many points; and the numerous drainage-ditches throughout the area frequently indicate a considerable depth of boulder-clay. In the sinking of a well at a point one mile to the south-west of Williamstown Castle, thirty feet of boulder-clay is said to have been passed through before the rock was reached.

The clayey matrix of the deposit varies in composition and colour in accordance with the nature of the rock from which it is derived. In the north-west it is a brown sandy and rubbly clay, while towards the south it is brown to gray, and stiff in nature. It always includes many stones, showing ice-scratchings, the boulders being sometimes very large, as, for instance, to the north-east of Shantrand School, where blocks 12 ft. by 9 ft. were noted. Among the included stones, limestone is the most abundant rock, especially in the south and south-east, where it furnishes fully 90 per cent. of the stones. In the north-west, towards the Shannon, boulders of Old Red Sandstone and Silurian grit are common, having evidently been gathered from the Old Red Sandstone and Silurian ground lying to the north of the river in the Cratloe Hill area. At Carrigogunnel, where a prominent hill of volcanic rock occurs, a train of stones evidently derived from it is found in the boulder-clay, trailing off in a south-south-east direction, showing clearly that the ice-carriage was from the north-north-west. Similar conditions exist to the south-south-east of the Kilpeacon and Roxborough volcanic areas. On the west side of the mouth of the Maigue River, where Old Red Sandstone occurs in place at Mellon Point, this rock in like manner sends a trail of its fragments south-south-eastward in the boulder-clay.

Besides the rocks above mentioned, some pebbles and boulders of far-travelled rocks are found in the drift, notably the easily recognisable porphyritic granite of Galway, and other varieties from that country, such as basic and acid granulites and mica-schist.

In places where boulder-clay of sufficient thickness rests directly on rock, fine glacial striæ may be occasionally found on the rock-surface by clearing off the clay, as for example near Carrigview and at St. Patrickswell Station.

The boulder-clay sometimes assumes the form of an elongated ridge or "drumlin," of which the longer axis is in the same direction as that of the striæ, *i.e.*, S.S.E. Examples of these drumlins occur in the neighbourhood of Mellon to the north of Kildimo, and also at a place about one mile west of Kildimo, at Court, and at Bushmount a little west of St. Patrickswell. Mondellihy House, north of Adare, is built on a drumlin, and the long prominent ridge to the west of Skool Bog appears to be of the same character.

At low tide, boulder-clay is seen in considerable thickness at many points along the tidal portions of the Maigue. In the low ground between Dromore Lough and Kildimo deep drains reveal the same material to a depth of over six feet, and a similar section is seen in a drainage-cut in Clarina demesne.

The boulder-clay appears to be but thinly spread in Adare Manor demesne, two quarries to the south and west of the house showing only two to three feet of clay on the rock. The flat country lying between the River Maigue at Adare and the

Croom Railway is also sparingly covered with thin drift, the rock cropping out through it here and there in low knobs. Similar conditions prevail very generally to the eastward along the southern margin of the map, past Crecora.

Boulder-clay occupies the low ground about Ballynagarde House, and extends southward in a feature resembling a drumlin, traversing the higher levels at Rockstown, where deep drains cut into it for over eight feet. At a few places within this area, thin lenticular layers or wisps of gravel and sand occur in the boulder-clay. A pit was opened in a deposit of this kind on the hill a little to the south-west of Carnane School, a mile west-south-west of Williamstown Castle. Another deposit, apparently of similar character, occurs in the extreme south-west, a little over a mile west of Kildimo, and is again sparingly developed on the high ground half a mile to the west of Ballynagarde House.

A little to the south of Bolane House, west of Kildimo, there occurs a small east and west ridge of coarse material resembling morainic drift, consisting of gravelly clay with very large angular and sub-angular boulders of limestone. This singular drift may have been accumulated at the temporary margin of the ice-sheet while the main mass was moving up over the steep rock-ridge to the south from the low ground now occupied by the Dromore and Bleach Loughs. This was the only example of moraine-like drift noticed in the western area of the map south of the Shannon.

Glacial Gravel and Sand.—As will be seen from the map, Glacial gravel and sand is widely distributed over the area, but mostly in the form of isolated mounds and small patches, though in a few instances it is developed in the long ridge or esker form. The most pronounced instance of the latter type of deposit occurs in Adare Manor demesne, on the east side of the River Maigue. It begins near the railway on the north, and continues with a well-defined and somewhat sinuous course for over a mile in a south-south-east direction, afterwards fading off on the boulder-clay flat. The ridge is very prominent towards the middle portion of its course, and is about an eighth of a mile in breadth. Old pits in it show sections of sharp whitish sand, with gravel layers, up to a depth of fifteen feet, but no fresh openings have been made for a number of years, as it now lies within the demesne.

On the south side of Adare Bridge, just inside the demesne, and opposite the old Castle of Desmond, a thin spread of gravel is noticeable, but it forms no feature on the ground.

To the north of St. Patrickswell a well-defined esker-ridge extends with a north-north-westerly course for over three-quarters of a mile from immediately north of the village. Good sections are revealed by several pits in the gravel and sand up to and exceeding twenty feet in depth. In the large pit at the north end of the esker, several boulders of far-travelled rocks, such as the well-known Galway porphyritic

granite and basic and acid granulites, were noticed, all of which have evidently been derived from the schistose and metamorphic districts of Connemara. The occurrence of "Galway syenite" in this drift has been previously mentioned by Mr. G. H. Kinahan in the Memoir on Sheet 143, p. 33. The sand of this esker, which occurs in irregular lenticles up to about four feet in thickness, varies from fine to coarse, and is very sharp and free from clay, and therefore valuable for building and other purposes. Limestone constitutes fully 80 per cent. of the stones, some of the larger blocks still showing traces of ice-scratching. Many fragments of Old Red Sandstone and Silurian grit and slate are also present, as well as occasional boulders and pebbles of the Carboniferous volcanic rocks. The main or general dip of the lamination is in a southerly direction. Very remarkable contorted and puckered lamination and reversed faulting and shearing are sometimes exhibited in the sand of the esker, of which a fine example was noticed on a freshly-dug surface in the large sand-pit at the northern end of the ridge. In the bottom of this pit a large surface of Carboniferous Limestone shows striæ going in the normal S.E. direction, but it is doubtful if the rock is *in situ* or merely a boulder.

A large pit on the south side of the railway half a mile south of Coolah Bridge shows up to twenty feet of gravel and fine sharp sand, with occasional large scratched boulders of limestone embedded in the deposit. This gravel mound has been cut across by the Greanagh River, which flows northwards into the River Maigue. A trail of smaller gravel mounds, which looks like a broken esker, occurs to the south of the main mound, and continues northwards by Coolah Bridge and Curraghbridge House in the form of elongated low ridges, generally resting on the solid rock or on very thin boulder-clay.

To the north of Kildimo, on the west side of the Maigue, we find two considerable spreads of gravel, forming mounds, which have a general north-westerly trend. The accumulation to the north of Bleach Lough rests mainly on the bare limestone, and forms a hill over one hundred feet in height, the gravel and sand being evidently of considerable thickness, some pits showing sections of over fifteen feet. The long mound of gravel and sand a mile to the north of Kildimo rests also on the rock, and is apparently of fair depth, several openings showing over 6 feet. At both places the gravel and sand is of the usual character, *i.e.*, sharp and clean, and the stones are well rounded and consist mainly of limestone, with occasional sandstone and Silurian slate-fragments. On the east side of Bleach Lough a small area of gravel, over eight feet in thickness, has been banked on the south slope of the bare rocky hill.

An east-and-west mound of fine sand and gravel, seen to a depth of about 12 feet in a large pit, rises out of the broad alluvial flat, a little north of Cartown House, south of Mellon Point. This mound has been cut across by the small stream

which runs northwards into the Shannon flat. Immediately north of Carrigogunnel Castle a thick deposit of sand and gravel has accumulated on a hollow surface of the limestone, and a section showing over twenty-five feet of clean fine sand occurs in a large pit on the east side of the road. A little to the north-west of this deposit two small mounds occur, and further north again a long row irregular ridge shows over ten feet of gravel and sand of the usual character, with included large boulders.

To the west of Old Kildimo, on the rough rocky ground, several small oval patches of gravel are found resting invariably on the limestone. One elongated low ridge of gravel and sand a quarter of a mile long rests on the rock between two peaty flats, an open pit showing over eight feet of clayey gravel and sand, with large included ice-scratched boulders of limestone. In the flats of alluvial clay three-quarters of a mile to the east of Old Kildimo the stratified drift occurs in two small low spreads, and one rather prominent mound; pits in the latter show over eight feet of gravel and sand.

To the south-east of St. Patrickswell Station three mounds of gravel and sand rise out of the peaty flat in the hollow east of Attyflin Park; and again, in the boggy alluvial flat a mile to the south, four oval gravel mounds occur. A mile to the west of the boggy flats two small north-and-south ridges of gravel appear to rest directly on the boulder-clay; and on the east side of the River Maigue, a mile south of the old Franciscan Abbey, a mound of gravel rests on the boulder-clay. Between Richmond Villa and Crecora three mounds or ridges of gravel and sand occur alongside the road, the graveyard being situated in the one next Crecora. A long narrow north-north-west ridge of gravel is found on the bluff skirting the alluvial flat near Jockey Hall, the deposit resting partly on the rock and partly on boulder-clay. West of Jockey Hall there are three mounds of gravel which also rest on boulder-clay, the deposit alongside the road showing to a depth of over five feet in some old pits.

West of Ballinavilla Castle a north-west ridge shows five feet of gravel in pits. On the west margin of the Shannaclogh Bog there is a nearly east and west ridge of bouldery clayey gravel, in which pit-sections are opened to a depth of over twelve feet; and at the southern end of the bog, near the road, a long narrow ridge of clayey gravel rises above the peaty flat, and is worked in many pits to a depth of six feet or more. At Ballycahane cross-road an irregular spread of moundy gravel is found resting on boulder-clay, which is visible in the bottom of some of the pits. Isolated patches of gravel also occur at places within the parish of Fedamore.

Gravel and sand has been spread on the southern slope of the craggy limestone hill to the north-east of Ballynagarde House, and over the undulating ground beyond, to a considerable extent. The same drift-material appears to extend

under the peaty flat, rising up again for some distance on the hill to the south, thirty feet of it being visible in old pits at the 300-ft. contour line. Gravel also skirts the alluvial flat by the roadside a little north of Williamstown Castle.

On the northern slopes of Shoot Hill thick deposits of gravel and sand are banked on the rock at the 300-ft. contour, and continue down the slope for at least fifty feet, where they rest on the boulder-clay of the flat. A pit at the junction-line where the boulder-clay sets in shows ten feet of coarse gravel upon five feet of sand. South-east of Cloghane Bridge gravel and sand spread to some extent over the boulder-clay, and are found again on the hill-slope, half a mile further south-east, shallow pits having been opened in the deposit.

From the above descriptions it will be seen that, although the gravel and sand sometimes rest on the boulder-clay, in the majority of cases they have been deposited on bare rock. Indeed the presence of rock-knobs appears in some way to have been favourable to the deposition of the gravel and sand. The reason for this association may possibly be that the higher temperature of the underlying rock had the effect of rendering the superincumbent ice thinner above the bosses and therefore more susceptible to fissuring and funnelling, and that by this means the fluvio-glacial material was washed into the hollows beneath. The stones in the gravel are always well rounded and water-worn, and consist of similar rocks to those found in the boulder-clay.

Glacial Striæ.—Twenty-two examples of glacial striæ were noted in the area, the prevailing and general direction being toward south-south-east. The finest example of ice-planing was observed in the bottom of a recently-cut drain along the course of the Barnakyle River, a mile to the south-east of Clarina. Good striæ are also seen in the railway-cutting a little north-east of Adare Station, where the knobs of limestone also show fine *roches moutonnées*. In the large quarry close to St. Patrickswell Station, striæ were noticed on the limestone under thin boulder-clay. On the banks of the Shannon, a little east of Mellon Point, well-marked striæ going S. 30° E. are seen on the Old Red Sandstone under a few feet of red rubbly boulder-clay. Striæ in a direction of S. 10° E. were noted on the low limestone bluff at the north end of Dromore Lough. Three-quarters of a mile north-east of Clarina many well-defined striæ running S. 10° E. occur on the planed limestone surfaces under thin boulder-clay. In a quarry by the roadside a quarter of a mile north-west of Massy's Bridge fine striæ going S. 35° E. were noticed on the rock-surface under a covering of three feet of boulder-clay, and again half a mile to the north-east, on the east side of the road under Vermont, and on a boss of rock by the roadside half a mile east of Old Kildimo, the direction varying from S. 15° E. to S.S.E. It is unnecessary, however, to give further details regarding the

occurrence of these markings, as they are recorded by means of a characteristic symbol, showing the direction of ice-flow, on the one-inch map, to which reference should be made.

Glacial scratchings might have been expected to occur still more abundantly in this region, over which evidence of ice-action and movement are so apparent; but the limestone weathers so readily that the traces have disappeared, except where fresh openings occur, or where the boulder-clay is still existing to preserve the scratches.

Peat and Alluvium.—Extensive tracts of alluvium border the River Maigue along its course from below Adare to the Shannon, towards which the alluvium broadens out considerably and forms extensive meadow-flats, or, as they are locally called, "corcasses." These flats have been reclaimed from the estuary by the system of embankments that was successfully carried out many years ago. The character of this alluvium is uniformly a grey loamy mud, varying in thickness from four to eight feet or more; along the river bed it is seen to rest sometimes on boulder-clay and sometimes on rock.

The minor streams and hollow places have deposits along and in them, and occasionally peat has accumulated to some extent where the drainage was arrested. Where peat is found, shell-marl usually occurs beneath it, in thickness varying from a few inches to several feet. The best examples of these latter conditions occur round Bleach and Dromore Lakes, to the north-west of Kildimo. It is quite evident that these two lakes originally formed one sheet of water, till the accumulation of shell-marl and peat on the shallow neck separated them into two. A trench cut into the peat and marl at the present time connects the waters of the two loughs.

Mr. R. Welch has very kindly supplied the following list of molluscs, all of freshwater origin, found by him in the shell-marl of Bleach Lough :—

Limnæa stagnalis (rare).
Limnæa peregra (several forms present).
Bythinia tentaculata (common).
Valvata piscinalis (rare).
Pisidium sp. (very rare).

Mr. Welch remarks that the deposit does not seem to be very old.

In the long peaty alluvial stretch one and a half miles north-west of Adare, bones and horns of Megaceros have been found in the marl beneath the peat. The peat varies in depth from a half to two feet, the bottom being a grey marly alluvial mud, with a thin layer of shell-marl occurring between the grey alluvium and the peaty overgrowth. Shell-marl also occurs east of Mundellihy House, as well as in the flat west of Rockfield Bridge, and in a boggy tract a mile to the east of Rockfield House.

" Skool Bog," to the south of Williamstown Castle, has been entirely cut away and reclaimed, and the residual peaty soil now yields good crops. The original peaty growth was several feet thick, and rested on the usual grey marly and muddy alluvium. Along the narrow northern strip of this deposit, recent drainage-openings showed over six feet of stiff grey plastic clay, with very few included stones; this could probably be used as a brick and pottery clay.

At a few places in the south-west of the area, an alluvial deposit of stiff red-brown clay was noticed that might also yield brick and pottery clay. One tract of this kind occurs on the east side of the River Maigue, half a mile east of Adare Manor, and another along the Greanagh River, west of Adare. This deposit appears to consist of the fine material that has been washed out of the boulder-clay; but, as it is confined to the extreme south-western part of the map, the reason of its limited local occurrence cannot be satisfactorily explained until the country to the south-west of the sheet comes to be examined.

The district around the City of Limerick and the country for five miles to the southward,

Six-inch Sheets No. 5 and 13, *Co. Limerick.*

By H. J. Seymour.

The area lying between the Crompaun River and the Shannon.—A large portion of this area is covered with a thick deposit of alluvial mud, which attains its greatest development on the west and south, most of the remaining ground consisting of boulder-clay, with minor areas of bare limestone rock. The most extensive sheet of alluvium occurs between Clonmacken House and the Crompaun River, and covers an area of some two square miles, the continuity of the deposit being broken only in the Coonagh district by a slightly elevated tract of rock and boulder-clay, which forms, as it were, an island in the alluvium. The latter consists of a tenacious blue-gray clay, which in places contains numerous shell-fragments, mostly of the species *Bythinia tentaculata*, which render the deposit quite marly. In the extensive excavations close to Lansdowne Bridge, where this alluvial deposit is being used for the manufacture of bricks, the best sections noticed in the area under description occur. The depth varies from twelve to fifteen feet without reaching the bottom of the alluvium, and the material consists of a dark blue clay with some shelly layers, and with a certain amount of vegetable debris, consisting of branchlets and occasional trunks of trees, stated to be oak and fir. This locality is the site of a discovery of the remains of *Cervus giganteus*, Blum. (Megaceros). Latterly very few vertebrate remains have been found, but it is reported that a few years ago numerous skulls, stated to be " dogs' heads,"

were discovered. Unfortunately, in the absence of specimens, of which none were preserved, nothing definite could be learned respecting these remains, which is the more to be regretted, since it is just possible that the skulls may have been those of the Irish wolf-dog, or perhaps of the Irish wolf, which are of rather rare occurrence.

Remains of *Cervus giganteus* were also obtained in the alluvium lying in the eastern angle between the junction of the Shannon and the Crompaun River, the material again being a blue alluvial mud, occasionally loamy. South-west of Coonagh there are some minor excavations up to eight feet in depth, the material being manufactured into bricks of rough quality.

A few hundred yards south-west of Coolraine House is a deep drainage-cut (4 to 6 ft.) in the alluvium, the upper few inches consisting of a peaty or moory clay overlying a dark-gray clay, containing abundant shells in places, and also organic debris mostly of vegetable origin.

The following land and freshwater species of shells have been kindly identified by Mr. R. Welch, of Belfast, as occurring in this deposit, viz., *Helix rotundata*, *Cochlicopa lubrica*, *Clausilia bidentata*, *Succinea elegans*, *Limnæa peregra*, *L. palustris*, *L. truncatula*, *Planorbis marginatus*, *Bythinia tentaculata*, *Valvata piscinalis*, and *Pisidium* (sp.)

To the north-east and north-west of Longpavement railway station is a large area of alluvial clay, which, however, does not appear to be so thick as that just described. The district in which it is developed is quite flat and very marshy in places, especially east of Castle Park. It is drained by numerous more or less shallow trenches cut through about four feet of peaty alluvial clay.

The eastern part of this district is mainly overspread by limestone boulder-clay of very variable thickness. The best sections (4-6 ft.) occur in the neighbourhood of the Condensed Milk Factory, in the railway-cutting (8-10 ft.) south and south-west of Castle Park, and in the scarp (6-12 ft.) to the north-east of the windmill-pump supplying water to the factory above mentioned. In a well-section 200 yards north-west of the North Strand Reservoir some six feet of boulder-clay were seen to overlie the limestone, which latter is excavated for about ten or twelve feet. The area covered by boulder-clay has a characteristically smooth and gently undulating surface. There is no marked development of drumlins such as occur in the district further east and south.

The area mapped as bare limestone is of limited extent, and for the most part is covered with a very thin layer of boulder-clay and local rock rubble, especially on the higher and flatter ground; but the steep slopes are generally quite devoid of drift. The top of the limestone is generally well striated, the striæ pointing E. 10° S., which is the prevailing direction in the low-lying districts bordering the Shannon in the vicinity of Limerick city.

The erratics in the boulder-clay were mainly blocks of limestone, which were sometimes of large dimensions (see p. 64). One pebble, 10 inches by 9 inches by 7 inches, of a green schist, such as occurs in Connemara, was noticed in the townland of Ballygrennan in a wall some 500 yards south-west of Castle Park.

Limerick City.—The greater portion of the area on which the city of Limerick is built is nearly devoid of drift, with only a thin coating of local detritus derived from the weathering of the underlying rock. Towards the south-west, however, boulder-clay forms a smooth covering to the underlying rock, which frequently crops up through it or is reached in shallow excavations.

Again, on the east, there is a scanty development of loamy boulder-clay overlying the volcanic ash in the vicinity of the Garryowen Reservoir.

The rock-surface under portions of the city is much more irregular than is now apparent, for, owing to the arching up of many of the streets in the south and south-west, an artificially graded surface has been produced.

Borings in various parts of the city supply much information as to the original contour. Thus there is a fairly extensive depression in the limestone reaching from Wolfe Tone Street on the south to the neighbourhood of the New Markets. The deepest portion of this hollow appears to lie near St. Michael's Church (Perry Square), where it is stated that excavations for foundations revealed the following section :—

Soil and yellow clay, ...	22 feet.
Gravel (water-logged), ...	5-6 ,,
Limestone, ...	at bottom.

Close by, in St. Joseph's Street, a cutting for drainage purposes was made in 18 feet of drift, about seven feet of which was a tough alluvial puddling-clay, then boulder-clay, resting on "gravel." The boundary of this drift-filled area is difficult to trace in the absence of sufficiently precise information, but the southern edge of it lies between Wolfe Tone Street and St. Joseph's Street, and another edge is traceable between Messrs. Matterson's and Bannatyne's premises, near the top of Roche's Street. In the premises of the first-named, borings for water passed through some 18 feet of "surface soil and boulder-clay,' while, at Messrs. Bannatyne's, rock crops out on the surface at the base of the chimney-shaft. Rock is also stated to be close to the surface in Thomas Street and High Street, while some 16 feet of drift occurs near Cathedral Place (Messrs. Denny), and 9 feet to 10 feet on either side of Mulgrave Street near the New Markets. Still further east, rock comes to the surface at the Prison, which would appear to stand on the eastern limit of the depression just described. Close to the eastern boundary of the People's Park rock occurs

near the surface, and again near the entrance to the railway station. Rock was formerly quarried in the former locality, the excavations being filled in with debris, which is now being re-excavated for the foundations of the new library.

King's Island.—The ridge on which is built that portion of the city lying between Ballsbridge and Islandgate, together with the less-elevated tract containing the site of Cromwell's Fort, appears to constitute a drumlin of boulder-clay, the longer axis of which is approximately parallel in direction to that of the striæ observed in the vicinity.

The thickness of this boulder-clay is not easily estimated, but it would not seem to be very great; indeed, the presence of rock 200 yards south-west of Cromwell's Fort, and again in the river-bed near the Female Prison, would seem to point to the presence of a solid core to the ridge. Some 6 feet of boulder-clay is seen 200 yards north of Cromwell's Fort, in the cutting behind the embankment next the Shannon. In the angle between the Shannon and the Abbey River, between Bedford Row and Ballsbridge, the ground is a flat of river alluvium, the south-eastern edge of which coincides with West Watergate Street, the site of part of the old city-walls. Several of the streets in this area are artificially raised above the original ground-level.

Corbally District.—This area, extending from the canal to Corbally House, is a fairly steep-sided ridge of boulder-clay over a mile long. Rock crops out at the northern end, where the drift is apparently thin, but at the southern end there are deep sections in which no rock is visible. For example, to the south of Avondale the railway is carried through a cutting showing some 15 feet or more of boulder-clay. The presence of rock at the northern end and of deep drift at the southern end, together with the fact that the axis of the ridge coincides approximately with the direction of the ice-striæ in this neighbourhood, makes it probable that we have here an example of crag-and-tail structure, the drift being deposited on the lee side of a projecting outcrop of rock. The low ground on either side of this ridge is occupied by extensive flats of alluvium of the usual character; this, however, becomes loamy and even sandy as the banks of the river are approached.

South-west of the city is a large area of alluvial deposits formed mainly at the junction of the Ballynaclogh River with the Shannon. The ground occupied by this deposit is in the main flat, with some low ridges and undulations of minor importance. Sections up to 10 feet are shown in some of the stream-cuts and drainage-ditches, the material being mainly a gray alluvial mud, loamy or sandy in places, or sometimes marly from the presence of abundant shells.

The country east of Limerick, to Kilmurry Church.—The superficial deposits in this area are mainly boulder-clay and

alluvium, the former predominating; there are also minor areas of gravelly drift, especially on the extreme east, and extending from Peafield Bridge to Kilmurry Church.

Alluvium is chiefly developed on either side of the Groody stream, where it occupies an area of about one square mile. It is usually clayey in character, except near Ballysimon, where it is rather loamy. A second area of alluvium occurs near Clino Cottage, and is connected with that of the Groody River by a narrow strip passing along a shallow valley past Singland House. The material is again a finely laminated alluvial clay, over 12 feet thick, resting in a basin lined with boulder-clay, the junction between the two being well exposed on the western side at the brick-works. Fairly good bricks are being made at this locality, but on a comparatively small scale. On the high ground on both sides of the valley of the Groody River there are areas of stratified drift. On the west the material is a fine red sand with some gravel, and was formerly much sought after for building purposes, but the pits are now closed. A fine red sand is also exposed in some small pits north of the farm-buildings lying to the north-east of Groody Bridge. This deposit forms a ridge-like feature banked against the hill-slope, and, like that on the opposite side of the valley, was probably deposited in late glacial times by streams flowing between a lobe of ice occupying the valley and the higher ground on either side.

The boulder-clay in this area is a typical "till," with many scratched stones, the best sections being exposed in the railway-cuttings due south of Clino Cottage. Further north, however, it becomes rather loamy; this is possibly due to its having incorporated more or less sandy detritus from the underlying volcanic ash, as well as to its being extensively cultivated for market-gardens. At Park Bridge, over the canal good sections of typical boulder-clay are exposed in numerous deep cuttings. In the Newcastle area the boulder-clay is probably thin, and is also of a loamy nature. It overlies a volcanic ash in this locality. This rock, on the high ground especially, is well striated, the striæ running nearly south-east, which in this, and in the district to the south, appears to represent the direction of ice-movement during the period of maximum glaciation. The striæ may be well seen on the rock-surface forming the foundation of the wall on the north side of the road to Kilmurry, and about 300 yards west of the ruins of New Castle. Again, near the old lime-kiln, 400 yards south of the New Castle reservoir, there are good striæ running S. 35° E.

Some 250 yards north-west of Ballysimon Creamery is a small esker-like ridge of gravel, while to the south-east, at Peafield, is rather moundy ground on either side of the Groody stream, consisting of stratified drifts. These deposits seem to be of the nature of delta-gravels deposited in the slack waters of a lake, which possibly existed here before the rock-gorge at Ballysimon (old marble works) was cut down to its present

low level. North-west of Peafield House are some curious terrace-like features, the precise interpretation of which is rather obscure; but they may possibly be connected with the supposed lake above mentioned.

The Shannon Valley.—One of the most noticeable features in connection with the present channel of the Shannon, so far as it lies within the area now being described, is its very new character. There is no mature valley in any part of its course, nor are there any deposits of river-gravels arranged in terraces on either side, with the unimportant exception of that occurring north of Plassy House, which is of very limited extent. Opposite Willow Bank House, and about three-quarters of a mile east of Plassy Bridge, the Shannon cuts right across a drumlin, and has only now reached the solid rock which forms the rapids at this locality.

The country to the south of Limerick City.—This tract constitutes, as a whole, a rather level or gently undulating plain, which becomes craggy and hilly on the west, as around Mungret and Greenmount (east of St. Patrick's Well), and again on the east near Cahernarry, and on the south-east in the townlands of Raheen and Toberquin. The general elevation of the higher ground in the first-named localities is from 70 to 151 feet, and in the last-mentioned from 300 to 395 feet, west of Edwardstown House.

The drifts consist chiefly of boulder-clay, with minor areas of bog and alluvium, and a rather sparse development of gravels, occurring as small isolated mounds, and occasionally as eskers. Besides these, there are also extensive tracts of shell-marl, usually underlying a deposit of peat.

The ground in the vicinity of Mungret is rather bare of drift, as is also the high ground to the south-east in the townlands of Cahernarry and Toberyquin. In these localities the rock-surface is often well striated, the average direction on the west being towards the south-east (S. 50° E.), with an occasional more easterly trend S. 80° E., as near Barnakyle, the average direction on the eastern side near Cahernarry being practically south-east. Cross-striæ were observed in two localities, viz., in the old quarry south of South Hill, and on the west side of the road (S. 10° E. and S. 50° E.), and again in the small quarry at the crest of the hill on the road to Cahernarry, about a mile from the Mount St. Lawrence Cemetery. The striæ in this last mentioned locality are very well preserved, and from their shape it is possible to decide that the direction of ice-flow was towards the east, viz., S. 40° E., and S. 60° E.

Between these areas of high ground stretches a gently undulating plain covered with a fairly thick coating of limestone-boulder-clay, diversified by numerous hollows now occupied by

deposits of peat, shell-marl and alluvium. Many of the hillocks in this area look like typical drumlins, but where cut through by the railways some of these appear to have a core of solid rock.

The thickness of the boulder-clay is variable, but exceeds 30 feet in many places, according to information derived from well-borings. Like the boulder-clay further north the chief stony constituent is the limestone, but erratics of other kinds were frequently noticed on the surface of ploughed fields and in boundary-walls. The most interesting erratics found were pebbles of a porphyritic granite with large pink orthoclase phenocrysts, quartzites, green schists, and one pebble of a sillimanite-gneiss, also a few chalk-flints. All except the last mentioned are similar to types met with in Connemara, while the flints may possibly have been introduced by human agency.

East and south of Lemonfield House there are abundant large boulders of coarse volcanic ash scattered about on the surface of the ground, though no outcrop of ash *in situ* was seen in the immediate vicinity.

Over a large portion of the area covered by boulder-clay a very noticeable peculiarity is the occurrence of huge slabs of limestone which make it difficult at times to decide whether one is dealing with erratics or with rock *in sitû*. The evidence available, however, in the numerous quarry-sections tends generally to favour the former view, though showing also that the solid rock is in such cases not far from the surface. It was noticed in nearly every quarry that the upper beds were much disturbed and broken up, evidently by the pressure and onward movement of the ice-sheet. Massive beds of limestone became broken up, and the once-continuous bands divided into blocks, which have been twisted out of their former positions and sometimes completely incorporated with the boulder-clay. In places where the rock in pre-glacial times was unequally disintegrated, the ice-sheet has pushed out the less-resisting portions, forming miniature valleys in the rock, now filled in with a much tumbled boulder-clay, full of large angular blocks of limestone. Sometimes whole beds or portions of beds of limestone have been pushed bodily forward so as to form a kind of roof over these excavated valleys; in other cases, a thin band of the limestone has been carried along till it became bent into S-shaped folds, owing to one end becoming fixed, while a certain amount of forward motion went on in other parts. The foregoing phenomena are well seen in the large limestone quarry near Ballysimon.* (Plate V.)

In the quarry north of Raheen Chapel the lower layers of the boulder-clay are full of large, almost angular, blocks of rock, which are obviously portions of one of the uppermost bands of limestone which existed there in early or pre-glacial times. The same thing may be observed in the large lime-

* *Cf.* F. W. Sardeson, Journ. of Geology, vol. xiv. (1906), p. 228.

To face p. 64.

PLATE V.—Section at west side of Limestone quarry, a quarter mile W. of Ballysimon, showing the tumbled nature of the boulder-clay overlying the limestone, which is well striated beneath it. Note the bed of limestone at top contorted and carried along in the boulder-clay.

stone quarries near Limerick City (on the south-west). Further west, and about a mile south of Donaghmore Chapel, there is a great thickness of boulder-clay intimately incorporated with the disintegrated upper bands of the limestone.

Stratified drift occurs sometimes intercalated in the boulder-clay, more often in isolated mounds and ridges on hill-slopes, and in one or two instances in the form of eskers.

The largest area of stratified drift in the district under description occurs in the vicinity of Ballysimon, and forms the western limit of a much larger area lying mostly outside the area under notice (p. 78). Gravels intercalated in boulder-clay occur about a half-mile due south of Lickadoon Castle. In the gravel pits open here the following section may be seen :—

Soil, ...	2 feet.
Boulder-clay, ...	4 ,,
Loamy Boulder-clay, ...	3 ,,
Sand, ...	4-5 ,,
Boulder-clay, ...	at bottom.

A second locality where a similar deposit may be seen occurs about 150 yards N. by E. of the farm-buildings about one-third of a mile north-east of Friarstown House. The following section was visible at the time the district was surveyed :—

Soil, ...	1 foot.
Boulder-clay, ...	3 feet.
Gravel, ...	2 to 3 feet.
Boulder-clay, ...	5 feet to bottom of section.

Smaller areas of intercalated gravel occur to the north and north-west of the last-mentioned locality, and also to the south of Derryknockan House.

On and around the summit of the hill east of Lemonfield House there is an apparently thin covering of gravel and sand underlying a few inches of surface-soil. No deep sections were seen, however, so that its thickness and extent are uncertain.

In several places in the area under description, and in nearly all cases on the higher portions of the sloping sides of valleys, more or less conspicuous mounds or ridges of gravel and sand are developed. Occasionally one long ridge occurs in the bottom of the same valley and centrally situated in it. This is the case in the broad valley extending parallel to and half a mile east of the road from Ballyneety to Cahernarry. The long central ridge seems to be an esker, and extends from a point less than quarter of a mile W. by N. of Edwardstown House to within a short distance of the road south of Knockea. Further north along the same valley, and on both sides of it, are several ridges of gravel and sand banked up against the slopes of the valley, a short distance south of the point where it becomes quite narrow (half a mile N. by E. of Knockea Chapel). These gravels were no doubt formed under conditions akin to those already referred to (p. 62) in the case of similar deposits on either side of the Groody River, that is

to say, they were deposited in drainage channels between the lobe of ice occupying the valley and the hill-slopes on either side. A similar type of deposit occurs 250-300 yards north-east of the farm lying to the north-east of Toberyquin. Gravel deposits of doubtful origin occur south of Friarstown House and to the south-east of Cloghane bridge.

The Ashfort Esker.—In the townland of Ashfort occurs an aligned sequence of mounds or ridges of stratified drift which at one time were probably connected together to form a continuous esker-ridge about one and a quarter miles long. At present there are four distinct masses of sand and gravel of a more or less ridge-like character, the longer axis of each lying in an approximately straight line or gentle curve, forming an angle of some 30 degrees with the direction of glaciation in the district. The ridges are separated one from another by bog and marl at either end, and by a narrow strip of boulder-clay in the middle on the high ground west of Ashfort House. There are pits opened along the entire length, but the largest and more important are those to the east of Dooneen bridge at the southern end of the esker.

As is usual in such deposits, steep bedding is well developed, and also current-bedding on a minute scale in places. The most remarkable structures present, however, are the well-marked faults in the stratified deposits, seen in a very clear manner in the large sand-pit east of Dooneen bridge, which now supplies most of the sand required in Limerick for building purposes. These are mainly reversed faults or overthrusts, and several more or less parallel ones occur in this pit. One of the best examples (Plate VI.) shows a displacement or thrust of about two feet. In addition there are minor crumplings and foldings recalling in places the structures seen in a plicated gneiss, and quite similar to those described as occurring at Faha (p. 54). The overthrusting shows that this stratified drift-material was considerably compressed subsequent to its deposition. The structures may be possibly explained on the supposition that the bottom of the esker rested in the first instance on ice, and that the latter melted more rapidly on the floor than on the containing walls. This would result in the esker being gradually lowered to ground-level within a progressively narrowing channel, and hence there would be lateral compression, the esker growing higher but narrower. Lateral compression may also have occurred through the coming together of the side-walls of the ice-channel in which the gravel and sand were deposited. The Ashfort esker, as it may be termed, is known to be some 40 feet thick in places, and to rest on a red clay, probably boulder-clay. As it rises up over the high ground west of Ashfort House, the material becomes finer and the deposit thinner. Towards the north the material becomes more clayey, till at its extreme northern limit it is practically a gravelly boulder-clay.

To face p. 66.

PLATE VI.—Section in Fsker sands and gravels east of Dooneen Bridge, showing a reversed fault with a displacement of about two feet. Total height of section is six feet approximately.

Peat, Marl, and Alluvium.—In the numerous hollows in the boulder-clay area occur deposits of alluvium, sometimes thick, but occasionally forming only a surface-layer of a few inches. The principal deposits occur along either side of the Barnakyle River.

Occasionally, in addition to a certain amount of alluvium, we have in favourable situations considerable deposits of shell-marl, which again is usually covered with a layer of peat from six inches to three or four feet in thickness. The chief deposits of peat occur to the north and south of Ashfort townland, and both intersect the esker already referred to. In each of these bogs deposits of marl occur. A typical section in the bog north of the railway line is as follows :—

Peat, ...	1 to 3 feet
Marl, ...	1 foot
Boulder-clay, ...	—

In the bog lying south of the above we get :—

Peat, ...	2-3 feet
Marl, ...	3 feet
"Green Mud" and Boulder-clay at bottom.	

Another fairly extensive bog, which, like the foregoing, has the peat almost entirely cut away, lies to the west of Friarstown, and consists of about a foot of peaty or moory soil resting on gray alluvial mud over boulder-clay. Shell-marl occurs here and there, but apparently not in any great quantity. Shell-marl also occurs in the flat ground lying south-west of South Hill, sections up to two feet in thickness being visible in some of the drain-cuts at the southern end.

The most extensive area of shell-marl occurs to the S. by W. of Donaghmore Church, covering about 150 acres. Generally the marl deposit is about two feet thick, but is sometimes as much as three or more feet. Its very white colour forms a striking contrast to the dark moory soil which usually covers it for a depth of from six inches to one foot. In this locality some shallow excavations revealed the presence of numerous large boulders apparently embedded in the marl. It was found on digging a deeper section that the boulders (which showed partly obliterated glacial scratches) really rested on a tough alluvial clay, or on a coarse gravel. They are therefore to be regarded as residual material left after the erosion of a boulder-clay hollow, out of which all the more easily transported stones and clay were washed, probably by late glacial or post-glacial flood-waters.

The drainage-system of this district does not show any very pronounced characteristics. A good deal of it is probably carried on underground, as in most other limestone districts.

The drainage of Loughmore is one instance. In this case, the surface-waters flowing from the higher ground to the south are carried in a subterranean channel under Loughmore Common, the channel being connected with the surface by means of a "swallow hole" west of St. Nessan's Presbytery. In wet weather the underground passage is apparently unable to carry away all the water flowing into it, and the latter rises in the swallow hole as from a safety vent and overflows, forming a lake over a hundred acres in extent. There is no outlet or inlet for this lake except through the swallow hole, and, after a spell of fine weather, the water sinks down through it again, leaving the whole area dry.

The following is a list of the localities in which glacial striæ were observed, together with their directions :—

Localities.	Direction of Striæ.
SHEET No. 13—	
S. of Templemungret,	Towards S.E.
300 yards N.E. of Mungret,	S. 50° E.
S. of South Hill,	S. 50° E. & S. 10° E.
1 mile S. of South Hill,	S. 55-60° E.
½ mile E.N.E. of Rathbane House,	S. 50° E. & S. 30° E.
½ mile S.W. of Donoghmore Church,	S. 55° E.
½ mile W. of Ballysimon Iron Ry. Bridge, (two places),	S. 50-55° E.
Tobersenan, N. of Cahernarry Hill,	S. 50° E.
½ mile W. of Tobersenman	S. 45° E.
Cahernarry Hill (three places),	S. 45° E.
500 yards S.W. of Cahernarry Obelisk,	S. 45° E.
½ mile N.E. of Barnakyle Bridge,	S. 80° E.
⅔ mile S.W. of St. Nessan's Presbytery,	S. 50° E.
⅓ mile W. by N. of Ashfort Cottage,	S. 55° E.
⅓ mile N. of Knockea Chapel,	S. 40° E.
SHEET No. 5—	
300 yards S. of Moylish House on Main Road (two places),	S. 80° E.
150 yards S. of Ballynanty House,	S. 80° E.
350 yards N.N.W. of Union Workhouse,	S. 75-80° E.
Quarry 200 yards N. of Hawthorne House,	S. 80° E.
Quarry 250 yards S.W. of Ashbourne House,	S. 75° E.
Quarry behind Corn Store near Floating Dock,	S. 65-70° E.
Fitzgerald's Quarry, Ballinacurra,	S. 45° E.
Quarry (Ash) at Pennywell,	S. 60° E.
Site of Nurses' Home, St. John's Hospital,	S. 35° & 70° E.
Large quarry S. of Railway Station (two places),	S. 50° E.
200 yards W. by S. of Beech Hill Cottage,	S. 45° E.
Roadside 200 yards W. of New Castle	S. 35° E.
300 yards S. of New Castle Reservoir,	S. 35° E.

The Eastern and South-eastern part of the Map, in County Limerick,

Included in the Six-inch Sheets 6 *and* 14, *with the northern part of Sheet* 23.

By J. R. Kilroe.

The district here described extends from the falls of Doonass on the Shannon, near Castleconnell, southward to the margin of the new map; and from its eastern margin to the Shannon near the great bend, and thence along a north-and-south line to the southern margin near Rockstown. The largest populated place in this area is the village of Caherconlish.

The prevailing flatness of the area is broken by an important ridge, and a few minor hills, the chief of which are Benvult (427 ft.), east of Caherconlish, an outlying spur of the ridge; Carrigparson (287 ft.), three miles north-west of the village; Knockagorteeny (285 ft.), near Annagh Bridge; and Knockbrack (270 ft.), near Lisnagry. The ridge mentioned trends west by south near Caherconlish, and culminates in Knockroe (672 ft.), south of Inch St. Lawrence. The foothills of the Slievefelim group appear within the eastern margin of the sheet, being represented by Cappanahanagh Hill, which reaches a height of 494 feet.

The middle portion of the district is traversed in a north-westerly direction by the Mulkear River, which enters the area at Brittas, and joins the Shannon at Mount Shannon, below Annacotty. It receives some large tributaries along its course. One of these, the Slievemoghera River, which drains upwards of 80 square miles, joins the Mulkear, within the present area, three-quarters of a mile south of Barrington's Bridge. In all, the water contributed to the Shannon by the Mulkear is that of a drainage area of about 240 square miles. The amount of fall along the last ten miles of its course is about 70 feet; it is rapid at some half-a-dozen points, advantage of which has been taken for utilizing the water-power.

The Slievemoghera or Killeenagarriff River is formed by the junction of the Annagh and Newport Rivers, which take their rise in the Slievefelim and Keeper groups, and drain the great bog and alluvium tracts south-east of Castleconnell. The ground on the east and west sides of Annagh Bridge is 132 feet and 55 feet, respectively, higher than the alluvial land on each side of the river—about 142 and 65 higher than its rocky bottom at Killeenagarriff Bridge. The rock appears

on the summits of the high ground on each side; we must therefore infer that the drainage of the Slievefelim group must have maintained its southerly direction along this course, notwithstanding that the parallel course of the Shannon is only some three and a-half miles distant.

Two streams drain the above-described ridge at Caherconlish; one is the Groody River, which occupies an apparently long-established course. It is marked by an important alluvial deposit, which at certain points shows just recognizable terraces of somewhat older alluvium than that lining the present stream. Another stream is one which, flowing northward, near Ballyneety, enters the Groody River along a natural course by Bohermore Chapel. The small alluvial flat through which the stream flows, to the north of Ballyneety, has been drained by a deep artificial cut at its northern end, and a portion of the drainage carried into the flat by the stream finds exit by this new course.

The superficial deposits of this portion of the map consist of boulder-clay, sands and gravels, lying flat or forming eskers, alluvium, and bog, which conjointly form an extensive covering throughout, the rock appearing only scantily except in the hills and ridges.

Boulder-clay.—The boulder-clay in the lower ground occurs generally in flat-lying or gently undulating sheets. Its material has been chiefly derived from limestone, from which the principal portion of its stones and large striated boulders have been obtained, with a greater or less proportion of the argillaceous matrix. An important difference is noticeable between the limestone boulder-clays in the low-lying tract drained by the Mulkear and Groody Rivers, extending southwestward to Ballyneety, and that covering the hill-slopes and the more rapidly undulating ground bordering the Shannon south of Castleconnell. In the former case the argillaceous component ("clay") is in large proportion, frequently preponderating, especially in the uppermost few feet, yielding impervious soils covered with rushes, and scarcely distinguishable from clayey alluvium. This is particularly the case in the ground bordering the flats of the Groody River. On the other hand, the boulder-clay about Thornfield, Annacotty, and near Castleconnell, as well as at Ballyneety, and north and south of the ridge running by Caherconlish, commonly bears the local name of "limestone-gravel," and seems to have been used formerly as road-metal of an inferior kind, as well as for top-dressing. It contains a proportion of clay and scratched blocks sufficient to justify its separation on the map from the material represented as gravel and sand. In many cases, however, it has been difficult to decide whether the very gravelly boulder-clay should not be shown as gravel, and *vice-versa*.

There does not appear to be any difference in the local character of the limestone to account for the above-mentioned difference in the boulder-drift; but the explanation of this diversity may probably be found in the different modes of deposition from the ice-sheet during its melting. The boulder-gravel and gravelly boulder-clay may have been subjected to a certain amount of washing during their deposition, while the more argillaceous drift cannot have undergone such a process; and the tendency of the gravelly deposits to assume a moundy surface, and to adhere to hill-flanks, seems confirmatory of this explanation. The occurrence of the boulder-clay in drumlins in this area is comparatively infrequent. The tailing out of the drift in a high ridge near Ballyneety may be regarded as a partially-formed drumlin; and a drumlin moulded on a rock-core is seen at Castle Troy, west of Annacotty—both ridges having their longer axes tending north and south. A few other hillocks of less regular form are to be observed east of Ballyneety and east of Mount Shannon.

The uppermost few feet of the limestone-boulder-clay is usually yellowish brown, contrasting with the more or less dark grey colour of the lower portions; the upper portion is usually also more argillaceous than the lower, owing chiefly, perhaps, to the solution of much of its original stony contents. There are comparatively few sections in which a depth as great as six feet of boulder-clay may be observed.

The information obtainable from well-sinkings is somewhat scanty and unsatisfactory, but the following details from this source may be cited. A well was sunk in the townland of Rivers, half a mile west by north of Annacotty, through sand and a thickness of 18 feet of underlying "loam"—in other words, boulder-clay. Another well, east of Thornfield, in Laghtane, was sunk through 18 feet of boulder-clay and "gravel," the former being the higher. On the west side of Knockagorteeny, near the foot of the hill, a well 15 feet deep revealed boulder-clay over "white sand"; and on the north-east side boulder-clay, over sand and gravel, was met with in a well 20 feet deep. Wells were sunk through 9 feet of boulder-clay, and through 40 feet of boulder-clay and rubble, at the Smithy, nearly half a mile E. by N. of Sheehan's Cross; and one in Ballybrickan South, at a farmyard, was driven through 4 feet of loam and 16 feet of gravel, into the underlying rock.

A section 10 feet deep, on the railway near Killonan Station, shows a few feet of red clay resting upon yellow clay, with stones. The Mulkear cuts through 10 feet of limestone-boulder-clay north of Kishyquirk. The stream flowing through Caherconlish, draining the peaty tract half a mile south-east of the village, has been cut through 5 to 12 feet of gravelly limestone-boulder-clay. A road-section between Shehan's Cross and the gravel-pits, a quarter of a mile west

of the Cross, reveals 8 feet of limestone-boulder-clay. Another road-section of about the same depth, midway between Inch and Caherconlish, shows sand and gravel resting upon boulder-clay, and overlain by red clay containing human bones. The section is at the site of an old "fort," Knockaunconneely, which doubtless accounts for the occurrence of these remains. The sand and gravel seem to be of esker origin; and the red clay covering them, in which are few stones, resembles a deposit covering the sides of the Bohergar esker, near the R.C. chapel, to be afterwards described.

Judging from details of well-sinkings, and the thickness of superficial covering upon rock in many quarries in the low ground, it would appear that the boulder-clay, though so continuous, is generally of no great thickness. Sections revealing depths up to 20 feet have been laid open in railway cuttings; and the Shannon at Castle Troy cuts through more than 20 feet of boulder-clay with many boulders of limestone and a few subangular boulders of igneous rocks. Fragments derived from the Carboniferous volcanic rocks of the area are frequently to be noticed in the boulder-clay, but far-travelled erratics, such as granite, are very rare; limestone fragments prevail throughout, and have been noticed in the drift at the 200-feet contour on Knockbrack Hill, near Lisnagry, and above the 400-feet contour on Knockroe, south of Inch St. Lawrence.

The flat-lying sand south of the Knockroe range, presently to be described, is usually covered with a few feet of loam, which when traced eastward and westward of Sandville, south of Ballyneety, becomes thicker, and contains boulders of local origin; and the tract covered by this deposit has been mapped as boulder-clay, even where sand or gravel is known to set in at a depth of some four feet below the surface. But the boundaries drawn under such conditions are necessarily somewhat conjectural, especially as the only field-evidence available is that afforded by shallow drains or ditches, though this has been supplemented as far as possible by information obtained from well informed residents.*

The material represented as "sand and gravel," from Toberguile Cross in Cappanahanagh, northward to Ashroe, presents a surface of sandy and gravelly loam, and contains large scattered blocks of local Old Red Sandstone and gravel derived from the same. Sand and gravel are to be seen along the narrow road which leads from Killeen Burial Ground to the hill, crossing the main road; and in a sandpit at the margin of the cut-away bog the materials are stratified. Usually, however, the deposit is more of the character of a sandy

* The information of S. Barry, Esq., of Sandville, most fully and courteously given, was of much value in this particular.

boulder-drift, probably in part representing an upper boulder-clay of strictly local origin. Owing to the arenaceous nature of the originating rock (sandstone), it is difficult to draw even an approximate line between such material and the water-borne sand and gravel.

Red clay rests upon esker-sands, &c., at a few points, as will hereafter be mentioned. It contains few stones, is indeed almost devoid of them; and both the character and the colour of the clay, as well as the manner in which it rests upon the sands, are suggestive of the conclusion that the surface of the ice-sheet where it adjoined the esker—in other words, the esker-river valley—was, at a late stage of the melting, liable to flooding with mud-deluges, from the high grounds of the somewhat distant Old Red Sandstone.

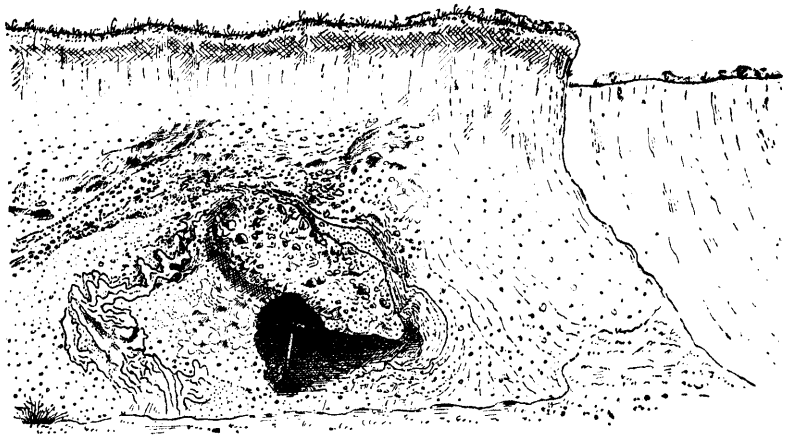
The boulder-clay resting upon the hill-flanks shows an intermixture of local rock-detritus with the components of the ordinary limestone-boulder-clay, the proportion of the former material becoming larger with the ascent, until only local rubble, resting upon its originating rock, forms the subsoil.

Striæ.—As represented on the new map, ice-striæ and groovings have been met with in many places, their direction varying from a little east of south, in the southern portion of the area, to a little south of east in the northern portion. Thus the striæ point E. 25° S. near Lisnagry Station on nearly level ground; and E. 10° S. on the north-westerly slope of Drominboy Hill, little more than half a mile to the east; while on the open northerly slope of Knockroe Hill, south of Inch St. Lawrence, they point S. 5° E. to S. 10° E. In the valley to the west of Knockroe, where the ice-flow was constrained, the directions indicated are S. 10° W. to S. 20° W. The direction taken by striæ three-quarters of a mile east of Caherconlish on the lee (southern) side of Benvult is W. 20° S., strongly transverse to the usual direction, and is exceptional.

Sands and Gravels.—A study of the sands and gravels of this district brings to light several points of interest. Commencing with those south of Ballyneety, they are in parts disposed with a fairly even surface. Here and there the surface undulates rapidly, and is occasionally hummocky, with "kettle-holes," as seen near the entrance to Ballinagarde demesne, on each side of the main road. The finest sand here, as elsewhere, is usually siliceous; but when it runs into coarser varieties, or contains gravel, a large proportion of the larger grains, and most of the contained pebbles, are of limestone. Sections exposed in a sandpit a quarter of a mile west of Sheehan's Cross, show sand, gravel, and shingle, stratified, chiefly consisting of well-rounded limestone-debris, with pebbles also of sandstone, igneous rocks of the locality, and a few of granite. Another sandpit in Ballymacreese, on the east side of the main road running southward, shows similar

materials also stratified, but with curiously contorted—as if laterally compressed—layers of fine sand, surrounding a central mass which displays boulder-clay structure. A sketch of this mass and the surrounding layers is here shown :—

Fig. 10.



Sketch from photograph taken in Ballymacreese sandpit, south by east of Ballyneety, showing irregular mass of gravelly boulder-clay, included in sand and gravel, which is in part stratified in accordance with the outline of the enclosed mass. Portions of the layers display excessive crumpling.

It will be noticed on the map that the hills and ridges are skirted, from place to place, with deposits of sand and gravel —sometimes consisting of sand with some scattered well-rounded stones, sometimes of sand, gravel, and shingle in alternating layers, the materials being similar to those of the boulder-clay, but lacking its argillaceous matrix, and usually well rounded. Both the state of the materials and their arrangement, as well as their position on hill-flanks, are naturally suggestive of littoral conditions, so much so that these gravels have been regarded by some geologists as evidence of a general submergence of the country beneath the sea. So far as the evidence in this small area goes, it does not, however, afford support to such a conclusion. These hill-skirting deposits are not continuous; and in one good instance at least, a mile south by west of Caherconlish, the well-stratified sand and gravel dips regularly towards Knockroe ridge, at an angle of 30°.

The circumstances more consistently point to deposition in a glacial lake almost free from ice, surrounding the hill-tops, encircled by an impounding ice-barrier, and receiving drainage from the melting, far-extending, and gradually declining sheet. It is noticeable that in a dry gap in Knockroe ridge, three-quarters of a mile south by west of Inch St. Lawrence, though the brows are glaciated, the opposing faces wear quite a fresh appearance, and are not glaciated. The bottom of the gap shows

neither a glaciated surface nor striæ, though the northern slope shows both, almost to the level of the gap; and the southern exit is cut up by water-channels bearing all the appearance of having been conduits of copious streams. It may be therefore that the impounded water of the supposed lake found egress through this gap, and probably through another a short distance to the east—that, in fact, the ice cleared away from the south of the ridge sooner than from the north. The wide gravel tract in the low ground of Ballybricken North, one and a half miles south of Inch, towards which the deeply eroded channels south of Knockroe gap are directed, probably represents the area of deposition covered by the escaping waters.

Several small linear areas of sand—from which, however, the sand has been almost entirely artificially removed—are to be seen to the north and north-east of Ballyneety and at Inch. The sand in these small areas seems to rest upon boulder-clay; and their formation appears to have been approximately contemporaneous with that of the larger area extending from Sandville to Ballyneety, which is independent of the Caherconlish ridge.

Eskers.—An interesting sand and gravel ridge, though its summit scarcely rises to 40 feet above the adjoining low ground, is traceable westward from Brittas at the margin of the map to Sandville in Newtown (Ballysimon) and Annacotty. It represents the old line of valley-drainage after the great ice-sheet had much declined, before the water was at liberty to take the lowest valley-level consequent upon the entire disappearance of the ice. If, as the writer believes, the great sand-deposit south-west of Annacotty belongs even in part to the esker, the interruption in its continuity near Killonan may be accounted for by supposing that the circumstances of the bed of the esker-river in this region were not favourable to deposition, except in a few small patches at Killonan Station, while the torrent carried forward its load of debris to Newtown (Ballysimon). A large accumulation is found there, and, as its highest point is about 70 feet higher than the general drift-level near Killonan, the bed of the esker-river, over which the sand-carrying waters passed, must have been at least 70 feet higher than the present ground—in all probability it was much higher. Special accumulations of sand and gravel that may be described as "nodal" are noticeable along the course of the esker, which may indicate merely excessive deposition at certain favourable points; or they may indicate successive termini of deposition, receding towards the head of the water-course in the ice-sheet, as the channel-walls gradually failed and melted away.

The interruption in the course of the esker at Killinure near Brittas, and a study of the directions and shapes of the esker about here, are suggestive of the conclusion that there were

at one period two channels, and that one of these ceased to receive debris—perhaps even water—while the other became the principal course and receptacle of sand, gravel, and shingle. It is remarkable that a large accumulation was formed at Brittas Bridge, on the west side of the Mulkear, containing moreover coarse shingle, as well as gravel and sand, all well washed, while the esker is not to be met with to the eastward.[1] This fact would bear out the supposition, already mentioned, that the accumulations may have been formed as termini, according as conditions of confined water-flow receded towards the origin of the channel. If this be the case, the conditions ceased generally after the Brittas sands and gravels, &c., were deposited. The height of the esker here is about 200 feet above datum, or 45 feet above the adjoining ground, while it is 40 feet above the adjoining ground at Bohergar, and 50 feet at Kishyquirk. Much of the sand, gravel, &c., has been removed from the esker throughout its course for building and other purposes; but good sections are still visible at and a little west of Bohergar Chapel, and in shallower openings at other points. The large pit west of the chapel presents a section 25 feet in depth, wherein sand, gravel, and shingle form a well-stratified series of alternating layers. The series rests upon gray boulder-clay below, and is covered by red clay with few stones, varying in thickness up to about 5 feet. This covering is scarcely apparent at the summit of the ridge, and becomes thicker downward, where it seems to pass into the ordinary boulder-clay of the adjoining ground; it rests unconformably upon the truncated edges of the sand and gravel layers. The well-rounded stones and pebbles of the shingle consist almost wholly of limestone, with an intermingled sprinkling of red and gray sandstone, igneous rocks, and other kinds. No pebbles of granite have been noticed in any of the openings along the esker.

On the east side of the road running northward from Bohergar Railway Station, near the chapel, in a pit from which much sand has been removed, a section is to be observed which exhibits a well-stratified series of sand and gravel, with some shingle. Portions of this have assumed a structure which is peculiar even when compared with the many interesting structures usually visible in eskers. Layers of fine light-gray siliceous sand, about 1½ inch in thickness, alternate with thicker layers of dark gray coarser sand and gravel mostly derived from limestone; so that the structure referred to, namely, a zig-zag arrangement of the layers, is easily perceptible. When closely examined, the zig-zag, which prevails throughout two sections at right angles to each other, is perceived to be the result of reverse faulting, with throws of different magnitudes up to six or seven inches; and above the zig-zag at one point a fairly distinguishable anticlinal curve

[1] *Cf.* Explanation of Sheet 144, p. 35.

was noticed, testifying, in conjunction with the reverse faulting, to the operation of a compressive force acting on the mass of material, while the layers were in a state sufficiently solid (*i.e.*, frozen) to prevent their obliteration. For the necessary compression, we must suppose a force acting laterally upon the deposits of the esker-river. Such a condition would have been supplied by a movement *en masse* of an adjoining portion of the ice-sheet, which at the time lay in the valley.

The sand and gravel in these sections are covered with one to three feet of red clay, which at the base of the covering fills pockets in the sand. The pockets look as if they had been gaping cracks on the surface of the stratified series when the semi-fluid red mud, already referred to (p. 73) reached this locality.

Small areas of sand, some of which are hummocky, and one or two adjoining rocky hills or hillocks, are to be seen north of the Mulkear, at Thornfield, Clonshavoy, Tobergarriff, Castle Comfort, and other points. Several sandpits have been worked from time to time in these areas. The chief pit at present is one about three-quarters of a mile west by north of Castle Comfort. Here, about fifteen feet in depth of stratified sand, gravel and shingle are to be seen, bearing a covering of one to three feet of yellow sandy loam. The pebbles of the gravel and shingle consist chiefly of limestone, with some of red and yellow sandstone, quartz, &c.

It may be pointed out that some of the areas assume a linear form, and that, in so far as they do, they seem in a general way to converge towards the locality of Barrington's Bridge. This is especially the case with regard to the esker-like tract running westward from Castle Comfort. Even the forked tract at Thornfield has a branch running south-eastward towards the point of convergence mentioned, and it is continued in a tiny but well marked ridge, on the west side of the Killeenagarriff alluvium.

There seems to be little doubt that we are here dealing with the relics of a former drainage-system, having a main course southward, which received tributaries from the declining ice-sheet near the present site of Barrington's Bridge.

An important group of eskers is to be seen south-east of Castleconnell, the trend of which is southward; that is, parallel to the Shannon, some three miles distant, and nearly identical with the position of the Newport River valley. It should here be explained that the pink colour on the map, which extends westward to the south-east end of Hermitage demesne, represents in part an area of gravel mounds which seem more distinctly related to the boulder-clay deposit than to eskers. The true esker ground extends no more than ¾ mile west from Bunkey Bridge; and, at this distance from the bridge, two or three characteristic ridges are to be seen running south-eastward. One of these eskers may be traced for half a

mile across the road leading directly to the bridge; and, though probably they represent one of the latest stages of esker-river deposition in the locality, their well-marked direction is suggestive of a tributary course to the main esker-river. To the latter are due the thick deposit of fine stratified sand in Drominboy, adjoining the Newport River alluvium on the west, and the two low oblong mounds surrounded by the present alluvium between the Newport and Annagh Rivers. The existence of these sand-hills points to a main drainage-course southward, traversing, and in places probably overspreading, an ice-sheet, depositing its load of sand and gravel at points now concealed, as well as where they are now visible, and flowing onward to join, or be joined by, esker-depositing streams in the vicinity of the present Barrington Bridge, previously mentioned; then turning westward towards the mouth of the Bohergar esker-river, to swell the mass of sand in Newtown (Ballysimon), and depositing a mass at Foyle, east of the railway where it crosses the Mulkear.

The sand-areas to be observed bordering the Shannon, to the north of, and in, Mount Shannon demesne, indicate an ancient line of drainage approximately identical with that of the present Shannon valley. The sand is for the most part flat-lying—a fine-grained siliceous deposit—though it is in parts gravelly, while, to the north of the demesne, slight ridges are apparent. This bears out the conclusion that several different areas, though not of the esker type, represent a stage of the drainage at which eskers were being formed in the neighbouring localities. The absence of sand between the areas may be owing to denudation subsequent to their formation; or possibly sand was never deposited in the intervening spaces. If its absence be no disproof of the continuity of the drainage over the spaces where sand is not now to be seen, as well as where it exists, it is more than likely that the great deposit around Sandville, at Newtown (Ballysimon) received contribution from the drainage now in question, as well as from those englacial water-courses previously described.

References to the area of sand at Newtown (Ballysimon) have been made in the foregoing paragraphs; it may now be stated that the extent lying within this district reaches almost one square mile; it presents an undulating surface, in parts hummocky, with a large kettle-hole near Monaleen Schoolhouse. Many old sand and gravel pits are to be noticed, most of which are now closed; the deposit was extensively worked at the diverging four roads near Sandville; and 300 yards northwest of this point, a pit is at present being worked, showing stratified sand and a little gravel.

Alluvium.—The Groody River originally followed a tortuous course of nearly five miles in length, through an extensive alluvial flat, which commences about ¾ mile north of Caherconlish. In the higher portion of the alluvium, old alluvial

terraces are distinguishable; since they are not continuous, nor very distinct in character from the newer deposit, no separating boundary is shown on the map.

An artificial cut has been made of about two miles in length to relieve the drainage, notwithstanding which the callows are still liable to flooding. The cut reveals six to eight feet of alluvial loam, which, partly because of its retentiveness, and partly owing to the flatness of the ground, is prone to be wet. The adjoining boulder-clay land is low-lying—so little difference of level does it show, to that of the surface of the alluvium, that it is difficult to draw an exact boundary between the deposits, from observation of the surface. Then, also, the stones in the uppermost portion of the boulder-clay, being almost wholly limestone, have weathered to such an extent that shallow ditch-openings reveal only clay; and, flood-waters in the past having been over the boulder-clay ground, the difficulty of drawing boundaries is increased.

An area of flat ground continuous with the above extends westward to Killonan railway-station, and consists in large part of cut-away bog. The remaining peat rests upon alluvial clay, so that doubtless all was alluvial ground prior to the peat growth, and was at one period probably covered with water.

Between the Groody River alluvium and Ballyneety occurs another alluvial area. The greater part of this is now moory, from the relics of the peat which has been cut away; but near the surface shell-marl, blanched clay, and other alluvial matter are to be seen. That the area has been once covered with water is manifest from a very discernible margin traceable almost continuously around, where several yards of sloping drift-ground lead to a sudden rise of feature in the boulder-clay, three or four feet above the surface-level of the flat. The natural drainage escaped by the Bohermore stream, and its flood-waters probably also by a stream flowing northward. At present an artificial cut made at the north end seems to be the principal exit for the waters. It may here be mentioned that this cut was made through a natural sand-embankment thrown across the valley-mouth. This embankment seems to have been formed in glacial times as the delta of a stream which discharged the waters of an ice-impounded lake. In addition, the stream laid down a low terrace of sand which now margins the alluvium, also at the northern end, and passes beneath the boulder-clay on the east side.

An important deposit of old alluvium spreads outward from the Mulkear River at a slightly higher level than that forming its immediate margin. This old alluvium on the south side of the river is a clay-loam, and may be seen to rest upon limestone-boulder-clay in some of the artificial water-channels which drain the flat: but on the north side the deposit is more sandy, resembling the recent alluvium which extends northward almost to Barrington's Bridge.

The great tract margining the Newport and Annagh Rivers shows deposits of at least two ages, the lower of which, if not the upper, has been the floor of an important peat-bog. Along the outer margins of the alluvium is a noticeable drift-feature traceable here and there—not continuously—the level of which is a few feet higher than that of the most recent portions of the alluvium, while it seems to correspond with that of the older portions. It carries the mind back to conditions in which an extensive lake existed, covering the entire alluvium, probably antecedent to the peat; much of the area is even now at flood-time covered with water. Thus, on the night of the 16th October, 1904, flood-water rose to within six inches of the top of the Annagh River embankment, where it is seven feet higher than the adjoining ground. The level of this ground is continuous with that of the older alluvium above referred to, which gives a distinct feature about 2 ft. 6 ins. higher than the more recent alluvium and cut-away bog, along the main road leading from Annagh old church, to the cross roads south-west of Ashroe. The nature of this alluvium is red clay, which here and there is more sandy than usual; and, north of the road above mentioned at Cappanahanagh wood, an artificial stream-course eight feet deep reveals a gravelly clay. Alluvial gray and, generally, blanched clay is to be seen in drains throughout the more or less moory tract extending southward from this wood to Knocknagorteeny; and yellowish clay-loam forms the alluvium from Annagh Bridge southward, though at Killeenagarriff Bridge the deposit is quite sandy. The river forms a delta-fan of sandy loam when it debouches upon the wide alluvial tract, north of Barrington's Bridge. The northern portion of this tract, opposite Killeenagarriff Bridge, is moory, while between that point and the former bridge the river and tributary stream cut through ten or twelve feet of alluvial clay.

Three stages of alluvial deposition are distinguishable in the tract extending from the Limerick water-supply pumping station—the Clareville Water Works—through Mount Shannon to Castle Troy. The highest alluvium is in part a water-logged sand-flat in the former demesne. This once extended northward nearly a mile beyond the demesne-boundary, and was denuded, leaving low esker-like ridges bordering, and parallel to, the river. South of the Mulkear this oldest alluvial deposit consists of four feet of clay-loam with pebbles, over coarse river-shingle. The alluvium of the middle stage covers nearly a square mile in area, and consists of clay-loam, generally moory. The most recent stage is represented by a small clay-deposit near Castle Troy. The alluvium of the last two stages is liable to floods.

Peat Bog.—The peat in the portion of the map here under description is almost entirely cut away. An area remaining in Drominboy, Knockbrack and Lisnagry, near the railway station in the last townland, still yields fuel, though it is now

in the second, and partly in the third, stage of cutting. According to figures given by local informants, the original thickness has been estimated at twenty-five feet; and the residue rests upon blue clay and white shell-marl. In a bog one and a half miles east of Annagh Bridge, peat attained the reputed depth of 18 or 20 feet; only "hand turf" is now made there. The remaining area of importance lies to the south of Caherconlish, in the townlands of Grange, Caherline, and Ballybrood. The peat here covered more than half a square mile; and if we may include two smaller outlying areas lying to the north of the larger tract, with which in all probability they were formerly connected, the aggregate area would have been more than a square mile. The peat north of Caherline House must have been of considerable depth; at present it is cut for fuel only at the southern end, where it is seen to rest upon shell-marl indicating the former existence of a lake; and three-quarters of a mile north by west of the hamlet of Caherline, between the main road and the east margin of the tract, peat is seen four feet in depth resting upon limestone-boulder-clay. The remainder of the area is now marshy, or rough grazing-land and meadow.

The North-eastern part of the Map, east of the Shannon.

Parts of Six-inch Sheet 1, *Co. Limerick, and of Sheets* 31 *and* 37, *Co. Tipperary.*

By G. W. Lamplugh, F.R.S.

Castleconnell District.—The county-boundary between Limerick and Tipperary runs nearly north and south through the Stradbally bogland at an average distance of about 1½ miles east of the Shannon, the well-known fishing village of Castleconnell on the eastern bank of the river being situated nearly midway between the northern and southern margins of the area in Co. Limerick. The area in this country will be first described, and afterwards the district in Co. Tipperary to the eastward of the boundary.

At the northern margin of the map the Shannon is bordered on the east by an alluvial flat, artificially drained and partly protected from floods by an embankment along the river-side, but still occasionally under water. This low tract, like many others of similar character which border the Shannon here and there on both sides farther southward, is not a river-flat due to erosion by the main stream, but appears to represent either an original hollow of the drift-covered surface which has been cut across by the Shannon or the valley of a small stream excavated without assistance from the Shannon. The flood-waters of the Shannon tend to fill up lateral hollows of this kind partly with their own sediment, and to a greater degree by arresting the muddy streams descending into the basin from

the adjacent country. In the present instance the alluvial deposit is gray silt and peaty clay, merging gradually into peat on the rising ground which bounds the flat on the north and on the south-east.

At the southern edge of the alluvial flat the Shannon is bordered by rising ground composed of glacial drift irregularly overlying Carboniferous Limestone. Some shallow pits close to the river-bank at the landing quay just above the first rapids reveal 5 or 6 feet of clayey gravel, full of well-scratched stones, mainly of the local limestone but with a sprinkling of Old Red Sandstone and Silurian pebbles. This material merges indefinitely into gravelly boulder-clay of similar composition, which is exposed to a depth of 10 feet in a road-cutting at Lacka House. The drift-covered slope is continued southward to Castleconnell, where the Carboniferous Limestone is close to the surface and is revealed in an old quarry 100 yards N.W. of the railway station, and in another quarry on the south side of Coolbawn House, in both cases with an irregular capping of bouldery limestone-drift. Knolls of bare limestone, surrounded by river-alluvium, rise above the river in Cloon Island and in the precipitous rock on which stand the picturesque ruins of Castle Connell. From this place southward for about $1\frac{1}{2}$ miles the Shannon is constantly interrupted by reefs and islands of the same rock, over which it hurries in broken rapids, sometimes tumultuously, as at the "Leap of Doonass," where the beauty of the river is far-famed.

A deep inlet of alluvium similar in general character to that above described, though bounded by higher and steeper slopes of limestone partly covered by boulder-clay, occurs immediately south of Castleconnell, severing the main part of the village from the drift-covered ridge bordering the Shannon on which the church and the court-house are placed. To the eastward of this alluvial flat the slopes are covered with stiff calcareous boulder-clay, well seen in a railway-cutting 350 yards S. of Castleconnell station, but limestone is quarried from beneath 5 to 10 feet of this drift on the higher part of the slope.

As it recedes eastward from the river the drift-slope becomes flatter, and is then covered by an accumulation of peat which, north of Castleconnell, forms a rude terrace 20 to 30 feet above the level of the Shannon, with its margin usually within 200 to 300 yards distant from that river. The boulder-clay appears to form a shallow basin beneath this peat; the edges of the bog have been largely cut away for fuel and the land brought under cultivation, but there is still a considerable quantity of peat remaining in the broader northern part of the tract, where a thickness of over 10 feet is exposed in some of the turbaries without reaching the bottom of the mass.

This bog must be regarded as an extension of the wide Stradbally bogland to the westward, which has spread over the edge of its basin around the ends of the gravel ridges that partly confine it. Until the paring away of their thinner

marginal portions for fuel the larger and smaller bog were in places confluent. As the original surface of the larger mass was 30 to 40 feet higher than that of the smaller, it is not improbable that there has been an actual transference of material by flow or creep from the higher to the lower bog. This supposition is strengthened by the fact that four or five years ago the north-western margin of the larger bog, just beyond the northern edge of the present map, began to move forward around the northern end of the confining gravel-ridge, causing alarm lest it should overflow the lower ground between its margin and the Shannon, as, indeed, might have happened had not the movement been arrested by the main-road embankment.

The gravel-ridge just referred to forms a most striking topographical feature, being about a mile in length and 400 to 500 yards in width, rising on its western side abruptly to a height of over 100 feet above the bogland at its foot. It terminates northward, slightly beyond the margin of the present map, in an equally abrupt slope, but falls away rather more gradually eastward and southward until enwrapped by the Stradbally bog. A pit near its base at the northern extremity reveals 12 feet of coarse bouldery gravel and sand, mixed in places with clay, dipping steeply toward the north. Its material is mainly derived from the Old Red Sandstone, of which some large boulders are seen in this pit (the largest measuring 5ft. × 3ft. × 2ft.) with a sprinkling of debris from Silurian slates and grits. Large blocks of Old Red Sandstone are also seen at the surface on the summit of the ridge, and on its western slope; but toward the east and south the gravel becomes finer in texture, and soft yellow sand becomes more abundant, until in the more easterly spurs the sand predominates. Two small rounded boulders of Galway granite were noticed in a pit on its western side half a mile south of the northern end, along with two or three fragments of other far-travelled igneous rocks whose source has not been determined.

This ridge forms part of a chain of hummocks and ridges of similar character which runs southward roughly parallel to the Shannon from O'Briensbridge, two miles north of the present map, or possibly from Birdhill, three miles still farther north. The southward continuation of the same series has been traced in the preceding description of the country east of Lisnagry (p. 77). That the gravels and sands represent the sediments of heavy floods draining the ice-sheet there can be little doubt; but whether the deposits were accumulated along the course of a single large river flowing over or under the ice, or whether they were thrown off as deltas along the margin of the receding ice-sheet must remain doubtful until the area to the northward of the present map has been surveyed. The latter supposition seems favoured by the curiously terraced summit of the ridge; by the association of stony clay with the gravels in the railway-cutting through a subsidiary spur which

lies half a mile to the westward of the main ridge at the northern margin of the map; and by the rapid change, as above described, from coarse bouldery gravel to fine gravel and loamy sand in the south-eastern part of the main ridge.

As already mentioned, the southern end of the ridge sinks beneath the Stradbally peat-bog which extends with an unbroken surface for a mile to the southward and then terminates against other hummocky ridges of gravel and sand. These ridges rise at first to a height of 20 or 30 feet above the bog-level, and are prolonged southward in a well-marked belt of still higher ground, as previously described (p. 78).

Stradbally Bog and its borders in Co. Tipperary.—To the south-east of the main gravel-ridge, the bog-land stretches for 1½ to 2 miles with an unbroken surface except where excavated at the turbaries, rising gently from the margins, where it has been extensively cut away and drained, to the smooth spongy flat of its interior on which the levels recorded by the Ordnance Survey average 140 feet above O.D., being about 55 feet above the level of the Shannon a mile to the westward. The greatest depth of the peat is unknown, but it is not likely to be less than 40 feet, the deeper sections revealing 12 to 20 feet without reaching the base except where near the margin of the bog. It is evident, however, that the peat rests upon an uneven surface, and has obliterated the original inequalities of hummocky drift, this being well seen at its northern margin, where spurs of gravelly and clayey drift project as dry headlands into the bog, while in the case of the most westerly of these spurs, some low gravelly mounds surrounded by peat-bog mark the prolongation of the hummocky ridge. The largest of these mounds, known as Toreheen Island, measures about 300 yards across, and shows the traces of excavations, apparently old gravel-pits. Wherever the base of the peat has been reached, it is found to rest on gravel or gray stony clay, and nowhere was any of the white shell-marl observed in this position, such as so commonly underlies peat in the smaller basins farther southward; but as it is only around its margin that the bottom of the bog has been reached, there is a possibility that the marly site of a lakelet may still exist beneath the peat in the deeper part of the basin.

The eastern limits of the bogland are defined by slopes of boulder-clay irregularly overlying Carboniferous Limestone, but it is only in a few places that the peat impinges upon these slopes, there being usually a strip of recent alluvium between them, brought down by the streams draining from the upland. The surface of the alluvium is generally several feet lower than that of the peat-bog. There is often a moderately steep bank of peat at the edge of the alluvium, which suggests at first sight that the margin of the bog has been eroded by the streams, but it is more probable that this bank marks the place where the growth of peat has been arrested by the deposition of muddy sediments brought down by the streams in flood, the

feature indicating that the rate of accumulation of peat has been greater than that of the alluvium. By this means the flood-waters have been gradually dammed back from the lower part of the basin and have been compelled to find their escape southward along its eastern edge. To relieve the flooding to which the alluvial flats are subject, a trench has been dug across the bog 700 yards N. of Shower Cross-roads to carry off the streams descending from Killeen and Mount Phillips, so that instead of finding their way into the Newport River above Shower, these waters now join that river at Bunkey Bridge.

The boulder-clay which covers the hilly ridges east of the bog-land differs from that of the Castleconnell district in containing a much larger proportion of Old Red Sandstone detritus, which renders it redder in colour and more loamy in texture. The ridges are moulded upon Carboniferous Limestone which in several places is close to the surface and has been excavated in quarries. It is, however, only in these quarries that the solid rock is exposed, except that flaggy sandstones, included with the Lower Limestone Shales, are seen in the bed of the Newport River at Bloomfield, and Old Red Sandstone occupies the same position at Newport just beyond the eastern margin of the map. Alluvial flats of boggy meadow-land intervene between the ridges, and are disproportionately broad as compared with the volume of the streams which flow along them. These flats are, in fact, long tongues of the wide alluvial flood-plain of the Newport and Annagh Rivers, presently to be described, and are due in greater degree to the flooding backwaters of these streams than to the insignificant tributaries now carried along them in artificial channels. The deposit underlying these flats is usually a brown clayey silt containing much vegetable matter; but east and west of Killeen House strips of true peat have accumulated along the margin of the flats.

Country between Newport River and Annagh River, Co. Tipperary.—The Newport and the Annagh rivers descend with rapid courses from the mountainous Silurian and Old Red Sandstone country to the north-east and east of the present map. Both streams leave deep gorges of the latter rock just before entering the map, and have thrown down wide detrital fans on reaching the Carboniferous Limestone plain. The valley of the Newport, for some distance above the town of Newport which lies just outside our map, is a pre-glacial hollow deeply filled with drift, through which the river has re-excavated its channel.

In a cliff on its west bank half a mile north of Newport the stream has cut through about 60 feet of drift, consisting mainly of red sandy boulder-clay, with well-glaciated blocks of sandstone and limestone, the former predominating, especially in the uppermost part of the section. The valley is here too narrow and the stream too rapid to permit the products of erosion to remain; but immediately below Newport

well-marked terraces of coarse river-gravel set in between rising slopes of boulder-clay and are continued on one or both sides of the river for over a mile, to the neighbourhood of Ballymackeagh House. The present stream at first occupies a trench cut through these gravels, but the surface of the terraces falls more rapidly than the fall of the stream, so that to the westward of Ballymackeagh the river when in flood still reaches the level of its alluvial flat and is artificially embanked. At this point, also, the confining slopes of boulder-clay disappear and the alluvial flat expands northward into the subsidiary valleys already described, and southward until it merges with the corresponding flat of the Annagh River over a mile distant. As the level of the alluvium descends the material becomes finer in texture, until it consists mainly of silty loam and clay with only occasional streaks of fine gravel. This alluvial flat has an area of about 1½ square miles, and consists mainly of artificially drained grass-land, frequently rushy and in places liable to floods, as the bordering rivers on both sides are only kept in their courses by embankments.

As previously mentioned, the alluvium is bordered on the west by the margin of the Stradbally peat-bog, which rises above the level of the alluvial flat and appears to have played an important part in its development by ponding back the streams and compelling them to find a southerly course. A few low mounds of drift, partly boulder-clay and partly sand and gravel, rise like islands above the flood-plain, and show that, as in the case of the peat-bog, an irregular surface of drift is buried under the alluvium. Drain-sections showing 6 to 8 feet of the silty clay are common, and it is evident that in some places the thickness of the alluvial deposit must be considerable; though no information as to its maximum depth was obtained, we were informed that the base of the soft clay was not reached at a depth of 18 feet in a well two-thirds of a mile S.W. of Ballymackeagh House. In many places, bogwood, sometimes in large stems, is abundant in the silt, and it is, no doubt, owing to the presence of decaying vegetable matter that the water in the ditches draining the flat is almost always strongly ferruginous. The difference between this rusty water and the clear water draining under similar conditions from the drift was found a useful indication in mapping the ground.

The general conditions under which the Annagh River reaches the plain are very similar to those of the Newport River, except that the Annagh, just before entering the map, emerges from a deep post-glacial ravine in Old Red Sandstone and not from a drift-filled valley, the river having apparently been diverted from its previous valley toward the close of the Glacial period, and driven to carve out for itself a new channel through the solid rock. The sides of this ravine are very steep—in places even precipitous—and the stream forms several cascades in passing through it. The delta of coarse

bouldery gravel where the river enters our map is the result of the erosion of this gorge, the coarse material, as in the case of the Newport River, passing into fine gravel and then into sandy loam and silt toward the outer margin of the delta. At Mount Rivers the stream is checked and diverted southward by a bold drift-covered ridge, along the base of which it flows for about a mile and then turns eastward again around the end of the ridge, beyond which its alluvium merges with that of the Newport River in the marshy flat already described.

The ridgy ground between the two rivers, to the eastward of the alluvial flat, is almost wholly drift-covered, the only outcrops of rock being along the top and western slope of the ridge one-third of a mile W. of Mount Rivers, and again half a mile W. of Dromore House, where Carboniferous Limestone is sparingly exposed. The prevalent drift is red loamy boulder-clay derived mainly from Old Red Sandstone, often so sandy in composition, especially along the crests of the ridges, that hesitation was felt whether it should be represented as ' boulder-clay ' or as ' sand and gravel ' on the map. In a heap of stones carted from the bed of the Newport River opposite Ballymackeagh House, two small boulders of Galway granite were noticed, which presumably had been derived from the drift; but these were the only far-travelled boulders observed in this area, though large blocks of Old Red Sandstone are almost everywhere abundant.

PART III. ECONOMIC GEOLOGY.

By J. R. Kilroe.

Metalliferous ores are sparsely distributed in this area. Lodes of argentiferous galena, blende, and iron pyrites have been mined to some extent in the vicinity of Askeaton; and lodes of copper and galena at Lackamore, Coonagh Castle, and Tower Hill, beyond the limits of the present map; but no deposits justifying outlay for mining have been met with in the region lying immediately around Limerick. Possible sources of magnesia are recorded at various points in the map, and good building materials are to be met with in several places. These, with deposits of brick-clay, and materials for the manufacture of Portland cement, are the chief products of economic importance which the area here described naturally yields.

Metalliferous Ores.

In the original memoir to the one-inch Sheet 144 it is stated (p. 37) "Small pieces or bunches of *Galena* were found in a quarry in Stonepark, which lies on the Limerick and Bruff road . . . and also in a quarry by the side of the same road, about a mile and a half S. of the Stonepark quarry." In the memoir to Sheet 143, p. 35, we also read of some insignificant indications of metallic deposits, thus: "A piece of galena . . . was found in a field a little to the east of Heathmount Lodge." The source of the piece is doubtful, but "it is mentioned as it might point to a mineral deposit somewhere in that vicinity." *Iron pyrites*, it is stated, has been "observed in some of the trappean rocks"; also "half a mile nearly W. of the Limerick Post Office [existing in 1860], at the junction of the townlands of Park and Singland, in green ash, there are two veins of this ore; they are of little or no commercial value, as the stone they are in is of too hard a nature." Mention has been made* of the occurrence of *copper ore* in the vicinity of Abington, but it was not possible to verify this report.

Building Materials.

Building Stone.—Numerous quarries have been opened upon the limestone, which is either exposed at the surface, or quite near it, throughout a large portion of the area—the portion of the map where drifts are not indicated. Many of those openings have been made to obtain stone for burning and road-metal, but, judging from the large quantities which have from time to time been removed, and from the fact that this rock forms the chief building material in Limerick, and throughout

* Lewis's Topographical Dictionary, vol. ii., p. 264.

much of the country around, it is likely that the very large openings to be met with have afforded supplies of stone for building. Many of the large quarries are now disused, and many smaller ones are closed. Massive limestone beds, capable of yielding very large-sized blocks, have been quarried near the Gaol and at the present Electric Power Station; and, of some large quarries on the southern outskirts of the city, some are closed, though capable of yielding large blocks of sound limestone, while others are being worked at present, yielding large supplies of material, some of which forms good building-stone. Light gray limestone, which would dress well, is to be also seen west of Limerick near Mungret, near Killonan on the east, as well as near Castleconnell, at Inch St. Lawrence, and north of Limerick between the Shannon and Cratloe.

It is noted in the memoir of Sheet 143 (p. 18) that "a mile due west of Cratloe cross-roads, at the boundary of the alluvial flat, there is a very superior building stone seen in an old quarry. It is a massive whitish yellow grit, and dips nearly W. at 5°."

A stone which is extensively used for rough strong building, as well as for farm-homesteads in its vicinity, is volcanic ash. The rock is not difficult to obtain by blasting, and is a good, not unattractive, building material, being of a warm olive-green colour when viewed from a distance. It was extensively used in the erection of the terminus of the original Waterford and Limerick Railway, now taken over by the Great Southern and Western Company.

Marble.—Limestone, which would by polishing form a black marble, has been mentioned in the original Memoirs* as occurring in the railway-cutting near Ballycarrane House, S.W. of St. Patrickswell, and in the large quarry near the gaol at Limerick, beneath the beds now exposed. Dark blue, nearly black, limestone, of similar character, is also to be seen half a mile west of Ballinagarde House.† Dark grey and black limestone occurs plentifully elsewhere in the area, but it is usually earthy, and weathers rapidly.

Variegated red and purple limestone beds have already been mentioned* as having supplied building material for Adare Manor. This stone seems to throw out iron stains, and is not so suitable for outdoor work as for internal decoration.

Dolomite.—In many places the limestone appears dolomitic, some of it being of a light pinkish or yellowish gray colour, which is not the result of external weathering, since it appears on freshly-broken surfaces. A magnesian limestone with far less magnesia than exists in true dolomite would, however, have an appearance similar to that of this rock. The

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* Explanation of Sheet 143, pp. 24, 28, 29.

† *Ibid.*, p. 25. *Ibid.*, p. 7, see p. 15 of this Memoir.

presence of fine sand as an impurity would also give to limestone some such appearance. In many places, therefore, in which indications of magnesian rock have been noted in this area, the proportion of magnesia may be insignificant. Beds of such rock are to be met with at several points along the Mulkear River, and in the quarries around Limerick, but chemical analysis should be resorted to before any could be indicated as profitable sources of magnesia. One instance, of which there can be little doubt, is that of a mass of dolomite which is crossed by the road to Newtown Point, about a mile to the north of Carrigogunnel Castle.

Bricks.—Tracts of brick-clay are to be met with amongst the alluvial deposits of this area. Some of these are utilized on a small scale, as, for example, that to the south of Coonagh Island, at Lansdowne Bridge, both in the county of Clare, westward of Limerick city, and at Clino, south-east of the city.

A circumstance noticed in the clay of the Clino alluvial deposit is that the deeper layers are, in certain places at least, calcareous. The calcareous matter, however, is in an extremely finely-divided state.

Portland Cement.—(The following paragraphs, to the words "cement factory," have been contributed by Mr. E. St. John Lyburn) :—

An investigation into the possibility of manufacturing cement in the neighbourhood of Limerick was carried out in 1904 by Messrs. Charles Spackman and E. St. John Lyburn, acting on behalf of the Department of Agriculture. The following is a digest of their report :—

No. 1.	Limestone.	From Thomond Gate quarry. Martin M'Mahon.
,, 2.	,,	Mungret No. 2. Exposure of limestone in road cutting.
,, 3.	,,	From Griffin's quarry, Ballyduan, Clarina.
,, 4.	,,	From Glass Corrane, near Ferry Bridge. James Buckley.
,, 5.	,,	From Kiltemple quarry. W. M'Queen.
,, 6.	,,	,, ,, ,,
,, 7.	,,	From Mungret quarry. Michael Boland. Lime used in Gas-Works.
,, 8.	,,	From South-hill, Rathbane. J. Clancy.
,, 9.	,,	From Rossbrien quarry. Owned by W. Blake.
,, 10.	,,	From Gilloge Lock quarry.
,, 11.	,,	Sample sent by Mr. Donnellan.
,, 12.	Mud.	From Shannon Grass Island.
,, 13.	,,	From Shannon, Ballinacragga Creek.
,, 14.	,,	From Shannon, Muckanish Point.
,, 15.	,,	From Corkamore.
,, 16.	Clay.	From Corkanree Marsh.
,, 17.	,,	From Ferry Bridge Marsh.

RESULTS OF ANALYSIS.

LIMESTONE.

—	1.	2.	3.	4.	5.	6.
Silica, Oxide of Iron, Alumina,	2·68	1·31	1·40	1·21	·75	·81
Carbonate of Lime,	95·01	96·91	97·00	93·13	97·55	96·92
Carbonate of Magnesia,	2·26	1·22	1·36	5·64	1·51	1·79
	99·95	99·44	99·76	99·98	99·81	99·52

—	7.	8.	9.	10.	11.
Silica, Oxide of Iron, Alumina,	1·21	1·99	1·04	2·97	·99
Carbonate of Lime,	97·50	94·81	94·11	95·33	95·35
Carbonate of Magnesia,	1·41	2·83	4·25	1·59	3·21
	100·12	99·63	99·40	99·89	99·55

SAMPLES OF MUD.

—	12.	13.	14.	15.	16.	17.
Silica as Quartz Sand,	44·53	35·57	44·67	46·41	36·76	39·06
Silica combined,	6·03	14·17	8·10	7·08	20·27	16·53
Oxide of Iron,	2·98	5·61	3·88	3·49	7·77	7·40
Alumina,	5·38	10·52	5·90	5·70	11·64	9·77
Lime	·69	·81	1·19	·59	·75	·79
Magnesia,	·53	·47	·55	·56	1·16	·87
Carbonate of Lime,	33·41	20·31	28·68	28·26	11·14	16·28
Carbonate of Magnesia,	1·98	1·80	1·81	1·38	1·11	1·31
Total Sulphur,	·26	·21	·16	·18	·10	·11
Combined Water and Organic Matter,	3·05	7·39	3·40	3·90	7·02	6·57
Alkali Salts (not determined),	1·16	2·64	1·65	2·45	2·28	1·31
	100·00	100·00	100·00	100·00	100·00	100·00

—	12.	13.	14.	15.
Water at 100 C.,	32·68	45·46	40·22	29·51

As regards the limestones, Nos. 4 and 9 are unsuitable on account of the high contents of magnesia. No. 11 cannot be absolutely condemned, but we would prefer that the magnesia should be below 3 per cent. We did not ourselves take this sample, which was sent to us by Mr. Donnellan from his quarry. All the others are of suitable quality.

The first thing to notice in the analysis of the samples of mud is their very irregular composition. In those only exposed at low water, and which would have to be obtained by dredging, Nos. 12 to 15, the carbonate of lime varies from 33 per cent. in No. 12 to 20 per cent. in No. 13. This in itself is not of vital importance, as it would have to be increased to a uniform percentage of 77 in the dry cement mixture. But the indiscriminate use of this mud, even if suitable in other respects, would involve great care in the manufacture, and a considerable amount of laboratory work. Nos. 16 and 17, obtained from the banks above high water mark by digging, differ in the same manner, but it is probable that at any one place the composition would be fairly uniform.

To obtain a proper idea of the clay value of these samples, it is necessary that the carbonate of lime and magnesia should be calculated out of the analysis. This has been done, with the results shown in the following table. This is followed by an analysis of the mud from the banks of the Medway, which is the clay material almost exclusively used in the London district.

SAMPLES OF MUD WITH THE CARBONATES OF LIME AND MAGNESIA CALCULATED OUT.

—	12.	13.	14	15.	16.	17.
Silica as Quartz Sand,	68·93	45·97	64·28	65·97	41·90	47·39
Silica combined,	9·33	18·31	11·65	10·06	23·10	20·07
Oxide of Iron,	4·62	7·26	5·58	4·97	8·86	8·98
Alumina,	8·33	13·60	8·49	8·10	13·27	11·85
Lime,	1·07	1·05	1·72	·84	·86	·96
Magnesia,	·82	·6	·79	·80	1·33	1·07
Total Sulphur,	·41	·27	·23	·26	·11	·14
Combined Water and Organic Matter,	4·73	9·55	4·84	5·54	8·00	7·97
Alkali Salts (not determined),	1·76	3·39	2·42	3·46	2·57	1·57
	100·00	100·00	100·00	100·00	100·00	100·00

ANALYSIS OF MUD FROM THE BANKS OF THE MEDWAY AT GILLINGHAM.

Silica as Quartz Sand,	38·41
Silica combined,	25·42
Oxide of Iron,	6·95
Alumina,	16·36
Lime,	1·12
Magnesia,	2·23
Total Sulphur,	·23
Combined Water and Organic Matter,	3·40
Alkali Salts (not determined),	5·88
	100·00

Comparing these results, we see that in the samples 12 to 15 the total silica varies from 78·26 per cent. in 12 to 64·28 in 13. In both 14 and 15 the silica is high, but somewhat lower than in 12. These two samples are fairly uniform in composition. On account of their highly siliceous character, Nos. 12, 14 and 15 are unsuitable for the required purpose, while No. 13 could be used with good results. However, the best material, and the one most economical to use, would be dug from the marshes above high-water mark. Of the two samples, 16 is the best, and with suitable limestone would produce Portland cement of high quality. There should be no hesitation in using 17, but 16 must be considered the best. By comparing its analysis with that of Gillingham mud, it will be noticed that they very closely resemble each other in composition, as regards their essential constituents.

Bulk samples of limestone from Mungret road cutting (sample No. 2) and alluvial clay from Corkanree (sample No. 16) were obtained, and Portland cement was manufactured from these materials and found to be of excellent quality. It would appear from the reports furnished that Limerick affords a good opening for a cement-factory.

Hydraulic Lime.—The limestone at many points in this area is of an earthly character, the earthly matter being mingled with carbonate of lime in probably very various proportions, giving a series of rocks intermediate between very pure limestone on the one hand, and calcareous shale on the other. From such a range a limestone could with little difficulty be selected which would on burning furnish a good hydraulic lime. Advantage of this fact, however, does not seem to have been taken to any appreciable extent, except in the following instance; hydraulic lime obtained from the limestone in a quarry at Gilloge Lock, two and a half miles north-east of Limerick, was used in building the dock at the city harbour, and seems to have served its purpose well.

Flagging, Paving Setts, Road-Metal.

The Old Red Sandstone is frequently flaggy but coarse, on the broad summit and gentle slopes west of Glennagross. Fine-grained, yellow, flaggy grit might be obtained W.S.W. of Ringmoylan Wood, and on the east side of the Shannon valley good flags are obtainable, in a quarry in Old Red Sandstone, 500 yards south of Wilton, just outside the present sheet-margin.

A quarry has been opened upon Millstone Grit at Longstone, also just outside the sheet-margin, about two miles south by west of Dromkeen Station, which yields good *flags*, of a grey fine-grained grit, and *paving setts* of similar rock. Until recently the setts used in Limerick city were brought from Wales and Arklow. At present, however, setts of excellent quality, manufactured at Longstone, are used instead. This

trade and that in the Longstone flags are at present in a forward state. The material is a fairly hard and tough siliceous grit, containing a little white mica, which is in some degree conducive to the setts retaining a rough surface on wear—an essential consideration for paving purposes. (See Plate VII.)

The following analysis of this stone has been supplied by the Department of Agriculture :—

Silica,	84·27
Alumina,	7·87
Iron Protoxide,	3·02
Manganese Oxide,	trace
Lime,	trace
Magnesia,	1·03
Alkalies,	2·14
Sulphur,	0·11
Water (hygroscopic),	0·31
Water (combined), &c.,	1·20
	99·95

Specific gravity at 15·5°c., 2·671. Weight of one cubic foot, 166·7 lbs.

Road-Metal.—Limestone, sandstone, and other rocks are at present used as road-making materials, almost indifferently, according as each kind locally prevails, and is therefore inexpensively obtainable. This principle (or lack of principle) in selecting, though seeming least expensive, and perhaps proving tolerable on roads having little traffic, is far from being the most economical in the long run, where traffic is great or even of a medium degree. The limestone and the sandstone of this region are both easily crushed and reduced to mud and sand. Hard-looking volcanic ash is extensively used around Limerick, but this rock also is easily crushed by traffic, and breaks down quickly into muddy gravel, which yields still further and readily to rain water when long exposed. The compact igneous rocks, those especially which are intrusive, and some lavas, are particularly well adapted to road-making, and are to be met with at many points throughout the area, being represented in dark reddish colours on the map. They are tough and hard; and yield less readily to the hammer; and though on this account they are more expensive as road-metal, they will, in the end, be found more economical than the other rocks at present used.

Sand and Gravel.—These materials for building in the city are largely obtained from the river-bed by dredging, near the junction of the Annacotty River with the Shannon. They are brought down in lighters to the canal quay, close to the city. The materials are also obtained, very free from clay, in the esker hillocks and flat-lying areas represented in pink on the map. The sand costs about one shilling per load at the pits.

To face p. 94.

PLATE VII.—Section in quarry at Longstone, two miles S. of Dromkeen Railway station, showing Flagstone beds of Coal-measure age. The average thickness of each layer is some four inches.

Water-Supply.

The city water-supply is obtained from the Shannon, being drawn off from the river at the Clareville Water-Works at the Doonass rapids, nearly a mile north of the Mount Shannon demesne, where it is filtered. It is thence raised by pumping into service reservoirs, from which it is distributed. A limited supply is also obtained from wells and deep borings, details of which are, unfortunately, not available.

In the country parts around Limerick, the supplies are in many cases drawn from streams and shallow wells. Deep wells are common at the better class of farm-homesteads, bored through boulder-clays, sand and gravel, and rock. The following may serve as illustrations :—

A well in Knockanbaun, east of Lisnagry, through 16 feet of sand.

Two wells in Laghtane, east of Thornfield, 18 feet and 20 feet of boulder-clay over gravel.

Three wells in Ballyvarra, south of Thornfield, 10 feet, 14 feet, 19 feet, boulder-clay over rock.

One well in Knockagorteen, east of Killeenagarriff, 15 feet through boulder-clay and white sand.

One well in Ballybrickan, east of Shehan's Cross, through 4 feet loam, 16 feet gravel and rock.

Notes on the Soils and Subsoils.

The area extending from near Castleconnell to Rochestown, and from Ashroe to Dromkeen, comprised in the present Sheet, is of more than usual interest from the agricultural point of view, forming as it does the north-west corner of the fertile region known as the Golden Vein. Viewed from the geological standpoint, the soils are fairly representative of all met with in the middle and western portions of the special Limerick map described in this Memoir; and they present a great diversity in character, much more so than in origin. The degree of diversity cannot be fully judged from the colouring of the map, for the exigencies of representation in mapping required that the different kinds should be grouped together, upon the basis of their origin, under about a dozen distinctive colours. These include some appropriated to solid strata and masses where the ground is devoid of drift-covering, but none the less shows in large part a shallow coating of soils and subsoils mostly consisting of local detritus.

That the reader may judge of the degree of diversity amongst the soils, it may be instanced that the boulder-clay alone, represented by one tint on the map, is present in at least five distinguishable varieties, which yield correspondingly different soils and subsoils. To the south of Castleconnell, as already mentioned (p. 70), a considerable area is occupied by gravelly boulder-clay, which yields open gravelly and stony

loams. Along the wide valley drained by the Mulkear, the deposit contains a large proportion of clay, which forms highly retentive soils, with bad natural drainage, and difficult to till. South-westward and south-eastward of Thornfield and eastward of Ballyneety, the boulder-clay is of intermediate character, and forms stony clay-loams. South of Caherconlish range, the deeper portion of the subsoil consists of sand, gravel and shingle, with little clay, while the soil and immediate subsoil are loamy with a good proportion of clay, after thin upper boulder-clay; they possess good natural drainage and form dry pasture land. The portion of the Slievefelim group, which enters the Sheet on the north-east, shows soils and sub-soils after locally derived boulder-clay. This deposit, except for its texture and for analogies in the district, which entitle it to be regarded as boulder-clay, might almost be represented as sand and gravel on the map; its soils are quite sandy. Another kind of boulder-deposit is the red clay with few stones which ascends the sides of the eskers in certain places noted in the foregoing description. It seems to be a glacial fluviatile deposit containing variable proportions of sand, and forming correspondingly variable soils.

In the portions of the map represented as devoid of drifts, alluvium, &c., the rock is not actually exposed throughout. It is, as already stated, in large part covered with a thin coating of local detritus, usually containing an almost negligible admixture of débris borne from a distance. The capability of such a mixture, as a soil-forming material, is determined by the nature of the rock which it partially conceals. Very little of the limestone in this part of the area is so earthy as to produce very retentive soils. The massive igneous rocks and volcanic ashes yield porous soils, admitting of free percolation, where these, with their subsoils, are no more than a couple of feet in depth; and the Old Red Sandstone gives soils which are scarcely more than stony and pebbly sand.

From what has been stated, it will be seen that the variety of soils met with in this comparatively limited area is considerable, particularly when the composition of the soil-components is taken account of, as well as the soil-texture and physical characteristics. To the several kinds of soil which take their characters from the circumstances described, must be added those which cover the areas of sand and gravel also represented in the map, and which range from a shallow surface-layer in which humus, plant-residues, and living vegetation form the binding matrix, to sandy and gravelly loams of good depth —occasionally two feet. Those formed of cut-away bog and of different kinds of alluvium must also be added to the number of varieties. Those of the alluvial tracts vary from highly retentive clays, to sand with humus and peaty matter, commingled with fine and coarse gravel in various proportions.

The drift-map, therefore, provides a classification of the superficial deposits, the details of which, especially as regards the soils, must be filled in by the laboratory-examination of samples collected in the field. An exhaustive examination

could not be attempted, and what is here aimed at is a description of a few leading type-samples. These have been taken from the principal kinds of deposits and local detritus. The samples collected were about 2 lbs. each in weight, as they occurred in the field, inclusive of the stony contents up to the size of a large walnut. The coarser siftings were carried out with the samples dried at 70° F. The sieves used had round holes, respectively 2 millimetres and 3 millimetres in diameter, the latter being used to separate the coarser gravel for the petrological examination of the pebbles.

The samples for examination were selected as follows:—1 to 11 inclusive were from boulder-clay; 12 to 23 from areas represented on the map as sands and gravels; 24 and 25 from the wide area of alluvial deposit in Mount Shannon demesne; and the remaining samples from locally formed covering mingled with a small proportion of transported material.

TABLE of Soils and Subsoils, showing their Localities, Nature, Depths and the Petrological character of their contents.

ABBREVIATIONS :— S. = soil; Ss. = subsoil; cl. = clay; s. = sand, sandy; gv. = gravel, gravelly; l. = loam, loamy; *y.* = yellow; *g.* = gray; *r.* = red; *b.* = brown; *l.* = light-coloured; *d.* = dark-coloured.

No.	Locality.	Description.	Depth of Sample in inches.	Percentages by Weight in Samples of			Presence (×), and percentage of different kinds of stones, &c., in the "stones and gravel coarser than 3 mm."						
				Fine matter.	Gravel coarser than 2 mm.	Stones and Gravel coarser than 3 mm.	Limestone and Calc. grit.	Sandstone.	Chert and Quartz.	Basic Igneous Rock.	Acid Igneous Rock.	Slate.	Other Contents.
1	Opposite Hermitage entrance gate, Stradbally, S.	*y. b.* S.	9	69·1	6·4	24·5	17·6	47·4	35·0	–	–	–	–
2	Do., do.,	*l. y. b.* Ss.	20	81·2	9·	9·8	–	46·2	46·4	–	–	6·4	–
3	West of road in Drominboy,	*r. b.* S.	9	77·1	10·4	12·5	–	20·0	–	30·3	6·0	4·2	–
4	East of road in Knocksentry.	*r. b.* S.	7	85·0	9·0	8·0	–	24·0	69·2	3·8	3·0	–	–
5	Do., do.,	*l. r. b.* Ss.	18	84·3	5·2	10·5	17·0	22·8	50·0	–	–	6·5	3·7
6*	East of road in Lismullane,	*g. b.* S.	7	85·5	14·2	·3	×†	–	×	–	–	×	–
7*	Do., do.,	*y. g.* Ss.	20	84·0	16·0	Nil.	×	–	×	–	–	–	–
8*	North of main road, Castleerkin, N.	*l. g. r. b.* S.	7	82·0	15·6	2·4	–	15·8	10·3	73·9	–	–	–
9*	Do., do.,	*l. g.* Ss.	24	83·8	15·8	·4	–	–	×	×	–	–	–
10	½ m. E. by N. of Sandville, near Shehans Cross.	*b.* s. l S.	9	80·0	6·9	13·1	2·3	3·1	13·0	53·2	–	–	–
11	Do., do.,	*r.* s. l. Ss.	20	77·9	8·9	13·2	–	42·3	32·7	16·3	–	8·7	–
12	Near Hermitage, S. of 2, in Ballymacourty.	*l. b.* S.	9	64·0	7·0	29·0	×	65·4	27·5	–	7·1	–	–
13	Do., do.,	*l. y. b.* Ss.	20	70·1	8·9	21·0	×	42·6	46·9	–	–	10·5	–
14	200 yds. S.E. of Mountshannon Ho.	*l. r. b.* S.	9	83·3	5·3	11·4	×	43·9	55·3	–	–	1·0	×
15	Do., do.,	*l. b.* Ss.	24	71·0	6·0	13·0	×	50·1	47·3	–	–	1·6	×
16	"Rabbit Warren," Mountshannon Demesne.	*r. b.* cl. S.	9	90·0	5·9	4·1	–	23·7	71·0	–	–	5·3	–
17	Do., do.,	*r.* s. Ss.	24	84·2	5·8	10·0	–	42·8	57·1	–	–	·1	–
18	1 m. S. by W. from Bunkey Br., in Drominboy.	*l. r. b.* S.	10	84·9	7·5	7·6	–	8·9	59·3	17·4	8·5	5·9	–
19	Do., do.,	*l. r.* Ss.	24	90·3	6·7	3·0	–	33·0	42·2	16·0	6·6	2·2	–
20	N. slope of Annagh Hill, S.W. of old church.	*l. r. b.* Ss.	10	89·8	5·2	5·0	6·0	62·3	20·3	–	–	7·2	4·2‡
21	Do., do.,	*r. b.* S.	14	88·9	6·4	5·0	5·5	59·0	7·1	–	–	5·5	–
22	S. of road running N.E., Ashroe.	*r. b.* S	7	89·0	5·6	5·6	–	67·9	18·9	–	–	13·2	–
23	Do., do.,	*l. r. b.* Ss.	18	76·6	5·8	17·6	–	76·4	10·0	7·5	–	6·1	–
24	Alluvium S.W. of Mountshannon Ho.	*d. r. b.* S.	7	94·6	4·7	·7	–	69·9	29·9	–	–	×	×§
25	Do., do.,	*y. l. b.* Ss.	20	83·8	16·0	·2	–	×	×	–	–	×	×‡
26	½ m. W. of Lisnagry Railway Station.	*l. g. b.* S.	9	84·1	7·0	8·9	×	10·2	86·3	–	–	3·5	–
27	Do., do.,	*l. b.* Ss.	18	73·1	13·0	13·9	×	14·9	77·6	–	–	7·5	–
28	Knockroe,	*d. b.* S.	8	59·2	12·1	28·7	–	–	–	–	–	–	–

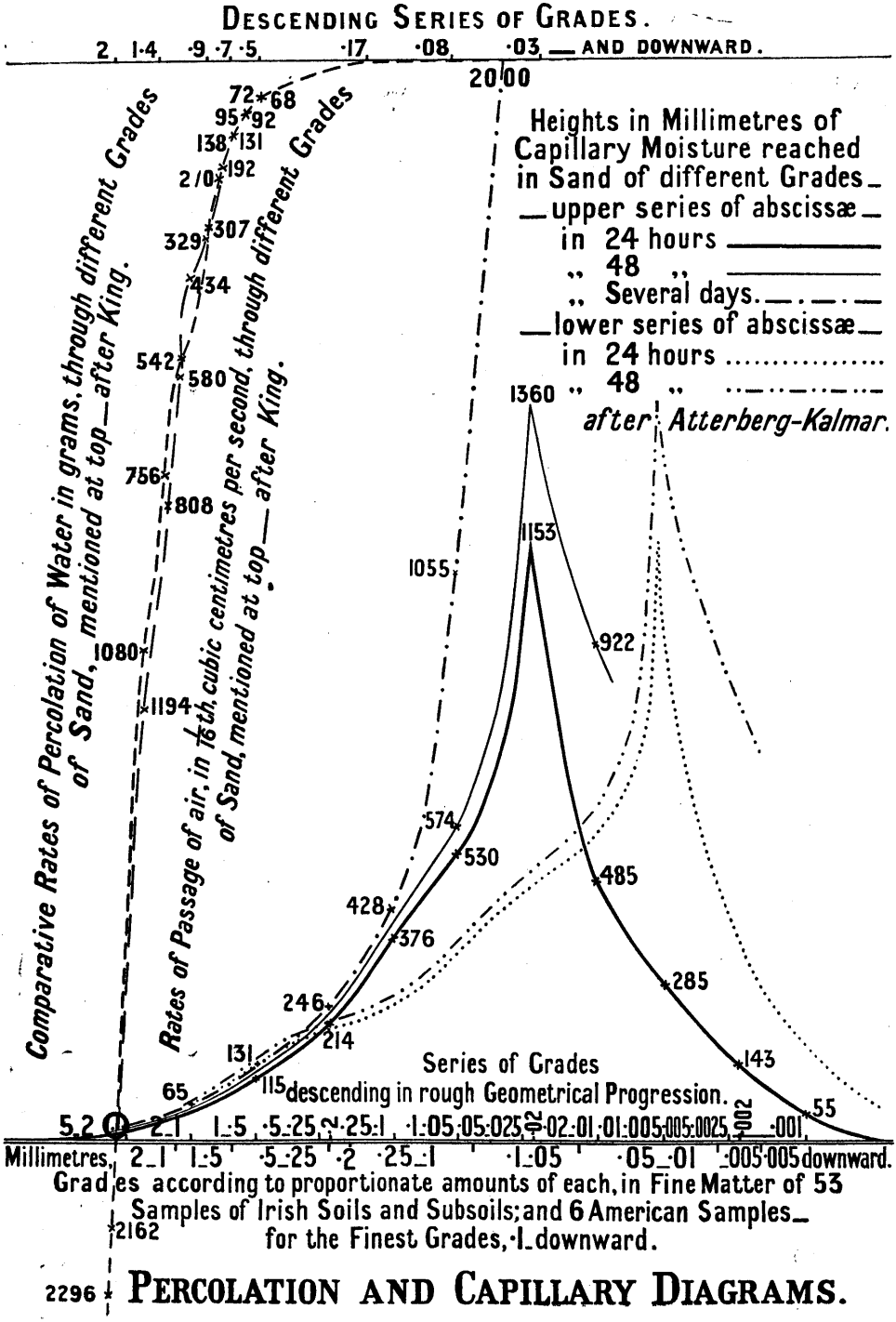
* Rain-wash over boulder-clay.
† In this and several succeeding cases, the material indicated was present, but in too small an amount to be reckoned.
‡ Added lime.
§ Added lime and cinders. This sample also contained a pebble of chalk-flint, probably a natural occurrence, and from Co. Antrim.

The fine matter was submitted to further detailed examination, which was carried out with the aid of the centrifugal apparatus described in the Economic Proceedings of the Royal Dublin Society, vol. i., part v. (1904), and with sieves of meshes 1 mm. ·5 mm., ·25 mm., and ·1 mm.; the material less than this grade was found by difference. The results of this examination are given in the next table.

TABLE, showing Percentages of Fine Gravel and Sand of various Grades in Fine Matter of previous Table: Samples correspondingly numbered in both Tables:—

No.	Fine Gravel and Sand.				Silt and Clay.	No.	Fine Gravel and Sand.				Silt and Clay.
	mm. mm. 2—1.	mm. mm 1—·5.	mm. mm. ·5—·25.	mm. mm. ·25—·1.	Less than mm. ·1.		mm. mm. 2—1.	mm. mm. 1—·5.	mm. mm. ·5—·25.	mm. mm ·25—·1.	Less than mm. ·1.
1	1·35	4·55	17·10	17·625	59·375	16	·90	3·60	17·25	33·25	45·00
2	2·10	4·75	10·45	14·95	67·75	17	·95	3·45	17·45	29·40	48·75
3	1·75	5·50	14·80	22·00	55·95	18	1·10	6·45	21·65	22·85	47·95
4	1·75	5·20	17·10	22·30	53·65	19	2·65	7·00	13·45	22·90	54·00
5	·60	4·65	24·00	18·85	51·90	20	1·25	6·05	20·30	23·60	48·80
6	·60	4·00	7·45	13·80	74·15	22	3·50	11·50	22·30	22·45	40·25
9	2·85	4·75	6·00	13·00	73·40	23	2·05	9·65	20·95	17·80	49·55
10	1·95	9·90	22·10	17·20	48·85	24	3·25	13·75	17·75	13·90	51·35
11	2·40	7·80	17·80	16·90	55·10	25	·35	1·65	12·5	24·40	61·10
12	3·25	6·20	19·35	20·65	50·55	26	2·25	6·10	20·30	20·80	50·55
13	4·85	7·40	16·90	19·95	50·90	27	3·85	5·40	11·25	15·40	64·10
14	1·85	8·10	27·75	20·35	45·95	28	10·60	10·90	17·03	11·98	49·50
15	7·60	7·55	21·40	23·05	40·40						

The soils and subsoils crowning the deposits of sand and gravel present a greater variety, as regards texture and components, than might have been expected. In some instances a fair proportion of clay mingles with the coarser substances. In the "rabbit warren" of Mount Shannon demesne a strong clay-loam forms the soil, while the subsoil and deeper portions of the deposit are sand and gravel. A strong contrast is thus noticeable between the results of the mechanical analyses of numbers 16 and 17 in the table. The contrast is accounted for by the stratified manner in which the sands and gravels were laid down; and the varieties of texture noticeable elsewhere in these deposits may be similarly explained. The samples from the boulder-clay also present a great variety. In certain cases, as in those noted at foot of the larger table, the uppermost few feet sometimes consist of strongly tenaceous clay, owing to rain-wash flowing over gently sloping, nearly flat-lying, boulder-clay; this has in time past carried the finer particles from the higher ground and deposited them elsewhere.



PERCOLATION AND CAPILLARY DIAGRAMS.

FIG. 11.

Diagrams have been prepared and are here shown to illustrate the comparative values of different grades of sand and silt, in determining the leading physical properties of soils in their natural state (that is, without the aid of tillage) which admittedly is of the greatest importance. Amongst the chief functions, in the processes of plant-growth, which soils are expected to fulfil, are the free admission of air to their interstices, the facilitating of the passage downward of superfluous water, and the ability to distribute a supply of moisture upward in times of drought, by means of capillary attraction. Fig. 11 shows two diagrams; one,* on the left-hand side, giving the rates at which air and water pass through different grades, under a certain constant pressure. The other diagram sets forth the comparative capillary power of the different grades.

Referring to the first, the curves have been traced from figures obtained in actual experiments, which run as follows :—While a total of 2,296 grams (*i.e.*, cubic centimetres) of water passes, under certain circumstances, through gravel the grains of which are 2·54 mm. in diameter, gravel of 1·45 mm. allows, under the same conditions, the passage of 756 cc.; and gravel of ·71 mm. diameter of only 138 cc. Experiments on the passage of air show that it will, under certain conditions, pass through the first-named gravel at the rate of 135 cc. per second, through the second gravel at 50·5 cc. per second, and through the third at only 8·1 cc. per second ; and so on for intermediate varieties, as indicated by the curves. Percolation of air or water practically ceases in silt of ·17 mm. grade—showing the necessity for artificial loosening of the soil in which much clay and fine silt exist, or a loosening of it by frost, plant-roots, and such like natural agencies.

The second diagram refers to the capillary power of various grades, and has been made out on the basis of data given† by Dr. Albert Atterberg-Kalmar, and in the following way. First, the grades have been placed in a series, in rough geometrical progression, and represented by *abscissæ* from O to the right. The comparative heights to which water is lifted in twelve hours, twenty-four hours, and the maximum height, are measured by scale on the *ordinates* drawn at each grade stage. Thus for the first series of *abscissæ*, if 2,000 units of height, corresponding to 2,000 mm. in the experiments, represent the maximum capillary lift of water by silt of ·05 to ·02 mm. diameter, then 428 is the maximum lift for sand

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* Prepared from data furnished by King (Physics of Agriculture, pp. 123, 126), which show remarkable correspondence with results obtained from mathematical considerations of the sizes of soil-particles, their mode of arrangement in juxtaposition, and the pore space, investigated by the U. S. Geological Survey, 19th Annual Report, Part II., p. 107, *et seq.*

† "Die rationelle Klassifikation der Sande und Kiese." (*Chemiker-Zeitung*, 1905, Bd. 29, No. 15.)

·2 mm. to ·1 mm. in diameter, 376 and 396 being the heights in twelve hours and twenty-four hours respectively for the same grade of silt; and so on for other grades, as represented on the diagram in figures and curves. The ordinates of other curves in this diagram are drawn at points represented in the second series of *abscissæ*, determined by the proportions in which the grades occur in fifty-three samples of Irish boulder-clay and detrital soils. These were taken because of being the most prevalent in this country; but the averages for them agree closely with the averages for sixty-six Irish samples examined by the writer, including those of Recent Alluvium, Old River Gravels, Glacial Gravels and Sands, and Marine Slob, over an aggregate area of 39,533 acres. For the finer grades, viz., ·1 mm. downwards, the proportions had to be taken according to those given for six representative American soils by Wiley.*

It will be seen that percolation decreases rapidly with the grading, it being only one-fifth in the 1·09 mm. grade of that which it is in coarse gravel (2·54 mm. grade), and one-thirty-fifth at ·5 of that which it is in the coarse gravel; also, that by far the greatest capillary power is in the grades intermediate between ·1 and ·01, that which possesses a maximum of the power lying between ·05 and ·015.

It is needless to point out that in practice an admixture of the very fine grades greatly modifies the results which otherwise might be expected from the coarse and medium grades. We may also conclude that an admixture of the coarser and medium grades with the finer quickens the sluggish tendencies of the latter.

APPENDIX I.

Petrographical Notes on the Limerick Igneous Rocks and the Volcanic Ashes.

By H. J. Seymour.

A considerable amount has been written about the interesting series of rocks occurring in this district. Probably the earliest notice was contained in Weaver's paper on the Geological relations of the South of Ireland (Trans. Geol. Soc., Ser. 2, Vol. v., 1840), where the district was described as "constituted of seven or eight great alternating beds of Limestone and Trap." In 1832 Dr. James Apjohn (Journ. Geol. Soc. Dublin, Vol. i., p. 30) controverts the accuracy of Weaver's statements, which he says are "entirely unsupported

* Principles and Practice of Agricultural Analysis: Soils, Part I., p. 249.

by facts," as to the 'trap' being stratified. He describes the limestone as lying on the trap, which had elevated and disrupted it. The following year Mr. W. Ainsworth gives it as his opinion (Journ. Geol. Soc. Dub., Vol. i., p. 112) that some of the traps are altered (*i.e.*, metamorphosed) arenaceous rocks, while others 'effused' in beds or dykes. In the same Journal (p. 185, 1836) Dr. Scouler makes the definite statement that none of the 'traps' had sent out veins or dykes, or spread as sheets over the country; but he thought that the detached masses had all been elevated after they had consolidated, and in every case protruded through the limestone. After a considerable interval, Mr. C. W. Hamilton comes on the scene, and in his paper "On the trap rocks of Limerick" (Journ. Geol. Soc. Dub., Vol. iii., p. 53, 1844) is decidedly of opinion that the trap rocks are of a distinctly sedimentary character and are conformable to the subjacent limestone. Regarding the ashes and breccias, one notes that Mr. Hamilton thinks that the brecciated or conglomeratic appearance of the rock at Carrigogunnel "might be owing to some cause affecting the rock, while in its original position, and not to the agglomeration of fragments once separated and then cemented together." (See *ante*, p. 27). He agrees with Ainsworth that the traps are the result of the metamorphism *in situ* of impure limestones, shales and grits, and in a subsequent paper in the same journal still adheres to his original opinions, which appear not to have been accepted by Griffith in his revised Geological Map of Ireland (pub. 1855).

The next contribution to the literature of this interesting region was the Geological Survey Explanation to Sheet 143, written by Jukes, Kinahan, and Wynne, and published in 1860. It was not, however, till 1873 that any paper dealing with the petrology of the Limerick rocks appeared, and to Prof. Hull must be accorded the credit of acting as a pioneer of this science in Ireland. His paper on the "Microscopic Structure of the Limerick Carboniferous Trap-rocks (Melaphyres)" (Journ. R. Geol. Soc. Ireland, Vol. iii. p. 112, 1873) is interesting, therefore, as being the first one describing some of the types occurring in this area, though in the state of petrographical science at the time one finds, not unexpectedly, that stress is laid on points of little importance. Mr. G. H. Kinahan follows later in a short paper (*loc. cit.*, p. 149), impugning the accuracy of some statements made by Prof. Hull, and giving his own classification of the Limerick rocks. The important addition made by him to our knowledge is the recognition of both basic and acid types of igneous material in the district.

Finally, in the "Guide to the Collection of Rocks and Fossils belonging to the Geological Survey" (p. 93), published in 1895, Prof. W. W. Watts gives a modern, though necessarily brief account of the petrography of the Limerick rocks. The nomenclature of the types described has been adopted by

Sir A. Geikie in that portion of his "Ancient Volcanoes of Great Britain," dealing with the Limerick basin. From the foregoing summary it will be seen that considerable differences of opinion exist with regard to the stratigraphy of this region, and reference to earlier portions of this memoir (p. 28) will serve to indicate some of the yet unsolved problems presented by the igneous series of rocks.

As regards the petrographic types occurring in the area of the new drift-map, these are roughly divisible into porphyritic rocks, with about 60 per cent. of silica, and basalts, besides which are a number of volcanic ashes and breccias principally made up of basic lapilli. It may be here mentioned that during the progress of the recent drift-survey, and chiefly in that area mapped by the writer, a number of additional outcrops, some of considerable extent, of igneous rock and ashes were discovered, all of which seem to have been overlooked by previous workers. These areas will be specially referred to in subsequent pages. The descriptions which follow are based on an examination of some 50 rock-slices, 16 of which have already been described by Prof. Watts, the remainder being prepared specially for the present memoir. It is proposed to describe successively the more or less circumscribed areas in which the rocks occur, commencing with the most north-westerly outcrops.

The Carrigogunnel Area.

The igneous rocks in this area are essentially basic, and belong to the basalt group. The rock under a portion of the Castle is a compact black altered basalt or basaltic andesite, containing in places numerous amygdales now composed of calcite. On the opposite side of the road, east of the Castle, the basalt is much fresher and very basic in composition, approaching the limburgite type. Olivine is represented by calcareous and chloritic pseudomorphs. Two generations of augite occur in the rock, which also contains abundant magnetite. About one mile S.W. of Carrigogunnel and N. of Meelick House, is a small outcrop of an olivine-basalt like the last described, but more finely crystalline. There is very clear evidence of flow-structure in this rock, all the plagioclase laths having a common orientation. Half way down the hill-slope one mile N. of the Castle, an outcrop of a dolomite is seen. The material is a yellowish-white crystalline rock, and is slightly cavernous. In section it is seen to consist of small more or less granular individual crystals with only occasionally straight crystal-outlines.

The newly-discovered outcrops of Igneous material.

The most westerly of these occurs as a well-marked ridge half a mile S.W. of Ballycummin Castle, and was previously mapped as limestone. It is a well-bedded volcanic ash made up of angular fragments.

These consist mostly of vesicular basalt and andesite, scattered through a highly calcareous ground made up of fine dust, in which plagioclase fragments are noticeable. This rock may be termed a calcareous ash. At and around Ballycummin (formerly Roche's) Castle is a very large outcrop of ash and basalt, which hitherto seems to have escaped detection. The greater portion of the outcrop consists of coarse ash of the type common in the Limerick area, but at the N.E. side is a small area of basalt, which appears to lie on the ash, and again on the S.W. is a similar rock. The basalt varies considerably in texture from compact to coarsely amygdaloidal. In section, the compact type is seen to be rather altered and rather finely amygdaloidal; the ground between the amygdales is an altered glass in which plagioclase laths are distinguishable. The ferromagnesian constituents are completely altered, and only the plagioclases are in a fresh condition. A more obviously and coarsely amygdaloidal type of basalt also occurs in this area, the amygdales being now composed of calcite. The ground is formed of plagioclases with subordinate amount of magnetite and secondary calcite. Continuing to the north-east, we reach the townland of Ballysheedy, in which some half a dozen small outcrops of igneous material occur. These are mainly ashes of varying degrees of coarseness, but a few are of compact basalt not unlike the types which occur further south of Roxborough. To the east of Ballysheedy, at Rathurd, it was found that the boundary line between the ashes and the limestone extended considerably further east and north than shown on the published map, and in addition another outcrop of amygdaloidal basalt occurred at this place. Both rocks are of the types common in the district, and need not be described here. Still further eastward, a new area of basalt was found to outcrop under the school and chapel at Donaghmore, on the crest of the hill in this locality. This rock is a compact basalt with phenocrysts of plagioclase (labradorite) and augite, both in a comparatively fresh condition. Olivine is represented by chlorite and magnetite pseudomorphs. There is a little calcite in patches in the ground which is made up of fine plagioclase laths (basic labradorite) with some altered interstitial glass. Magnetite is fairly abundant. The last of the new igneous outcrops discovered in this area occurs at the railway-bridge over the lane leading from Ballysimon to Donaghmore. This is a grayish compact rock, evidently much altered, and containing many small cubes of pyrites. In section it is seen to be a rather compact and glassy or fluidal type of basalt with irregularly shaped vesicles, around the edge of some of which the plagioclase laths of the ground are arranged tangentially. Some inclusions of ash-like material occur in the section.

The Roxborough Area.

The igneous material occurring in and around the Roxborough demesne is apparently entirely basalt, no outcrop of ash having been met with. As before, the types present are

compact basalts, porphyritic on the western side, and markedly amygdaloidal in the central and higher portion of the outcrop.

In section the rock on the west is seen to be an altered porphyritic basalt, the only fresh constituent being the plagioclases (andesine probably) which occur in crystals of two generations. Those of the ground form lath-shaped and sometimes stumpy individuals in a finely crystalline to glassy base dusted over with minute magnetite. The phenocrysts of plagioclase are completely altered. Traces of augite and olivine are noticeable here and there in the section. On the east the rock is a very compact and little altered basaltic andesite, showing traces of flow-structure; augite crystals are still recognizable in the ground, which also contains altered magnetite.

Kilpeacon Area.

The rocks of this district are quite similar to those just described, and a very compact flinty type of basalt occurs to the S.E. of the main outcrop. Still further south, huge blocks of a coarse ash are strewn over the fields, indicating the near presence of ash *in situ*, though no actual outcrop was noticed in the vicinity. About 1½ miles S.E. of St. Patrickswell is a small conical hill, the upper portion of which consists of a finely banded calcareous ash. In section, the ground is mainly calcite, in which are scattered numerous fragments of andesite, mainly vesicular.

The Drombanny Area.

The extent of the outcrop of igneous rock in this locality is much more restricted than is shown on the previous 1-inch map No. 143. The basalt actually forms two small and separate areas, as now shown, while the ash area is correspondingly increased. A specimen taken just at the V formed by the two roads S. of Drombanny Castle is seen in section to be a typical ash made up of small fragments of andesite, with subordinate quartz and felspar and secondary calcite. The rock at this locality was shown on the previous map as a basalt. A deep well-section at the farm on the eastern slope of this hill was sunk entirely through a green ash, varying in degrees of coarseness. There is no special point of interest about the igneous rock at this locality, as it is practically identical with that at Roxborough and also at Cahernarry.

Cahernarry Area.

A large quarry under the church at this locality is opened in a porphyritic olivine basalt, containing phenocrysts of both plagioclase and augite. Olivine is now represented by pseudomorphs in chlorite. The augite and plagioclase phenocrysts show secondary marginal growths. A good deal of magnetite is present, but no secondary calcite. This rock is suitable for use as road-metal, and is much superior to the local limestone used for this purpose.

Limerick City Area.

Numerous outcrops of ash of all degrees of coarseness occur to the east of the city and again at Newcastle. At Pennywell the rock is much quarried for road-metal, but is not suited for this purpose. In section this rock is a typical ash, bluish-green in colour and well banded. Nearly half the bulk of the rock consists of cementing material, essentially calcite, forming a mesh-work in which the fragments of andesite and basalt lavas are embedded. The latter fragments are mainly vesicular to amygdaloidal, and occasionally glassy. On the decay of the cementing calcite, the rock falls to powder, producing large quantities of mud in wet weather, much more than would be produced by a homogeneous limestone, such as that at Thomond Gate. Near the railway bridge W. of Clino Brick Works, the ash is rather calcareous, passing into an ashy limestone. At and around Newcastle the ash is fairly coarse, and occasionally contains pebbles which are fairly well rounded, indicating shore-conditions (see *ante*, p. 39).

Other Igneous areas in Sheet 143.

Before passing on to the larger and more interesting areas of igneous rocks to the west reference may be made to two small outcrops north of the Shannon.

At Gilloge lock (on the canal) on the previously published map, there was indicated a fairly extensive outcrop of ash. A recent examination showed that the only evidence for this was an interbedded sheet of calcareous and shaly ash some 6 inches thick, overlain and underlain by massive beds of crystalline and fossiliferous limestone. It has therefore been shown on the present map as a narrow band running along the strike of the slightly tilted limestone bands. There is abundant evidence that, with the exception of this narrow band, the remainder of the area is limestone.

Near Meelick House, half a mile N. of Lansdowne Bridge, is a small outcrop of fairly coarse ash similar in type to those occurring near Limerick city. This outcrop is the only one of igneous origin occurring in Co. Clare within the area of the present map.

Knockbrack Area.

On the eastern side of the new composite map, and some two miles S. of Castleconnell, is a small circumscribed area of ashes and basalt. The former are greenish in colour and are well banded. A fine ash resting on limestone (see p. 22) in this locality is weathered out in a spheroidal manner closely resembling basalt at first sight. The constituent particles and fragments are of the usual andesitic type ; the igneous rock developed near the summit of the hill is a slightly amygdaloidal basalt. It contains a good deal of augite in crystals of two generations, also plagioclase phenocrysts and pseudomorphs probably after olivine; secondary calcite and chlorite are also present.

Maddyboy Area.

The rock in this locality is of a peculiar type, and is similar to that forming a number of isolated bosses in and outside the Limerick volcanic basin. All are regarded as being definitely intrusive, and are considered by Prof. Watts as "a somewhat anomalous class of rocks," for which he proposes the name of Ivernite.* They have many features in common with trachytes, but are crystalline throughout, and in the field have a red granitic-looking appearance. The term orthophyre, as used by Rosenbusch, would include most of the varieties. In section the ground is made up of a felt of felspar laths, essentially orthoclase, but with a few plagioclases. Occasionally small phenocrysts of orthoclase occur, also traces of mica and hornblende. Interstitial quartz is present, but is scarce. The silica, according to Prof. Watts, amounts to 60-61 per cent. It would appear that this type of rock occupies near Maddyboy a somewhat larger area than that shown on the map, as a few hundred yards N.W. of Ballyguy a new outcrop was discovered during the examination of the drifts. This rock is pinkish in colour and dotted over with dull green patches of chlorite, representing an altered ferromagnesian constituent. In section it is quite similar to that at Maddyboy. There are some minute magnetite crystals in the ground, also a little interstitial quartz.

Carrigparson Area.

The rocks here are all ashes, and present no special features of petrographical interest, being similar to types already dealt with in these notes.

Boughilbreaga and Knockroe Area.

In this district there occurs the largest development of igneous rocks within the area of the present map, both trachytic and basic types occurring, and also andesitic ashes.

West of Shehan's Cross Roads are some small knobs of a compact black basalt, somewhat altered, especially in regard to the ferromagnesian constituents. The rock is slightly porphyritic, the phenocrysts being plagioclase. At Stonepark limestone quarry is an amygdaloidal sheet or sill of basalt interbedded with the limestone, which beneath it is altered to a depth of 3 or 4 feet to a crystalline dolomite like that at Carrigogunnel. A specimen from the slightly columnar rock forming the western crags of Boughilbreaga shows the rock here to be a compact and slightly amygdaloidal basalt. In section the ground is made up of abundant plagioclase laths and altered granules of augite. Olivine was originally present, but is now represented only by pseudomorphs of calcite and chlorite.

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*McHenry and Watts, "Guide to the Collection of Rocks and Fossils, Geol. Survey of Ireland," 1895, p. 93.

One half-mile S.W. of Knockroe, near a bench-mark indicating 402 feet, is an outcrop of rock quite similar to the Maddyboy variety in all particulars. The felspars are essentially orthoclase with a little plagioclase. Occasionally the felspar phenocrysts are close on 2 cm. in length and fairly fresh. Nearer to Knockroe, the rock is green in colour and looks more basic, this character being more obvious in a thin section. The constituent felspars in the majority of cases have a higher refractive index than Canada balsam and show repeated twinning. Augite is present in minute crystals, sometimes partly or entirely altered. Iron ore is present in a decomposed condition. This latter rock might be termed a trachytic andesite. About 1 mile S. by E. of Inch St. Lawrence, and a few hundred yards S.E. of △ 344, basic rocks occur belonging to the basalt group. Close by is a volcanic ash containing angular pebbles of basic lava. In section the ashy portion is seen to contain numerous lapilli of basic lavas mostly altered, and also several crystals of augite. Secondary calcite and chlorite are present, and also a few crystals of biotite. One large basic inclusion contains a good deal of augite in the ground, numerous pseudomorphs after olivine, magnetite granules, and a little felspar. It appears to be a limburgite, examples of which have been noted by Prof. Watts outside the area now being described.

Caherconlish Area.

A short distance N. of the village of Caherconlish is an outcrop of porphyritic rock which possesses a well-marked columnar structure (see plate III.). The rock is a grayish-green colour dotted over with yellowish to pinkish white porphyritic crystals of orthoclase and plagioclase, the latter having a low index of refraction. The ground in a thin section is finely crystalline and trachytic in texture, the constituent felspars being mostly orthoclase. The felspars show fairly evident fluxion structure round the phenocrysts, which latter usually show a narrow outer zone of re-crystallised material in contact with the ground. Some ferromagnesian mineral was originally present, but is now too altered for determination. Magnetite, secondary calcite, and chlorite, are present. This rock may be termed an orthophyre.

About one mile S.E. of Caherconlish is an outcrop of a reddish coloured rock somewhat similar to that occurring at Maddyboy, and also porphyritic. In section the phenocrysts are seen to be orthoclase with rather rounded outlines; these occur singly or in glomero-porphyritic groups composed of three or four individuals. The ground is markedly trachytic in structure, the constituent felspar laths being simply twinned orthoclase. There is also a number of greenish altered crystals of minute size which seem to be pyroxene; magnetite, somewhat altered, is present in small patches throughout the ground. The most interesting point about this rather acid rock is the presence of much-altered phenocrysts of olivine,

a mineral rather rare in this class of rock. We here find an exception to the statement of Zirkel that olivine is entirely absent from the normal trachyte types, though it occurs in those rocks verging on the augite-andesites (Lehrbuch der Petrographie, Bd. II., p. 370). The rock from Monte Olibano (an olivine trachyte) is rather similar to the above, but contains larger crystals of the ferromagnesian minerals, and is of course in a much less altered condition.

Half a mile E. of the last-mentioned outcrop is a small exposure in a field of a pinkish felsitic rock, which seems to be a more altered and finer grained variety of that just described. Still further east is a dark coloured greenish rock, which appears to belong to the trachytic andesite variety. The exposure of this rock occurs at the point west of Castle-erkin, where the symbol for glacial striæ is engraved on the map.

APPENDIX II.

List of Memoirs and Papers referring to the Geology of the Area included in the Map of the Limerick District.

1652.

BOATE, GERARD.—Ireland's Naturall History. Chapter viii. (Strafford's proposals as to Shannon navigation).

1773.

COWAN, JOHN.—Chart of the River Shannon from Limerick to Athlone. Three sheets.

1773 ?

COWAN, JOHN.—Chart of the River Shannon and Fergus.

After 1794.

COWAN, JOHN.—Chart of the River Shannon, from its Source to its Mouth. Three sheets in one.

1830.

THE IRISH INLAND STEAM NAVIGATION CO.—The Traveller's Map of the River Shannon . . . from the Survey made by John Grantham . . . under the direction of the late John Rennie. Fifteen sheets. See Sheets 4-7.

1832.

APJOHN, JAMES.—Observations on a Trap District in the County of Limerick. *Journ. Geol. Soc. Dublin*, vol. i., pp. 24-33.

HART, JOHN.—Observations on the Fossil Deer of Ireland. *Ibid.*, pp. 20-23.

1833.

AINSWORTH, WILLIAM.—A further account of the Limerick Trapp Rocks. *Ibid.*, pp. 112-128.

1834.

Report from Select Committee on River Shannon. *Parliamentary Papers*, 1834, vol. xvii.

1836.

Report of the Commissioners . . . for the Improvement of the Navigation of the River Shannon. *Parliamentary Papers*, 1836, vol. xlvii.

SCOULER, JOHN.—Remarks on the Trap Rocks which occur in the vicinity of Limerick. *Journ. Geol. Soc. Dublin*, vol. i., pp. 185-196.

1837.

Second Report of the Commissioners . . . for the Improvement of the Navigation of the River Shannon. *Parliamentary Papers*, 1837-8, vol. xxxiv.

1838.

Third Report *ibid.* *Ibid.*

1839.

LARCOM, THOMAS A.—A General Map of Ireland to accompany the Report of the Railway Commissioners, showing the Principal Physical Features and Geological Structure of the Country. (Geology by RICHARD GRIFFITH.)

Fifth Report of the Commissioners . . . for the Improvement of the Navigation of the River Shannon. *Parliamentary Papers*, 1839, vol. xxviii.

1840.

WEAVER, THOMAS.—On the Geological Relations of the South of Ireland. *Trans. Geol. Soc. London*, 2nd ser., vol. v. (read 1830 and 1835). For Co. Limerick see pp. 35 and 40-42.

1841.

HALL, S. C., and Mrs.—Ireland: its Scenery, Character, &c. London. 8vo. P. 391. (List of remains of *Cervus giganteus* preserved in the County of Limerick.)

1842.

Third Report of the Commissioners for the improvement of the Navigation of the River Shannon. *Parliamentary Papers*, 1842, vol. xxiv.

1843.

Fourth Report *ibid.* *Ibid.*, 1843, vol. xxviii.

1844.

Fifth Report *ibid.* *Ibid.*, 1844, vol. xxxi.

HAMILTON, C. W.—On the Trap Rocks of Limerick. *Journ. Geol. Soc. Dublin*, vol. iii., pp. 52-56.

1845.

IBID. Presidential Address. *Ibid.*, p. 106.

IBID. Further remarks on the Trap Rocks of the County of Limerick. *Ibid.*, pp. 145-149.

WILKINSON, GEORGE.—Practical Geology and Ancient Architecture of Ireland. London. 8vo. Pp. 221-225, &c.

1846.

HAMILTON, C. W.—Presidential Address (with notes on his preceding papers). *Journ. Geol. Soc. Dublin*, vol. iii., p. 172.

1855.

LARCOM, THOMAS A., and GRIFFITH, RICHARD.—New edition of the General Map of Ireland (see 1839), with geological revision.

1857.

KELLY, JOHN.—On the subdivision of the Carboniferous Formation of Ireland. *Journ. Geol. Soc. Dublin*, vol. vii., pp. 251, 256.

JUKES, J. BEETE.—Notes on the Calp of Kilkenny and Limerick. *Ibid.*, pp. 277-281.

1859.

BAILY, WILLIAM HELLIER.—Notice of Upper Silurian Fossils from Ballycar South, County of Clare, one mile and a half west of the village of Trough. *Journ. Geol. Soc. Dublin*, vol. viii., pp. 109-110.

1860.

GEOLOGICAL SURVEY OF IRELAND.—Sheets 143 and 144 of the Geological Map of Ireland.

IBID. Explanations to accompany Sheet 143 . . . illustrating part of the counties of Clare and Limerick.

IBID.—Explanations to accompany Sheet 144 . . . illustrating parts of the counties of Limerick, Tipperary, and Clare.

1861.

JUKES, J. BEETE.—On the Igneous Rocks interstratified with the Carboniferous Limestones of the Basin of Limerick. *Rep. Brit. Association for* 1860. Transactions of Sections, pp. 84-86.

GEOLOGICAL SURVEY OF IRELAND.—Explanation to accompany Sheet 153 . . . . . illustrating parts of the counties of Limerick and Cork. (P. 8.—W. H. Baily on fossils of Limerick District).

1862.

Ibid.—Explanations to accompany Sheet 133 . . . . . illustrating a portion of the County of Clare. (Pp. 9-20.—W. H. Baily on Silurian fossils, north of Limerick).

1869.

COX, ROBERT.—Letter on " *Megaceros Hibernicus*, the gigantic Irish Deer," describing a discovery at Schuile (? Skool, parish of Fedamore). *Geol. Magazine*, 1869, p. 523.

1873.

HULL, EDWARD.—On the Microscopic Structure of the Limerick Carboniferous Trap-rocks (Melaphyres). *Journ. R. Geol. Soc. Ireland*, vol iii., pp. 112-121.

KINAHAN, G. H.—The Carboniferous Ingenite Rocks of the County Limerick. *Ibid.*, pp. 149-150.

1874.

GEOLOGICAL SURVEY OF IRELAND.—Revised editions of Sheets 143 and 144 of the Geological Map of Ireland.

HULL, EDWARD.—The Volcanic History of Ireland (Anniversary Address, 1874.) *Journ. R. Geol. Soc. Ireland*, vol. iv. (1873-7), pp. 26, 27.

1878.

KINAHAN, G. H.—Manual of the Geology of Ireland. London. 8vo. Pp. 200-201, 255, 258, 260, &c.

1882.

KINAHAN, G. H. and MCHENRY, ALEXANDER.—A Handy Book on the reclamation of Waste Lands. Ireland. Dublin. 8vo. Pp. 68, 105.

1889.

KINAHAN, G. H.—Economic Geology of Ireland. *Journ. R. Geol. Soc. Ireland*, vol. viii. (1885-9), and separate publication. For references see index to the volume.

1892.

ANON.—Note on remains of *Cervus giganteus* at Cappagh Bog, Adare, Co. Limerick. *Proc. & Papers, R. Soc. Antiquaries of Ireland*, ser. 5, vol. i., p. 485.

1895.

McHenry, Alexander, and Watts, W. W.—Guide to the Collections of Rocks and Fossils belonging to the Geological Survey of Ireland. Pp. 87, 93-95.

1897.

Geikie, Archibald.—The Ancient Volcanoes of Great Britain. London, 8vo. Vol. i., p. 430; vol. ii., pp. 41-49.

1901.

Geological Survey of Ireland.—Revised Editions of Sheets 143 and 144 of the Geological Map of Ireland. (See 1860 and 1874.)

1905.

Hind, Wheelton.—Notes on the homotaxial equivalents of the beds which immediately succeed the Carboniferous Limestone in the west of Ireland. *Proc. R. Irish Acad.*, vol. xxv., Sect. b, pp. 93-116.

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