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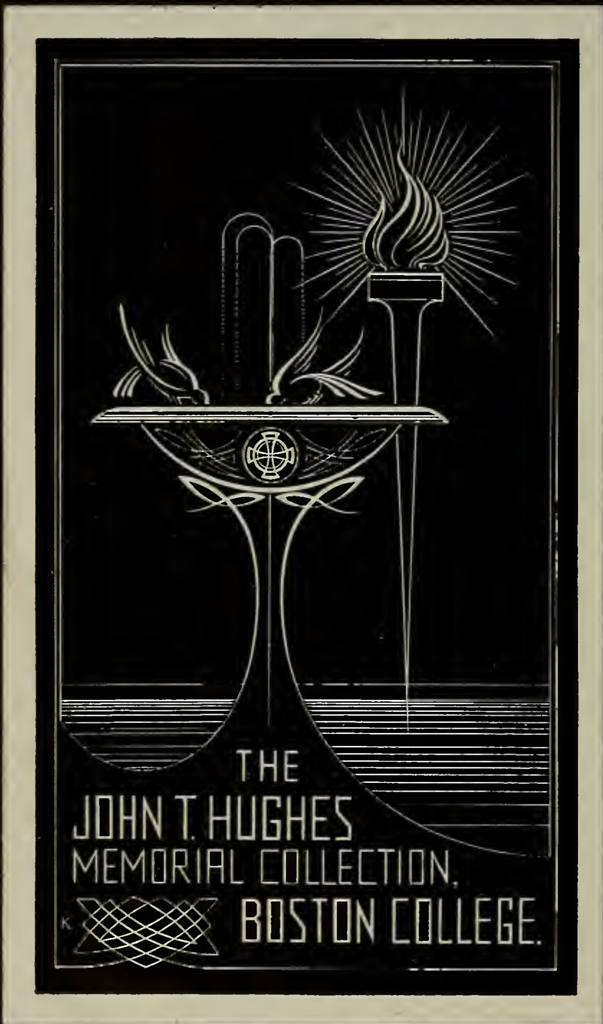
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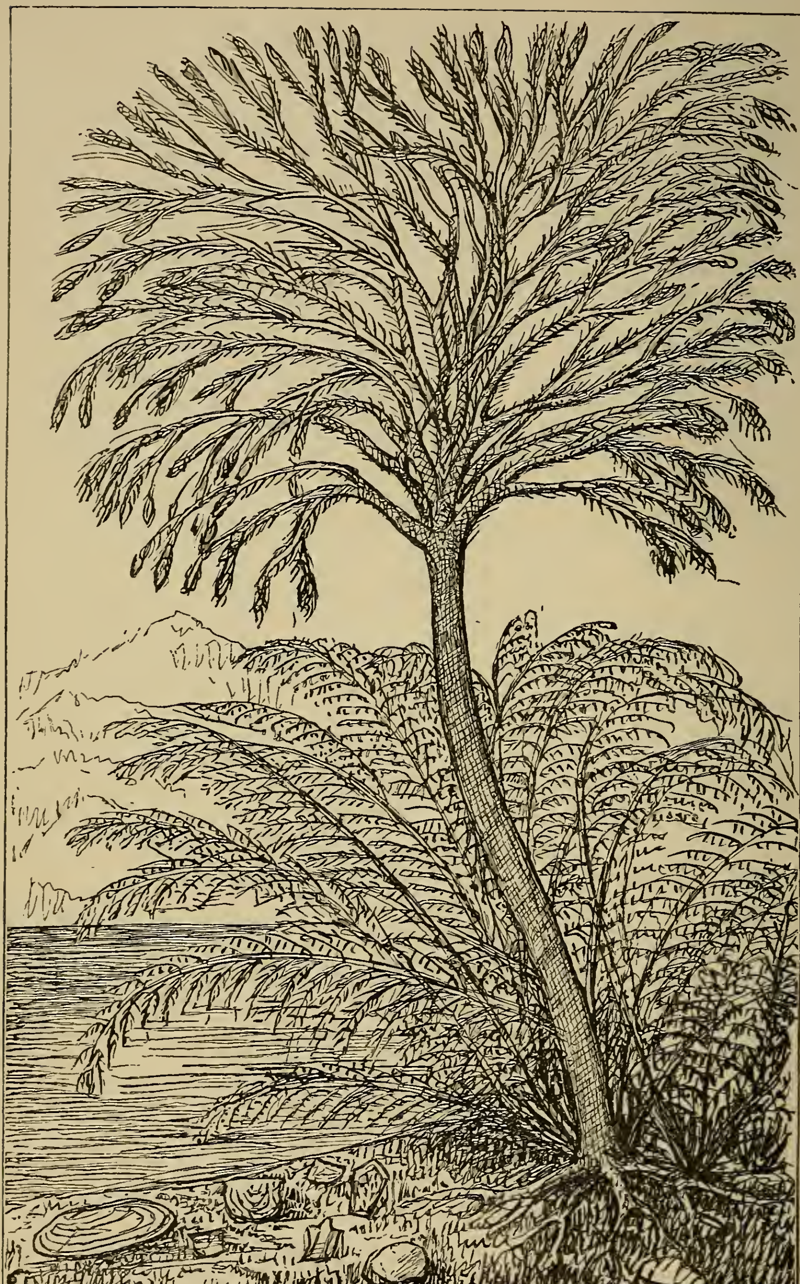
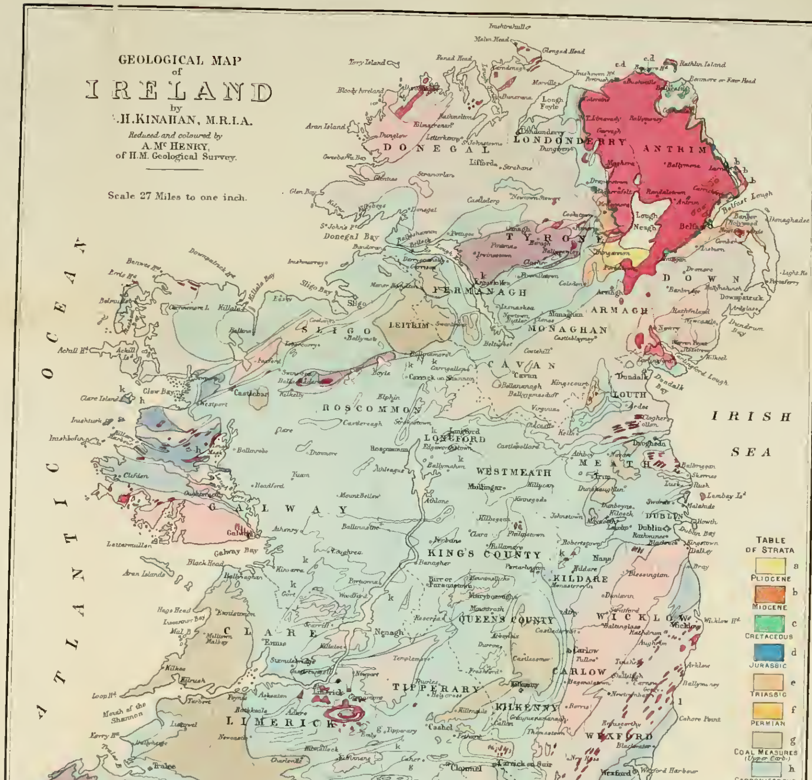


*W. H. Baily, del.*

Sagenaria Bailyana (restored), and other Fossils of Kiltorcan, County Kilkenny.

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July 1882

# MANUAL

OF THE

# GEOLOGY OF IRELAND


BY

G. HENRY KINAHAN, M.R.I.A., ETC.

OF H.M. GEOLOGICAL SURVEY


*WITH ILLUSTRATIONS AND MAP*

ARBOR SCIENTIÆ
ARBOR VITÆ




LONDON

C. KEGAN PAUL & CO., 1, PATERNOSTER SQUARE

1878

# Dedication.

DEAR SIR RICHARD GRIFFITH,

I CANNOT FULLY EXPRESS MY THANKS FOR YOUR KINDNESS IN ALLOWING ME TO DEDICATE THIS BOOK TO YOU, THE "FATHER OF IRISH GEOLOGY," FEELING, AS I DO, THAT IT IS DEFICIENT IN MANY RESPECTS, AND UNWORTHY THE HONOUR YOU HAVE CONFERRED UPON IT.

I AM,

DEAR SIR RICHARD,

YOURS MOST SINCERELY,

G. HENRY KINAHAN.

TO SIR R. J. GRIFFITH, BART.,

FITZWILLIAM PLACE,

DUBLIN.

[illegible]
July 1882

# PREFACE.

In his Explanation to his exhaustive list of the Irish Carboniferous Fossils, that able and veteran Irish Geologist, Sir Richard J. Griffith, Bart., states that it had always been his intention to publish a Geology of Ireland, but that his official duties pressed so heavily on him, that the time to accomplish the task was never at his disposal. Under these circumstances I have, therefore, been induced to attempt it.

I have not relied solely upon my own personal knowledge of the country, but have consulted all public and private records and papers relating to the Geology of Ireland to which I could get access.

First and most important in the list are the invaluable maps and writings of Sir R. J. Griffith. I would here allude to the personal obligations I am under to that gentleman, as, since I first knew him, nearly a quarter of a century ago, he has never refused an opportunity of enlightening me on the entangled and obscure points of Irish Geology, and of directing my attention to those points still to be worked out.

Next in importance are Jukes's maps and writings. Of these I have availed myself largely; whilst in regard to the Geology of the North of Ireland, Portlock's maps and publications have been extensively used and quoted.

Other public documents are the publications of the Geological Survey of Ireland, which include the maps and reports of my present colleagues, and those of my former colleagues, Doctor Oldham, Prof. Warington Smyth, and Messrs. Wyley, Wynne, Duffen, and the late Sir H. De la Beche, Messrs. Du Noyer, Willson, Foot, Warren, and W. B. Leonard.

The private books and other writings that have been consulted are too numerous to give in detail, but I may especially mention Weaver's excellent Memoirs, Sir R. Kane's "Industrial Resources of Ireland," and Mr. Ralph Tate's papers on the Rocks of Ulster.

I am personally indebted to Doctors King and Melville, of the Queen's College, Galway, with respect to the Geology of West Ireland; to my English colleagues, Messrs. H. B. Woodward and Rutley; to Messrs. Traill and Egan, who have also given valuable assistance in correcting the manuscripts and proofs; to my old friends and colleagues, Messrs. O'Kelly and Baily; the former would have been, a joint author with myself of this book, had not ill-health unfortunately deprived me of his assistance; while Mr. Baily has corrected the lists of species and prepared the plates of characteristic Irish fossils; to my colleague, Mr. A. McHenry, who reduced and prepared the maps and all the sketches, except those by Messrs. Baily and Wyley; to my old friend and former colleague and instructor, Mr. A. Wyley, late Geologist for the Cape Colony, for the copperplate of Plate V. and for the vignette on the cover of the book; but especially to the Rev. M. H. Close, President of the Royal Geological Society of Ireland, who has revised the manuscripts and proofs. I must not, however, commit my friend to all the conclusions put forward. We have worked at and amicably fought over many points in Irish geology, as to which we did not agree; and although Mr. Close has kindly done what I have stated, some of my opinions, in regard to the Physical Geology, he still strenuously opposes. There are many others also, whose names are hereafter mentioned, who have been most prompt in giving me information; to these, likewise, I now return my sincere thanks.

In the geological map, each tract of the metamorphosed sedimentary rocks is given the colour adopted for the Formation to which it belongs. There are points presented in this Manual which will probably meet with more or less opposition—namely, the including of the Old Red Sandstone in the Carboniferous rocks, the classing of Quartz-rock* (as distinguished from quartzite or quartz-schist) among the Eruptive rocks, and the chronological classification of the Granitic and other Eruptive rocks. These, however, are questions to which I have paid particular attention, and, after over twenty-five years' study and minute examination of the Irish rocks, I am forced to come to the conclusions now given.

I would also point out that there are a few tracts of obscure or complicated geology still to be worked out. One occurs in the NW. of Ulster, and includes the metamorphic rocks of Donegal and adjoining counties; these rocks are, possibly, of the same age as those of Galway, viz., Cambrian and Cambro-Silurian. Others are the district about Fintona, in Fermanagh and Tyrone,

* In the Counties of Dublin, Wicklow, and Wexford I have found quartz-rock in *unaltered* Cambrians, in the County of Wexford in *unaltered* Cambro-Silurians, in the County of Mayo in *unaltered* Silurians, and in the Counties of Galway and Clare in the Old Red Sandstone; and these facts alone ought to demonstrate that quartz-rock should not be included among the Metamorphic rocks, and that it is a distinct rock from quartzite or quartz-schist, the latter being a true Metamorphic rock.

also areas in Sligo and Roscommon near Loughs Gara and Key, and elsewhere, where the rocks, as suggested by Griffith, are probably equivalents of part of the "Dingle Beds." My attention was directed by Sir R. Griffith to six groups in Ireland of apparently somewhat similar age, namely: I.—Dingle Beds, Co. Kerry; II.—Glengariff Grits, Co. Cork; III.—Louisburgh, and IV.—Croaghmoyle Groups, Co. Mayo; V.—Ballaghaderreen and Lough Key Group, Counties of Sligo and Roscommon; and VI.—The Fintona and Slievemore Group, Counties of Fermanagh and Tyrone. Of these those near Louisburgh and Croaghmoyle are, I know, Silurian, and are coloured as such on the map. The Dingle Beds lie conformably on the fossiliferous Silurians, but are similar to the Glengariff Grits in which are found plants allied to Carboniferous types; it was these plants which caused Jukes to place the groups *temporarily* in the Old Red Sandstone; not giving them a definite position, until the similar rocks in Mayo, Sligo, Roscommon, Fermanagh, and Tyrone had been examined. The Ballaghaderreen and Lough Key rocks are very similar to those at Croaghmoyle, and Berdoe-Wilkinson suspects that the Ballaghaderreen rocks lie conformably on fossiliferous Silurians; and the Firoda and Slievemore rocks are very like those of the Ballaghaderreen and Louisburgh groups. As hereafter stated, I would suggest that the rocks in these tracts ought not to be included among the "Old Red Sandstone" (Lower Carboniferous), but should be placed as the uppermost group in the Silurians. Nevertheless, as I have not sufficiently examined them, they are, for the present, given a separate colour on the map, and are classed together as DINGLE BEDS.

In the "Handy Book of Rock Names," I gave reasons why I prefer Dana's termination of *yte* for *rock* names, as distinguished from names of *minerals*. Although I am still of the same opinion, yet, in deference to my publisher and others to whom I am indebted, I have used the old termination of *ite* in this book.

G. HENRY KINAHAN.

OVOCA, *September* 1*st*, 1877.

P.S. I, as well as my old colleagues on the Irish Geological Survey, have to regret the premature death of Doctor Thomas Oldham, at Rugby, July 17th, 1878. Oldham was an eminent pioneer in Irish geology. If his name is only once mentioned in this Manual, this is solely due to his official work, except the maps, having been published by Portlock and Jukes.

*August* 1*st*, 1878.

# CONTENTS.

PAGE

INTRODUCTION . . . . . . . . . . . 1

SECTION I.—SEDIMENTARY ROCKS.

CHAPTER I.

CAMBRIAN . . . . . . . . . . . . 11

CHAPTER II.

CAMBRO-SILURIAN . . . . . . . . . . 23

CHAPTER III.

SILURIAN . . . . . . . . . . . . 38

CHAPTER IV.

CARBONIFEROUS; CORK TYPE . . . . . . . . . 50

CHAPTER V.

" LOWER . . . . . . . . . . 63

CHAPTER VI.

" UPPER . . . . . . . . . . 95

## CHAPTER VII.

PAGE
Permian, Triassic, and Jurassic . . . . . . . . 130

## CHAPTER VIII.

Cretaceous . . . . . . . . . . 148

## CHAPTER IX.

Cainozoic . . . . . . . . . . . 156

# SECTION II.—METAMORPHIC AND ERUPTIVE ROCKS.

## CHAPTER X.

Metamorphic Action . . . . . . . . . 172

## CHAPTER XI.

Metamorphic Rocks . . . . . . . . . 182

## CHAPTER XII.

Eruptive Rocks . . . . . . . . . . 194

## CHAPTER XIII.

Chronological Classification of the Metamorphic and Eruptive Rocks . . . . . . . . . 213

# SECTION III.—SUPERFICIAL ACCUMULATIONS.

## CHAPTER XIV.

Drift . . . . . . . . . . . . 223

CHAPTER XV.

PAGE

Glaciation, Erratic Blocks, Raised Beaches, and Submerged Land and Forests . . . . . . . . . . 241

CHAPTER XVI.

Peat-Bogs and Pre-historic Remains . . . . . . . 267

CHAPTER XVII.

Soil; Post-Pliocene Mammalia . . . . . . . . 287

## SECTION IV.—PHYSICAL FEATURES.

CHAPTER XVIII.

Escarpments, Cliffs, Hills, and Cooms . . . . . . 299

CHAPTER XIX.

Valleys and Subterranean Rivers . . . . . . . 314

CHAPTER XX.

Bays, Lagoons, Lakes, and Islands . . . . . . . 328

## SECTION V.—ECONOMICAL PRODUCTS.

CHAPTER XXI.

Mines and Minerals . . . . . . . . . . 339

CHAPTER XXII.

Quarries, Mineral Manures, and Water Supply . . . . 374

## APPENDIX.

Glossary of Geological and Celtic Terms . . . . . 409

# EXPLANATIONS OF THE PLATES.

MAP OF IRELAND GEOLOGICALLY COLOURED.

PLATE I.—CHARACTERISTIC FOSSILS OF KILTORCAN, COUNTY KILKENNY . . . . . . . . *Frontispiece.*

Sagenaria Bailyana (*Schimper*)—restored,* the original over 20 feet high.

Palæopteris (Adiantites) Hibernicus—restored,* the original over 5 feet high.

Anodonta Jukesii—considerably reduced, originals 7 inches by 3 inches.

Fish remains, Coccosteus, &c.—considerably reduced.

PLATE II.—CAMBRO-SILURIAN AND SILURIAN FOSSILS. Irish forms. To face page . . . . . . . . . 23

Fig. 1. Palæasterina Kinahani (*Baily*)—natural size, Cambro-Silurian, Loftus acre, Bannow, County Wexford.

,, *2a-b.* Orthis Bailyana (*Davidson*) — natural size, Cambro-Silurian, Ballyborough, County Wexford.

,, *3a-b.* Strophomena Jukesii (*Davidson*)—natural size, Cambro-Silurian, Grangegeeth, County Meath.

,, 4. Holopea concinna—natural size, Cambro-Silurian, The Chair of Kildare

,, 5. Trochus multitorquatus—natural size, Silurian, Boocaun, County Galway.

,, *6a-b.* Helminthochiton Griffithii — natural size, Silurian, County Galway.

,, 7. Acidaspis Jamesii—natural size, Cambro-Silurian, Duncannon, County Waterford.

* These restorations were made specially for this work by Mr. Baily.

PLATE III.—LOWER CARBONIFEROUS FOSSILS. Irish forms. To face page . . . . . . . . . . 63

Fig. 1*a*. Palæchinus elegans — natural size, limestones, Hook, County Wexford.
,, 1*b*. ,, ,, Spine enlarged.
,, 2. Aviculopecten Sowerbyi, showing bands of colour—natural size, limestone, County Kildare.
,, 3. Pleurorhynchus Koninckii (*Baily*) — reduced one-third, Fenestella limestone, Rathkeale, County Limerick.
,, 4. Modiola Macadami—natural size, shales, Clogher, County Tyrone.
,, 5. Loxonema impendens—reduced one-third, Fenestella limestone, Rathkeale, County Limerick.
,, 6. Chiton Thomondiensis (*Baily*)—reduced one-third, Fenestella limestone, Rathkeale, County Limerick.

PLATE IV.—UPPER CARBONIFEROUS (Coal Measures) FOSSILS. Irish forms. To face page . . . . . . . . . 95

Fig. 1. Aviculopecten papyraceus—reduced one-third, Boulea, County Tipperary.
,, 2. Posidonomya Becheri—reduced one-third, Loughshinny, County Dublin.
,, 3. Posidonomya membranacea — reduced one-third, Balla, County Mayo.
,, 4. Myacites fabaformis (*Baily*)—natural size, Bilboa, Queen's County.
,, 5. Anthracosia Bilboensis (*Baily*) — natural size, Bilboa, Queen's County.
,, 6. Lunulacardium Footii (*Baily*) — natural size, Rosscliff, County Clare.
,, 7. Macrocheilus inflatus (*Baily*)—natural size, Foynes Island, County Limerick.
,, 8. Loxonema minutissima (*Baily*)—natural size, Foynes Island County Limerick.
,, 9. Orthoceras minimum (*Baily*)—natural size, Foynes Island County Limerick.
,, 10*a*. Belinurus Regina (*Baily*)—natural size, Bilboa, Queen's County.
,, 10*b*. Belinurus arcuatus (*Baily*)—natural size, Bilboa, Queen's County.
,, 11. Keraterpeton Galvani (*Huxley*)—reduced one-third, Jarrow Colliery, Queen's County.

Plate V.—Sand-Duns (Æolian) St. Helens, County Wexford. *A. Wyley.* To face page . . . . . . . 240

Plate VI.—To face page . . . . . . . . . 269

Fig. 1. Section of bog with Oak and Deal Corkers.
,, 2. Stone-crannog (*Kinahan*)—Bola Lake, County Galway.
,, 3. Wicker wall and floors (*Foot*)—Lough Rea crannog.
,, 4. Section of a crannog (after *Wilde*).

Plate VII.—To face page . . . . . . . . . 278

Fig. 1. Restored Crannog. Showing section.
,, 2. Cashel Hill, County Galway (*G. H. Kinahan*).
,, 3. Twelve Pins, County Galway (*A. McHenry*).

Plate VIII.—To face page . . . . . . . . . 300

Fig. 1. Knock-a-dober, County Kerry (*Harriet A. Kinahan*).
,, 2. Burren Hills, County Clare (*Miss Atkinson*).
,, 3. Cooms, Formnamore tableland, County Mayo (*G. H. Kinahan*).

# LIST OF WOODCUTS.

PAGE

*Vignette on cover*—Fastnet Rock. *A. Wyley.*

1. Oldhamia antiqua. *Dr. J. R. Kinahan* . . . . . . 12

2. ,, radiata. *Dr. J. R. Kinahan* . . . . . . 14

3. Map (*a*) and section (*b*) of the entangled Cambrians and Cambro-Silurians, Bannow, County Wexford . . . . . . . 18-19

4. Diagrammatic section of the Cork and Dingle rocks, showing the unconformability in the latter . . . . . . . . 54

5. Diagram illustrating the changes from the Shore-beds into the Carboniferous Limestone . . . . . . . . 65

6. Benbulben, Limestone hills, County Sligo. *A. B. Wynne* . . 91

7. Diagram illustrating the formation of the Granitic and other Eruptive rocks . . . . . . . . . . 176

8. Map of "Baked rocks" around vents of eruption, Owenduff, County Wexford . . . . . . . . . . . 184

9. Map of isolated patches of Hornstone and Felstone, Tigroney (Ovoca), County Wicklow . . . . . . . . 185

10. Slievemore (quartzite hill), Achill, County Mayo. *A. McHenry* . 211

11. Lugnaquillia and adjoining mountains, County Wicklow. *G. V. Du Noyer* . . . . . . . . . . . 229

12. Diagrammatic section of the "Raised beaches," Valley of the Barrow . . . . . . . . . . . 238

13. Cloghcurril, County Galway. *G. H. Kinahan* . . . . 248

14. Ballynakill Harbour, with Terraces, County Galway. *G. H. Kinahan* . . . . . . . . . . . 255

15. Lugs and Terraces at Leenaun, Killary Harbour, County Galway. *G. H. Kinahan* . . . . . . . . . 257

16. Terraces in Limestone, Burren, County Clare. *A. B. Wynne* . 260

PAGE

17. Pre-historic road, Duncan's Flow-bog, County Antrim . . . . 274
18. ,, ,, ,, ,, . . . . . 275
19. ,, ,, ,, ,, . . . . . 275
20. Gap of Dunloe, Co. Kerry, looking north. *Harriet A. Kinahan* . 305
21. Iveragh Mountains, County Kerry, from Ballinskelligs. *Harriet A. Kinahan* . . . . . . . . . . . . . . 307
22. Aughrim River Valley, County Wicklow. *Harriet A. Kinahan* . 318
23. Map showing the Fault-rock in Kilmacrea Pass, County Wicklow . 319
24. Skelligs, County Kerry. *Harriet A. Kinahan* . . . . . 336
25. Diagram showing the section of a "Placer mine," County Wicklow. 343
26. Gold Washing, Gold Mine Valley, County Wicklow. *A. McHenry* 345

# MANUAL

OF THE

# GEOLOGY OF IRELAND.

## INTRODUCTION.

THE general principles of geology are explained in the numerous treatises on that science; it is unnecessary to repeat them here. In those or kindred books will be also found the different theories put forward from time to time as to the genesis of the earth, and the various changes that have taken place therein, until it reached its present condition. Such subjects, therefore, need not be entered into here, and we may confine ourselves to giving in this Introduction (1) a short account of the physical features of Ireland, (2) the classification of the rocks which is adopted in this Manual, and (3) an epitome of the geological history of our Island.

The central parts of Ireland consist of a low undulating plain, ramifications from which extend in different directions. More than one-third of the country is less than 250 feet above the present sea level, and if the sea were to rise 500 feet most of it would be submerged ; two archipelagos only remaining, one in Ulster with West Connaught, and the other in Munster with South Leinster, while Central Ireland would be an all but uninterrupted expanse of sea.

The central plain may be roughly described as a wide valley running E. and W., separating the northern from the southern hilly district. Most of the valleys between the mountain masses are characterized by their depth and narrowness, also by being arranged in systems running nearly north and south, or transversely to that direction. These systems combine to divide the country into areas, each of which have sub-systems of nearly parallel valleys ; but in each tract, whether large or small, all the principal valleys and axes of the hills have similar general directions, which, in most cases, are different from those in the adjoining country. In some one area there may be two different systems, the second system being transverse to the first, and forming deep narrow gorges, or *maums*, across the axes of the hills ; these gorges may be in some places so deep that the drainage of one valley is suddenly diverted out of it, through a line of hills, into another valley ; this is well exemplified in the west portion of the County Cork. These deep valleys have also a considerable effect on the appearance of the hills ; for, although none of the Irish hills are of great altitude, Carrane-Tual, or Mahony's Reek, County Kerry, the premier hill, being only 3,414 feet in height, yet, when they rise steeply from one of these narrow valleys, they have the full effect of their height, and are most imposing. Hereafter, the different groups of hills will be more specially mentioned.

The continuations of some of the valleys, especially towards the westward, are submerged in the sea. This causes the coast-line to be indented by long, narrow bays, as those in West Cork; or by fiords like Killary Harbour, between the counties of Mayo and Galway, or the triple-branched fiord that forms the estuaries of the Suir, the Nore, and the Barrow.

On account of these deep valleys, the Irish hills rarely form continuous masses of high ground; the group that partakes most of this character is that of the Dublin and Wicklow mountains. The mountain groups of Kerry and Cork are so traversed by valleys that the peaks are more or less isolated; the longitudinal and some of the transverse valleys are generally very deep and narrow, while none of the numerous maums or connecting gaps are excessively high.

It might have been expected that more lakes than those which actually occur would have been found in the low lands. Many old lake basins, however, are probably filled up by the peat so general in every hollow and low place. Of those that exist some are very extensive, like Loughs Neagh and Corrib; others are most picturesque, like those of Killarney and the lakes in the cooms among the Kerry hills; in some districts they are very numerous, as in Connemara; while on the coast of Wexford and elsewhere there are some lagoons.

The Irish rivers are remarkable for the absence of deltas at their *invers*, or mouths. All the large rivers deposit the detritus brought down by them principally in the flats through which they flow, and carry only a small portion into their estuaries; as will be mentioned hereafter, in the descriptions of the rivers and their valleys.

All classifications of the rocks must be more or less arbitrary, there being no hard lines in Nature, every rock in some way graduating into others; still some classification is indispensable in treating of them. Various classifications have been proposed by different authorities, and of these this threefold division seems to be best; namely, SEDIMENTARY, ERUPTIVE, and METAMORPHIC Rocks.

The Sedimentary rocks form two sub-classes: AQUEOUS, or those deposited in water; and METEORIC, or those accumulated on land. The Sedimentary rocks may also be classified according to their method of formation; as they may be *mechanically*, *chemically*, or *organically* formed.

The Eruptive rocks may be GRANITIC or CATOGENE; that is, rocks formed beneath the surface of the earth at greater or less depths; and ANOGENE, or rocks formed on or close to the surface of the Earth.* These two classes are divided into groups and sub-groups.

The Metamorphic rocks were originally Sedimentary and Eruptive rocks, which were subsequently altered by heat, pressure, and chemical action. Three classes of metamorphism can be distinguished by their effects. The *first* is regional, or extends over large areas. It seems to be due to intensely heated water or steam, which, as it were, stews the rocks; from this it may be called METAPEPSIS. The *second* is very local, and its effects are usually found immediately adjoining intruded masses of rocks, or in the vicinity of vents of vulcanicity. When typical, it produces in the rocks the appearance of having been baked, from which it may be called PAROPTESIS. The *third* is also local, and is due to the introduction and action of chemical substances from without; it has been called METHYLOSIS.

* These two classes are also called, though not very correctly, *Hypogene* and *Hypergene*.

The geological grouping here adopted is set forth in the following table :—

TABLE OF GEOLOGICAL SYSTEMS.

| | *Periods.* | *Sub-Periods.* |
|---|---|---|
| | | Recent. |
| Neozoic (*Forbes*) | Tertiary, or Cainozoic (*Phillips*) | Pliocene (*Lyell*). |
| | | Miocene ” |
| | | Eocene ” |
| | Secondary, or Mesozoic (*Phillips*) | Cretaceous (*Fitton*). |
| | | Jurassic. |
| | | Triassic (*Brown*). |
| | | Permian (*Murchison*). |
| | Primary, or Palæozoic (*Phillips*) | Carboniferous (*Conybeare*). |
| | | Silurian (*Murchison*). |
| | | Cambro-Silurian (*Phillips*). |
| | | Cambrian (*Sedgwick*). |
| | | Laurentian (*Logan*). |

Forbes would make only two Periods ; and, probably, such a division is more correct than the triple division usually adopted. The proper position of the Permian is disputed. Some authorities relegate it to the Mesozoic, others to the Palæozoic period. Some, indeed, of the latter go so far as to say it is part of the Carboniferous formation. Some of the geologists, to whose aid I am indebted, consider that I ought to give more prominence to the " Old Red Sandstone." However, as is described hereafter, it appears to me that in Ireland no separate formation intervenes between the Silurian and the Carboniferous. Two distinct groups of rocks have been called " Old Red Sandstone." But the older (Dingle and Glengariff beds, Counties Kerry and Cork ; Louisburg beds, County Mayo, and the older rocks of the hills between Pomeroy and Lough Erne, Counties Tyrone and Fermanagh) really belongs to the upper part of the Silurian formation; while the newer rocks so called, not only graduate into the Carboniferous rocks proper, but occur with them on different geological horizons.

A brief summary of the geological history of our island is as follows:—The oldest known rocks are of Cambrian age. These, in the SE. (Wexford, Wicklow, and Dublin), were uplifted, denuded, and in part metamorphosed prior to the Cambro-Silurian rocks being deposited on them. In West Ireland (Mayo and Galway), however, there is a continuous sequence from the Cambrian into the Cambro-Silurian rocks. There are records in the SE. of two periods of vulcanicity during the accumulation of the Cambrian rocks, and prior to the deposition of the Cambro-Silurian rocks; the first period being when the interbedded eruptive rocks were formed, and the second when the rocks were metamorphosed and in part changed into granite.

Next in order to the Cambrians come the Cambro-Silurians. These, again, were uplifted, metamorphosed, and denuded prior to the Silurian age; there being everywhere in Ireland a marked break between the rocks of these different formations. Here also there is evidence of two periods of vulcanicity; one, that of the pouring out of the interbedded eruptive rocks; and the other, the time of the metamorphism of the Cambro-Silurian rocks and the intrusions of the masses of granite.*

The next rocks in an ascending order are the Silurians. These, in the west of the County Cork, have no defined upper boundary, but form part of a continuous sequence, which extends up through the Lower Carboniferous (Old

* Some of the interbedded eruptive rocks of West Galway probably belong to an additional period of vulcanicity, between the Cambrian and the Cambro-Silurian ages.

Red Sandstone) into the Upper Carboniferous rocks (Coal Measures).* In Kerry, Galway, and Mayo, however, the Silurians were upturned and denuded prior to the Lower Carboniferous rocks being deposited on them. In the Silurian rocks there seems to be evidence of only one period of vulcanicity, during which the interbedded masses of igneous rocks and tuffs were ejected and their associated granites formed.

During the Carboniferous period very different conditions seem to have obtained at one and the same time in different places ; as otherwise the co-existence of the arenaceous and argillaceous accumulations in the SW., and the calcareous accumulations elsewhere, cannot be accounted for. But subsequently, the conditions seem to have been nearly uniform everywhere while the Coal Measures were accumulating, or at least that portion of them of which we have remains. In the Carboniferous rocks we have records of two periods of vulcanicity. During the first were formed sheets of igneous rock in the lower beds (Old Red Sandstone) of the Lower Carboniferous. During the second, the action appears to have been intermittent, as eruptive rocks occur in different places between the lower beds of the Lower Carboniferous and the basal shales of the Coal Measures.

After the Carboniferous period there is generally, in Ireland, a vast gap in the history of the rocks, and, except in the province of Ulster, there are no pages of that history to which we can refer. That the Carboniferous rocks were contorted and extensively denuded prior to the Triassic time

* Griffith was the first who worked out the Cork rocks. Jukes, in the Geological Survey maps, mapped Griffith's Silurian as "Glengariff or Dingle beds," and left it an open question as to whether they should be called Silurian or Old Red Sandstone.

is certain; as the Trias of Ulster lies on contorted and greatly denuded Carboniferous rocks. There are in Ulster rocks that are classed as Permian. Some of these rocks are conformable to the Carboniferous rocks and contain similar fossils; others, however, have Permian fossils; but these seem to be at the base of the Triassic group.

The Secondary and Tertiary rocks of Ulster thin out westward and southward. That these rocks once far exceeded their present limits, seems to be suggested by the large outlier of Trias found as far south as the latitude of Dundalk Bay. The Triassic rocks did not undergo much disturbance or plication prior to the deposition of the Jurassic; indeed, towards the north-west and eastward, one group seems to graduate into the other. There is the record of one period of vulcanicity during the deposition of the Triassic rocks, as interstratified beds of igneous rock occur among them.

The Jurassic rocks were probably extensively denuded prior to the Cretaceous period, as only small isolated patches of them are now found.

The Cretaceous rocks were denuded prior to the deposition of the Cainozoic rocks upon them; as in most places, between them and the overlying rocks, there is a bed of shingle or gravel, made up of chalk flints.

The Cainozoic period has left its traces in Ireland, in the shape of products of vulcanicity; great fissure eruptions succeeded one another at short intervals, pouring out great sheets of molten matter. At times, however, there seem to have been intervals of greater or less extent, during which, as pointed out by Jukes and Du Noyer, lacustrine accumulations were formed in limited areas. Subsequently great displacement and denudation took place, which is proved by the isolated outliers separated from the main mass by deep and wide valleys.

The next undoubted stage in the geological history was that when the country was covered by an Ice-sheet; after which there were local systems of glaciers in some of the mountain groups, and the sea covered the low country. Eventually the ice gradually disappeared, the sea retreated, and the present island was formed.

The descriptions are divided into five sections. In the first are described the Sedimentary rocks; in the second, the Eruptive and Metamorphic rocks; in the third, the Drifts and other superficial accumulations; in the fourth, the physical features and the relations of the rocks to the form of the ground; in the fifth, the Economical products of the country and the Water Supply; while in the Appendix, is given a glossary of Geological and Celtic terms used in the descriptions.

# SECTION I.—SEDIMENTARY ROCKS.

## PALÆOZOIC.

## CHAPTER I.

### CAMBRIAN (Sedgwick).

LOWER SILURIAN (Murchison).

ROCKS older than the Cambrian formation are not known in Ireland; but Jukes suggested that some of the highly metamorphosed rocks of the north of Ireland might possibly be Pre-Cambrian.

No attempt has been made to divide the Irish Cambrians into groups. In eastern Ireland it does not appear possible to do so; while in western Ireland, as the rocks are metamorphosed and all the fossil evidence destroyed, any classification would be unsatisfactory.

Rocks evidently belonging to the Cambrian formation occur in Dublin, Wicklow, and Wexford. They probably belong to the Lower Cambrians of Sedgwick, as some of the fossils of the Longmynd group are found in them; while in no case have they yielded Upper Cambrian fossils.

### HOWTH GROUP.

On the south side of the Howth promontory, the rocks are all more or less metamorphosed.* They are prin-

* The Metamorphic rocks are fully described in Section II. chapters x., xi., and xii.

cipally argillites (clay-schist), and incipient quartzites (quartz-schist) ; but on the north side of the promontory they are unaltered, and the late J. R. Kinahan, M.D., found at Puck's rocks, on the north coast, in greenish shales, *Old-*

FIG. 1.—Oldhamia antiqua (Dr. Kinahan, Trans. R.I.A.).

*hamia antiqua ;* this fossil, however, occurs so sparingly, that it is only to be obtained by diligent search.

In this area there are intrusions of quartz-rock—those on the north being unaltered ; while those associated with the schist, in the southern part of the promontory, have an incipient foliation developed in them. Wyley, on his maps, has called attention to the great difference that may be observed here between the *quartzites* produced by the metamorphism of the arenaceous rocks and the altered *quartz-rocks.* The difference is important from an economical point of view ; as the quartz-rocks, altered and unaltered, are eminently water-bearing rocks, while the quartzites produced by the metamorphism of the grits and sandstones are hard non-water-bearing rocks. It is from the quartz-rocks that the principal portion of the water will be procured, if, as has been proposed, the neighbouring hamlet of Baldoyle should obtain its water from the Hill of Howth.

## Bray Head Group.

These rocks are best exposed in the hill of Bray Head; but they also spread westward and southward over an area which, according to Jukes, extends along the coast to Killoughter, a few miles north of the town of Wicklow, and from thence south-westward to the valley of the Avonmore, forming an irregular triangle. Wyley, however, believed them to extend much farther SW., his boundary reaching the valley of the Ow river, NW. of the village of Aughrim.

In the north part of Bray Head, the rocks are principally purplish, red, and green shales, slates, and grits; some of the latter being massive and very hard, especially those through which the new tunnel for the Dublin and Wexford Railway was excavated. Southward of this, however, the strata are thin-bedded shales and grits alternating.

Fossils are found in many of the shale beds; but the species are few in number. Dr. Kinahan records *Oldhamia antiqua* and *radiata* (figs. 1 and 2); these he considered to be Zoophytes allied to Sertularia; but other highly competent judges think they are probably polyzoan. He mentioned also annelid tracks and burrows, *Histioderma Hibernicum*, *Arenicolites didymus* and *sparsus*, and *Haughtonia pœcila*; he also figures tracks which he believed to be molluscan.

In the section exhibited in the Bray Head sea cliff, there is apparently a great thickness of the rocks displayed; the beds, however, are in some places inverted, and the section is made up of a number of sharp synclinal and anticlinal curves; so that the real thickness of the rocks is much less than what it might appear to be at first sight from the section; Jukes and Du Noyer estimated their thickness to be between 3,000 and 4,000 feet.

Associated with the Cambrian rocks of this group at Bray Head, the Great and Little Sugar Loaves, Carrickgollogan Hill, and elsewhere, there are great reefs and protrusions of quartz-rock. These have been shown, by the late Mr. John Kelly, to be intrusive, or else to have

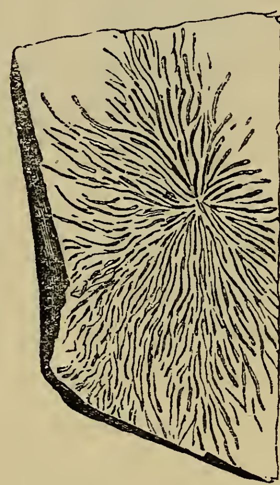


Fig. 2.—Oldhamia radiata (Dr. Kinahan, Trans. R.I.A.).

been produced under circumstances different from those under which the associated rocks were formed; the nature and probable origin of quartz-rock will be considered in Chapter XII., Section II., among the other Eruptive rocks.

The actual junction of the Cambrian rocks with the Cambro-Silurians is not anywhere seen. In the Dargle valley, at the confluence of the Cookstown with the Dargle rivers, black Cambro-Silurian shales, dipping N. at 40°, are found close to the Cambrians; but the actual contact of the two is not visible.

At Greystones, south of Bray Head, the rocks are very similar to those near Bray, and contain similar fossils. Farther SW., between Newtownmountkennedy and the Roundwood reservoir, a hard massive quartzose grit, similar to that at Bray Head, was passed through when making the tunnel for the Vartry Waterworks. Some miles south-east of Roundwood, in the conspicuous outlier forming Carrick Mountain, there is a remarkable assemblage of massive cakes of quartz-rock. They are associated with fossiliferous purple, green, and grey shales. In these occur *Oldhamia radiata*, *O. antiqua*, and *O. discreta*, the latter being an intermediate form.* The Cambrian rocks in Carrick Mountain, and in the country to the north and north-west, seem in general to have been forced up into their present positions by faults; in one place, however, on the north slope of Moneystown Hill, the Cambro-Silurian rocks can be seen lying unconformably on the Cambrians.

As previously mentioned, Jukes ends off the Cambrian rocks south of Togher or Roundwood; while Wyley would have made them reach to the valley of the Ow river. The rocks east of Jukes's boundary are unaltered, while west of it all are metamorphosed. The latter consist, for the most part, of larger or smaller masses of altered quartz-rock associated with schists, which are very different from the black schists also associated with them. The first are possibly altered Cambrian rocks, while the others are altered Cambro-Silurians. Wyley, therefore, may be partly correct; for here, as at Carrick Mountain, masses of the Cambrians may possibly have been forced in amongst the Cambro-Silurians, while all were subsequently metamorphosed together. It is now, however, extremely difficult to separate them.

* J. R. Kinahan, M.D., *Trans. Roy. Irish Academy*, vol. xxiii. p. 547.

## Wexford Group.

These rocks appear to lie more regularly than the others in east Ireland. They are partially metamorphosed, but not to such an extent as to obliterate their original general characters. An estimate has been made of their thickness from the sections exposed in the valley of the Slaney, in the Forth Mountain, and in the country to the south near Carnsore.

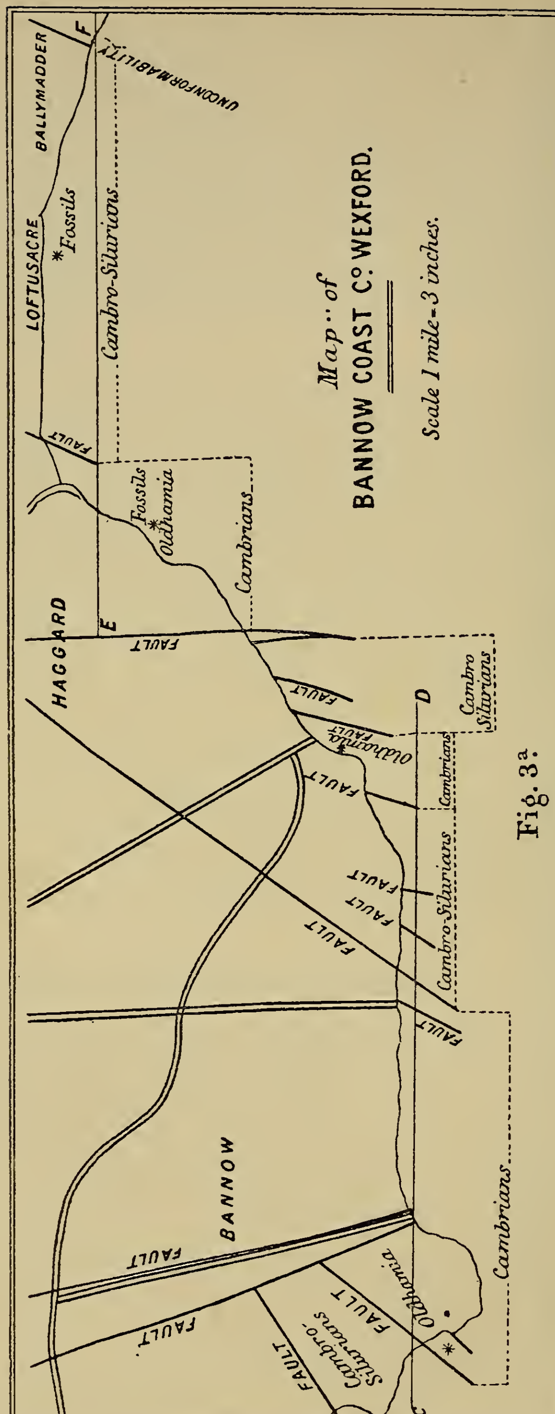
| | | | | |
|---|---|---|---|---|
| 4 | Railway section Slaney valley ... | ................................ | about | 7,000 |
| 3 | Forth Mountain and county SW. of Wexford | Schists, with many associated masses of altered quartz-rock | „ | 4,000 |
| 2 | Rocks covered by a basin of Carboniferous rocks........................................ | | „ | 1,00C |
| 1 | Schist graduating through gneiss into granite | | „ | 2,000 |
| | | | | 14,000 |

These rocks occupy an irregular tract. They are met with on the coast, a few miles north of Cahore Point, and extend southward nearly to Wexford Harbour and SW. to Bannow Bay. On the SE. they are covered by a long basin of Carboniferous rocks; but to the SE. of that again they reappear in the Carnsore district. In the country about Greenore and Carnsore they are very much altered, being changed at Carnsore and in the Saltee Islands into granitic rocks; but they graduate northward through gneiss into schist (the latter belonging to the sub-metamorphic rocks) and thence into unaltered rocks. Associated with the metamorphosed sedimentary rocks, in the country between Greenore and Carnsore, are interbedded and intrusive beds or masses of eruptive rocks and of tuffs that were altered along with them.

Northward and westward of Wexford the Cambrians are more or less altered but at the north end of this tract, near Cahore, as also along the NW. margin and to the SW. at Bannow, the rocks are unaltered. In the altered rocks of the Forth Mountain there are cakes of quartz-rock, very similar to those previously mentioned as seen in Carrick Mountain ; except that here the metamorphic action has developed foliation in them, changing them into quartzite.

To the north of Cahore Point, near Pollshone Harbour, there is a small outlying exposure of Cambrian rocks, and in these are found burrows, like those of *Arenicolites*, and tracks. This outlier, as seen in the sea cliff, is bounded on one side by a fault ; while, on the other, black Cambro-Silurian shales are deposited against the Cambrian rocks. Farther south, at Rooney's Rocks, in a thin bed of red shale, close to an intruded mass of quartz rock, *Oldhamia antiqua* is to be found. A few portions of the same fossil were found in a green, arenaceous shale at Cahore Point, also tracks and burrows ; while in red shale, at the bathing-place to the north of Cahore House, are markings of *Oldhamia radiata.*

To the SW., on the coast south-east of Bannow, fossils are very numerous ; *Oldhamia antiqua* and *discreta* (?) being abundant in some beds, while *O. radiata* also occurs. With these were found burrows of *Arenicolites*, two or three other kind of tracks, and markings that look very like *Graptolites*. Here the Cambrian and Cambro-Silurian rocks are very much entangled together (Figs. 3*a* and 3*b*) ; while in both there are intrusions of quartz-rock, some of these being evidently contemporaneous with the deposition of the Cambrian rocks, while others are newer than the Cambro-Silurians. It is remarkable that while the


BALLYMADDER
F
UNCONFORMABILITY
LOFTUSACRE
*Fossils
Cambro-Silurians
FAULT
Fossils
Oldhamia
Cambrians
Map of
BANNOW COAST Co. WEXFORD.
Scale 1 mile - 3 inches.
E
HAGGARD
FAULT
FAULT
D
Cambro Silurians
FAULT
Oldhamia
Cambrians
FAULT
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FAULT
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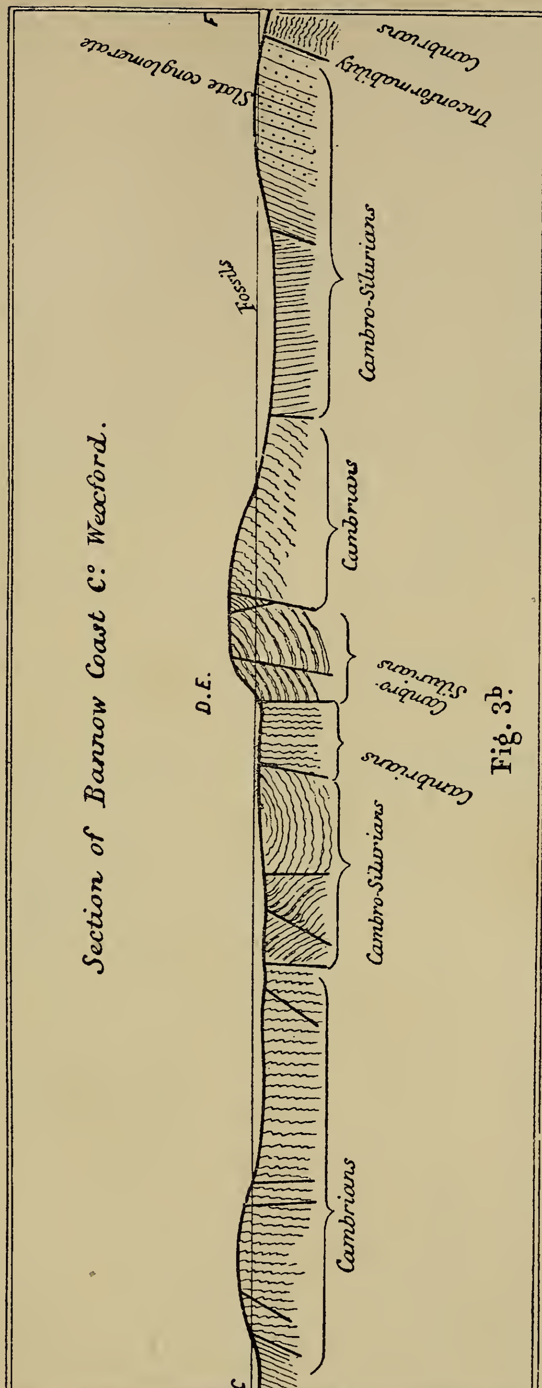
Fig. 3a.




Section of Bannow Coast Co. Wexford.

Fig. 3b.

Cambrians to the east, under the Cambro-Silurian conglomerate, are metamorphic, the Cambrians entangled with these are unaltered.

In the mountainous country eastward of Slievenaman, County Tipperary, as also in the Galtymore range, Counties Cork and Tipperary, there are green and purple rocks whose age is uncertain. On the Geological Survey maps they have been coloured as Cambro-Silurian, as no fossils were found to determine their age; but it is possible, if not probable, that they belong to the Cambrian formation. They will be described hereafter among the Cambro-Silurian rocks, but they are very similar to some of the Wexford Cambrians.

## West Galway Group.

In West Galway and Mayo, between Clew and Galway bays, there is a vast thickness of submetamorphic and metamorphic rocks lying in a great anticlinal curve. The lower groups of these were supposed by Griffith and King (D. Sc., of the Queen's College, Galway) to belong to the Cambrian formation, and subsequent research confirms this opinion. These rocks, which evidently constitute a regular sequence, are at the least 11,000 feet thick; and as the upper 2,000 or 3,000 feet are known to be of Llandeilo, or newer, age, it appears probable that the lower groups are Upper Cambrian; one formation running conformably into the other in this part of Ireland. The rocks are cut up, shifted, and displaced by innumerable faults; nevertheless, a probably approximate estimate of their thickness can be formed, as the rocks are so extensively exposed to view in that district. The following are the estimated thicknesses of the rocks to the north and south of the anticlinal curve.

| | North Side. | | South Side. | |
|---|---|---|---|---|
| 12 Croagh Patrick beds, with inliers of serpentine, steatite, limestone, and hornblende-rock | over 1,000 | Cambro-Silurians | over 1,500 | Lettermullen beds, with inliers of limestone, hornblende-rock, &c |
| 11 These in part are unaltered (Doolough beds), and contain Llandeilo fossils | „ 1,000 | | „ 1,000 | Hornblendite and talcite series |
| 10 Great micalite series, containing, above, inliers of hornblende-rock, ophite, steatite, &c. | „ 2,500 | Cambrians | „ 3,000 | |
| 9 Lettermore quartzite series | „ 30 | | „ 200 | |
| 8 Kylemore series, containing many limestones | „ 1,600 | | „ 1,800 | Ballynahinch limestone series |
| 7 Middle micalite series | „ 300 | | „ 1,000 | |
| 6 Great quartzite series | „ 1,000 | | „ 600 | |
| 5 Small micalite series | „ 600 | | „ 100 | |
| 4 Ophiolite and dolomite series | „ 300 | | „ 200 | |
| 3 Quartzitic micalite series | „ 1,000 | | „ 1,000 | |
| 2 Streamstone limestone series | „ 400 | | „ 400 | |
| 1 Lower micalite series | „ 100 | | „ 100 | |

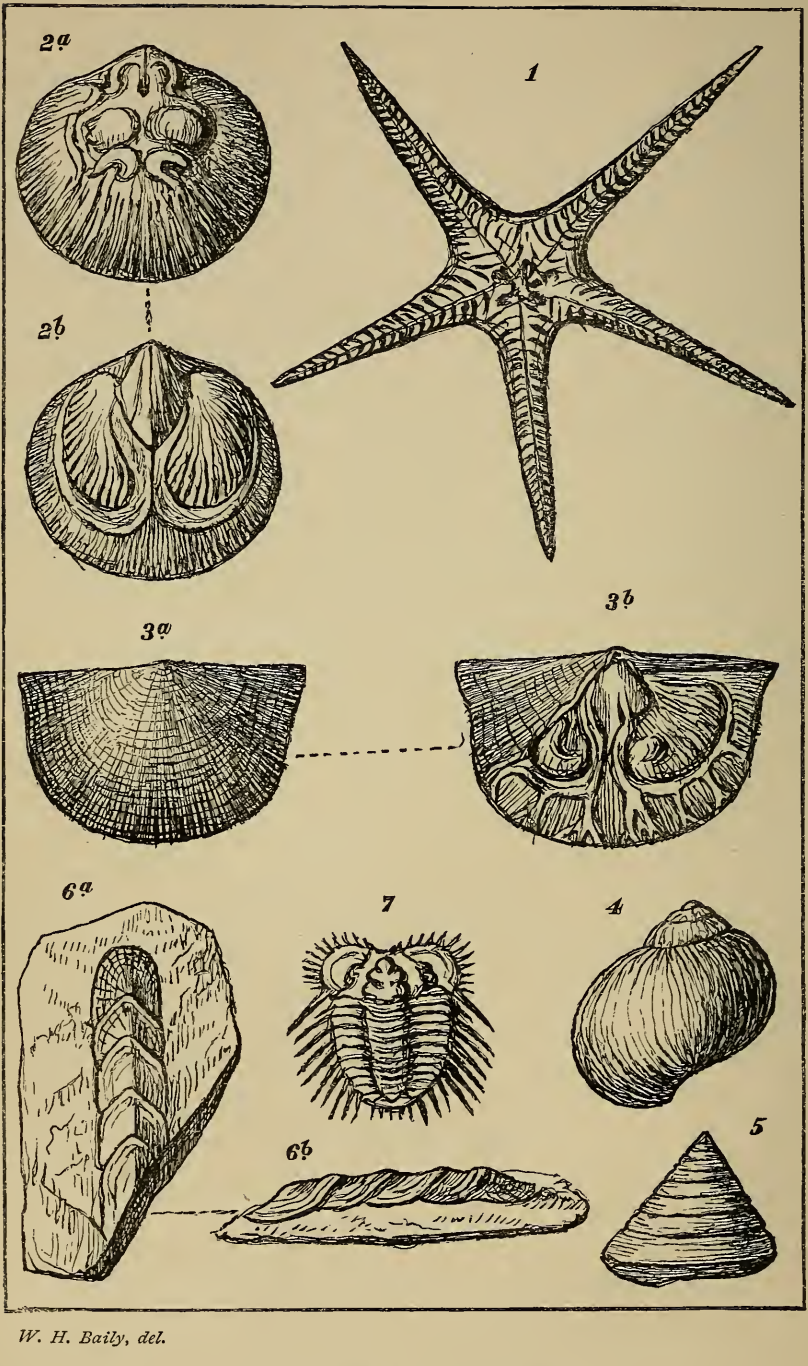
Groups 11 and 12 are evidently of Cambro-Silurian age, while possibly group 10, or part of it, may belong to that formation. The other groups must necessarily belong to the Cambrian, if we follow the classification adopted by Ramsay and other English geologists.

## Supposed Cambrians.

To the east of Granard, County Longford, there are red and green grits, shales, and slates, that were considered by Foot to be of Cambrian age, and to be overlaid uncomformably by the Cambro-Silurian rocks. However, as the unconformability could not be proved, and as no fossils were found in them, Jukes included them provisionally in the Cambro-Silurians.

In the north of the County of Down, to the south of Belfast Lough, there are green and purple rocks that were mapped by Du Noyer as Cambrians; Jukes, however, considered them to belong to the Cambro-Silurians.

In concluding this chapter, it should be mentioned that in places it is difficult to separate the Cambrian and Cambro-Silurian rocks. Both are often metamorphosed, while some of the thin-bedded green and grey grits and shales of both formations are very similar. In the Cambrians, however, green and purple rocks predominate, while black rocks rarely are found. In the Cambro-Silurians there is usually a large proportion of black and dark coloured shales and other rocks, especially in the lowest group, which contain Llandeilo fossils, and the latter are usually the rocks that lie directly on the Cambrians in SE. Ireland, but in places, higher rocks are brought down against them by faults or dislocations.




*W. H. Baily, del.*

Cambro-Silurian and Silurian Fossils.

# CHAPTER II.

## CAMBRO-SILURIAN (Phillips).

UPPER CAMBRIAN (Sedgwick).

LOWER SILURIAN (Geological Survey).

IN reference to the name of this formation, Jukes was of opinion that "it was advisable to adopt for it the distinctive term CAMBRO-SILURIAN, first suggested by Professor Phillips, in order to show that it is very distinct from the so called Upper Silurian, and that they are not mere sub-divisions of one formation." In Ireland there are certain affinities between the Cambrian and the Cambro-Silurian rocks, and those of one system have often been mistaken for those of the other; while the Cambro-Silurian rocks, except perhaps in the Clare hills north of the city of Limerick, are quite distinct from, and unconformable with, the Silurians.

The Irish Cambro-Silurian rocks are often more or less metamorphosed. They occur in most of the hill groups, or in the adjoining country, occupying tracts from a few perches in extent to miles in area. Of all these different exposures, that of the counties of Wexford and Wicklow gives the most continuous and most typical sections, and from it the other Irish rocks can be classified; the rocks of these counties shall, therefore, take precedence of the others.

### SOUTH-EAST IRELAND.

In the counties of Wexford and Wicklow the Cambro-

Silurian rocks can be divided into two groups; the best sections of the strata being seen in the sea-cliffs at Ballymoney, between Courtown and Kilmichael Point. In this section the rocks occur in a compound synclinal curve, much cut up and displaced by faults, so that no correct estimate can be made of the thickness of the strata, although their relations to one another are evident. At each end of the section similar rocks occur; those to the south being seen to lie on Cambrian rocks. The different rocks at Ballymoney occur in the following order :—

| | |
|---|---|
| BALLYMONEY SERIES | 3. Greenish and grey, but sometimes purplish and blue, grits and shales, associated with interstratified igneous rocks (felstones, eurites, and gabbros), tuffs, limestones, and agglomerates; and containing subordinate black shales with two thin anthracites, which lie on fireclay and are overlaid by black carbonaceous shale. |
| | 2. Purple and green shales and slates. |
| DARK SHALE SERIES | 1. Greenish, greyish, blue, and black shales, slates, and grits; the dark-coloured rocks usually predominate, while the grits are generally thin bedded. |

The purple and green shales to the north of Ballymoney seem to lie over the others, but to the south, at Courtown and elsewhere in the counties of Wexford and Wicklow, they occur between the rocks of the *Dark Shale series* and the typical Ballymoney rocks.

Although in this section the grits in the *Dark Shale series* are usually thin bedded, yet in other places groups of thick green grits come in. In places these rocks are fossiliferous; the fossils usually being of Llandeilo type, but in some places associated with Caradoc fossils. In the rocks of the *Ballymoney series*, the assemblage of fossils is to be compared with that of the Bala rocks, but Caradoc fossils are not uncommon ; while whenever black shales occur, no matter on what horizon, they nearly always contain fossils of Llandeilo type.

This tract of Cambro-Silurians occupies the greater portion of east Waterford, and extends from the valley of the Barrow, NNE., into the County Dublin, being found on both sides of the Leinster granite range. To the NW. of this range, in the counties of Dublin, Kildare, and Carlow, the Cambro-Silurian rocks are altered along the border of the granite ; to the SE. and S., also, of the granite range, counties of Wicklow and Wexford, they are altered, but in oblique zones, or in patches ; the unaltered rocks being often fossiliferous.

In this area, the rocks of the *Ballymoney series* extend obliquely across from the County Waterford to the east coast of Wexford at Ballymoney. But they are not continuous, being considerably ruptured and displaced by faults ; the largest displacements being due to the nearly north and south dislocations that occur in the valley south of Waterford, in the valley of the Barrow, in the valley of the Slaney at Enniscorthy, and in the valley east of Gorey. Farther north there is an outlying basin of these rocks, extending SW. from the coast between Arklow and Wicklow. These rocks are highly fossiliferous in the Ballymoney cliff.

North of Wexford, and a little north-west of Castlebridge, there is a small, narrow outlier of black Cambro-Silurian schist, brought down into its present position among the Cambrians by a fault, with a downthrow to the northward. Its south boundary seems to be at this fault ; to the north the rocks seem to lie unconformably on the

Cambrians, as shown in a section a little NE. of the village of Crossabeg.

Near the SE. extremity of Wexford, a little NW. of Greenore, there are two small patches of fossiliferous Cambro-Silurians lying unconformably on schist and gneiss, which appear to be of Cambrian age. Three years ago a very instructive section across one of these outliers was exposed on the coast a little NW. of Greenore Point; but since Ballygeary pier was constructed, the sand has collected over the place, and now scarcely any of the Cambro-Silurian rocks can be seen. They consist of purplish conglomerates, sandstones and shales under fossiliferous black shales. A little to the NW., on the north of the village of Tagoat, the second patch is indicated by detached quarries containing fossiliferous grits and shales; while a little NW. of the village the basal conglomerate is seen lying nearly horizontal; the rest of the rocks being obscured by drift. On the south coast of Wexford, near Bannow, is the remarkable section where the Cambrian and Cambro-Silurian rocks are entangled together (Figs. 3*a* & 3*b*). To the east, lying on metamorphosed Cambrians, there is a massive slate conglomerate, having usually a black steatitic shaly or slaty matrix, but in places it is of a vivid red, or green, or mottled colour. Over the conglomerate are black and greyish shales and grits, in which fossils of Llandeilo and Caradoc types occur; a new star-fish also has been found, which has been called by Baily, *Palæasterina Kinahani* (Fig. 1, Plate ii.).

Towards the west these dark rocks are brought down by a fault against purple and green Cambrian slates, and, further westward, patches of black and grey Cambro-Silurian rock are let down by faults into Cambrian rocks. These rocks can only be seen on the coast; consequently their boundaries cannot be followed inland. Still farther westward, on the east coast of Bannow Bay, there are greyish and blackish rocks brought down by a fault against fossiliferous Cambrians. These rocks are supposed to be of Cambro-Silurian age, as they agree in strike and dip with the Cambro-Silurians farther north; besides being slightly metamorphosed like the Cambro-Silurians of Bannow Island. This locality, as also the exposure near Greenore, the section at Crossabeg, the section north of Pollshone, and the section at Moneystown Hill (the last two being mentioned in Chapter I.) are important, as they are the only places recorded at which the actual contact of the Cambrian and Cambro-Silurian rocks can be seen.

To the west of Bannow Bay, in the east cliff section of the Baginbun promontory, there is a massive slate-conglomerate, which has been supposed to be the basal bed of the Cambro-Silurians. It is somewhat like the slate-conglomerate SE. of Bannow, and seems to lie unconformably on the rocks to the south of it; but this cannot be so, for the latter are in part black shales, in one of which, after diligent search, a Llandeilo graptolite was found. Farther south, at Baginbun Head, there is a peculiar conglomeritic rock, the inliers in which are massive grit blocks; it is very unlike all the rocks observed in the Cambro-Silurians of the country, but like some in the Cambrians, such as the rocks in the cliffs west of the Slaney, at Ferry-Carrig, near Wexford.

In the County Waterford, fossils are not uncommon in the rocks of the *Ballymoney series*, they being very plentiful, but imperfect, in calcareous beds along the coast line near Tramore. Farther westward, at Ballydowane Bay, there are peculiar fossiliferous seams of green ophiolite (Serpentine) in calcareous shales.

At Ballydowane Bay, as also farther eastward at Bunmahon Head, at Knockmahon, and to the east thereof at the Stage lode, there are remarkable conglomerates associated with red beds, and let down into the Cambro-Silurian rocks. These rocks were at first considered by Willson and Du Noyer to be "Old Red Sandstone" (Lower Carboniferous arenaceous rocks), but subsequently after a consultation with Jukes, they were mapped as Cambro-Silurian, on account of their similarity to the Cambro-Silurian conglomerates and sandstones near Greenore. Of late years, however, Mr. Hore, the managing agent at Bunmahon, of the Mining Company of Ireland, has proved that they are of newer age, and lie unconformably on the Cambro-Silurians. This is best seen at the small outlier at the Stage lode; the lode extending under it but not up into it; while in the old open works at the coast line, a red sandstone under a conglomerate is seen to lie nearly horizontally on the Cambro-Silurian slates. At Knockmahon, as also at Bunmahon Head, the lodes in the Cambro-Silurian rocks are cut off by the conglomerates. At Ballydowane, the relations between the conglomerate and the Cambro-Silurian rocks are obscure; but as the conglomerates and red rocks are evidently the same as those at the Stage lode and Knockmahon, they must be newer than the Cambro-Silurian rocks, and either of Silurian or Lower Carboniferous (Old Red Sandstone) age. Probably the latter, as they are somewhat similar to the basal arenaceous Carboniferous rocks near Waterford; besides, no Silurian rocks are known to exist in this portion of Ireland.

To the north of the rocks of the *Ballymoney series*, south-west and west of Portlaw, there are rocks that seem to belong to the *Dark Shale series*, and, in various places, fossils, principally of Llandeilo type, are found in them.

It has been mentioned that thin seams of anthracite occur in the rocks of the *Ballymoney series;* some seem to occur in the older rocks also. These seams, although not of any commercial value, are interesting, and those discovered may be enumerated. The two seams in the Ballymoney section just referred to, are remarkable for lying on regular, although thin, fire clay, which has a "rock seat," while over them are "slate roofs," so that they are similarly circumstanced to a regular Coal Measure coal. Farther northward, NW. of Kilmichael Point, at the mearing of the Counties Wicklow and Wexford, there is a 4-inch coal standing perpendicular. To the south, SW. of Enniscorthy, a seam of anthracite was discovered by Col. Alcock on the Wilton property; another occurs in the vicinity of the Blackwater on the Castle Talbot property. A coal seam is said to exist in the barony of Forth, under the black shales on the coast, NE. of Greenore, and a second at Coalhill, close to Tagoat Church; the last locality, however, seems to be in the Cambrian rocks, but, possibly, a Cambro-Silurian outlier may exist there obscured by the drift. In Doonooney, west of Wexford, and a few miles north of the village of Taghmon, there is a seam of anthracite, said to be associated with plumbago; while at Slieveroe, the small hill in County Kilkenny, a few miles NE. of Waterford, there is an anthracite seam two inches wide.

## SLIEVENAMAN.

In the mountains northward of Carrick-on-Suir and eastward of the summit of Slievenaman there is a considerable tract of slaty rocks. Those to the SE. (NE. of

Carrick) were pronounced by Jukes to be of Cambro-Silurian age; while the age of those to the NW., between Slievenaman and Nine-mile-house, he left an open question, provisionally classing them with the Cambro-Silurians. The rocks in the SE. of the tract are similar to those of the *Ballymoney* and *Dark Shale series* of Wexford. Recently, Mr. Hughes, Junr., the under-agent of the Victoria slate quarries, has discovered in these rocks, at the quarries, graptolites, bivalves, and other fossils which have been submitted to Baily and pronounced by him to be of Llandeilo type. These rocks contain many beds of slates.

In the NW. portion of the area the rocks are principally of purple and green colours, and, in aspect, very similar to some of the Cambrians of Wexford, while they are unlike any of the Cambro-Silurian rocks of that country. The relations between these rocks and the Cambro-Silurians to the SE. are obscure, on account of the envelope of drift, and their age will have to remain an open question for the present; in the meantime they may be placed provisionally with the Cambro-Silurians.

### Galtymore and Slievenamuck.

Nearly due west of Slievenaman, west and south-west of Galtymore, there is a tract of rocks of which also the age is uncertain, some apparently being the representatives of ~~the~~ *Dark Shale series*, while others are of purple and green colours like Cambrians. As no fossils have been found in any of them, they are provisionally classed with the Cambro-Silurians.

In Slievenamuck, southward of the town of Tipperary, and on the south-side of a great fault which brings down Coal Measures against them, are some rocks, also of an undecided age, forming a long tract; these for reasons similar to those just mentioned must be placed provisionally with the Cambro-Silurians.

### Slieve Phelim and Kimalta, Cratloe Hills, Slieve Bernagh and Arra, Slieve Aughta, Knocksheegowna, and Slieve Bloom.

These are the groups of mountains clustered about the junction of the provinces of Connaught, Leinster and Munster; and in all of them there are greater or less exposures of Cambro-Silurian rocks.

In Slieve Phelim and Kimalta, or Keeper mountain, which form one group of hills, principally in the County of Tipperary, the Cambro-Silurian rocks, from their aspect and the assemblage of fossils found in them, would seem to be the equivalents of the *Ballymoney series;* but according to Wynne's description, they do not contain interstratified eruptive rocks. Numerous fossil localities in these rocks could be mentioned, and exhaustive lists of the fossils, many of which are new to science, are given by Baily in the Geological Survey Memoirs, Explanations of sheets, 134, 135, 145 and 146.

The Cratloe Hills lie to the north of the city of Limerick, in the County of Clare. In them there is a long narrow exposure of Cambro-Silurian rock, bounded, on the north, by a very continuous fault which can be traced eastward across the valley of the Shannon into Limerick, Tipperary, and perhaps even the King's County; its course being past Birdhill, Silvermines, and Toomavara, into the country near Moneygall.

The general group of the fossils in these rocks would make them to be of Bala or Caradoc age (*Ballymoney* *series*), except in one locality, in the townland of Ballycar, where the following were collected : *Heliolites interstinctus, Favosites alveolaris, Petraia elongata, P. Du Noyeri, Cyathophyllum, Cornulites serpularia, Encrinurus punctatus, Phacops caudatus, Proetus latifrons, Sphærexochus mirus, Athyris tumida, Atrypa marginalis, A. reticularis, Orthis elegantula, Rhynchonella Wilsoni, Strophomena depressa, S. euglypha, S. funiculata, S. pecten, Euomphalus funatus, E. lautus*, and *Murchisonia Lloydii.* As to this assemblage Baily is of the opinion that it indicates a Silurian age for the rocks, the fossils being of Upper Llandovery types. A little to the north of Ballycar there are other rocks containing fossils of Bala and Caradoc types, while, between the two localities, there seems to be a perfect sequence in the rocks, no unconformability of any kind occurring. Therefore in this area there is no break between the rocks of the Silurian and Cambro-Silurian formations ; unless, which is not impossible, the fossils at Ballycar are only a Silurian colony in Cambro-Silurian rocks.

To the NE. of the Cratloe Hills are Slieve Bernagh (County Clare) and Slieve Arra (County Tipperary), separated from one another by the south arm of Lough Derg. In Slieve Arra and the eastern portion of Slieve Bernagh, the Cambro-Silurian rocks seem to belong to the *Ballymoney series.* They contain various beds of good slate, also a peculiar fine conglomerate, having a greenish matrix full of quartz particles which are rarely larger than small peas. Various beds are fossiliferous.

In the western portion of Slieve Bernagh the rocks belong to the *Dark Shale series ;* and at Belvoir, in black shales, there is a rich locality for graptolites and other fossils, including *Theca cometoides.* Baily's lists of the fossils found in these mountains and in the Cratloe Hills are given in the Memoirs of the Geological Survey, Explanations, sheets 133 and 143.

Slieve Aughta lies to the north of Slieve Bernagh, at the junctions of the Counties Clare and Galway. In the south, or Clare portion of the group, the rocks belong to the *Ballymoney series*, and, near Lough Graney, have eurites or gabbros associated with them. In the north, or Galway part of the group, the rocks principally belong to the *Dark Shale series.*

Knocksheegowna, or "the hill of the goblin calf," rises as a sharp, conspicuous, although a small hill, from the low country south-west of Birr or Parsonstown. From Wynne's description of the rocks and the fossils contained in them, they probably belong to the *Ballymoney series.*

Slieve Bloom lies eastward of Birr at the mearing of the King's and Queen's Counties. In it, coming up through the Lower Carboniferous conglomerates (Old Red Sandstone), there are various small irregular tracts of Cambro-Silurian rocks, which, according to O'Kelly's description, seem, in part, to belong to the *Ballymoney*, and in part to the *Dark Shale series.* No fossils appear to have been found in them.

## Small Exposures.

Coming up through the Carboniferous rocks of the central plain there are various isolated patches of Cambro-Silurian rocks ; of these, the most interesting, and perhaps the best known, are in the hills to the NW. of the Curragh, called the Chair of Kildare. These are very similar to those at *Ballymoney*, and, although the exposures are small, we find in them interstratified gabbros and limestones; the latter affording fine specimens of different trilobites and other fossils. Forbes' list of these fossils is given by Baily in the Explanation to accompany sheet 119.

There are other exposures at the following places, namely:—at Ireland's Eye, north of Howth, where black shales and slates lie on rocks supposed to be Cambrian; the age of the latter, however, is not satisfactorily determinable; there are, however, quartz-rocks associated with them which may be of that age; at Lambay Island; at Donabate, where there is a station on the Dublin and Drogheda railway, and where some of the beds are very fossiliferous, a list being given in the Explanation to sheet 102; at Sionhill, north of Killucan, County of Westmeath; at Slievegalry, a few miles south-east of Longford; close to Longford; at Slieve Bawn, County of Roscommon, and at a few other localities.

## South-east Ulster.

In south-east Ulster and extending slightly into Leinster (where there is a detached area about Balbriggan, at the junction of Meath and Dublin) there is a large triangular tract almost entirely occupied by Cambro-Silurian rocks. Its base extends from Belfast Lough to the River Boyne, while its apex is at Lough Forbes, one of the lakes on the River Shannon.

In this area the places not occupied by these rocks are —a tract of Triassic and other rocks, eastward of Belfast —an area of granitic rocks and an outlier of Carboniferous rocks, about Carlingford Lough—a large outlier of Carboniferous and newer rocks, north and south of Carrickmacross

—a small outlier of Carboniferous rocks, a tongue of the last—an outburst of granite near Cavan.

In this large area of Cambro-Silurian rocks, as also in that at Balbriggan, there seems to be a system of anticlinal and synclinal folds, having generally, but not always, a somewhat east and west bearing. These repeat the strata and bring up, alternately, patches of rocks belonging to the *Ballymoney* and to the *Dark Shale series;* the latter being in excess of the first. Many interesting fossils have been discovered in places in these rocks, especially in the vicinity of the Boyne and in the County Down, lists of which will be found in the published and forthcoming Memoirs of the Irish Geological Survey.

As previously mentioned, Du Noyer mapped the rocks near Craigowen, on the south of Belfast Lough, as Cambrian, they being similar in aspect to certain rocks at Bray Head, while Foot considered some rocks NE. of Granard, in Longford, to be of the same age; as, however, their age has not been proved in either places by fossil evidence they may be provisionally joined with the associated Cambro-Silurians.

## North Ulster.

In Antrim, Londonderry, and Tyrone there are metamorphic rocks, which seem to be of Cambro-Silurian age; while in Donegal there are others of a different class. The latter may be of either earlier or later age; if of earlier, they may be either Cambrians, or, as suggested by Jukes, Laurentians; if of later age, they must be Silurians. This, however, must be left an open question until the country is properly examined, and at present all may be mapped provisionally as Cambro-Silurians.

At Pomeroy, in the County Tyrone, and at Lisbellaw, County Fermanagh, there are important, although small, tracts of fossiliferous rocks, to which special attention was directed by Portlock, who, in his "Memoir on the Geology of Tyrone and neighbouring Counties," gives lists of the fossils found at both places.

## Connaught.

In North and West Connaught there are tracts of metamorphic rocks, some small, others very extensive. Most of such rocks in the Counties of Sligo and North Mayo are probably of Cambro-Silurian age; but McHenry is of opinion that there are certain older rocks, Cambrians, in portions of NW. Mayo; but there it is difficult to trace out the relations of one exposure to another, on account of the envelope of bog and drift so prevalent in that country.

Of the rocks in SW. Mayo and W. Galway a section has already been given (p. 21), in which it was shown that the lower rocks are of Cambrian age; while they extend upward, in a continuous sequence, into fossiliferous Cambro-Silurian rocks (Doolough beds, No. 11 in section), the latter apparently being older than certain other metamorphic rocks (Croagh Patrick and Letter Mullen beds, No. 12 in section). The Doolough beds on the north of Killary Harbour, and consequently their equivalents in the country to the south, seem, from their aspect and their fossils, to represent the rocks of the *Dark Shale series;* while the Croagh Patrick beds to the north, and the Letter Mullen beds to the south, have characters that indicate their being of the age of the *Ballymoney series.*

From this description of the Irish Cambro-Silurian rocks it will appear that, although the Irish rocks are, as to certain characters, different from those that occur in England; yet that there is a close connection between both, and that in all the different exposures in Ireland there are characteristics persistent enough to enable the rocks to be given a general classification similar to that of the typical section in the County Wexford.

# CHAPTER III.

## SILURIAN (Jukes).

UPPER SILURIAN (Murchison and Geological Survey).

THE Irish Silurian rocks are divisible into groups which somewhat conform with those into which the English Silurians have been divided; but in one of the Irish groups there is a zone of beds that contains an assemblage of fossils eminently characteristic of the Caradoc beds, a group in the English Cambro-Silurians.

The Silurians have only been found in a few parts of Ireland, and in those places there is a conspicuous unconformability between them and the Cambro-Silurians; except, perhaps, in the case of the rocks at Ballycar, in the hills of south-east Clare; which rocks have already been described at page 32. In Waterford, east and west of Bunmahon, there are the conglomerates and sandstones already referred to, which undoubtedly belong to a newer formation than the associated Cambro-Silurian rocks, and may possibly be of Silurian age; although, for the reasons already given, it is more probable that they belong to the "Old Red Sandstone," or Lower Carboniferous arenaceous rocks.

### DINGLE GROUP.

These rocks have been divided by Jukes and Du Noyer into series named after the localities at which they are best developed.

| | |
|---|---|
| 4. Croaghmarhin beds. | Ludlow ? |
| 3. Ferriter's Cove beds. | Wenlock ? |
| 2. Smerwick beds. | |
| 1. Anascaul beds. | Llandovery ? |

The *Anascaul beds* are principally black glossy slate, becoming, in some localities, variegated red and green slate, and occasionally dark grey flags. From the fossils found in them near Bull's Head and on the slope of Caherconree, they are supposed to be the lowest rocks shown in the promontory, and to be possibly of the age of the Llandovery beds. Some of the fossils found in certain limestones at one part of the slope of Caherconree would seem to be those of rocks of Bala or Caradoc age, while those found in some dove-coloured limestones, on another part of the same slope, may possibly be Llandovery fossils. No information as to the age of the rocks can be gained from their stratigraphical relations, as they are only seen at rare intervals, and always appear to be violently contorted and displaced, dipping at high angles in different directions ; but, as will be shown hereafter, a zone in the Llandovery rocks containing Caradoc or Bala fossils seems to be a characteristic of the Irish Upper Llandoverys.

The fossils near Bull's Head, as determined by Salter and Baily, are *Favosites alveolaris*, *Halysites catenularis*, *Petaia elongata*, *P. subduplicata*, *Syringopora bifurcata*, *Athyris tumida*, *Atrypa hemispherica*, *A. marginalis*, *A. reticularis*, *Orthis elegantula*, *O. rustica*, *Spirifera plicatella*, *S. trapezoidalis*, *Strophomena depressa*, *Discina perrugata*, *Euomphalus alatus*, *E. funatus*, *Calymene Blumenbachii* and *Proetus latifrons*. In the dove coloured limestones on the south-west slope of Caherconree, Baily gives the following *Favosites alveolaris, Stenopora fibrosa, Orthis Actoniæ, Rhynchonella borealis, R. nucula, Spirifera plicatella, Strophomena depressa, S. applanata, Acroculia haliotis, Cheirurus bimucronatus, Encrinurus sexcostatus,* and *Illænus Bowmanni.* In the grey limestones were found *Acidaspis Jamesii* and some other Cambro-Silurian forms.

The *Smerwick series* consists of purplish or brownish, and green and yellow, sandstones and flagstones with some bright red shales. No fossils are found in them, but they seem to dip conformably under the Ferriter's Cove series. They are apparently about 2,000 ft. thick.

The *Ferriter's Cove series* begin with thin bands of conglomerates of a greenish colour; and above one of these bands fossils appear. Over these are green sandy slates or shales several hundred feet thick, interstratified in their upper part with felspathic tuffs, above which are bands of red sandstone and slate. The aggregate thickness of this series is estimated at about 2,500 ft. According to Salter the rocks are full of fossils of those species which are abundant in the Wenlock rocks of the typical Silurian districts. An exhaustive list of the fossils, determined by Salter, will be found in the Memoir of the Geological Survey to accompany sheets 160, &c. of the Geological Map.

In the *Croaghmarhin series* the lowest rocks are pale, greenish grey, sandy flags and some thick, hard, brown, calcareous grits, passing into an impure arenaceous limestone. Their total thickness is perhaps as much as 1,000 ft. These beds occasionally contain *Pentamerus Knightii* and other fossils, determined by Salter and Baily to be similar to those characteristic of the Ludlow rocks.

The Croaghmarhin series dips conformably under the *Dingle beds.* As the Dingle or Glengariff beds are intimately connected with the Carboniferous rocks of the Cork Type they will be described together in the next chapter.

## Killary District.

The Silurian rocks of this area are found north and south of Killary Harbour, the fiord that separates Galway and Mayo, as also thence eastward to Loughs Mask and Corrib. They are very interesting, as, in a distance of a few miles, the characters of the groups become quite different. They form five distinct groups, which may be called the Culfin, the Lough Corrib, the Mweelrea and Toormakeady, the Creggaunbaun, and the Louisburgh groups.

## Culfin Group.

The rocks thus classed are very conspicuously exposed at Gowlaun and Salrock, on the Atlantic, south and north of the Culfin valley, and extending eastward to Loughs Mask and Corrib; the complete section of the rocks, however, is best developed, or rather preserved, to the west, and gives the following thicknesses:

*Salrock and Gowlaun Section.*

| | |
|---|---|
| 4. Salrock series | 2,000 feet. |
| 3. Lough Muck series | 1,600 „ |
| 2. Eurites and tuffs | 800 „ |
| 1. Gowlaun series | 2,700 „ |
| | 7,100 „ |

The *Salrock series* consists, for the most part, of bright red shales and slates, over which are some green and red grits and shales, with, in places, a grey or reddish limestone.

From the limestone no fossils have been obtained; but many of the red shales are full of a minute lingula, determined by Baily to be *Lingula Symondsii*, of which he states, "they are pronounced by Thomas Davidson, the eminent authority on Brachiopoda, to be a characteristic Upper Llandovery fossil." Other fossils found in the same rocks are *Pterinia retroflexa* and *Trochus multitorquatus*. These rocks, however, are undoubtedly the highest Silurian rocks in this series; and the lowest of the lingula shales is, at the least, 5,000 ft. above the base of the Silurian formation.

The *Lough Muck series* consists, for the most part, of alternations of grits and shales or slates; in some places the argillaceous, and in others the arenaceous, rock predominating. In one locality, on the north-east shore of Lough Mask were found *Graptolithus tenuis*, *Holopea concinna*, *Murchisonia obscura*, and *Illænus*—sp. undetermined—a group of fossils which Baily states indicates a Cambro-Silurian age; but in higher and lower beds there are other fossils that indicate a Llandovery age. Here, then as in the Dingle Silurians, we find a Cambro-Silurian fossil zone in rocks of Llandovery age.

The *Eurite series* at Lough Muck, is altogether made up of extruded rocks, although eastward and westward they become interstratified with sedimentary rocks, sometimes fossiliferous, the fossils being of Upper Llandovery type.

The *Gowlaun series*, to the west, consists of conglomerates below, with a great thickness of slates over them, which higher up alternate with massive green grits. Farther eastward, however, the mass of slates disappears, and is replaced by alternations of grits and shales or slates; the conglomerate also splits up and becomes interstratified with shales. Some of these shales are very calcareous, and are full of *Rhynchonella Llandoveriana* and *Atrypa hemisphærica*, while in places they contain other fossils also, but all eminently characteristic of the Upper Llandovery rocks.

The rocks of the Culfin group are bounded on the north by a great fault with a downthrow to the southward, which is broken and shifted by newer faults. This fault to the westward begins in the Little Killary, and runs eastward through the maum called the Pass of Salrock, and along Killary Harbour to Dernasliggaun, where it is shifted southwards over a mile by a NW. and SE. fault. East of the NW. fault, it can be traced eastward to the Maum Valley, in which it is shifted southward nearly to Maum, and from the Maum Valley it extends eastward to the Kilbride promontory, in Lough Mask. The oblique faults mentioned are those that have the greatest effect on the boundary fault; but there are numerous other transverse faults that displace it in places, and break up the continuity of the beds. The Salrock beds, as they are followed eastward, are found to be more or less cut out, entirely disappearing a little west of Lough Mask.

To the eastward the Lough Muck and Gowlaun series merge into one, the eurites that separate them dying out west of the Maum Valley. Other changes also take place. East and west of the Maum Valley, at the base of the Culfin group, a series of red shales comes in; but the most remarkable change occurs in reference to the contained fossils. It has been already mentioned, that the characteristic fossils of both the Gowlaun and Lough Muck series are of Llandovery type. These are found west of the Maum Valley, and east of the Maum Valley to Kilbride Bay; but in the rocks of the Kilbride promontory, although apparently on the same geological horizon, quite a new assemblage of fossils appears, which has been pronounced by Salter, King, Harkness, Baily, and others, to be characteristic of the Wenlock rocks. Thus we have in apparently the same series of beds, on the west, Llandovery fossils with an inlying zone of Cambro-Silurian fossils, and, on the east, Wenlock fossils.

### Lough Corrib Group.

There are detached portions of a tract of Silurian rocks on the south side of Lough Mask, on the north shore of Lough Corrib, in the Doorus promontory, farther south than the last, at Currareavagh, in some of the islands of Lough Corrib, and in the promontory of Ballymacgibbon. These rocks are generally very fossilifercus, especially near Ballymacgibbon; and the fossils are usually similar to those at Gowlaun, although a few are like those in the Kilbride promontory. In the vicinity of Lough Corrib, dykes and protrusions of gabbro and granitone occur in these rocks.

### Mweelrea and Toormakeady Group.

This group is separated from the Salrock series on the south, by the above-described boundary fault. The rocks can be traced from the Atlantic eastward to Lough Mask, they being shifted southward by the different cross faults already mentioned as affecting the rocks of the Culfin group.

In the Mweelrea mountains these rocks lie in a great synclinal curve, the estimated thickness being :—

*Mweelrea Section.*

| | | |
|---|---|---|
| 2. | Mweelrea beds | 2,000 feet. |
| 1. | Eurites interstratified with sedimentary rocks | 1,250 ,, |
| | | 3,250 ,, |

Beds of eurite nearly always occur at the base of this group. In the Mweelrea mountains there are from three to seven of these beds; but they decrease in number as they are followed eastward; and to the north of the synclinal in Glenmask, between the Formnamore and Partry mountains, only one bed occurs which is the basal bed. Farther eastward, on the north slopes of Slieve Partry, this felstone is replaced by a peculiar quartz-rock, which fills up the interstices in the under-lying Cambro-Silurians, and, consequently, has no defined basal line. To the south of the synclinal, from the Maum Valley to Lough Mask, and on the east slopes of Slieve Partry, the eurites are very conspicuous, being massive and associated with thick tuffs, conglomerates, and agglomerates, and, in places, with limestones and calcareous tuffs. The limestones are very remarkable. In a few places they are grey rocks, but more often they are mottled from the fossiliferous variously-coloured limestone concretions, which are enveloped in a limestone matrix. These limestones invariably graduate into more or less calcareous tuffs, and none of them were found farther west than Lough Nafooey. The fossils collected in these limestones are considered to be of Caradoc (Cambro-Silurian) type by Baily, who writes: "a somewhat similar set of fossils was collected from a tuff bed a little west of Mount Partry; the list from the limestones contains *Leptæna serica*, *L. quinquicostata*, *Orthis elegantula*, *O. insularis*, *O. tenuicincta*, *O. testudinaris*, *Cheirurus bimucronatus*, *Cybele verrucosa*, and *Illænus Bowmanni*." These Caradoc type fossils are immediately above the eurite beds, just as in the Culfin section; here, however, no Llandovery fossils were found in the associated beds. The eurites of Slieve Partry are seen to lie on upturned Cambro-Silurian rocks.

In Slieve Partry, above the eurites, the group is made up almost entirely of conglomerates; in the Formnamore mountains there are massive pebbly grits below, but above are grits and shales alternating; while in the Mweelrea hills, we have below, conglomerates, pebbly grits and shales, and above, shales principally. In places, however, the shales predominate in the lower beds; and fossils are found in them which Baily pronounces to be of Caradoc type. These were obtained in three localities, viz., at Derreennawinshin, which is on the south slope of Mweelrea, at Uggool, which is west of that mountain, and at Bellawaum, which is on the NE. side of the same; being, in all three places, in beds a little above the eurites. Lists of these fossils are given in the Survey Memoirs, Explanations to sheets 83, 84, &c.*

## Creggaunbaun Group.

In the low country, between Mweelrea, Louisburgh, and Croagh Patrick, there is a tract of Silurian rocks. These, for the most part, are metamorphosed; but in one locality, Creggaunbaun, they are not so. The rocks at Creggaunbaun are very fossiliferous, and contain a group of fossils nearly identical with those found in the promontory of Kilbride, which, as before pointed out, are the eastern

* In this memoir the fossils are given as of Cambro-Silurian age, as at that time the Cambro-Silurian zone in the Silurians was unknown to Mr. Baily.

continuation of the Gowlaun rocks, although the fossils are not similar. The fossiliferous rocks of Creggaunbaun to the west, south, and south-east, are, in their upper parts, a conglomerate associated with one or two beds of limestone, and lie unconformably on fossiliferous Cambro-Silurian (Doolough) beds. The conglomerate is similar to that which, on the south-west of Croagh Patrick, dips south-westward; the Silurian area apparently lying in a synclinal basin, which, to the eastward, is broken up by the Corvockbrack intrusion of granite.

We have, therefore, north and south of the rocks of the Mweelrea group, rocks different from those of Mweelrea but similar to one another; in the rocks to the south, at about 2,000 or 2,500 feet above their base, there are eurites which appear to be on the same geological horizon as the eurites at the base of the Mweelrea group; it may, therefore, be suggested that the Mweelrea rocks were accumulated on a ridge of Cambro-Silurian rocks, the summit of which was not enveloped until a considerable thickness of strata was deposited to the north and south of it. And, moreover, that a little after the eurites had been poured out while the rocks at Mweelrea, at Toormakeady, and at Lough Muck were being deposited, the conditions were such that colonies of Cambro-Silurian animals existed in the Silurian Sea.

### Louisburgh Group.

These rocks, and also certain similar rocks found in the hills between Lough Erne and Pomeroy (Counties of Fermanagh and Tyrone) Griffith supposed to be equivalents of parts of the Kerry and Cork rocks called "Dingle" or "Glengariff Grits" by Jukes, and described in the next chapter. This, to us, appears to be very probable. In part they are like the red beds already mentioned as occurring east and west of the Maum Valley, and in part they are like the pebbly Mweelrea grits; but, if their stratigraphical relations to the Creggaunbaun beds are considered, they would appear to be the latest Silurian rocks in the country. No fossils could be detected in them except a few tracks and burrows like those of Annelids.

North of Louisburgh a massive brecciated conglomerate adjoins the older schists, and associated with the conglomerate is a great thickness of red shales, above which are flaggy sandstones and bluish shales. In the hills west of Louisburgh, red and other shales are interstratified with massive pebbly grits like those of Mweelrea.

In Clare Island, to the NW., rocks of this group also occur. The *Croaghmoyle Group*, to the NE. and N. of Westport, in the country east of Clew Bay, consists of massive conglomerates with some red sandstone and shales; these rocks are supposed to be of the same age as those near Louisburgh.

## Ballaghaderreen.

A small tract of Silurian rocks occurs in the north of the County Mayo, a little west of Ballaghaderreen. Jukes has described these rocks as the representatives of the Lower Wenlock and Upper Llandovery strata, his opinion is shared in by Baily from his subsequent examination of the fossils. They consist of reddish, purple, and bluish shales, grits, and flagstones, some of which are highly fossiliferous, as is also a blue, earthy, concretionary limestone; of the fossils in the last, Baily states they are very like those of the Kilbride promontory, Lough Mask. An exhaustive list of the fossils of this area is given by Baily in the Memoirs of the Geological Survey, Explanations to sheets 76 and 77.

The following table gives a general classification of the upper Palæozoic rocks of Ireland, with their supposed English equivalents:—

SILURIANS.

| *Locality.* | *Irish Groups.* | *English equivalents.* |
|---|---|---|
| DINGLE PROMONTORY | Dingle or Glengariff Grits............... | |
| | Croaghmarhin beds.. | Ludlow? |
| | Ferriter's Cove beds. | Wenlock? |
| | Smerwick beds ...... | |
| | Anascaul beds ...... | Upper Llandovery |
| WEST CONNAUGHT | Mweelrea beds ...... | Ludlow? |
| | Salrock Slates......... | |
| | Lough Muck beds ... | Upper Llandovery? |
| | Gowlaun and Kilbride beds ......... | Wenlock and Upper Llandovery. |

CAMBRO-SILURIANS.

| | | |
|---|---|---|
| WEXFORD AND IRELAND GENERALLY | Ballymoney Series... | Bala and Caradoc. |
| | Dark Shale Series... | Llandeilo. |
| WEST CONNAUGHT | Croaghpatrick and Letter Mullen beds | Bala? |
| | Doolough beds ...... | Llandeilo. |

CAMBRIANS.

| | | |
|---|---|---|
| | Connemara, or West Galway Group ... | Upper Cambrian. |
| | Bray Head and South-east Ireland | Lower Cambrian? |

# CHAPTER IV.

## CORK ROCKS.

CARBONIFEROUS in part.

SILURIAN in part.

IN this description these rocks will be divided as follows :—

| | |
|---|---|
| CARBONIFEROUS | 5. Coal Measures.<br>4. Carboniferous Slate, including the Coomhoola Grits.<br>3. Yellow Sandstone.<br>2. Old Red Sandstone. |
| SILURIAN | 1. Dingle or Glengariff Grits. |

These rocks occupy a long tract lying principally in Kerry and Cork, and extending thence eastward into Waterford; it is bounded on the north by the valley running from Dingle Bay to Dungarvan; there is also an isolated tract to the north of Dingle Bay.

Griffith, after he had completed his survey of Ireland, came to the conclusion that the upper rocks in these areas were on the same geological horizon as the Limestones and associated Carboniferous rocks of the central plain, both belonging to the Carboniferous formation; but the lower strata in both Cork and the central plain he divided into Old Red Sandstone and Silurian. His conclusions were based on the fact that rocks, similar to the lowest in the County Cork, are found lying conformably on beds containing Ludlow fossils in the Dingle promontory; while the upper rocks in the County Cork, as they are followed eastwards, graduate into Limestone. In the promontory of Iveragh and Dunkerron and in that of Bear, north and south of the bay called Kenmare River, he made a base to his Old Red Sandstone of certain conglomerates and massive pebbly grits that can be found, more or less, in those areas, and also in the country to the eastward. During the researches carried on under Jukes, these divisions proved to be, in the main, correct; but Jukes thought it expedient to join the Dingle or Glengariff grits to the overlying rocks rather than to the Silurians, as the only fossils found in them were certain plants and tracks allied to others found in the Carboniferous rocks. In this chapter the rocks will be described under Griffith's names, except the lowest group, for which Jukes' names will be adopted.

Of the typical Carboniferous rocks of Ireland those of the County of Limerick are nearest, and the following is a general tabular series of the relations that exist between the Silurians, the Cork rocks, and the Carboniferous rocks of Limerick.

| | *Dingle and West Cork.* | *Limerick.* |
|---|---|---|
| UPPER CARBONIFEROUS | Coal Measures | Coal Measures |
| LOWER CARBONIFEROUS | Carboniferous Slate | Limestones<br>Lower limestone shale |
| | Yellow Sandstone<br>Old Red Sandstone | Lower Carboniferous Sandstone and shales |
| SILURIAN | Dingle or Glengariff Grits<br>Ludlow (?)<br>Wenlock (?)<br>Upper Llandovery (?) | Not represented |

DINGLE OR GLENGARIFF GRITS (Jukes).
SILURIANS (Griffith).

In the Dingle promontory, apparently lying conformably on rocks containing Ludlow fossils, there is a vast series of rocks, estimated by Jukes and Du Noyer to be at least 10,000 feet in thickness. These consist of green and purple grits and slates which pass up into beds of coarse thick sandstones and grits of greenish and reddish tints, like those in the neighbourhood of Glengariff, County Cork, and interstratified similarly with purple slates. There are, however, in the Dingle rocks many bright red slates, some liver-coloured beds, and thick beds of conglomerate full of rounded and angular pieces of sandstone and other rocks. Some of the rolled pebbles in the conglomerate, called the "Inch Conglomerate," contain fossils apparently of Llandovery age; but no fossils proper to the group have ever been found in the Dingle promontory. The upper rocks of this series are not here seen; as the highest beds plunge into the sea, or are *unconformably* covered by the Lower Carboniferous sandstones and conglomerates (Old Red Sandstone of the Geological Survey) of the central plain.

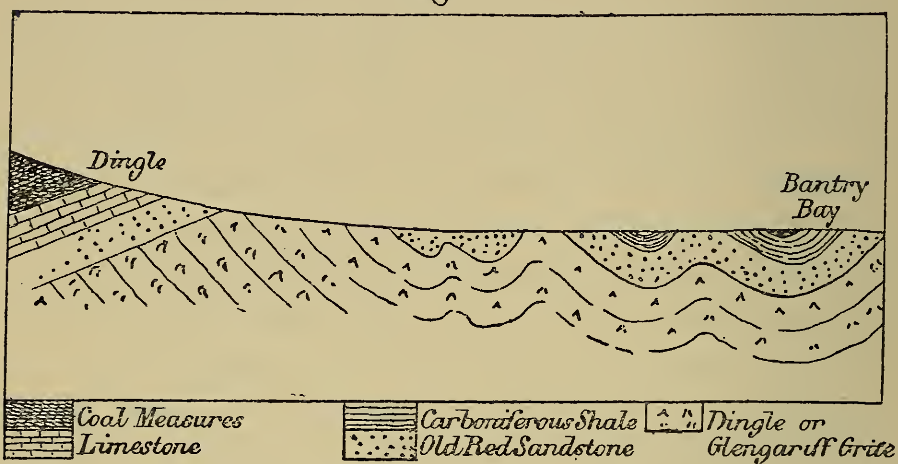
But in the Iveragh and Dunkerron promontory the base of the Dingle grits is not seen; and there is a *conformable* sequence upwards into the Carboniferous Slate and Limestone (*see* Fig. 4). In Valentia and the country to the south, the lowest beds are principally green and purplish slates and grits with beds of fine breccia; but inland the massive grits, like those in Dingle, predominate. Some of the beds of slate are of good quality, but they are only worked on Valentia Island. In all these rocks at different horizons are calcareous beds, usually associated with iron and manganese ores; they being more prevalent in some places than in others; they are also found in the Old Red and Yellow Sandstones.

North of Valentia Harbour is a massive conglomerate that can be traced ENE. to Kells, where, in the river valley, a little SSE. of the hamlet at the Coach road, there is either a fault or an unconformability; the rocks in the valley to the east striking at the conglomerate. Eastward of this valley the conglomerate seems to be represented by massive pebbly grits. This conglomerate and the pebbly grits are the rocks taken by Griffith as the boundary between his Silurians and Old Red Sandstone. Farther southward, in the promontory of Bear, the rocks are similar, except that the sequence continues up to the Coal Measures; rocks of the latter group lying on the Carboniferous Slates in Whiddy Island, Bantry Bay.

(The fossils that have been found in the Glengariff grits, south and south-east of Dingle Bay, are tracks, probably Crustacean,) on compact purple slates, on the shore west of the Lighthouse, Valentia Island, obscure markings like either fucoids or tracks of marine animals on the shore of Valentia river, obscure plant-like markings in purple slates on the south side of Beginish, and on the shore opposite Puffin Island. On the west side of Coomasaharn Lake, SE. of Kells, are plant stems, some of them an inch and a half in diameter, and irregularly ribbed in a longitudinal direction; and farther eastward rude and imperfect plant stems, observed by Du Noyer, who states that the most perfect are in the Owenreagh valley north of Windy Gap. Ripple-marks are extremely common on the surfaces of the beds, often running in different directions on adjoining surfaces.

The rocks in the tract now being described lie in complex anticlinal curves, the main axes having a general bearing of about N. 30° E.; the synclinal curves being in the valleys now occupied in part by the Kenmare river, and the other bays to the southward. The accompanying section gives the general features of these curves, leaving out the minor flexures, while it shows the unconformable

Fig. 4.




Diagrammatic section of the Cork and Dingle rocks, showing the unconformability of the latter.

overlie of the Lower Carboniferous sandstones, limestones and shales upon the "Dingle or Glengariff grits" as these latter beds occur in the Dingle promontory.

The rocks in the Iveragh and Dunkerron promontory are cut off to the north and north-east by the great fault that extends from Dingle Bay through the Killarney valley, and eastward along the valley of the Flesk and the Blackwater and the continuation of the valley eastward to Dungarvan. This fault to the south of Castlemaine Harbour, as also farther eastward in the valley of the Flesk, brings down the Coal Measures nearly against the Glengariff grits.

## Old Red Sandstone (Griffith).

These rocks are usually of red and purplish colours, consisting of grits, gritty-slates, and slates, the argillaceous rocks generally predominating over the arenaceous. They are supposed to bound the Glengariff grits to the north, at the south margin of Dingle Bay, but eastward are cut off by the great fault in the Dingle and Dungarvan Valley. Farther south they form a band between the Glengariff and the Carboniferous Slate of the synclinals in Kenmare River and Bantry Bay; while still farther southward, in Muntervary, Mizen Head and Cape Clear promontories, the nearly parallel anticlinal axis (about N. 30° E.), brings up long tracts of this Old Red Sandstone.

The thickness of the Old Red Sandstone of the County of Cork is about 5,000 feet to the west, but eastward it seems to become thinner: this, however, may be more apparent than real, as a portion may be cut out by faults; but as all the other groups thin away eastward, it may do so also.

## Yellow Sandstone and Carboniferous Slate (Griffith).

## Upper Old Red and Carboniferous Slate (Jukes).

The upper Cork rocks, next below the Coal Measures, have been proved by Griffith to be the equivalents of the Lower Carboniferous rocks of the rest of Ireland, except, perhaps, the previously mentioned arenaceous rocks in the Counties of Fermanagh and Tyrone. That eminent geologist published, in the Journal of the Geological

Society of Dublin (now the Royal Geological Society of Ireland) for 1860, an exhaustive list of Irish Carboniferous fossils, arranged according to the stratigraphical subdivisions of the Carboniferous system adopted in his geological map of Ireland. This shows the numerous fossils common to the ordinary Irish Carboniferous and the upper Cork rocks, and to this list we must refer those who are interested in this subject.

The subject of the age of the Cork rocks recalls the labours of Jukes for the determination of that question. That geologist is next to Griffith in the ranks of those who have thrown light on Irish geology, having so perfected the general systems, that his successors have been left, as regards that matter, only details to work out. Jukes came to Ireland firmly believing in the Devonian rocks as a distinct formation, and for years he battled against Griffith's classification. However, he gave way eventually, but not until he had, with his usual energy, worked out similar groups of rocks on the continent of Europe and in England. In those regions he found that one portion of the rocks of the Carboniferous formation may be principally calcareous accumulations ; while another portion, on exactly the same horizon, may be composed entirely of arenaceous or argillaceous materials.

Here it may be observed, that the facts made known by the recent researches of the *Challenger* and other exploring ships, show that over certain large portions of the bed of the ocean calcareous accumulations and arenaceous shore beds are being formed, while in deeper portions argillaceous sediments are being thrown down ; also that with the latter there are remarkable deposits of iron and manganese ore. Something similar may have taken place during the Carboniferous period ; there being a great thickness of calcareous rocks with their associated shore beds in the central plain; while in Cork and thereabouts there are great argillaceous and arenaceous deposits, the argillaceous, in many cases, having in them peculiar seams and concretions of iron and manganese ores.

The upper Cork rocks have two distinct characters; those below (Yellow Sandstone) being of bright colours, while those above (Carboniferous Slate) are dark; but the boundary lines of the groups are very arbitrary. In the purple and green rocks of the underlying Old Red Sandstone fossils are of very rare occurrence, and those that do occur are nearly always indistinct; but in the overlying yellowish rocks plant remains are not uncommon in the shale partings. As these plant remains are usually above all the purple grits, the highest rock of this kind has been taken as the base of the Yellow Sandstone; while the lowest blue or blackish shale, above which in any bed marine fossils may occur, has been taken as the base of the Carboniferous Slate—such boundaries necessarily vary, consequently the thickness of the group. Some of the officers of the Geological Survey have made the Yellow Sandstone only 500 feet thick, or even less; while others have given it as much as 1,200 feet. It is, however, an important group, as it is the one in which all the copper lodes of the country occur; in some places quantities of the ore are disseminated through many of the beds, which, after being broken into, rapidly become spotted all over with minute specks of the green carbonate; while some shales contain a sufficient quantity to be worked for the mineral.

The upper Cork rocks give the following general section:—

| | |
|---|---|
| 4. Blackish or dark - coloured shales, having, in places, subordinate beds of impure limestone and calcareous shale.<br>3. Principally blue and grey grits and shales or slates, but locally containing green grits (*Coomhola grits*), which sometimes occur in mass. These series of grits occur on different horizons. | CARBONIFEROUS SLATE, about 5,000 feet thick. |
| 2. Principally yellow, grey, and greenish thick-bedded grits, with subordinate beds of shale or shale partings, the latter often containing plant remains. In this series beds of red and purple slate are rare.<br>1. Yellow, liver - coloured, and bright green slate, with some bright red and variegated beds. | YELLOW SANDSTONE, about 1,000 feet thick. |

Remarkable changes may be observed in these rocks in passing from one place to another. The bay called Kenmare River has been denuded in the trough of a synclinal curve, and to the north and south of the bay are patches of the upper Cork rocks. At Sneem, to the north, and at Kilmakilloge, to the south of the bay, the Carboniferous Slate is at least from 800 to 1,000 feet thick; but from 6 to 8 miles towards the ENE., in the vicinity of Kenmare, it has totally disappeared, and the bright red rocks of that locality, which seem to represent the Yellow Sandstone, are directly covered by from 50 to 100 feet of Lower Limestone Shale (like that of the central plain), over which comes the Limestone itself. The Limestone at its base is very cherty and fossiliferous, but the rest of it is slaty, apparently from true cleavage. Here the change from Carboniferous Slate into the Limestone and Lower Limestone Shale cannot be observed, as the tracts of

Carboniferous Slate at Sneem and Kilmakilloge are cut off to the eastward by faults.

In the next bay southwards, Bantry Bay, we find, similarly, margins of Carboniferous Slate to the south and north; they are not cut off at the head of the bay, but are continuous north-eastward for a considerable distance. At the NE. of Whiddy Island, which is situated at the head of the bay, there are black shales identical with the lower shales of the Coal Measures, and containing the characteristic fossils *Posidonomya Becheri*, *P. membranacea*, *P. costata*, &c. Here, therefore, we have the full thickness of the Carboniferous Slate, which has been estimated by Jukes at 5,000 feet.

The synclinal trough of Bantry Bay, as it goes north-eastward, splits into two; the northern arm extending to Macroom, and from thence eastward to a little north of Cork; while the southern arm runs south of Cork to the sea at the mouth of Youghal Harbour. The upper Cork rocks are not continuous along these troughs, and when they reappear, in one trough, west of Macroom, and in the other, near Kilmurry, the Carboniferous Slate has been replaced by the Limestone and its associated shales. The Lower Limestone Shale is about 200 feet thick, while the underlying Yellow Sandstone is losing its normal character, and consists of pale whitish grey flagstones and silicious sandstones associated with dusky grey, olive, greenish and blue shales, and some peculiar beds of pale whitish grey and pink mottled fossiliferous shales that contain well-preserved casts of crinoidal fragments and *Fenestella*.

Extending eastward from Dunmanus and Roaringwater Bays, as also along the south-east, there are strips of Carboniferous Slate which all unite and form one tract south of Bandon, but again split up a little west of Cork Harbour.

This is a most important area ; to the south, in the promontory of the Old Head of Kinsale, the basal shales of the Coal Measures come in on the Carboniferous Slate, as also at Ballyheedy, between Kinsale and Ballinhassig, and also to the east of Ballinhassig ; but in the latter locality there are a few feet in thickness of Limestone between the Coal Measures and the Carboniferous Slate ; while, in the neighbourhood of Cork Harbour, the Carboniferous Slate splits up and gradually gives place to the Limestone.

To the west of Spike Island there is a considerable thickness of Carboniferous Slate between the Limestone and Yellow Sandstone ; it gradually thins away eastward to Ballycottin Bay, where the Carboniferous Slate takes many of the characters of the Lower Limestone Shale. Furthermore, as first pointed out by Jukes, on the south side of the promontory of Ringaskiddy, west of Cork Harbour, beds of dark grey shale and grits come in over 800 or 900 feet of thick, grey, crystalline limestone ; "these look very much like beds of Carboniferous Slate beginning to be intercalated between beds of the Limestone, or like beds of the Carboniferous Slate coming in over the Limestone, and as if the Limestone was beginning to die away as an inlier in the Slate."

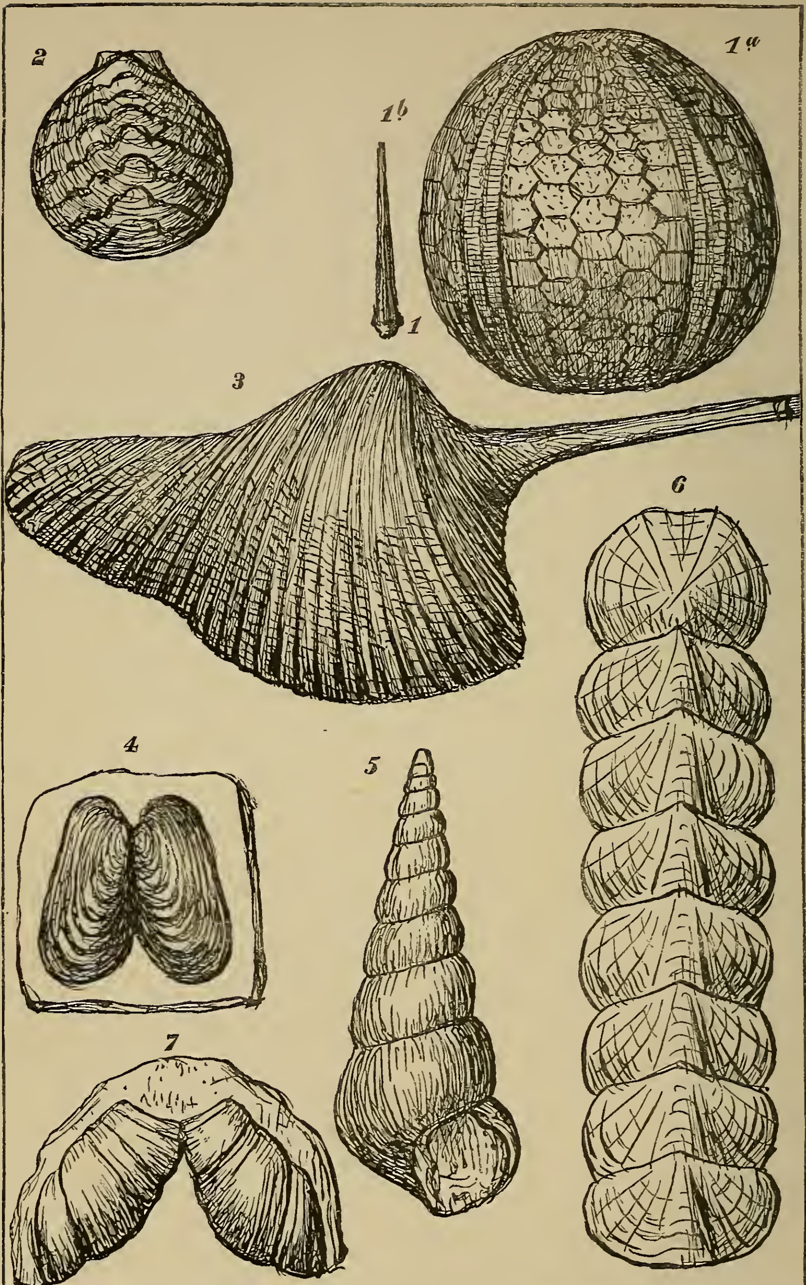
East of the longitude of Cork, although the Old Red Sandstone keeps very much its original character, yet the upper groups have changed. The Carboniferous Slate not only thins away, but it also takes characters of the Lower Limestone Shale and of the Limestone ; while the Yellow Sandstone loses its typical character and assumes those of the Lower Carboniferous Sandstones and conglomerates of north and east Munster.

Griffith's great list of Irish Carboniferous fossils has been already mentioned; and here attention should be drawn to Baily's excellent lists of the fossils found in these rocks in Cork, Kerry, and Waterford, published in the Survey Memoirs, Explanations to sheets 176, 187, 192, and 197, of the map of the Geological Survey in Ireland.

Special attention may be directed to a few of the most important of these fossils. At Reenydonagan Point, near Bantry, a Brachiopod, supposed by Davidson to be *Cystina heteroclita*, is found associated with characteristic Carboniferous Limestone fossils. That eminent palæontologist considers this most interesting "from this shell, which is found in many well-known foreign Devonian localities, never having hitherto been recognized in any true Carboniferous bed or locality." At this place *Phillipsia pustulata* occurs, and this Carboniferous Limestone trilobite was also found farther west at, and north-eastward of, Blackball Head, and at the NE. point of Whiddy Island, Bantry Bay; all of these localities being in typical Carboniferous Slate, while at the last place it occurs close below the Coal Measures. many fossils including found

In the Yellow Sandstone, *Anodonta Jukesii*, ~~was~~ have been found at the Lower Glanmire road, a mile and a half east of Cork, and at Gokane Point, west of Toe Head, where are also associated with it the plants *Adiantites Hibernicus* and stems of *Sagenaria;* the plants, only, are found between Toe Head and Castlehaven. In these localities the Yellow Sandstone is under Carboniferous Slate; but in the Yellow Sandstone, under the Lower Limestone Shale at Tallow Bridge, junction of Cork and Waterford, a like assemblage of fossils occurs.

It might seem that the famous fossil localities at Kiltorcan, south-west of Thomastown, County Kilkenny, and in the promontory of Hook Head, County Wexford, should be here mentioned; these, however, are apparently in the "Old Red Sandstone," or Lower Carboniferous Sandstones and shales like those of the central plain, and the question of their age will be discussed in the next chapter.




*W. H. Baily, del.*

Lower Carboniferous Fossils.

# CHAPTER V.

## CARBONIFEROUS FORMATION.

### Lower Carboniferous.

In the previous chapter are described the Carboniferous rocks peculiar to SW. Ireland; they being most typical in the county of Cork. In this and the succeeding chapter is given a brief history of the Carboniferous rocks of the rest of the country, divided into Upper and Lower. The *Lower Carboniferous* includes all the rocks from the base of the arenaceous rocks, generally called "Old Red Sandstone," to the uppermost bed of the Upper Limestone, while the *Upper Carboniferous* is represented by the Coal Measures.

The *Old Red Sandstone* is included in the Carboniferous formation, because in no place in Ireland has it a defined upper boundary, one group graduating into the other; and usually the lowest grey and blue beds of grits or shales of the Carboniferous formation are taken as its uppermost limits. Furthermore, only in Munster and in the hills between Lough Erne and Pomeroy, Counties of Fermanagh and Tyrone, is the Old Red Sandstone at the absolute base of the Carboniferous formation; as in all other places the rocks so called and described are on different geological horizons, ranging up to the base of the Coal Measures. This will be explained presently.

Any classification of the Lower Carboniferous rocks, as at different times pointed out by Portlock and Jukes, is only locally applicable. This local grouping, however, is so far useful, that thereby is indicated the lithological character, whether calcareous, argillaceous, or arenaceous, of the rocks likely to be found in any particular place ; but it has also its disadvantages, as it causes confusion in many places.

The oldest Carboniferous rocks (*Old Red Sandstone*) are bright-coloured conglomerates, sandstones, grits, shales and clay-rocks, which graduate upward through dark-coloured grits and shales, into the various limestones. But as the floor of the Carboniferous sea was very uneven, and the sea was, in places, studded with islands, or had promontories jutting out into it, *Shore-beds*, which, from the conditions under which they were formed, are, both in aspect and as to the contained fossils, very similar to the oldest rocks, occur, notwithstanding, on very different geological horizons. Or, as Portlock writes, "they partake of a double position ; partaking at once of the character of a geological and mineralogical designation—geological when below, at the base of the Carboniferous formation ; mineralogical, when occurring above on different horizons in the rocks of the formation."

These shore accumulations cause much confusion, as they usually graduate horizontally into beds like the Lower Limestone Shale; while their real positions may be much above that group.

This is represented in the accompanying diagram. The *Shore-beds a′* and *b′* are margined by *Fenestella* Limestone *c′*, which is characteristic of the Lower Limestone, while the true position of said *Shore-beds* is in the Burren, or Upper, Limestone, represented to the right hand of the diagram, when the groups *a*, *b*, *c*, *d*, form a regular sequence upwards from the "Old Red Sandstone" (*a*).

In Kerry and Limerick, in the province of Munster, the rocks of the Carboniferous formation seem to be best

Fig. 5.

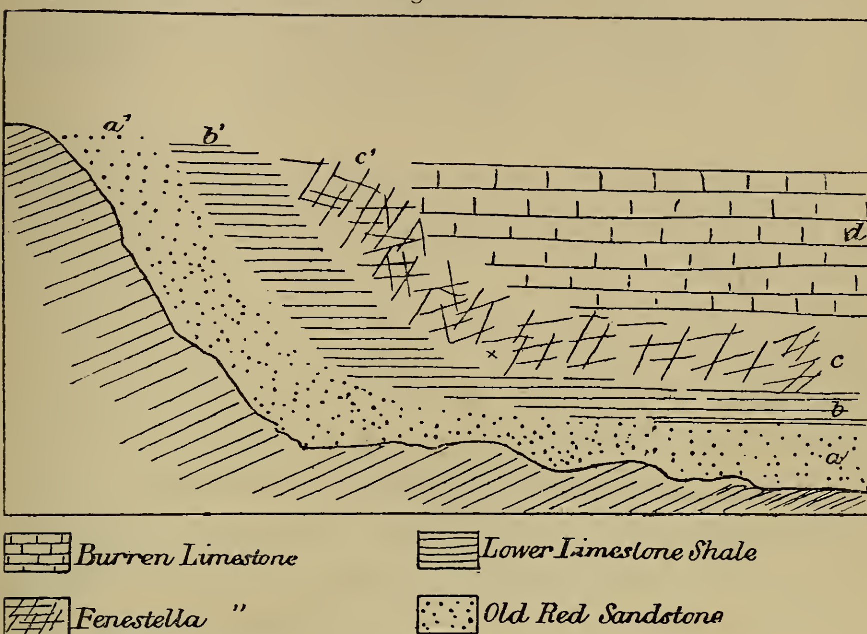



Diagram illustrating the changes from the Shore-beds into the Carboniferous Limestone.

developed; if we except those previously mentioned in Tyrone and Fermanagh. A general classification of these Munster rocks may be given, to which the rocks in the rest of Ireland can be referred.

*Table of the Classification of the Lower Carboniferous Rocks of Limerick and Kerry.*

| | |
|---|---|
| 4*b*. Upper Limestone of the Burren type. | Bedded limestones, having in places inliers of sandstone or shale.<br>Cherty zone. |
| 4*a*. Upper Limestone of the Calp type. | Earthy limestone, sandstones and shales, having in places "coal rods," or coaly seams.<br>Cherty zone. |

F

| | |
|---|---|
| 3. Lower Limestone. | *Fenestella* limestone (Wynne).<br>Lower cherty zone.<br>Lower shaly limestone. |
| 2. Lower Limestone shale. | |
| 1. Old Red Sandstone, or Lower Carboniferous grits and shales. | Red, purple, green, yellow shales and clay rocks, with some grits and sandstones.<br>Principally red and yellow grits, sandstones, and conglomerates, with subordinate shales and clay rocks. |

The groups 4*a* and 4*b* are purely lithological divisions. In general, the rocks of both types occur separately, but, when together, either of them may be uppermost, but usually those of the Burren type, or they may be mixed up together. In those places where both are represented, there is usually a cherty zone separating the two groups. In some places a higher cherty zone separates the Lower Carboniferous from the Upper or Coal Measures. However, under the Coal Measures in Munster and part of Leinster, this zone is totally absent.

In the previous chapter it was pointed out that the Carboniferous rocks of Cork, when followed eastward and northward, lose their own peculiar characteristics and assume some of those of the Carboniferous rocks of the rest of Ireland. It was also shown that, while in Cork the Glengariff Grits and the Old Red Sandstone are conformable, in the Dingle promontory there is a break between them. A diagram showing the changes is there given (fig. 4, p. 54). It will be seen by this diagram (which is not made to scale, but gives a general idea of the Section between the Dingle promontory and Bantry Bay) that in the Dingle promontory, County Kerry, the Carboniferous rocks of the ordinary type lie unconformably on the Dingle or Glengariff grits; but to the south, in the Iveragh promontory, there is a continuous sequence up from the Glengariff grits into the Carboniferous rocks of the Cork type; while farther southward, at Bantry Bay, it extends up into the Coal Measures.

In the Dingle promontory, the Lower Carboniferous rocks, which lie unconformably on the Dingle beds, were estimated by Foot to be of the following thickness:—

| | |
|---|---|
| 4. Coal measures. | |
| 3. Limestone . . . . . . . . | 1,800 feet. |
| 2. Lower Limestone shale . . . . . | 400 " |
| 1. Old Red Sandstone, or Lower grits and shales | 4,000 " |
| | 6,200 " |

In this county the Old Red Sandstone of this type and the Lower Limestone Shale is thicker than elsewhere in Ireland, except in Fermanagh and Tyrone, while the Old Red Sandstone is of about a similar thickness to that of the Cork type in the west of that county. Between the rocks in the upper and lower parts of the Limestone (No. 3) there is a marked difference, yet they cannot be definitely separated, as one graduates into the other. Chert is more common above than below; moreover, shaly beds are more frequent towards the middle of the series, but they do not appear to be always on the same horizon.

At the Lakes of Killarney, immediately above the Lower Limestone Shale, which here lies on "Old Red Sandstone" of the Cork type, the limestones are very cherty, similar to those at Kenmare, mentioned in the last chapter. In this vicinity, branches from the great *Dingle and Dungarvan Valley fault* cut out portions of the strata, and prevent any correct estimate being made of the thickness of the rocks.

In the valley running from Dingle to Dungarvan bays, the great fault of the valley nearly cuts out the Limestones on the west of Banteer (between Killarney and Mallow) bringing down the Upper Carboniferous rocks (Coal Measures) against the Glengariff grits. Farther eastward in this valley, to the bounds of the County of Cork, the Lower Limestone Shales and a considerable portion of the Limestone is cut out by the fault ; but in the Waterford part of the valley, to Dungarvan, there are rocks like Carboniferous Slate and Yellow Sandstone (Cork type) under the Limestone.

In the Blackwater portion of the valley, between Millstreet and Mallow, the strata to the north and south of the fault have inverted dips, the Coal Measures apparently dipping under the Glengariff grits ; at Banteer, however, it is evident in the limestone quarries that the Limestones turn sharply in depth and dip to the northward. In a small outlier situated in the alluvial flats of the Blackwater, between Banteer and Mallow, an irregular lenticular bed of earthy culm is enclosed in the Limestone.

In Waterford, the south portion of Kilkenny, Limerick, Tipperary, Queen's County, King's County, Clare, and the south part of Galway, the Lower Carboniferous Grits and Shales (or Old Red Sandstone) are well displayed, although in some places very thin ; but to the north of the parallel of Galway, the similarly constituted rocks that margin the different tracts and exposures of the Lower Palæozoic rocks, except those already mentioned in Fermanagh and Tyrone, are on much higher geological horizons. Thus, the so called "Old Red Sandstone" of Oughterard, County Galway, is high up in the Burren Limestone. To the north of Oughterard, there are conglomerates and sandstones dipping southward and graduating upwards through shales into the Burren Limestone ; while west of Oughterard, the marginal rock is a conglomerate graduating eastward, or along the strike of the beds, into Burren limestone. Here, in the townlands of Billymore and Lemonfield, the graduation is exhibited by some of the limestone beds being conglomeritic (with particles of quartz from the size of a bean to that of small shot), whilst inter-stratified with pure Burren limestone; these conglomerates being frequent in Billymore but dying out eastward, and having quite disappeared near the east margin of Lemon-field, at Lough Corrib.

Similarly, in the Counties of Galway and Mayo, between Loughs Corrib and Mask, as also farther northward, con-glomerates, sandstones, and shales margin the Lower Palæozoic rocks, but farther away they graduate horizon-tally into limestones of the Burren type. This takes place also in the central plain of Ireland, near all the isolated exposures of Silurian or older rocks protruding through the rocks of the Carboniferous formation.

In west Mayo, there are, in different places, rocks very similar as regards their appearance, and also the fossils they contain, to both the "Old Red Sandstone" and the Lower Limestone Shale; yet they all graduate horizontally into limestones of the Burren type.

The true "Old Red Sandstone," or basal arenaceous rocks, were evidently deposited under similar circumstances with the "Shore-beds" found on the different geological horizons; being more or less littoral accumulations. The fauna of the basal beds, being of littoral character, accom-modated themselves to the but slightly changing con-ditions under which the "Shore-beds" must always have accumulated, and thus their fossils range upwards through the successive groups of strata to the Upper Carbon-iferous.

The "Shore-beds," in general, only partially margined the old lands in the Carboniferous sea. From Galway towards the NW., nearly to Oughterard, the limestone rests on the granite and other old rocks; but at Oughterard there are "Shore-beds" which were evidently deposited in an ancient bay. Farther north, east and west of Cong, there are also "Shore-beds" clearly formed in similar situations. At Ballyhean, a few miles north of Lough Mask, there was an ancient island, south and south-east of which "Shore-beds" were formed, while limestone of the Burren type was deposited against it to the NW. and N. A nearly similar description would apply to the accumulations round the different islands that existed in the Carboniferous sea of Central Ireland, such as at the Chair of Kildare, where patches of "Shore-beds" are found to the NE. and SE.

On the north-west slopes of the Dublin and Carlow Mountains, there are a few isolated patches of sandstone; but usually the limestone lies directly on the older rocks; while, on the Dublin coast, near Lough Shinny, a shore conglomerate, or breccia, is found immediately under the Coal Measures.

## Limerick.

To return to Munster. It has been shown that in Kerry there are no marked divisions in the Limestone. But in north-east Cork and Waterford, over the Lower Limestone Shale, there are blue, argillaceous, shaly limestones, capped by the *Lower Cherty Zone;* which is a series of cherty beds interstratified with calcareous shales. In these parts of Cork and Waterford, the Upper Limestone is not represented, or it is cut out by faults; but in the

County Limerick and the adjoining portion of Tipperary, there are well-marked divisions.

*General Section, County Limerick.*

| | | | |
|---|---|---|---|
| Upper Limestone, of Burren type. | Bedded limestone | 240 | feet. |
| | Cherty zone | 20 | " |
| Upper Limestone, of Calp type. | Limestones and shales | 1,000 | " |
| | Cherty zone | 40 | " |
| Lower Limestone | *Fenestella* limestone | 1,900 | " |
| | Lower cherty zone | 20 | " |
| | Lower shaly limestones | 280 | " |
| Lower Limestone Shale | | 100 | " |
| Basal, or Old Red Sandstones | | 2,000 | " |
| | | 5,600 | " |

Interstratified with these rocks, there are, in the Counties of Cork, Limerick, and Clare, zones of eruptive rocks, the best developed being at the junction of the Fenestella and Upper Limestone. The base of the Old Red Sandstone of this area is only seen in the County Clare, to the north, and in the County Tipperary, to the east; in both places, the series consists, below, of conglomerates and sandstones, with subordinate shales, and, above, of shales and clay-rocks with some sandstones and grits. In some places, the basal bed is a peculiar quartz-rock or a silicious limestone.

The Lower Limestone Shale is rarely seen, being obscured by deep drift; but that it is a constant member of the series seems proved by its being found in all the ravines and valleys that cut through the drift. Below, this group graduates into the Old Red Sandstone. Plants, which may be referred to the genus *Sagenaria*, have been found in the Old Red Sandstone. In the Lower Limestone Shale, fossils are very numerous, but there is not much variety. They are as follows: *Fenestella flabellata*, very abundant; *Orthis Michelini, Spirifera striata, Streptorhynchus crenistria, Strophomena analoga, Acroculia vetusta, Nautilus dorsalis,* very rare; *Actinocrinus costatus, A. polydactylus,* and *Platycrinus lævis.*

Between the Lower Limestone Shale and the Lower Shaly Limestone there is only an arbitrary boundary, one graduating into the other. The limestones, when freshly raised from a great depth, are of a bright, light green colour, which, in a few days, changes to a dark, dull blue. These limestones occur in every locality where the true Old Red Sandstone is found. The fossils are abundant in some beds, the most characteristic being the coral *Michelinia favosa,* after which the Lower Shaly limestone is sometimes called; others are *Cyathophyllum ceratites, Lithodendron junceum, Ceriopora gracilis, Fenestella flabellata, Glauconome grandis, Orthis Michelini, O. resupinata, Producta margaritacea, P. semireticulata, Rhynchonella pleurodon, Spirifera cuspidata, S. glabra, S. lineata, S. striata, Streptorhynchus crenistria, Crinoidal* joints and stems, very abundant, and the trilobite *Phillipsia pustulata,* very rare.

The Lower cherty zone makes a marked base to the Fenestella limestone. In this limestone, the *Polyzoa,* after which it was called by Wynne, are very numerous, whole masses of the rock being sometimes made up of them. Brachiopoda are well represented, *Terebratula hastata, Spirifera striata, Rhynchonella pleurodon, R. pugnus, Orthis resupinata,* and *Producta semireticulata* being most numerous. Of Conchiferous mollusca, the *Aviculopectens* are the most numerous, *Cardiomorpha oblonga* is very characteristic, also species of *Edmondia* and *Pleurorhynchus,* a large and new species of the latter being called *Koninckii* by Baily. The Gasteropoda and Cephalopoda are very characteristic of this group, most of them, apparently, coming in and dying out with it. Of the former, *Euomphalus pentangulatus* and *Natica elliptica* are the most abundant, but others are plentiful, such as *Euomphalus Dionysii*, *Turritella suturalis*, *Trochella prisca*, and *Loxonema Lefebvrei*; a new chiton, *C. Thomondiensis*, has been found in this group of rocks. The most abundant of the Cephalopoda are *Nautilus biangulatus* and *dorsalis*, some of the latter being very large; *Goniatites sphæricus*, var. *crenistria*, are also common; *Nautilus discites*; several species of *Orthoceras*; *Gyroceras* also occurs, a Cephalopod new to Britain. In only one instance have fish remains been found, the fossil being a large scale referred to *Holoptychius Portlockii*. Baily's list of the other numerous fossils is given in the Explanation, sheet 158.

The characteristic *Fenestella* limestone is massive, destitute of bedding, and of a blue or grey colour; occasionally, however, it contains red and purple beds, these being generally at the base or top, but sometimes in intermediate positions. In some places the rock changes to a compact unfossiliferous, cherty-looking limestone, having innumerable small veins of calcite in it, and an appearance as if it had undergone metamorphism; this is very characteristic of the Fenestella limestone of Cork and Limerick. Jukes states of this altered rock, that it is similar in colour and aspect to specimens which he broke off the modern coral reefs in the Australian seas—large tracts are more or less magnesian or dolomitic.

The *Fenestella* limestone, when typical, is always capped by a cherty zone, the basal beds of the Upper Limestone. In places, the limestone under these cherty beds is entirely made up of well preserved fossils; as if the vulcanicity which erupted the igneous rocks that occur on the horizon of these cherty beds, had suddenly destroyed most of the life in the sea. One of these great burial places was opened up at Doohylebeg, near Rathkeale, in the making of the Limerick and Foynes railway. The rock cuttings brought innumerable fossils to light; some of the shells were beautifully coloured; but, unfortunately, on exposure to the air, the colours rapidly faded and disappeared; in some mineral pitch was found.

The cherty zone at the base of the Calp in the Counties of Limerick and Clare is well developed. It is, in a few places, over 200 feet thick, but the average thickness may be put down at 40 or 50 feet. Above this cherty zone are thin-bedded, dark blue, or black, argillaceous, fetid limestones with shale and clay partings. Some beds are fine and compactly crystalline, and would make marble. Some massive beds are affected by a structure that seems to be cleavage, although Dr. W. King, of Queen's College, Galway, considers it to be a variety of jointing. (*Trans. Roy. Irish Academy*, vol. xxv., p. 905.) Sometimes the Calp is so thin-bedded as to yield flags. The Upper Limestone is often magnesian, and sometimes quite a dolomite; some of the dolomites are oolitic. Griffith discovered a coalrod, or parting of coaly matter, in the Calp near Rathkeale.

Fossils are very rare in the Calp, as compared with the Fenestella limestone; *Bellerophons,* however, are very numerous in some beds, also *Phillipsia Derbiensis* and *pustulata, Chonetes papilionacea, Producta mesoloba,* with *Crinoidal* stems and joints.

In the west of the district, Upper Limestone of the Burren type comes in, but only with a thickness of a few hundred feet. It is separated from the rocks of the Calp type by a cherty zone. In the neighbourhood of Ballybrood, however, in the south-east part of the county, there seems to be, in places, a thickness of between 400 or 500 feet margining the Coal Measure outlier; but eastward the limestone is cut out by eruptive rocks, which come in on the same horizon; the latter are described in Chapter XII.

The well marked divisions in the Lower Carboniferous rocks of the County Limerick disappear or change as the rocks are followed northward or eastward. The *Lower Shaly limestone* is found in Clare, Limerick, Tipperary, north-east Cork, Waterford, Kilkenny, and perhaps in Carlow, and Kildare, but not elsewhere. The *Fenestella limestone* is generally found in the southern half of Ireland; elsewhere it does not occur as a distinct group; although there are, in places, local off-shore accumulations (see fig. 5) connected with the shore-beds, which are sometimes similar in appearance to that group.

The *Calp*, as it is followed northward, gives place to the Upper Limestone of the Burren type; but, towards the north-east, it becomes thicker, and in Ulster may be divided into distinct groups. The *Burren* limestone is a very important group in the barony of Burren, County Clare, from which locality it was named by Foot; it is so, likewise, farther northward, being the sole representative of the Lower Carboniferous rocks in a great portion of Connaught and Ulster. These different changes will be better understood after the different typical sections have been described.

## Leinster.

In Tipperary, adjoining the province of Leinster, in the King's County, Queen's County, part of Kildare, Carlow, and Kilkenny there seems to be a three-fold division in the limestones. Below, there are bedded limestones, more or less like the Lower Shaly limestones, which, as followed upwards, lose their bedded character, and take on that of the Fenestella type between these groups. There may be a distinct boundary between these groups; but on account of the great head of drift or bog in these different counties, this cannot be proved. The lower division in Kildare, Carlow, and part of Kilkenny, lying on the Leinster granite, is nearly always a bedded dolomite.

In north-west Kilkenny and the adjoining county, the central division is principally a dolomite, but in other places the limestones are bluish or black (often making a good marble) and associated with shales, the thickness of the latter being sometimes considerable. The upper rocks are somewhat like the Burren limestones, and chert is a characteristic of them; but they are not so regularly bedded. A very characteristic fossil is *Producta gigantea*, others are *Cyathophyllum regium*, *Lithostrotion striatum*, and *Lithodendron fasciculatum* and *irregulare*. In these counties, there is, in places, above this limestone and under the Coal Measures, a considerable series of cherty beds.

In part of Kildare, in Dublin, Meath, and Louth, limestones of the Calp type are the principal representatives of the Lower Carboniferous rocks; there are, however, in them subordinate beds which contain fossils characteristic of the Burren limestone, and other subordinate beds with fossils characteristic of the Lower Limestone. On account of the fossils in these subordinate beds being much more numerous than the fossils in the beds of the Calp type, the whole assemblage from the mass of the limestone, has rather the character of a Lower Limestone or of a Burren limestone, than of a Calp group.

The mixing together of the fauna of the different types of limestone may be thus accounted for. While elsewhere, in the area covered by the Lower Carboniferous rocks, first Lower Limestone and afterwards Calp and Burren limestone, were being deposited, in the Dublin district, on the contrary, the rocks being laid down were principally of the Calp type. But, at intervals, the circumstances of the sea in the Dublin area favoured the life typical of the other divisions, and during such times different animals emigrated from other areas, to live for longer or shorter periods in this part of the sea. However, as often as the conditions became unfavourable, these forms of life disappeared, to be subsequently succeeded by similar forms when the circumstances became again favourable. Exhaustive lists of the fossils collected in Dublin and the neighbouring counties are given by Baily and Jukes in the Explanation, sheets 102 and 112 of the Geological Map.

In the north of the County Dublin, at Portraine, on Lambay Island, and near Skerries, are conglomerates and sandstones associated with the Calp; while between Lough Shinny and Skerries are peculiar limestones, having the aspect of the Lower Limestone. Jukes, however, considered that these beds belong to the Calp, and were onshore accumulations in the neighbourhood of the land to the northward. The reasons for and against these rocks being true Lower Limestone are discussed in the Survey Memoir just now mentioned, page 61.

The arenaceous rocks at the base of the Lower Carboniferous in this area require some notice. In the valley of the Barrow, County Kilkenny, south of Goresbridge, the true "Old Red Sandstone" seems to die out; as, northward of that, the limestone lies directly on the older rocks. South-east of Thomastown, at Kiltorcan, is the famous Lower Carboniferous Sandstone quarry, in which the *Adiantites Hibernicus, Sphenopteris Hookeri, Anodonta Jukesii, Coccosteus, Bothriolepis,* and *Pterichthys* are found. It seems probable that the sandstones there belong to the basal beds of the Lower Carboniferous, but the *Adiantites Hibernicus* and *Sphenopteris,* are also found in the country to the SSE., in the promontory of Hook, where they are in shore-beds adjoining rocks of the Calp type. The rocks of this detached basin in the south of Wexford may be now described.

Extending NE. from the mouth of Waterford Harbour to Wexford Harbour, there is a tract of Carboniferous rocks, which are evidently the eastward extension of those at Dungarvan. These rocks seem to have accumulated in a narrow bay, which shallowed out eastward, while extending northward from it along the line of the present valley of the Barrow, there was a north branch which is now occupied by the conglomerates and sandstones which are to be seen north and south of the junction of the Barrow and the Suir. At the west end of this SW. and NE. strip of Carboniferous rocks, in the promontory of Hook Head, there are conglomerates and sandstones margining shales like Calp, over which are bedded limestones like the Lower Shaly Limestone of the Limerick section. Farther north-east the rocks have a similar aspect ; but at their north margins they graduate into conglomerates, sandstones, and red shales ; while at the south margin only a few subordinate beds of sandstone and shale are interstratified among them.

If the Hook Head rocks are not the true Old Red Sandstone, it is evident that the plants just mentioned were not confined to the beginning of the Carboniferous period, but that they flourished on the land near the seas or lagoons during the course of the age, and may be found in any littoral or estuarine accumulation. In the previous chapter, when describing the Carboniferous rocks of the Cork type, it was mentioned that assemblages of fossils very similar to those at Kiltorcan, are found in the Yellow Sandstone near Tallow Bridge, County Waterford, and near Toe Head, County Cork.

## Clare and Galway.

In south-east Clare the section is very similar to that of Limerick, except that the Old Red Sandstone, the Lower Limestone, and the Calp, are much thinner, and the Upper Limestone of the Burren type, as followed northward, rapidly thickens.

The following is the general section of the rocks :—

| | | | |
|---|---|---|---|
| Burren Limestone | Bedded limestone, with chert layers | 1,500 | feet. |
| | Cherty zone . . . . . | 40 | „ |
| Calp . . . | Black limestone, shale, &c. . <br> Cherty zone . . . . . | 400 | „ |
| Lower Limestone | Fenestella limestone . . . | 300 | „ |
| | Lower cherty zone . . . . . | 100 | „ |
| | Lower shaly limestone . . . | 400 | „ |
| Lower Limestone Shale . . . . . . . . | | 150 | „ |
| Old Red Sandstone or Basal beds . . . . . | | 1,000 | „ |
| | | 3,890 | „ |

The Old Red Sandstone, the Lower Limestone Shale, and the Lower Limestone, do not occur north of the parallel of Galway, in the middle parts of Ireland ; the rocks of similar composition that are found in that region being on higher geological horizons; but in South Ulster, towards the NE., they again appear. The Calp is replaced, to the northward, by the Burren limestone ; but to the north-east it thickens, and, in the neighbourhood of Loughrea, it is well developed, having in it very arenaceous beds; it is in part thin bedded and yields good flags. A little west of Portumna, there are a few thin sandstones and a coal-rod, or very thin seam of carbonaceous or coaly matter. Further eastward, in the vicinity of Portumna, immediately over the middle cherty zone and under the Calp, there is about 200 feet in thickness of Burren limestone; this mass, however, is evidently, lenticular. The Calp of Galway and that of North Leinster are probably connected; but they cannot be traced into one another on account of the great head of drift and bog on the intervening country.

In the Old Red Sandstone of this tract, fragments of plants are found in various places; the best locality being Derroran, County Galway (Explanation, sheets 124 & 125), while at Caherhurley, two miles SE. of Newmarket-on-Fergus, County Clare, plants occur associated with bivalve shells. In the latter locality, the Lower Limestone Shale is very fossiliferous, the fossils consisting of bivalve shells, a few univalves, corals, trilobites, and plant fragments.

The Upper Limestone abounds in corals. In the Burren, beds formed almost entirely of one kind of coral can be traced for miles. The most typical of the corals are *Lithostrotion affine*, *L. junceum*, *L. striatum* or *basaltiforme*, and *Alveolites depressa*. The latter often become silicious, and these silicious lumps, weathering out from the surface of a bed, sometimes leave holes like the footmarks of men, horses, dogs, &c., which have given rise to various legends. *Phanerotinus cristatus* is very abundant in some beds near Lough Cooter, County Galway.

In NE. Galway, at Mount Mary (a little SW. of the town of Roscommon) as also at Slieve Dart, the hill north of Dunmore, there are tracts of sandstone which seem to be high up in the Burren limestone, although the rocks are similar to the Old Red Sandstone. In Mount Mary conglomerates are exposed in two or three places only, while close to the hill is a quarry of black earthy limestone, full of chert and shale, like the Calp of the County Dublin. In Slieve Dart no arenaceous rocks are found *in situ;* to the SW. of the hill are rocks very like Calp, and, in one place, rocks like the Fenestella limestone ; but nearly everywhere else in the neighbourhoods of both hills the rocks partake more or less of the Burren type.

## Mayo, Sligo, and Roscommon.

West, north-west, and north of Lough Mask, as also north, north-east, and east of Clew Bay, there are conglomerates, sandstones, and bright-coloured shales, similar in aspect to the Old Red Sandstone, but evidently high up in the Burren Limestone, as seen at the north side of Lough Mask where one class of rock is interstratified with the other. East and north of Clew Bay, shales, like Lower Limestone Shale, margin the arenaceous rocks, the latter being of considerable thickness. Still, it is evident that all these rocks are high up in the Carboniferous formation ; for as we there recede from the ancient lands, they graduate into Upper Limestones ; furthermore, at Beltra and Levaly lakes, between Clew Bay and Lough Conn, limestones very similar to those of Burren seem to lie directly on the arenaceous rocks. Farther northward in Tirawley, there is a large area occupied for the most part by arenaceous and argillaceous rocks, which contain so-called typical Lower Limestone Shale fossils. These rocks, however, graduate eastward horizontally, into Upper

Limestone, and, consequently, must also be only shore-beds.

In south Roscommon, west and north-east of Castlereagh, there are shaly and arenaceous rocks, which, although they contain Lower Limestone Shale fossils, must be shore-beds in the Burren limestone. Further north, ENE. and WSW. of Lough Gara, there are arenaceous and argillaceous rocks lying on metamorphic and other Silurian rocks. The exact relations between these and the associated limestones are uncertain, as the geology is obscured by drift and bog. Some of the arenaceous rocks have been called, by Bedoe-Wilkinson, Old Red Sandstone, and of these he says: "they appear to be conformable with the Silurian beds, but are overlapped unconformably to the north and south by the Lower Carboniferous Sandstones." These Lower Carboniferous Sandstones of Bedoe-Wilkinson seem to be of Burren age; for, although the mass of the fossils found in the associated limestone are of Lower Limestone and Shale types, yet along with them are found such fossils as *Producta gigantea* and *Lithodendron affine*, eminently Upper Limestone types. Sir R. Griffith has mentioned to me in conversation, that in this vicinity, in the Curlew Mountains near Boyle, as also in the hills about Fintona, County Tyrone, he met with rocks very like those of the Glengariff Grit type, but that he never had time to work them out. These rocks and those about Fintona are probably of Silurian age, as mentioned at page 85.

In the Curlew Mountains, SW. and NE. of Lough Key, there are arenaceous rocks enveloping small exposures of Cambro-Silurian rocks. To the north of these are limestones of the Burren type, underlying the Coal Measures of Lough Allen. There may, indeed, be a great fault hereabouts, bringing up the older rocks; this, however, seems improbable, as at Drumshambo, to the south of Lough Allen, there is a section showing a regular gradation from rocks like the Lower Limestone Shale up to the Coal Measures.

In the section at Drumshambo, the lowest rocks are like Lower Limestone Shales, over which are rocks like Lower Limestone and Calp. To the east of Drumshambo, however, there are sandstones, which, to the south, seem to be margined by shales, and to the north, by limestone; while to the westward all these local peculiarities seem to disappear gradually, and limestones of the Burren type to come in. If there is not a nearly E. and W. fault, with an upthrow to the south, it is perfectly impossible that the arenaceous rocks about Lough Key, in the Curlew Mountains, can be true Old Red Sandstone; and if they are actually not so, they, and the associated shales WSW. and ENE. of Lough Gara, must be shore-beds of Burren limestone age. Such a fault seems improbable, on account of the character of the section at Drumshambo.

To the north and north-east of Slieve-Bawn, County Leitrim, and extending into the County of Monaghan, there is a large irregular tract of rocks like Lower Limestone Shale, lying apparently on the Cambro-Silurians, except in the vicinity of Cavan town, where sandstone intervenes between them. To these rocks we will hereafter return when describing the Lower Carboniferous rocks of Fermanagh, Tyrone, and Armagh.

In north Sligo the Carboniferous rocks are well exposed, and in Benbulben (Fig. 6) and the neighbouring hills they are as follows, according to Wynne:

4. Sandstones, the lowest beds of the Coal Measures.
3. Pale grey limestone, with magnesian limestone bands.

2. Thin bedded black shaly limestone, with magnesian limestone bands.
1. Olive, grey, and whitish sandstones, with black shale partings.

In the lower group there are remains of large plants, some of which are carbonized, with impressions of coiled shells. "The most characteristic fossil of the black limestone is *Zaphrentis cylindrica*." The pale grey limestones are less distinctly stratified than those below them, but "there does not seem to be any strongly marked division between the two." At Streedagh Point the fossil forms of *Z. cylindrica* are very numerous, "and project from the largely exposed, slightly sloping beds, like stumps in a cabbage garden, some of them being from 1·5 to 2 feet long, and 2 or 3 inches in diameter." There are also beds and great clusters of *Lithostrotion* in places. Wynne gives lists of fossils collected near Glencar Church and Kilsella in micaceous sandstones and rocks like Lower Limestone Shale, and from the limestone in other localities (*Dublin Geol. Soc. Journal*, vol. x.), the species having been determined by Baily.

Although the fossils would seem to indicate that the rocks belong to the Lower Limestone, yet they seem to be on a similar horizon to the limestones of Burren. They are situated immediately under the Coal Measures, and the entire thickness of them cannot be more than about 1,500 feet, as seen in the Benbulbin section. Wynne points out that the rocks show "signs of the splitting-up into alternations of silicious and calcareous deposits, such as occur in the Carboniferous rocks of Ulster."

### Fermanagh, Cavan, and Monaghan.

We have mentioned at page 83 that rocks like Lower Limestone Shale, lying above the Cambro-Silurians in

Cavan, extend NE. into the County Monaghan. These rocks are found for a short distance NE. of Monaghan town, after which the limestones appear to lie directly on the Cambro-Silurian. A north-west section, from Monaghan towards Omagh, County Tyrone, gives the rocks in the following order:—

1. Cambro-Silurians, covered unconformably by
2. Rocks like Lower Limestone Shale, dipping northward beneath
3. Grey and dark-blue limestone, with subordinate beds of shale, dipping northward beneath
4. The NE. and SW. ridge of Slieve Beagh, formed of light coloured sandstones and grits, with subordinate beds of shale, clay and thin, impure coal, lying in a synclinal curve, from beneath which rise northward

3′ Grey and dark-blue limestones, with subordinate beds of shale, from beneath which rise northward

2′ Rocks like Lower Limestone Shale, from beneath which rises northward

1′ A great thickness of sandstone, which occupies a large tract, extending nearly from Lough Erne, county Fermanagh, to Pomeroy, county Tyrone, the highest summit being Slievemore, 1,033 feet.

These rocks of Slievemore, according to Portlock, are true Old Red Sandstone, but Griffith suspects them to be partly Silurian, and representatives of part of the "Glengariff grits." * Portlock estimates them to be at least from 5,000 to 8,000 feet thick. According to Griffith, there are over them other sandstones (called by him Yellow Sandstone), which form a base to the Carboniferous rocks. North of these rocks, near Tubbrid and

* These are the rocks already mentioned as supposed by Griffith to be partly of Silurian age, and the representatives of the Dingle and Glengariff grits, counties of Kerry and Cork. The relations between the rocks of Slievemore and the Carboniferous limestones to the south have not as yet been worked out.

Omagh, are tracts of other sandstones, probably belonging to the Calp ; these will be mentioned hereafter.

From the arenaceous rock of Slievemore, westward, there is the following section :—

| | | | |
|---|---|---|---|
| 6. Coal Measures, having at Benbulben a group of sandstone at their base. | | | |
| 5. Splintery limestones . . . . . . . | about | 500 | feet. |
| 4. Calp sandstones, with shales, clays, and impure coals . . . . . . . . . | „ | 1,000 | „ |
| 3. Lower Limestone . . . . . . . | „ | 600 | „ |
| 2. Lower Limestone Shale ; principally grits and sandstones . . . . . . . . | „ | 200 | „ |
| 1. Sandstones, &c., of Slievemore. | | | |
| | | 2,300 | „ |

According to this calculation, the rocks (2, 3, 4, and 5) between the Coal Measures and the Slievemore rocks, are about equal in thickness to the rocks in Kerry that intervene between the Coal Measures and the Old Red Sandstone (see p. 67). In Kerry, however, those rocks were principally calcareous accumulations, while here, in a great measure, they are arenaceous and argillaceous. As already mentioned, coal-rods occur in the Calp in Limerick and Galway, while here there are regular seams, but so earthy and otherwise impure as to be valueless. Formerly the Calp sandstones of this county were supposed to be part of the Coal Measures ; but Griffith proved that they were a group in the centre of the Lower Carboniferous.

## Donegal, Londonderry, Antrim, Tyrone, and Armagh.

In Tyrone the section of the Lower Carboniferous rocks is very similar to that in Fermanagh and Monaghan ; but directly over the arenaceous rocks of Slievemore the

Lower Limestone seems to come in, or is brought down against them by faults. This is succeeded by the Calp; consisting of sandstones, shales, clays, and impure coals; over which is limestone, in part very like that of Burren, having also the typical fossils, but containing peculiar conglomeritic beds; pebbles or concretions of limestone being enveloped in a shaly calcareous matrix. In places, the beds are often ferruginous also, and in some localities, especially to the north, near Cookstown, there are inliers of sandstone.

Towards the SE., in the valley of the Blackwater, near Benburb, and also in the adjoining portion of the County Armagh, there are rocks having some of the characteristics of the Lower Limestone Shale and Old Red Sandstone, but others like those of the Upper Limestone; some of these are said by Professor Hull to be Permians. Portlock, however, considered all to belong to the Carboniferous formation, and Baily has pronounced the fossils in them to be typical Carboniferous; furthermore, Egan has shown that the limestones, shales, and sandstones are interstratified. This area has a special interest, as from thence was obtained a magnificent collection of fossil fish by the late Admiral Jones, many of which are figured as type specimens by Agassiz in "Recherches sur les Poissons Fossiles." A list of these fish is given by Portlock in his "Geological Report on Londonderry, Tyrone, &c.," page 461.

To these rocks it will be necessary to return again when describing the Permian rocks, but it should now be mentioned that some of the Armagh fossil fishes are also found in the Calp of Londonderry, in the Calp (coalfield) at Ballycastle, County Antrim, and in the Burdie House Limestone, Scotland; the last being apparently on the same geological horizon as the Irish Calp. A list of the fishes common to these different places will be given with the description of the Ballycastle rocks. The sandstones near Armagh, associated with the limestones containing these fossils, are very like those which, near Draperstown, County Londonderry, are associated with rocks containing similar fossils, as also to some of the sandstones (Shore-beds) at Ballycastle.

North of Cookstown, extending west-south-west from Moneymore, in Londonderry, to Lough Erne, in Fermanagh, there is a ridge or backbone of granitic and metamorphic rocks, north of which the Lower Carboniferous rocks are principally of the Calp type; they, however, often contain fossils or possess characters very like those of the Old Red Sandstone rocks and Lower Limestone Shale. Westwards, on the north, north-east, and east of Donegal Bay, there is a considerable area occupied by these rocks. These rocks principally have characters like the Lower Limestone Shale or the Calp, except in a tract towards the south, where the limestone has some characters like Lower Limestone, others like the Burren limestone.

North-east of Lough Erne, about Tubbrid and Omagh, is another tract, the rocks of which have characters common both to the Lower Limestone Shale and the Calp, except in a small area bordering Lough Erne, the limestone of which has generally more the characters of Lower than of Upper Limestone.

Farther northward, and SE. of Strabane, is a long irregular area in which the rocks are very like those to the SW., about Tubbrid.

From a little north of Moneymore there is a long irregular area of Lower Carboniferous rocks margining the Mesozoic and Cainozoic rocks of Ulster, which widens out and forms a considerable expanse at Lough Foyle. In the south of this tract, on the west of Draperstown, and margining the metamorphic rocks, there are rocks very like Old Red Sandstone, consisting (as seen in the Moyola river, west of Moneyneany) of a massive conglomerate that has a structure like bedding. This structure, however, must be false bedding; as otherwise the rock should be taken as over 2,000 feet thick, while in reality it can only be one or two hundred. About Draperstown are sandstones very similar to those of the Calp, but containing a vast thickness of shales identical in appearance, but not in fossils, with those of the Coal Measures, but having above them, on the slopes of Cullion, beds of earthy shaly limestone.

To the north-east of Cullion, in the neighbourhood of Desertmartin, are limestones quite separate and distinct from those of Cullion. They are like those of Burren, and contain some of the typical fossils. These limestones are supposed by Portlock to overlie the rocks between them and Draperstown. This is possible, as the Desertmartin limestones seem to be let down into their present position by faults. If the latter supposition be correct, they probably are the thickening eastward of the Cullion limestones, which when in mass have taken more decided character.

The connection between the red rocks west of Draperstown and the strata between that and Desertmartin is obscure, the former being cut off by a fault that runs about NNW. But when the sections exposed in the different tributaries of the Moyola river are examined, it is found that the black and yellow rocks in various places suddenly change into red rocks, and that such red patches always margin small tracts of metamorphic rocks ; from which it would appear probable that the red and other coloured rocks are different portions of the one group ; those accumulated near the shore lines being of red colour. Somewhat similar red rocks also occur to the west of Maghera, and to the north and west of Moneymore, the age of which is uncertain; but probably they are of similar age to the other red rocks. In the yellow and black rocks coal-rods occur, but no workable coals have been found.

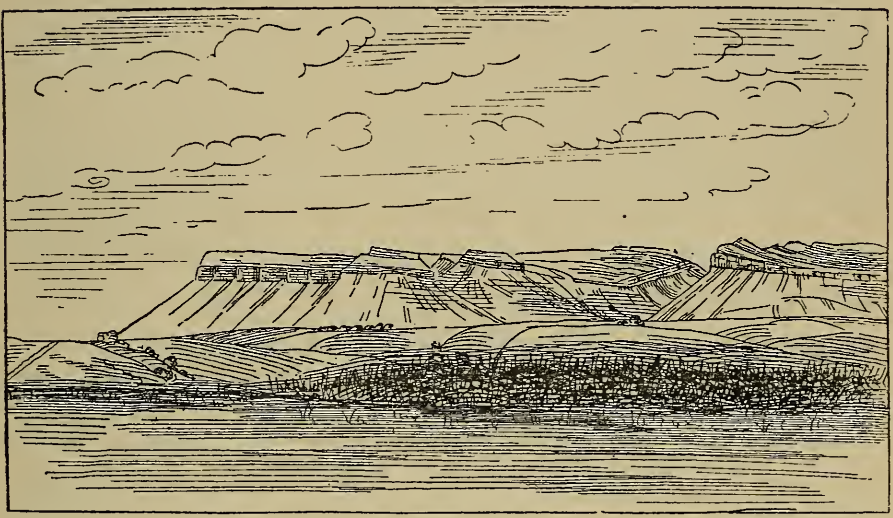
Farther northward, about Dungiven, and in the neighbourhood of Lough Foyle, the Carboniferous rocks are somewhat similar to those near Draperstown ; the red rocks, however, are not as prevalent. In some of these rocks are the remarkable fish remains before referred to.

To the east, in the valley now occupied by Lough Neagh, are great, nearly north and south, faults ; one or more of which seem to shift the ridge of Lower Palæozoic rocks at Moneymore, considerably northward ; these old rocks appearing again in the country between Cushendall and Ballycastle. To the SE. of this ridge or exposure of metamorphic rocks, and extending south-west from Cushendun Bay, is a small tract of tuffose arenaceous rocks like some of those near Pomeroy, County Tyrone ; while to the north-west of it is the Ballycastle Coalfield.

The rocks of the Ballycastle Coalfield are, in some respects, not very different from the typical Coal Measures of Ireland ; they contain various workable beds of bituminous coal. But these rocks have been proved by Griffith and others to be of the same age as the "Lower Coal Measures" of Scotland, which, from the sections exposed near Edinburgh, are evidently on about the same geological horizon as the Irish Calp.

A short *resumé* of the Calp rocks will show the relations between the rocks here and in the other localities. In the County of Limerick there are, in the Calp, shaly beds and at least one coal-rod or parting of coaly matter. In the County of Galway, besides shales there are arenaceous rocks, and, in one locality, a typical sandstone with a coal-rod. In the County of Dublin are sandstones, flags, and shales, with carbonaceous clays and coaly seams. In Fermanagh and Tyrone much of the Calp consists of sandstones and shales, in which are clays and im-

Fig. 6.



Benbulben Limestone Hills, County Sligo.

pure coals. In these counties the shales have not the characters of the Coal Measures, but when we proceed northward, past the ridge of Lower Palæozoic rocks, into Londonderry, the shales are identical in aspect with those of the Coal Measures, but have not the characteristic fossils. Associated with these shales are interstratified limestones, grits very like those of the Coal Measures, and various thin coal-rods of good coal, but no seam over a few inches in thickness is known to exist. Farther to the north-east, however, in the Ballycastle Coalfield, are rocks similar to those of Londonderry, but having in them good valuable seams of coal.

In the Ballycastle Coalfield there seems to be a different number of coals in the different parts of the area; however, they have not been as yet systematically worked out. Interstratified with the coal-bearing rocks are others; some of which are like Old Red Sandstone, others like Lower Limestone Shale, and others having the characters of the Upper Limestone. In reference to these Ballycastle rocks, Baily writes, "the prevailing plants are *Sigillaria* and *Stigmaria* (its roots), *Lepidodendron rimosum*, *L. dichotomum*, and *L. Veltheimianum*. An absence of ferns was remarkable. Many marine shells were collected from the associated shales and limestones of true Carboniferous Limestone characters; *Lingula squamiformis* being very abundant in the shales. Fish referred to *Ctenacanthus*, and palatal teeth of *Helodus planus* were also met with in the coast section."

The fossil fish found in these rocks have been already referred to; in the following list are given some of those that are stated by Portlock to be found in Armagh, Fermanagh, Tyrone, Londonderry, Ballycastle and Burdie House, Scotland.

*Amblypterus* (?).—Ballycastle; Maghera, Londonderry; Fermanagh, in calp.

*Gyracanthus formosus.*—Maghera, Londonderry.

*Holoptychius.*—Maghera, Ballinascreen, and Dungiven, Londonderry; Tyrone; Fermanagh; Hollywood; Down; Burdie House, Scotland.

*Psammodus porosus.*—Armagh; Derryloran, Tyrone; Desertmartin, Londonderry, in limestone somewhat like that of Armagh.

*P. rugosus.*—Armagh; Carnteel, Tyrone.

*P. cornutus.*—Armagh; Fermanagh, in calp (?) shales.

*Cochliodus magnus.*—Armagh; Desertcreat, Tyrone.

## County Down.

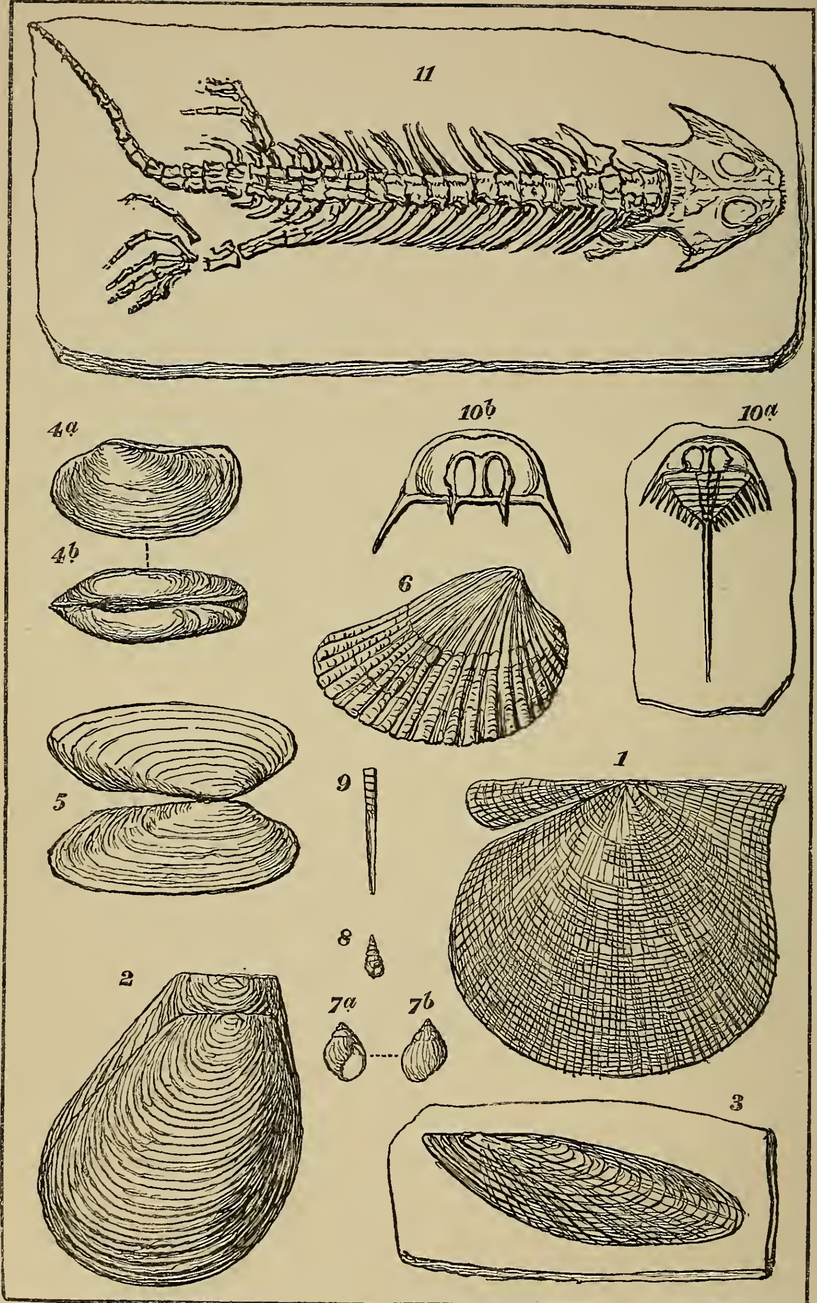
In the County of Down, at Holywood, near the SW. end of Belfast Lough, and near the north end of Strangford Lough, at Castle Espie, there are small exposures of Carboniferous rocks. Those in the first locality consist of shales, sandstones, and conglomerates, having, among other fossils, the fish *Holoptychius*, mentioned in the above list; while at Castle Espie are limestones like those of Armagh, with red shales and sandstones, but in this locality fish have not been found; these rocks probably belong to the Upper Limestone, for although the assemblage of fossils would indicate an older group, yet some of the fossils are eminently of Upper Limestone types; *Producta gigantea* is of large size, while *Actinoceras giganteum* is exceedingly large, and locally called "pillars."

## Carlingford and Dundalk.

In the north portion of the County of Louth, in the vicinity of Carlingford and Dundalk, are limestones and other rocks, having many characters and fossils of the Calp and Burren limestones; but, in places, with these rocks others are associated that are like Lower Limestone Shales. The latter probably are shore accumulations, while the whole group seems to belong to the Upper Limestone. In them Griffith found a few seams of coaly matter. Near Carlingford, these rocks are traversed by a network of dykes of eruptive rocks.

## Carrickmacross.

In the County of Monaghan, about Carrickmacross, and extending southward into the Counties of Cavan, Louth and Meath, is a large irregular triangular area of Carboniferous rocks ; near Nobber, the Coal Measures rest on the Lower Carboniferous rocks. These rocks, from lithological characters, may be divided into three groups, corresponding to Lower, Calp, and Burren limestones ; but, evidently, when those of the Burren type thicken, those of the Calp type die out. That the rocks of the different lithological divisions are of uneven thickness, and fully developed only here and there, is proved ; as, near Nobber, the Coal Measures lie on limestones, while to the NW. they appear to rest directly on the Cambro-Silurian rocks. West of Ardagh, the limestones contain a group of fossils which in Munster would be regarded as presenting a Lower Limestone *facies;* and yet a little NW. of the same place are shales, which, as appears by their contained fossils, clearly belong to the Lower Coal Measures. Here, therefore, there seems to be the same confusion as in the rocks to the south, in the County Dublin ; colonies of fossils characteristic of lower parts of the Carboniferous Limestone in Munster, occurring here high up in that formation. In places at the margin of the underlying Cambro-Silurian rocks, are local patches of bright-coloured sandstones and shales. Very small outlying patches of Carboniferous rocks occur to the SW., a little westward of Kells, and towards the NW., at Stradone, on the east of Cavan.




*W. H. Baily, del.*

Upper Carboniferous (Coal Measures) Fossils.

## CHAPTER VI.

### Upper Carboniferous.

#### Coal Measures.

In Chapters IV. and V. it was shown that the rocks of the Lower Carboniferous group are variable in character. In the SW. of Ireland, particularly in the SW. of the County Cork, there are no limestones in the group; in north Munster, and part of Leinster, there is the greatest thickness of limestone strata; while, in Ulster, there are arenaceous and argillaceous rocks, but of different types from those in south-west Cork, which in a great measure replace the limestones. The rocks called *Coal Measures* in Ireland, lie directly on all these different types of rocks, and apparently on one and the same geological horizon. These Coal Measure rocks, however, in some places overlap the Lower Carboniferous rocks, so as to lie immediately and, of course, unconformably on the Lower Palæozoic and other older rocks. It was also shown that the coal-bearing rocks of Ballycastle, County Antrim, belong to the Calp type of the Upper Limestone, and are probably of the same age as the "Lower Coal Measures" of Scotland.

Several attempts have been made to correlate the Irish Coal Measures with those of England; all, however, have failed. Neither lithologically nor stratigraphically can any correlation be made. According to Baily—"If the fossil fauna alone is considered, and the flora ignored, a forced correlation may be made with the Lower Coal Measures of England; but if the flora alone is taken into account, and the fauna ignored, the Measures can be made to seem of the same age as the Upper Coal Measures of England." From the uppermost beds of the Upper Limestone, to the highest bed of the Coal Measures found in Ireland, terrestrial, freshwater, estuarine, and marine fossils are mixed up together; it would, therefore, appear that the Irish Coal Measures have a type of their own, or that they cannot be correlated with the English rocks, except, perhaps, some of them with the "Culm Measures" of Devonshire.

Although the rocks of the Irish Coal Measures vary irregularly amongst themselves in certain respects, yet there are certain persistent differences amongst them, extending over the whole of Ireland, which make them capable of being subdivided into groups convenient for their description. These may be called, The *Upper*, *Middle*, and *Lower Coal Measures*, and their average thicknesses are as follows:—

GENERAL SECTION OF THE IRISH COAL MEASURES.

| | SW. CORK. | WEST MUNSTER. | EAST MUNSTER. | LEINSTER. | CONNAUGHT. | ULSTER. |
|---|---|---|---|---|---|---|
| UPPER MEASURES. | *Not represented.* | 2,050 *feet,* with an unknown number of coals in the northern portion, and over six in the south, or County of Cork. | 1,295 *feet,* with seven regular beds of coal. | *Thickness disputed.* | *Not represented.* | *About* 900 *feet,* in which are eight or nine workable coals, also smaller local coals and thick beds of fire-clay. |
| MIDDLE MEASURES. | *Not represented.* | 1,000 *feet.* To the north there appears to be a greater thickness than in the County Cork, where they seem to be about 900 feet. | 900 *feet.* | 800 *feet.* In these measures are beds of kelve and fire-clay, with a few coal rods. | 600 *feet represented,* in which are three coals, one being a good, workable coal. | 1,000 *feet,* with two seams of coal near the base. This thickness is a loose calculation, and probably too great. |
| LOWER MEASURES. | 200 *feet represented.* Coal Measure fish remains in the lower beds. | 500 *feet* to the north, and about 700 feet to the south. Coal Measure fish remains in the lower beds. | 600 *feet.* | 500 *feet.* Coal Measure fish remains in the lower beds, counties of Meath and Louth. | 600 *feet.* | 600 *feet.* |

The rocks of the Coal Measures in Munster and Leinster seem to have undergone an incipient metamorphism, as the coals are anthracites, while the other rocks are in general grits, shales, and indurated clays; the metamorphic action, however, was not intense enough to obliterate the fossils. In north-east Connaught, there seems to have been a very slight action, as the coals are more or less bituminous; while in Ulster there seems to have been little or no change, most, if not all, of the coals being bituminous, and the shales of Munster being represented by laminated clays. In Ireland both the bituminous and non-bituminous varieties are called *Coal;* when compact and laminated, *Cannel coal;* when soft and laminated, *Culm. Kelve* and *Pindy* are more or less argillaceous or arenaceous culms, that graduate into carbonaceous shales; *Buddagh* is carbonaceous clay, and *Coal-rods* or *Crow coals*, are thin local seams, or mere partings of coal, or coaly matter. There are also other local terms, but of limited use.

In the LOWER MEASURES, in the Counties of Cork, Kerry, Clare, Limerick, Meath and Louth, there are fish remains at the base of the series. These, when submitted by Jukes to Egerton and Huxley, were pronounced to belong to the genus *Cœlacanthus*, a fish of a true Coal Measure type.*

This division is usually composed, for the most part, of argillaceous rocks, except at the base, where a small thickness of flaggy grits comes in; but in north-east Connaught these arenaceous rocks are represented by a regular series of grits, hundreds of feet in thickness; the fossils of the arenaceous rocks seem always to be terrestrial, while

* Very similar fish occur in the *Upper Measures* in the Dungannon coal-field, County Tyrone, near Coal Island.

those of the shales are marine. In Connaught and Ulster, there are also subordinate thin beds of limestone.

At the base of the MIDDLE MEASURES there is, in general, a *Flagstone series;* in some places, however, it is not well represented, while in other places it is higher up in the series. Peculiar tracks are always found on these flags, which have been figured and described by Baily in the Geological Survey Memoirs, Explanations sheets 128 and 140.

In these Measures in Munster and Leinster, kelve, coal-rods, and fire-clays occur, but no workable coals; while in north-east Connaught and in Ulster, workable coals do occur. The fossils of these rocks are very much mixed up; they are usually marine in the argillaceous rocks, and terrestrial in the arenaceous. There are, however, exceptions to this rule, as in some of the grits and flagstones estuarine or marine fossils occur.

In some of the shale beds, but especially in certain beds near the top of the Middle Measures, there are seams or layers of nodules of Clay-iron-stone, which were formerly extensively worked in the Provinces of Leinster and Munster.

The UPPER MEASURES are irregular alternations of grits and shales, associated with beds of coal, fire-clay, and clunch; also seams and nodules of Clay-iron-stone.

The base of these Measures is a more or less arbitrary line, as the rocks in them and those in the Middle Measures are somewhat similar. It was, however, found by Jukes and his colleagues that in all the Irish Coal Measures (except, perhaps, in those of Tyrone, province of Ulster, where no section of Middle Measures can be seen) there is a thin Coal from about 1,200 to 1,500 feet above the Limestone and a little over the shales, formerly extensively worked for Clay-iron-stone; this was adopted as the base of the Upper Measures.* This seam, although most important geologically, from its being so universal, appears to be commercially of little value, for in no place has it been found to be a workable coal.

It is remarkable that such a thin coal should extend over so great an area. In the Leinster Coal-field it has been proved in numerous places in the vicinities of the ancient iron-ore workings; in the East Munster Coal-field a coal is found on about the same horizon, and also in that of West Munster. In the outlying patches of Coal Measures in Munster, Leinster, Connaught, and Ulster, wherever they are from 1,200 to 1,500 feet thick, this coal has always been found; and even in the Tyrone Coal-field it probably exists, as in one place there is a thin coal that may represent it.

In several places argillaceous limestone beds have been found containing fossils of a *Lower Carboniferous* type; hand specimens of the rocks being nearly undistinguishable from Lower Limestone Shale. They were first recorded by Willson, in 1855, from the Kilkenny portion of the Leinster Coal-field,† where they are above two or three of the Coals; subsequently we ourselves found either two or three beds, of a similar character, high up in the Coal Measures of Limerick, above some of the principal coals, but the exact height above the Upper Limestone could not be determined; and more recently Foot recorded a very continuous bed in the County Clare, estimated by him to be over 2,000 feet above the base of the

* In some of the places unexamined when this horizon was decided upon, a thin coal, occupying a very similar position, has since been recorded.

† Mr. Hardman has recently found a similar rock near Castlecomer, County Kilkenny, which is probably that first noticed by Willson, or part of the same bed.

Coal Measures. In the other fields no limestone of this character has been recorded.

It has already been mentioned that such authorities as Egerton and Huxley consider the fish remains in the very lowest beds of the Irish Lower Coal Measures to be of true Coal Measure type ; and Baily, who stands prominent in his knowledge of the fossils of the Irish Coal Measures, has furnished us with the following epitome of his Report on those fossils, read before the Royal Irish Academy, January 25, 1877 :—

"These results show that in the south of Ireland, as in the somewhat analogous Coal-field of Coalbrookdale, Shropshire, alternations of marine, estuarine, and probably fresh-water deposits occurred, containing the remains of plants and animals of a very similar character to those alluded to in Mr. Prestwich's description of that Coal-field in the 'Transactions of the Geological Society of London,' vol. v., second series. In the Leinster Coal-field the peculiar Limuloid Crustacean *Belinurus*, and the Fish *Rhizodus* and *Gyracanthus* are genera characteristic of this district, as well as of that of Coalbrookdale ; fossil plants of several species are also common to the Coal-fields of Tipperary and Castlecomer, and those of Shropshire and Newcastle. The marine shells *Aviculopecten papyraceus*, *Goniatites sphœricus* var. *crenistria*, with *Posidonomya Becheri* and its probable variety *P. membranacea* are abundant in the shales connected with certain Coals in the Tipperary and Castlecomer districts ; whilst other Coal seams are characterized by certain Plant remains ; this is especially the case at the collieries near Killenaule, in the County of Tipperary, several of them being remarkable for the abundance of Plant impressions, amongst which Ferns predominate, such as *Sphenopteris Hoening-*

*hausii*, *Pecopteris muricata*, *Alethopteris lonchitidis*, together with *Sphenophyllum Schlotheimii*, *Calamites Suckowii*, and *C. cannæformis*, and *Lepidodendron Sternbergii*.

"In the County of Limerick, in the Lower Coal Measure shales, marine fossils predominated, associated with comparatively few plant remains, and those of an indefinite character, such as *Nœggerathia*. Of the shells, *Posidonomya* were in profusion, *Aviculopecten* being also very abundant with *Myalina*, *Goniatites*, and *Orthoceras*.

"In the Munster district, at collieries near Kanturk, *Sigillariæ* were found to be remarkably abundant with *Stigmaria* in the underclay, *Calamites* of several species, *Lepidodendron*, also *Sphenophyllum Schlotheimii*, fossil ferns *Sphenopteris Hoeninghausii*, *Neuropteris Loshii*, *Pecopteris abbreviata*, and *Alethopteris lonchitidis*.

"In the County of Clare, in the Lower Shales, as in the Counties of Meath and Dublin, marine forms of identical species, including *Posidonomya membranacea*, *Aviculopecten papyraceus*, *Lunulacardium*, *Goniatites*, and Fish, probably *Cœlacanthus*, are abundant; and at Lahinch, in the same County, bivalve shells were obtained, like those found at Bilboa, in the Queen's County—*Anthracosia*, *Myacites*, *Myalina*, &c., *Aviculopecten papyraceus*, *Goniatites crenistria*, and *Orthoceras*, accompanied by the remarkable crustacean *Belinurus Regina*.

"In the Connaught Coal District, situated in the Counties of Roscommon, Sligo, Leitrim, and partly in the County of Cavan, fossil Plants of the genera *Lepidodendron*, *Stigmaria*, and *Calamites* occur in the sandstone associated with the 'Bottom Coal' near the Arigna Iron Works; and in dark grey shales, more distant from those works, marine fossils were obtained of similar species to those found at Rosscliff in the County of Clare, and on the

Banks of the Boyne, in the County of Meath, viz., *Aviculopecten papyraceus*, and *A. variabilis*, *Posidonomya membranacea*, *Goniatites crenistria*, *Crinoid* joints, and a few Plant fragments.

"In the Tyrone Coal-field, including those of Coalisland and Annaghone, the fossil assemblage contains comparatively few plant remains. Like that of Antrim, these are associated with marine beds containing Carboniferous Limestone species of shells. The conspicuous Plants are *Lepidodendron rimosum* and *L. selaginoides*, *Stigmaria*, *Calamites cannæformis*, *Sphenopteris irregularis*, and *S. tridactylites* with bivalve shells, *Anthracosia* and *Sanguinolites*, and the characteristic Carboniferous Limestone Brachiopod *Lingula squamiformis* so abundant at Ballycastle Colliery; also Cephalopod shells, *Goniatites crenistria* and *Orthoceras*. With these are associated fish scales, referred to *Palæoniscus*, and palatal teeth of *Helodus planus*."

The principal Irish Coal-fields are the WEST MUNSTER COAL-FIELD, including portions of Clare, Limerick, Kerry, and Cork; the EAST MUNSTER COAL-FIELD, part of Tipperary; the LEINSTER COAL-FIELD, in the Queen's County, Kilkenny, and Carlow; the CONNAUGHT COAL-FIELD, situated in Sligo and Roscommon, with the adjoining portions of Fermanagh and Cavan in Ulster; and the TYRONE COAL-FIELD, which includes those of Dungannon, Coalisland, and Annaghone. Besides these fields there are numerous small outliers, some interesting from the situations they occupy, others for the rocks or fossils found in them. Those found in West Cork shall be first described.

## West Cork.

In West Cork, Coal Measures occur at Whiddy Island, in Bantry Bay; near Ballyheedy, SW. of Ballinhassig; farther north-eastward, NW. of Carrigaline; and to the southward in the promontory of the Old Head of Kinsale. In all these places, except near Carrigaline, the Coal Measures lie directly on the Carboniferous Slate; in the vicinity of Carrigaline the Limestone begins to come in, and from ten to fifteen feet of earthy Limestone is found in one place under the Coal Measures. At the Old Head of Kinsale there are a few small patches occurring in sharp synclinal folds of the Carboniferous Slate.

In all these localities there seems to be a very small thickness of the Lower Shales; Jukes considered those near Ballyheedy to be not more than 100 or 200 feet thick. In the shales are such fossils as *Posidonomya Becheri* and *membranacea*, while near Ballyheedy are also found fish remains, of the genus *Cœlacanthus*, which Sir P. de M. Grey-Egerton "has never seen in any beds below the Coal Measures." Associated with these are other fossils of Coal Measure types.

## West Munster Coal-field.

In Clare, Limerick, and Kerry there appears to be a considerable thickness of Measures, much greater than in East Munster or Leinster, but very destitute of workable Coals. Foot was of opinion that the Measures in Clare were between 3,000 and 4,000 feet thick. But in Limerick and Kerry there are no sections from which good estimates can be made.

*General Section, Clare, Limerick (?), and Kerry (?).*

| | | | |
|---|---|---|---|
| UPPER MEASURES. | Upper beds with some coals over | 1,800 | feet. |
| | II. Coal . . . . | 2 | „ |
| | Intermediate beds . . | 250 | „ |
| | I. Coal . . . . | 0·5 | „ |
| | | 2,052·5 | „ |
| MIDDLE MEASURES . . . . . . . | | 1,000 | „ |
| LOWER MEASURES . . . . . . . | | 500 | „ |
| | | 3,552·5 | „ |

In the north part of ~~Clare~~, the "Coal Slate," as is locally named the black carbonaceous shale forming the "roof" of a coal, also the "seat clay" and the "seat rock" of Nos. I. and II. Coals can be found and traced, but the Coals are absent or represented by great stems of *Stigmaria.* Higher Coals occur in different places in the county, but all that are known, except a few near the Shannon, at the south of the county, are so thin that they are valueless. According to Foot, there is, at about 2,700 feet above the base of the Coal Measures, a bed of argillaceous limestone, generally over a foot thick, which contains *crinoid* joints, small *Orthoceras*, *Goniatites crenistria* in abundance, a few *Brachiopoda*, the Coral *Zaphrentis* and *Polyzoa.* This Limestone has thin beds of coal at some distances above and below it.

At Coosnabrien, near Killard Point, are very large specimens of *Stigmaria*, some over seven feet long ; and at Coor Spa, near Ennis, is a remarkable assemblage of fossils, in the Lower Measures, consisting of terrestrial plant stems, some very large and longitudinally ribbed ("Geological Survey Memoirs," Explanation sheets 131 and 132), associated with numerous marine fossils. At Rosscliff ("Geological Survey Memoirs," Explanation sheet 142) the Lower Measures are very rich in fossils, including, among many others, *Lunalacardium Footii*, a fossil characteristic of these Irish Measures, and remains of the fish *Cœlacanthus.**

South of the Shannon, in Limerick and Kerry, there are some workable coals, but, except in the case of Nos. I. and II. Coals, the height at which they are found above the base of the Coal Measures is unknown. To the east of Abbeyfeale, between two coals not far apart, are fossils similar to those found by Foot in the limestone band, County Clare. Here, however, the rock is not as pure a limestone, but more like the Lower Limestone Shales. Some miles east of Athea there is a very similar assemblage of fossils in a blackish shale immediately over a coal. These coals are evidently higher than No. II. Coal in the general section (page 105), but how much it is impossible to say. Near Glin there is a coal that seems to be higher than No. II., which has above it shales very rich in fossil plants. *Alethopteris heterophylla*, *Corynepteris stellata* (thus provisionally named by Baily, but now considered by him to be the fructification of *Alethopteris*), *Calamites cannæformis*, *Calamocladus grandis*, *Lepidodendron Sternbergii*, *Lepidostrobus ornatus*, *L. lepidophyllus*, *Sigillaria tessellata*, *S. Lindleyana*, *S. oculata*, and *Stigmaria ficoides*.

The plants in the above list are instructive, for, as pointed out by Baily, they are identical with species from the Coalbrookdale and Newcastle collieries of England.

In South Limerick the coals are very perplexing, as in certain places the strata are inverted, the "roof" being beneath, and the "coal-seat" and "clay" above the coals;

* These are bones of the head, like those found in the Lower Measures at Ballybunnion, County Kerry, and in the valley of the Boyne (Louth and Meath), to the WSW. of Drogheda.

the strata being so much crumpled that the positions of the coals in the sections are quite uncertain—this complication also occurs further south in the County of Cork; but here, in the Blackwater valley, the coals are more numerous than elsewhere in the West Munster coal-field.

In the Blackwater collieries six coals are worked. In the west portion of the valley it is impossible to calculate the height of the coals above the Limestone, as the previously mentioned great fault of the valley between Dingle and Dungarvan brings down the Coal Measures hereabouts, against the Glengariff grits (Silurians); while the Coal Measures are inverted and crumpled up. Farther eastward, however, in the cutting for the Railway, between Mallow and Dublin, the rocks occur in a regular succession, and contain coals that seem to represent those at the collieries; and this series has been taken as an index to the district; the following section, up to the first coal, having been calculated from it, above which the measurements at the collieries are given.

*General Section in the Blackwater Valley, County Cork.*

| | | | |
|---|---|---|---|
| UPPER MEASURES. | 6. Upper beds . . . . | not known. | |
| | VI. *South, or Harris's Bulk vein* | 1·5 to 5 | feet. |
| | 5. Intermediate beds . . . | 120 | " |
| | V. *Bulk vein* . . . . . | 1·5 to 7 | " |
| | 4. Intermediate beds . . | 125 | " |
| | IV. *Rock vein* . . . . . | 0·5 to 2 | " |
| | 3. Intermediate beds . . . | 100 | " |
| | III. *Coal or Sweet vein* . . | 1 to 2 | " |
| | 2. Intermediate beds . . . | 200 | " |
| | II. *Fourpenny vein* . . . | 1 to 1·5 | " |
| | 1. Intermediate beds . . . | 100 | " |
| | I. *Morgan's, or Castle vein* . | 0·75 | " |
| | | 663·25 | " |
| MIDDLE MEASURES. . . . . . . | | 900 | " |
| LOWER MEASURES. . . . . . . | | 700 | " |
| | | 2,263·25 | " |

The "bulk" veins Nos. V. and VI. are made up of two or more coals which, in places, join together or "bulk." When the subordinate beds separate, they are called "arms." In the Bulk vein No. V. the north arm always lies on a "seat" and has a "slate" roof, while the other arms have "slate" under and over them. When the south arms branch from the main, or north arm, there may be any thickness of a wedge of Measures between them, and sometimes these arms even dip at the main arm.* In this valley there is a repetition of the same series of beds, the two masses of stratification striking parallel and dipping toward the southward, as explained in the Survey Memoirs, Explanation sheets 163, 174 and 175.

In the rocks associated with No. II. Coal and higher Coals clay-iron-stone occurs in the county, both north and south of the Shannon, and at one time it was considerably worked. At the Knocknaboola Colliery, near Loghill, in the shales associated with the clay-iron-stone, a new fossil, *Loxonema minutissima*, occurs.

In the Middle Measures the *Flagstone series* is well developed in the Counties of Clare, Limerick, and Kerry; the flags have been worked at different places, especially at Money Point, to the north of the Shannon estuary, where they are rich in curious tracks.

In the Lower Measures near Ballybunion, County Kerry, are the previously mentioned remains of the fish *Cœlacanthus*; and at Foynes Island, County Limerick, there is a vast quantity of pyrites, principally associated with calcareous nodules, in which the fossils are uncompressed and very perfect, the most numerous being *Goniatites;* but there

* Foot records in Clare coals branching similarly, and in one place he found that the branches lay in the oblique or false bedding of the overlying bed.

were some new fossils detected by Baily, namely, *Orthoceras minimum*, *Myalina Foynesiana*, *Loxonema Galvani*, and *Macrocheilus inflatus*. One mile to the southward are fish-bones and scales (*Cœlacanthus*), while still farther south, at Mount David, near Shanagolden, are plant remains associated with marine or estuarine fossils. The same mixing-up of terrestrial and marine forms, but in the Middle Measures, occurs in the rocks close under the Coals at Loghill. Baily's list of the fossils of the West Munster Coal-field are given in the "Geological Survey Memoirs," Explanation sheets 131 and 132.

## Small Outliers in Munster.

To the east of the Munster Coal-field, at Ballybrood, in the plain of Limerick, is a small tract of Coal Measures; while a second occurs to the south-south-east at Garbally. In both these tracts the Measures are over 1,500 feet in thickness; and No. I. Coal occurs, but only a few inches in thickness. The Garbally tract is bounded to the south by the great Slieve-na-muck fault, which brings it down against either the Cambro-Silurians or Cambrians. In this tract the Flagstone series is well developed, and the flags have been worked in various small quarries.

Still farther south-south-east, in the Mitchelstown valley, south of Galtymore, is a considerable area of Lower Measures, which are here about 400 feet in thickness; while other isolated small outliers occur north-west of Clonmel, south-west and north-east of Fethard, and north of Cashel.

## East Munster Coal-field.

In this field every stratum, from the highest in the

Limestone to the highest of the Coal Measures, can be seen and measured. The following is the section :—

*General Section, East Munster Coal-field.*

| | | | |
|---|---|---|---|
| UPPER MEASURES. | 8. Upper beds | 60 | feet. |
| | VIII. *Parknaclea Coal* | 4 | " |
| | 7. Intermediate beds | 110 | " |
| | VII. *Clashacona Coal* | 2 | " |
| | 6. Intermediate beds | 30 | " |
| | VI. *Hanly's vein* | 1·5 | " |
| | 5. Intermediate beds | 90 | " |
| | V. *Crow Coal* | 2 | " |
| | 4. Intermediate beds | 140 | " |
| | IV. *Main Coal* | 2 | " |
| | 3. Intermediate beds | 200 | " |
| | III. *Pat. Maher's vein* | 0·75 | " |
| | 2. Intermediate beds | 500 | " |
| | II. *Upper Glengoole Coal* | 1·75 | " |
| | 1. Intermediate beds | 150 | " |
| | I. *Stinking vein* | 0·75 | " |
| | | 1,294·75 | " |
| MIDDLE MEASURES | | 900 | " |
| LOWER MEASURES | | 600 | " |
| | | 2,794·75 | |

No. I. and II. Coals surround the productive portion of the field, and also occur in a few outlying basins. No. III. is an insignificant local coal, and would not appear in the list but that it was cut in the long level connecting the Glengoole and the Earl's Hill collieries. The Coals above No. IV. only occur in a small basin at Earl's Hill, the remnant of some of the higher strata that once existed. No. VIII. is entirely worked out; No. VII. has a most peculiar roof, rising in arches, the coal thinning to a few inches, and then thickening in places to four or five feet; No. IV. is the best anthracite in the district, but it has a soft and bad roof which makes it expensive to work. This coal occurs in a few small out-lying basins, besides that at Earl's Hill; and in some of the shales over it are balls of clay-ironstone.

In the Measures associated with the lower Coals in the north portion of the West Munster field, marine or estuarine (?) fossils predominate, while in this field plant remains are very numerous, not only with the lower but also the upper Coals. Those most generally distributed are four or five kinds of *Calamites; Sphenophyllum* or *Asterophyllites* are also not uncommon; these plants being remarkable for a peculiar arrangement of the leaves in star-like whorls round the stems; but generally the most numerous plant impressions are those of ferns. The Lower Glengoole Colliery is a remarkably rich locality for some ferns, particularly *Sphenopteris Hoeninghausii*, *S. muricata*, and *Alethopteris lonchitidis*; the last-named, being widely distributed throughout all the Irish Coal Measures. At Knockalonga another species, formerly called *Alethopteris*, now *Pecopteris pteroides*, occurs; and at the same place *Sphenopteris tridactylites* and *Sphenophyllum Schlotheimii*. The only English locality yet known for this last-named fossil is in Staffordshire; but it is characteristic of the Coal Measures in Prussia and Saxony.

At the Commons, Crowhill, Boulea and Foilacamon, or Knockinglass Collieries, in the "roof" of the No. II. Coal there are small bivalves belonging to the genera *Anthracosia*, *Myacites*, and *Myalina*. Similar shells, as will be hereafter mentioned, occur in the "roof" of No. III. Coal, Bilboa, Queen's County.* The various other fossils

* Mr. Pat. Finlan, of Clogh Colliery, Queen's County, has stated that while he was working the coals at the Coalbrook Colliery, he found crustacea in the shales; he did not, however, preserve a specimen, and none of them have since been found.

recorded from these Coal Measures will be found in Baily's list, "Geological Survey Memoirs," Explanation sheet 146.

## Leinster Coal-field.

In this field, as in the West Munster field, the sections exposed or proved are unsatisfactory. To the west of the main field, in Galmoy, on the west of the valley of the Nore, there is a large outlying tract of Lower Measures. The main field, on the south-west, joins the East Munster Coal-field ; the measures being thickest in the table-land between the valleys of the Nore and the Barrow.

Griffith, who was the first to systematically examine this field, came to the conclusion that the coals in the centre, near Castlecomer, were higher than those to the east and west ; but afterwards, Messrs. B. B. Edge and Arthur Jacob maintained that the main coals near Castlecomer were the same as those to the east and west, and that the measures in the centre of the field had been brought up by faults ; and subsequently, during the survey made under Jukes, conclusions very similar to the last were arrived at. Griffith's calculation of the thickness of the measures in the different Coal-fields of Ireland have, by subsequent research, been found to be so accurate that any opinion of his must necessarily have great weight. It will therefore be advisable to analyse all that is known about the Leinster coal-field.

The Castlecomer tableland is traversed by numerous faults. It would appear that great, nearly N. and S., faults divide it into three parts—east, middle, and west. The western division is very little known, as it is covered more or less by deep drift, and few coals have been worked in it; but there appear to be actually less coals in it than in the other divisions. It is separated from the middle division by a fault, with an upthrow to the eastward, which runs northward from Dunmore past Castlecomer.

The thickest and most productive coals are found in the centre of the field in the middle division; but it is evident that to the east there are more coals than to the south, north, and west. The eastern is separated from the middle division by a fault, with an upthrow to the west, which runs south-eastward from Luggacurren. In this portion the Measures are known, and give the following general section.

*General Section of the Eastern Division of the Castlecomer Coal-field.*

(East of the Luggacurren fault.)

| | | | |
|---|---|---|---|
| Upper Measures. | Upper beds | over 100 | feet. |
| | V. *Ward's Seam*, Coal and Fire-clay | 5 | " |
| | Intermediate beds | 130 | " |
| | IV. *Rushes*, or *Towlerton Old Coal* | 1·5 | " |
| | Intermediate beds | 50 | " |
| | III. *Bilboa*, or *Towlerton New Coal* (?) | ·75 to 2 | " |
| | Intermediate beds | 180 | " |
| | II. *Kingscote Coal* | 1 | " |
| | Intermediate beds | 300 | " |
| | I. *Gale Hill Coal* | 0·5 | " |
| | | 770 | " |
| Middle Measures | | 800 | " |
| Lower Measures | | 500 | " |
| | | 2,070 | " |

In this section, from the highest bed of the Limestone to No. III. Coal, every bed can be seen and measured; and

No. III. Coal has been worked in the Bilboa and Coorlaghan collieries. When the survey was made in 1859, the "Towlerton New Coal" was not known to exist in Towlerton; and the "Old Towlerton Coal" was supposed to be the same as the Bilboa coal (No. III.); the difference in the measures over each being accounted for by the effects of a sudden change. Now, however, as the measures over the Towlerton New Coal are found to be somewhat similar to those over the coal in the old Coorlaghan Colliery, it would appear that there is an additional Coal in the eastern division of the field.*

To the west of the Luggacurren fault, in that portion of the central division that lies between Coolbaun and Newtown Collieries, the following Coals and Measures have been proved:—

*Section at the Coolbaun and Newtown Collieries.*

(West of the Luggacurren fault.)

| | | | |
|---|---|---|---|
| UPPER MEASURES. | Uppermost beds | 12 | feet. |
| | *Peacock Coal* | 1·75 | " |
| | Intermediate beds | 45 | " |
| | *Stony Coal* | 3 | " |
| | Intermediate beds | 21 | " |
| | *Double seam*, including middle fire-clay | 5 | " |
| | Intermediate beds | 110 | " |
| | *Old Colliery Coal* | 3 | " |
| | Intermediate beds | 170 | " |
| | *Jarrow Coal* | ·25 to 6 | " |
| | Intermediate beds | 296 | " |
| | Coal | ·25 to 0·5 | " |
| MIDDLE MEASURES (?). | Lowest beds proved | 80 | " |

In other places in the Middle division of the field there

* Mr. B. B. Edge is not of this opinion, as he suspects that the coals in Towlerton are only "branches" from one coal, and that eventually they will be found to join into one.

are various local coals or coal-rods on different horizons. The lowest Coal in this section was supposed by Jukes to be the "Gale Hill Coal," and the Measures under it are said to be similar to those at Gale Hill. Sir Richard Griffith, Mr. McCarthy Meadows, and others believe that the Jarrow and Old Colliery Coals are different from, and in higher Measures than, any of those in the eastern division, *i.e.*, east of the Luggacurren fault. Meadows' principal reason for supposing that the Old Colliery and the Rushes Coals are different is the great thickness of Measures over the Rushes Coal (No. IV.) in the Modubeagh Colliery, in which there is no coal in a thickness of 270 feet, while at Coolbaun there are three Coals in less than 210 feet of Measures over the Old Colliery Coal. The Rushes Colliery is next that of Modubeagh, yet in it, at 130 feet over the Coal, there was a workable Coal called "Ward's Seam." If, therefore, there can be such a change in the Measures between the Rushes and Modubeagh Collieries, greater changes might probably occur at Coolbaun.

In the Middle division, in the country to the south and south-east of Castlecomer, although numerous trials have been made, no coals that would represent the four or five coals known to exist east of the Luggacurren fault have been found. To the northward, in the Middle division, on the north of the Clogh Colliery, there are coals—one in the Broompark Colliery, and, farther northwards, two in Riesk, and one still farther northward, in the Queen's County, a mile NW. of the village of Swan—and these may possibly be representative of the coals to the east of the Luggacurren fault. Against such a supposition there are the following considerations :—

The strata to the northward of the Clogh Colliery lie at very low angles, and Mr. Finlan, from a series of bore-holes put down by him, came to the conclusion that the same Coals were repeated over and over again by a series of nearly east and west faults. Furthermore, there does not appear to be thickness sufficient to bring in the eastern Coals if they lie under the central division. At Doonane and Newtown Collieries it has been proved by bore-holes that none of these Coals can exist at a distance less than 400 feet below the Jarrow Coal, while the trial at Mayo would suggest that there were no workable Coals for a depth of over 600 feet below the Jarrow. The Coal in the Broompark Colliery is generally allowed to be the north outcrop of the Jarrow Coal, and if the Riesk Coals are lower Coals according to the dip of the strata, they must be less than 200 feet below it. Besides, the Measures under the lower Coal at the Riesk are identical with those under the Hollypark Coal, which all allow to be the east outcrop of the Jarrow.

Mr. Meadows has attempted to correlate the Coals of the Leinster field with those of the East Munster or Tipperary field. Such conjectures, however, seem to be of no practical use, because between Leinster and Tipperary there are vast differences in the number of the Coals ; somewhat similar to those before mentioned in the West Munster field, where, to the south, in the County of Cork, the Coals are much more numerous than to the north (Clare, Kerry, and Limerick). If the Leinster and Tipperary sections are compared, it will be seen that in the former, to the east of the Luggacurren fault, there are five seams of Coal (besides two thin crow coals) in 700 feet ; while in Tipperary there are only three Coals in a thickness of 850 feet. Of these, one is a workable coal, another, although constant, a thin coal, and the third a local *coal-rod*, only known to exist in one or two places; which would have been altogether ignored if it had not been cut in the Glengoole level.

Again, a fruitless attempt has been made to prove by the fossil evidence that the Measures to the east of the Luggacurren fault, as also those associated with the lower Coals of Tipperary, are of a marine character; while those to the west, associated with the Jarrow and Old Colliery Coals, and those associated with the upper Coals, Tipperary, are not so.

In Tipperary, as previously mentioned, the Measures associated with the lower Coals are, by fossil evidence, eminently terrestrial or freshwater, while of the fossils in the strata associated with the upper Coals very little has been ascertained. In the Leinster field, in the strata associated with the Coals to the east of the Luggacurren fault, the fossils are also either terrestrial or freshwater; although in higher beds in some places, as in the Glen Colliery, they are marine. To the west of the Luggacurren fault, in the strata associated with the Jarrow Coal, there are terrestrial and freshwater fossils, but in the strata between that and the Old Colliery Coal there are marine fossils; likewise above the Stony Coal, the highest coal but one in the district, there are marine fossils. If we go to West Munster, it is found that in the north part of the Coal-field marine types are the most prevalent; while in the county of Cork, at the same height over the Upper Limestone, the fossils may be freshwater as well as marine.

In the western division of the Leinster field, two different Coals, at least, have been worked; but what Coals these are it is difficult to say. Meadows is of opinion that they are below the Coals of the central portion of the field, yet the measures and contained fossils over the Skehana Coal are very similar to those over the Jarrow. It is in this division that the previously mentioned calcareous bed, discovered by Willson in 1855, occurs.

Lists of some of the Coal Measure fossils found in this field are given by Baily in the "Geological Survey Memoirs," Explanation sheets 128, 137, and 147. Sufficient opportunity has not, however, been afforded for eliciting the full palæontological evidence. Over the Coal at Bilboa, Queen's County, and over the Jarrow Coal, County Kilkenny, there are some very remarkable fossils. At Bilboa, associated with the bivalve shells *Anthracosia*, *Myacites*, and *Myalina*, similar to those found in certain places over the No. II. Coal in the Tipperary field, there are two new species of Crustacea, named by Baily *Belinurus Regina* and *arcuatus*. These new fossils were found only in a thin bed of black carbonaceous shale, about two or three inches thick, at the base of the "roof" of the Coal, associated with open and single valves of the bivalve shells; while the rest of the "roof" shale is studded with uncompressed, unopened shells, which from their form are locally called "beans."

In the year 1858 Mr. Pat Finlan, of Clogh, informed us that fossils "like large lizards and snakes with feet" occurred in the kelves and shales over the coal in the first Jarrow pit. Those workings were then filled up with rubbish, and Finlan could not produce any of the specimens he had picked up, except a few ring-like impressions, which by themselves were unintelligible. Subsequently, however, after a new pit was sunk, Mr. Samuel Bradley found what appeared to be similar Reptilia, which were brought under public notice by Mr. W. B. Brownrigg in a paper read before the Royal Geological Society of Ireland (vol. i. n. s., p. 145), and they were afterwards described in a joint paper by Drs. Huxley and Perceval Wright ("Transactions of Royal Irish Academy," vol. xxiv., Science, 1867, p. 351). In 1865 Mr. B. B. Edge found in the old shales at Doonane Colliery the impression of a fish, but the rock crumbled to pieces before he could get it examined or named.

### Outlying Tracts, Kildare, Dublin, Meath, and Louth.

In these counties, to the west and north of Maynooth, south-west and south-east of Navan, south of Balbriggan, south-west of Drogheda, and near Ardee, there are larger or smaller tracts, usually of the Lower Measures, although, in places part of the Middle Measures are represented, and near Ardee the No. I. Coal occurs. These patches lie generally on Upper Limestone of the Calp type, but in some places they overlap the Lower Carboniferous rocks, and lie directly on the adjoining Cambro-Silurian rocks.

The Lower Measures are very fossiliferous, the principal and most numerous fossils being *Aviculopecten papyraceus*, *A. variabilis*, *Posidonomya Becheri*, *P. membranacea*, *Goniatites crenistria*, *Calamites cannæformis*, and occasionally fish scales and defence spines with plant stems. Here, again, it will be seen that, as usual in the Irish Coal Measures, terrestrial plants are mixed up in the same strata with marine fossils.

### Connaught.

Near Balla, in the county of Mayo, are considerable tracts of Coal Measures, forming Slieve Carna and the neighbouring hill. In Slieve Carna there is a thickness of over 1,200 feet, a thin Coal or Coal-rod having been found in the highest beds. Here, therefore, are the representatives of the Lower and Middle Measures, which are of a similar type to those in the West Munster field.

Small patches of the Lower Measures are found in south Sligo, east and west of Lough Arrow; and in north Sligo, south-west of Lough Melvin. In the last a change comes in, as those of the Lower Measures represented are nearly all sandstones (see page 83).

In Fermanagh, south-west of Lough Erne, there is a considerable area of Coal Measures. This, although situated in Ulster, may be considered part of the Connaught field, as at Macnean it forms a continuation of that tract. In this area, according to Berdoe Wilkinson, the Lower Measures consist of—

| | |
|---|---|
| 2. Shales . . . . . | about 300 feet. |
| 1. Sandstones . . . . . | „ 200 „ |

The arenaceous rocks, similar to those in the outlier to the west in north Sligo, seem to lie on the Upper Limestone. In the Shales (No. 2) Clay-iron-ore occurs very abundantly.

## Connaught Coal-field.

The area which is generally known under the above name occupies portions of Sligo, Roscommon, and Leitrim, in the province of Connaught, and parts of Fermanagh and Cavan, in the province of Ulster. The general section gives the following thickness of the strata; the rocks all belonging to the Middle and Lower Measures.

*General Section of the Connaught Coal-field.*

| | | | | |
|---|---|---|---|---|
| Middle Measures. | | Upper rocks . . . . | over | 400 feet. |
| | III. | Kelve . . . . . . . | about | 1 foot. |
| | | Intermediate beds . . . | „ | 50 feet. |
| | II. | Coal . . . . . . . | „ | 3 „ |
| | | Intermediate beds . . . | „ | 50 „ |
| | I. | Kelve . . . . . . . | „ | 3 „ |
| | | Lower beds . . . . | „ | 96 „ |
| | | | | 603 „ |
| Lower Measures . . . . . . . . | | | | 600 „ |
| | | | | 1,203 „ |

In describing the Leinster and Munster Coal Measures, attention was directed to the kelve, coal-rods and fire-clays observed in the Middle Measures; and although these are there valueless, here, in Connaught, those indications are represented by at least one valuable Coal. This Coal Griffith states to be bituminous, which is confirmed by later observers.

The remarkable variations in the Lower Measures are worthy of observation. In the Lackagh Mountains to the north-west, at the base, lying on the Upper Limestone, there is from twenty to fifty feet of sandstone, while, in the overlying shales are thin beds of argillaceous limestone. To the south-west, in the country west of Lough Allen, the basal measures are alternations of shales and grits, the first predominating; and in Slieve-an-ierin, east of Lough Allen, below, for about 100 feet, the Lower Measures seem to consist of alternations of shales, sandstones, and subordinate thin limestones; while above are sandstones about fifty feet thick, the rest being shales. We have already given the section in the County Fermanagh portion of the field.

In the Lower Measures Clay-iron-stone abounds. Griffith and Jukes mention that the number of beds in some places is astonishing; some are thick, over ten feet, others not more than one inch; Griffith says that the thin veins generally contain the richest ores.

In the Middle Measures, in the shales over No. III. Kelve, there are innumerable thin beds of clay-iron-stone. These beds are on about the same horizon at which the iron ore was principally worked in the Leinster Coal-field; and in the latter, under the lower iron-ore beds, and on about the same horizon as the Connaught Kelve, a thin fire-clay has been proved, accompanied in places by a coaly parting or coal-rod.

To the south-east of the main field, and west of Upper Lough Erne, there is a considerable area of Coal Measures, in which the Lower Measures and a portion of the Middle seem to be represented.

## Ulster.

In the County Tyrone, between Dungannon and Lough Neagh, is situated the Dungannon and Coalisland Coal-field; and a little farther north, at Annaghone, east of Tullaghoge, there is a peculiar small tract of Coal Measures.

### Dungannon Coal-field.

(Including Coalisland.)

The Coal Measures in this field are, in part, covered by Triassic and newer rocks, and, in part, obscured by deep drift. No correct sections of them can be given; and all the estimates of thickness that have been made are chiefly founded on those originally given by Griffith. From the known sections it would appear that the strata were in some places very irregularly accumulated; the measures in one portion of the field being very different as to thickness and the character of the strata from those in other parts. This may be due to the nature of the surface of the ground on which the rocks were deposited.

The following is a general section derived from Griffith's and Portlock's reports:—*

*General Section of the Dungannon and Coalisland Coal-field.*

| | | | |
|---|---|---|---|
| UPPER MEASURES. | In these are eight or nine workable beds of COAL . . | | about 900 feet. |
| MIDDLE MEASURES. | Upper beds . . | about 1,000 feet | 1,075 ,, |
| | Drumglass coals and fire-clays . . | ,, 15 ,, | |
| | Lower beds . . | ,, 60 ,, | |
| LOWER MEASURES. . . . . . . | | | about 600 ,, |
| | | | 2,575 ,, |

The Lower Measures were proved by a series of bore-holes between Dungannon and Drumglass. The thickness of the Middle Measures is very uncertain, as nothing has been positively proved as to the thickness of the Measures between the Drumglass coals and the lowest coal in the Coalisland portion of the field.

At Annagher Colliery the following strata and coals were proved by Griffith:—

* Since this description was written, Mr. E. T. Hardman's report on this field has been published ("Mem. Geol. Survey," Ex., sheet 35). It contains many new and interesting details, but it does not appear to add any positive evidence to that previously known in reference to the general structure of the field.

*Annagher Colliery Section.*

| | | | |
|---|---|---|---|
| | Upper beds | 25 | feet. |
| VI. | *Crow Coal* | 2 | " |
| | Intermediate beds | 33 | " |
| V. | *Annagher Coal* | 7·5 | " |
| | Intermediate beds | 36 | " |
| IV. | *Bone Coal* | 3 | " |
| | Intermediate beds | 38 | " |
| III. | *Shining Coal* | 2·5 | " |
| | Intermediate beds | 82 | " |
| II. | *Main Coal* | 5 | " |
| | Intermediate beds | 66 | " |
| I. | *Baltiboy Coal* | 2 | " |
| | | 302 | " |

Griffith reports that a bore-hole was put down over 270 feet below the Baltiboy Coal, in the Annagher Colliery, without finding any coal. In this Colliery the Coal Measures are covered by Triassic rocks.

All the coals of the Annagher Colliery are bituminous, easily ignited, and burn rapidly, except the Baltiboy Coal, which is very sulphurous and impure; it ranges from 3 feet to ·75 foot in thickness. The Annagher Coal is nearly, perhaps entirely, worked out. In other portions of the field there appear to be other coals found under the Baltiboy Coal.

In Hardman's Memoir, twenty-four coals are enumerated. Seventeen of them are in his "Coalisland Series" (*Upper Measures*); as to two of them, the Creenagh Coals (Nos. 6 and 7), he is uncertain; and five (Nos. 1 to 5) he places in his "Drumglass Series" (*Middle Measures*). Hardman's general section, and the accompanying details, do not seem always to agree; while the positions of some of the Coals that he has placed in regular order are still problematical. The following is his *Section of the Coal-island Series* :—

| | | | |
|---|---|---|---|
| 24. *Crow Coal* | | 2 | feet. |
| Intermediate beds | 39 | to 78 | „ |
| 23. *Annagher Coal* | | 9 | „ |
| Intermediate beds | 39 | to 54 | „ |
| 22. *Bone Coal* | | 3 | „ |
| Intermediate beds | 27 | to 39 | „ |
| 21. *Shining seam* | | 2·83 | „ |
| Intermediate beds | 72 | to 78 | „ |
| 20. *Brachaville Coal* | | 5 | „ |
| Intermediate beds | 48 | to 96 | „ |
| 19. *Gortnaskea Coal* (22 inches of Cannel) | | 6 | „ |
| Intermediate beds | 75 | to 105 | „ |
| 18. *Baltiboy Coal* | 3 | to 3·5 | „ |
| Intermediate beds | | 108 | „ |
| 17. *Monkey Coal* | | 1 | „ |
| Intermediate beds | 12 | to 21 | „ |
| 16. *Two-foot Coal* | | 2 | „ |
| Intermediate beds | 9 | to 12 | „ |
| 15. *Rock Coal* | | 1·33 | „ |
| Intermediate beds | | 18 | „ |
| 14. *Ten-inch Coal* | | 0·83 | „ |
| Intermediate beds | 21 | to 24 | „ |
| 13. *Derry Five-foot Coal* | 3 | to 5 | „ |
| Intermediate beds | | 9 | „ |
| 12. *Seat Coal* | 0·33 | to 0·66 | „ |
| Intermediate beds | 42 | to 120 | „ |
| 11. *Cracker Coal* | | 3 | „ |
| Intermediate beds | | 48 | „ |
| 10. *Yard Coal* | | 3 | „ |
| Intermediate beds | | 75 | „ |
| 9. *Two-foot Coal* | | 2 | „ |
| Intermediate beds | | 150 | „ |
| 8. *Sixteen-inch Coal* | | 1·33 | „ |

This list includes crow coals which ought not to have been put in a General Section. Coals Nos. 12 and 14, are thin and local; others also. The numerous faults prevent continuous sections being seen ; in some places the measures, like those over the Derry Coal (No. 13), have been proved, but in several others there seems to be a considerable amount of guess-work, and probably the number of Coals will be found hereafter to be less than what is given in the Memoir.

In portions of the field, as at the Creenagh Colliery, where there is a thick Coal, it is at present impossible to say whereabouts in the general section the Coals ought to be put. There are also the Coals at the Farlough and Edendork Collieries. These are put by Hardman in his "Drumglass Series." Their position, however, is uncertain ; they may possibly be representatives of some of the coals already given in his "Coalisland Series ;" but at the present time no reliable evidence as to the positions of the coals in reference to those in the General Sections is to be obtained. In these Upper Measures are many thick beds of valuable fire-clay, also some seams of clay-iron-stone. Baily's list of the fossils is given in the Memoir, Explanation, sheet 35.

In the Middle Measures, near their base, there are two seams of coal. The upper, or *Drumglass Coal*, which has been extensively worked, is a seam of varied thickness, consisting of about four feet of good coal, with bituminous shale and clay, the entire seam in places being over thirteen feet thick. The lower Coal was formerly worked a little ; but it is not of much value. It lies more than thirty feet below the upper Coal, and is either only a local coal or separated from the upper by a variable thickness of strata ; as, in places, trials through strata over seventy feet thick are said to have been made without reaching it.*

* Hardman states it occurs from 30 to 90 feet below the upper Coal. These two coals seem to be on about the same geological horizon as Nos. I. and II. Coals in the Connaught fields.

Under the lower Coal there is from fifty to ninety feet of grits which seem to represent the "Flagstone Series." In these Measures, unlike those of Connaught, clay-iron-stone does not seem to be plentiful.

The Lower Measures, as previously mentioned, are only known from evidence procured by bore-holes. They are principally shales with subordinate calcareous and sandstone beds.

## Annaghone Colliery.

This is a most peculiar narrow tract, in which there are at least three workable Coals. To the northward the Coal Measures are bounded by a fault with a downthrow to the southward, which brings them down against the Upper Limestones; at the south they are bounded by another fault, also with a downthrow to the south, which brings down the Triassic rocks against them; while a short distance westward of the outcrop of the highest Coal are Upper Limestones, proving that here also there must be a fault boundary, while eastward they are covered by the Triassic rocks.

It is said that in this little patch were found four workable beds of coal, which are very much twisted, and in places inverted. One of these coals was nine feet thick, while the existence of the lowest is problematical. The nine-foot bed has been nearly worked out in the townland of Annaghone, but there is no reason why it should not exist under the Triassic rocks to the south and east. To the north of the northern E. and W. boundary fault there are shales, very like the Lower Measures, lying on the Upper Limestone, which to the eastward are covered by the Triassic rocks. It seems probable that the Coal

Measures of the Annaghone Colliery may extend considerably toward the northward and north-eastward under the Triassic rocks, into Londonderry, in the neighbourhood of Coagh. The Main Coal in Annaghone is supposed by the colliers to be the same as the Annagher Coal; this, however, is scarcely possible, as it is very improbable that a wedge of Coal Measures nearly 2,000 feet thick is let down in this place, which would be necessary—unless the Coal Measures overlap the upper Limestone.

The Coal-fields of Tyrone may become the most important in Ireland, as pointed out by Geinitz,* but they have still to be developed, the coals, as yet, having only been worked near the surface, and never at considerable depths, where a vast supply may exist.

The Coal Measures probably extend eastwards to the valley of Lough Neagh, where they must be cut off by the north and south faults previously mentioned. But they may have been considerably denuded in that direction, as it is known that the overlying Triassic rocks thicken toward the east. East of the Lough Neagh Valley, as pointed out when describing the Lower Carboniferous rocks, the Coal Measures must be shifted considerably northward; however, it does not appear at all improbable but that they might occur under the Cainozoic and Mesozoic rocks in the country to the north-east of Antrim town. Farther north-eastward, between Larne and Glenarm, the thickness of the newer formations over them ought to be considerable, unless the Triassic rocks thin rapidly as they extend northward from Carrickfergus.

Some of the principal points of interest in this chapter

* "Die Steinkolen Deutschlands und anderer Länder Europas," &c. Von Dr. H. B. Geinitz, Dr. H. Fleck, und Dr. E. Hartig. 2 vols. 4to. Munich, 1865.

are the following:—The *Lower Measures* everywhere are of nearly equal thickness, but in Sligo and thereabouts the arenaceous beds, which in Munster were only a few feet thick, are considerable; at the base of the group, in Cork, Limerick, Kerry, Clare, Meath, and Louth, there are found fish remains of true Coal Measure types.

In the description of the Lower Carboniferous rocks it was pointed out that what are but traces of coal in the south-west become good coals in the north-east. Nearly similar phenomena occur in the Middle and Upper Coal Measures. In West Munster fire-clays occur in the *Middle Measures;* in Leinster, kelve, coal-rods, and fire-clay; while in the Connaught and the Tyrone Coal-fields there are good workable coals. The calculated thickness of the Middle Measures in Tyrone is probably excessive, as otherwise there must be an enormous fault to the west of the Annaghone Colliery of over 2,000 feet, which could scarcely be possible.*

In the *Upper Measures* of the north portion of Clare many of the coals are absent; farther south, in Kerry, Limerick, and Clare, they come in, but are very thin; while still farther south, in Cork, they are numerous and thick. To the east-north-eastward, in the Tipperary Coal-field, only two Coals occur in the lower part of the Upper Measures, but farther east-north-east, in the Leinster Coal-field, there are five or more; while to the northward, in the Ulster field, they are very numerous in a small thickness of Measures. We also find that the Measures in the SW. are collectively thicker than to the NE.

* According to Hardman's thickness of the Middle Measures in the Coal-island field, the throw of this fault would be much more considerable.

# MESOZOIC.

## CHAPTER VII.

### PERMIAN ROCKS.

THESE rocks, as previously stated, have an uncertain position as to classification, some geologists placing them among the Palæozoic, others among the Mesozoic rocks. The English geologists now seem inclined to connect them with the latter, while Horace Woodward, in his " Geology of England," as also others, would include both the Permian and Triassic in one formation, under Conybeare's old name, Poikilitic.

It is well known that the Permian and Triassic rocks are intimately connected in their lithological characters and probable method of formation. It is now believed that in England the Permian beds are invariably unconformable with the rocks of the Coal Measures ; but it is by no means proved that the Permian and Triassic beds are anywhere unconformable, since certain red accumulations, formerly included in the Permians on account of their colour, with which some Triassic beds are unconformable, have now been put in their proper place among the Carboniferous rocks ; thus, by the way, some of the so-called Permian plants have really come from stained Coal Measures.

The Permian beds were apparently deposited in deep hollows, extending over more or less restricted areas; while the succeeding Triassic beds often considerably overlap the margins of the earlier deposits.

In "Characteristic British Fossils," vol. i., page 76, Baily states that the Permian fossils "are of a decided Palæozoic type, and bear a considerable resemblance to those of the Carboniferous group." This authority, however, in his subsequent description of the fossils, points out that the forms seem to be degenerating, and agrees with Murchison that they were rapidly dying out. It has been suggested by Ramsay that the Permian rocks were accumulated in inland seas. If this suggestion be correct, which appears highly probable, some of the Carboniferous fauna and flora may have survived and continued to exist, but in a degenerate state, in such seas and on the land in their vicinity, and thus their remains may have been preserved in the Permian strata. But as the conditions became unfavourable for their existence, they died out, the deposits at the same time changing in condition and aspect, until eventually they graduated from the rocks called Permian into the typical Triassic. There would, therefore, be, in such areas, Permian rocks below, containing degenerate Carboniferous forms, which rocks would graduate upwards into the typical Mesozoic rocks of Triassic age.

In Ireland all the undoubted Permian rocks seem to be intimately connected with the associated Triassic rocks, but they must be called Permians from the fossils found in them. There are, indeed, some rocks that have been classed as Permians, which, as they contain typical Carboniferous fossils, can scarcely belong to that group. To this subject, however, we shall hereafter return. As the Irish Permians are so intimately connected with the Triassic, they are in this Manual classed as Mesozoic.

## Cultra Beds.

These occur on the south shore of Belfast Lough, east of Cultra Pier. In 1835 Dr. Bryce discovered a small exposure of dolomitic rocks containing fossils of Permian type, and subsequently these have been more minutely examined by King, Baily, and Warren; the last mentioned describing them as yellow and brownish magnesian limestones, below which are red marls. To the eastward they are bounded by a whinstone dyke, in a line of fault, while south-westward they extend along the shore for a short distance, when they turn westward and strike out into the sea. To the eastward of the whinstone dyke are Carboniferous rocks; these and the Permian rocks are only seen at low water.

Baily states that the fossils are similar to those of the Durham and Yorkshire Permians. Kane, in the "Industrial Resources of Ireland," mentions that the dolomite was formerly exported to Glasgow to be used in the manufacture of sulphate of magnesia.

## Lagan Valley.

About two miles south-east of Moira, in the valley of the Lagan, Du Noyer discovered a small tract of breccia with grey and purple shales that contained subordinate beds of argillaceous magnesian limestone. This tract he considered to be of Permian age; but no fossils have been as yet discovered in the rocks.

## Tullyconnell Beds.

At Tullyconnell, near Ardtrea, County Tyrone, there are some small exposures of buff-coloured magnesian limestones containing fossils, pronounced by King and Baily to be similar to those in the Durham Permians. A good many of these fossils are in the Survey collection, presented by Dr. King, and a list of them is given by Baily in the Explanation to accompany sheet 35.

A mile westward, in the river, there are cream-coloured crystalline dolomites, which are supposed by Hardman to be Permians, and to be the continuation of the Tullyconnell beds, but shifted to their present position by an E. and W. fault. Griffith records that at Templereagh, on the south of the Annaghone Colliery, Permian dolomites 16 feet thick were found in sinking a pit; the rocks, however, are not known to appear anywhere hereabouts at the surface of the ground.

The Permian rocks at Tullyconnell, as also those in the valley of the Lagan, seem to be intimately connected with the associated Triassic rocks.

South-east of Armagh, at the old marble quarries, over the Carboniferous Limestone, are about 20 feet of sandstone, breccia and conglomerates, considered by Professor Hull to be of Permian age. No fossils have been found in them, and in aspect they are very like the shore beds of the Calp in the Draperstown district, County Londonderry. As previously shown, the Carboniferous rocks near Armagh are probably of Upper Limestone age; and that the red and other coloured sandstones are interstratified with limestones has been proved by Egan. If the rocks at the marble quarries are Permians, it appears remarkable that in the associated limestones there should be fish similar to those that occur in the shales associated with the similar red arenaceous rocks, (Calp, or Upper Limestone) of the Draperstown district.

To the north-east of Armagh, near Benburb, in the valley of the Blackwater, there are other red and purplish rocks, that have also been supposed to be of Permian age. This, however, seems scarcely possible, as they contain fossils pronounced by Baily to be of undoubted Carboniferous age.

## TRIASSIC ROCKS.

The Triassic rocks are principally found in the province of Ulster, margining the Cainozoic rocks. It would appear, however, that at one time they extended much farther, as suggested by the small outlying tract near Kingscourt, in the Counties of Cavan and Meath.

### Kingscourt Beds.

These Triassic rocks occupy a narrow, nearly north and south, strip of ground; which, according to W. B. Leonard, is bounded on the west by a fault that brings them down against the Cambro-Silurians. Leonard divides them into—

*Red Keuper Marl.*—Red and grey shaly clays.
*Lower Keuper Sandstone.*—Thin-bedded, brownish, fine, and coarser sandstones.
*Bunter Sandstone.*—Red sandstones.

The sandstones called Lower Keuper are only a few feet thick and very indistinctly seen; they are said to contain subordinate beds of grey and red shale. The supposed Bunter Sandstones are seen in the Enniskeen river, north of Cabra Castle. At Derrynasrobe, NE. of Kingscourt, there is in the Keuper Marl a bed of gypsum, in one place 60 feet thick.

## Scrabo Hill.

The rocks in the neighbourhood of Scrabo Hill, County Down, between Belfast and Strangford Loughs, have been proved by Du Noyer to belong to the Triassic, and not to the Carboniferous, formation, as previously supposed. Portlock was of the opinion that the associated dolerites are interstratified with these rocks; similar dolerites are interstratified with the Trias near Ardtrea, County Tyrone, as will be afterwards mentioned. These Triassic rocks are supposed to represent portions of the Bunter and Keuper divisions. No fossils have been found in them, excepting markings of sun-cracks and supposed rain-drops.

## Lagan Valley.

Between Belfast and Lurgan, in the valley of the Lagan, is a long narrow strip of Trias. The rocks in this area are thus divided by Warren and W. B. Leonard:

*Keuper Marls.*—Red and greyish clays and shales, with thin bands of grey sandstone containing crystals of salt.

*Lower Keuper Sandstones.*—Brownish and yellow carbonaceous flags or thin sandstones, not more than ten or twelve feet thick, supposed by Professor Hull to be the equivalents of the "*Waterstones.*"

*Upper Mottled Bunter Sandstone.*—Red and yellow mottled and variegated soft sandstones, with subordinate red argillaceous sandstones. These are over massive sandstones, which lie on yellow shales and flaggy sandstones.

The Keuper Marl contains in some places layers of gypsum; it is supposed to be several hundred feet in thickness. Near Lisburn the Bunter sandstones have been sunk into for a depth of over 500 feet, without reaching their base.

Above the typical Triassic rocks are others, supposed to represent a portion of the RHÆTIC, or PENARTH BEDS. These rocks, as occurring elsewhere, are supposed to be the passage beds into the Jurassic rocks ; and in accordance with this they seem in Ireland also, to graduate not only into the Triassic rocks below, but also into the Jurassic rocks above them. Of these rocks a good section is exposed in Collin Glen, five miles SW. of Belfast.

To the sections in Collin Glen, attention was directed by Portlock and others ; but Mr. Ralph Tate was the first to point out that the rocks belonged to the Rhætic group, in a paper read before the London Geological Society (*Quarterly Journal, Geological Society, London,* vol. xx. p. 103). According to Tate's measurements, the rocks in this section are nearly 19 feet thick ; but according to the Geological Survey measurements, there is about 14 feet in thickness seen—an epitome of Tate's section gives:

| | |
|---|---|
| 2. Dark-coloured shales and argillaceous limestones, with a few thin sandstones at the base. In the shales are found *Axinus cloacinus*, *Avicula contorta*, *Cardium Rhæticum*, *Placunopsis alpina*, *Pecten Valoniensis*, and *Modiola* . . . | 11 feet. |
| 1. Black shales and clays, arenaceous shales, and thin sandstones. In two of the thin arenaceous shales are fish remains, *Natica Oppelii*, *Trochus Waltoni*, and *Avicula contorta* . . . . | about 8 ,, |
| | 19 ,, |

In the country to the SW. the Rhætic beds are found as far as Lisburn. For about 6 miles between Moira and Kilcorig they are absent, the White Limestone (Cretaceous rocks) lying direct on the Keuper Marl. To the north-east of Collin Glen, at Cave Hill, 3 miles north of Belfast, Tate gives the details of a section 16 feet thick; of another at Woodburn, 10 miles NE. of Belfast, 13·5 feet thick; and of that at Whitehead, 14 miles NE. of Belfast, 19·5 feet thick. On the east coast of Antrim, the Rhætic beds can be seen at various places; such as near Larne, where, according to Tate's estimate, they are over 100 feet thick; also south of Glenarm and at Garron Point. Tate has found fish remains in several of the localities.

### South-East and East Antrim.

Margining the Cretaceous rocks there is a nearly continuous fringe of Triassic rocks, extending from Belfast, along the north of Belfast Lough and the east coast of Antrim, to Ballycastle. In some places this tract is very narrow, but in others, especially in the different valleys, it is wide. There are also a few outlying exposures near Larne Lough and south-east of Ballycastle.

Of these Triassic rocks, those near Carrickfergus, on the north of Belfast Lough, are the most remarkable, as they contain beds of Rock-salt. These Salt Measures were discovered at Duncrue, between 1850 and 1852, while sinking in search of coal; the following are the thicknesses of the rocks passed through, as recorded by Mr. John Kelly in September 1852; but it was not until after his visit that the strata 1, 2 and 3 were proved.

| | | |
|---|---|---|
| 9. Red marl, containing thin beds of gypsum | 500 | feet. |
| 8. Rock salt | 15 | ,, |
| 7. Salt and blue clay | 6·8 | ,, |
| 6. Pure salt | 88 | ,, |
| 5. Salt mixed with blue and red clay | 30 | ,, |
| 4. Pure salt | 20 | ,, |
| 3. Do. | 2 | ,, |
| 2. Blue clay | 6·6 | ,, |
| 1. Grits and sandstones, one bed being very ferruginous | 16·6 | ,, |
| | 685·0 | |

In this section the total thickness of the Salt Measures is about 162 feet; but in the new pit, which was sunk about 500 yards north of the old one, they are only about 100 feet thick, and have over them 800 feet in thickness of the Red Marls. At the new pit, as at the old, there was a steady dip northward of 12° to 13°.

From these sections it is evident that there is a considerable thickness of the Triassic rocks in the neighbourhood of Carrickfergus; the Keuper Marls being from 800 to 1,000 feet thick, the Salt Measures over 100 feet, while the lower rocks (Bunter ?) have been estimated by Mr. Doyle as between 800 and 1,000 feet, or a full thickness of about 2,000 feet. The rocks immediately below the Salt Measures seem to represent the rocks which in the previous sections are called Lower Keuper Sandstones.

In the south-west of Duncrue trials have been made without finding the Salt Measures, and from the lie of the rocks it seems probable that in the valley of the Woodburn there is a NNW. and SSE. fault, which shifts the rocks to the west of it, southward. The Salt Measures, also, are probably in a lenticular mass or cake, of limited extent. The best rock-salt (bed 6) contains over 95 per cent. of pure salt.

Although rock-salt has been worked only at Duncrue, yet it is probable that it exists in other places. In the townland of Ballyedmond, near to the village of Glynn, there is a salt spring; about three miles south of Larne a bore hole was put down in 1839, for a depth of 174 feet, and at 150 feet Salt Measures were found; the work, however, was abandoned before a pure thick bed of salt was proved. Farther southward also, at Ballybig, salt is said to have been proved, while making trials in search of coal; and at the village of Eden there is another salt spring.

Gypsum has been found in the Keuper Marls at Cushendall and other places. The Rhætic beds, as previously mentioned, are seen, in places, on the Keuper Marls.

### South Tyrone and Armagh.

In the valley of the Blackwater, stretching northward past Dungannon, and eastward to the Portadown area of dolerite, is an irregular tract of Triassic rocks. These to the west and south lie on Carboniferous rocks; towards the north-east they are overlaid by newer rocks. In the Blackwater Valley, near Benburb, they are associated with the previously mentioned rocks that have been supposed to be Permians, although containing Carboniferous fossils.

In the southern portion of this area the rocks are sparingly exposed, but those seen or found in the sinking of the wells are bright red sandstones, supposed to be the equivalents of the Bunter Mottled Sandstone. Apparently over these rocks, in a few places in the valley of the River Colleen, there are hard red shales and reddish grey sandstones that are supposed to belong to the Keuper Sandstone.

In the northern portion of the area the rocks principally seen are red sandstones, locally called *Red Free*, but in places they are associated with considerable thicknesses of red and mottled clays and shales; all the rocks being probably equivalent to the Bunter.

In a red earthy sandstone at Rhone Hill, SE. of Dungannon, County Tyrone, Portlock found the fossil fish *Palæoniscus catopterus*, in great abundance, but only in a small lenticular layer which "was exhausted by obtaining the specimens." Portlock found, in an adjacent clayey layer, what was supposed to be a small shell, and was called *Posidonia minuta;* but it has been since proved to be a Phyllopod crustacean and named *Estheria Portlockii.*

## South Londonderry and North Tyrone.

This tract margins the Tertiary dolerites, west of Lough Neagh, and extends from a little south of Stewartstown, County Tyrone, to Maghera, County Londonderry. The rocks are exposed only as far north as Desertmartin; but, as suggested by Portlock, they probably bound the Desertmartin limestones on the east, as the drift along the margin of the dolerite is, for the most part, made up of their detritus.

Associated with the Triassic rocks at Tullyconlish, near Ardtrea, are the previously mentioned dolomites containing Permian fossils, and in the same vicinity is a bed of dolerite in the Triassic rocks.

Farther southward the rocks seem to be very much displaced by faults, which have lifted them up or let them down. At the Annaghone Colliery, SE. of Tullaghoge, the Triassic rocks on the south of the Coal Measures have been sunk into for over 100 feet without getting through them; and the features of the country suggest numerous other dislocations, which cannot be positively ascertained on account of the drift covering.

To the southward, near Stewartstown, the Triassic rocks seem to be very thin, as there is not room for more than 20 or 30 feet in thickness between the Chalk and the Carboniferous rocks; although a little to the north, at

Annaghone, as just mentioned, they are over 100 feet thick. Farther north, at the mearing of the two counties, the rocks seem to thicken; and near Coagh, on the Tyrone side of the Ballinderry river, a pit and bore-hole was put down, for 280 feet, without reaching the bottom of the Trias. In this trial red and variegated greenish and yellowish clays and shales containing layers of gypsum were found below and above red sandstones.

In the large quarry to the ESE. of Moneymore, at the mearing of Doluskey, the base of the Chalk is exposed, and below it, lying on the "Red Free," is a thin calcareous or dolomitic grit and a whitish sandstone, which seem to belong to the *Rhætic beds*. Here the thickness of the Triassic rocks cannot be estimated, on account of the drift banked against the escarpment. Farther north, north-west, and west of Magherafelt, as also still farther northward, on the south of Gulladuff and Maghera, it must be very thin.

The Triassic rocks on Slieve-Gallion-Carn, NW. of Moneymore, are at an altitude of 1,200 feet; while those just mentioned, to the east of the Moneymore Valley, seem to be nowhere above the 250 feet contour line. Between these places there must be a fault with a down-throw to the eastward, as all the rocks in the valley of Moneymore are nearly horizontal.

In Slieve-Gallion-Carn the Triassic rocks can be very little more than 20 or 30 feet thick, and farther northward, at Mullaghmore, to the north of Moneyneany, they seem to be less than 10 feet thick.

## North Londonderry.

A narrow, nearly N. and S. strip of Triassic rocks extends from a few miles SE. of Dungiven to the sea, at a little east of the entrance into Lough Foyle. The rocks are generally red sandstones; although in some places they are associated with clays and shales.

To the north-east of Limavady, from a little north of where the road from Limavady to Coleraine crosses the escarpment to the sea on the north, there are Rhætic beds which margin the Chalk, and which Portlock correlates with the Collin Glen beds near Belfast. Of these rocks Portlock gives the following section at Ben Evenagh:—

| | Ft. | in. |
|---|---|---|
| 7. Black shales, with *Avicula contorta* and *Cardium striatum*. | | |
| 6. Calcareous gritty shales and grits with bivalves . . . | 0 | 5 |
| 5. Black shales . . . . . . . . . . . | 0 | 7 |
| 4. Calcareous grit, with bivalves and fish remains . . . | 0 | 0·5 |
| 3. Black shales . . . . . . . . . . . | 0 | 9 |
| 2. Calcareous grit . . . . . . . . . . | 0 | 0·5 |
| 1. Compact blackish shale and clay, the bottom of which is not seen. | | |

On the one side of the grit No. 4 are the impressions of the bivalves, while on the other are the teeth and scales of *Saurichthys apicalis*, *Gyrolepis Albertii*, *G. tenuistriatus*, *Acrodus minimus*.

"The total thickness of this deposit, as seen here, is not more than 7 or 8 feet." It is said, however, that to the west of the section shales are found on excavating beneath the surface. Hereabouts there are great landslips, which break up the strata and leave their true position uncertain; but from the fossils found in the detritus that margins the Rhætic beds and separates them from the Chalk, it seems probable that over them are rocks of Jurassic age.

It has been already mentioned that the Permian rocks of the country seem to be rather a group of beds at the base of the Triassic than a separate formation. It is quite palpable that the Triassic rocks are of very unequal thicknesses, on account of the circumstances under which they were deposited; a great thickness having accumulated in a deep hollow in the neighbourhood of Belfast Lough, and another near Lisburn. In these places we find the rocks with Permian fossils under the typical Trias; but elsewhere the Triassic rocks seem to thin out; the lower (Bunter) being absent, and the formation being represented by rocks of the upper groups (Keuper). But in some places, in the north of Tyrone and Londonderry, the rocks partake of characters typical of both the Keuper and Bunter, as at Coagh, where there is over 100 feet of Keuper marls that could scarcely ever have extended on to the adjoining Bunter. We also find that in such places, where denudation has not removed the upper rocks, they graduate through the Rhætic beds into the Jurassic. It would, therefore, appear that although the Irish Triassic rocks are of a much less thickness than those in England and elsewhere, yet the whole formation is represented, the strata constituting a regular sequence from the Permians below to the Jurassic above.

## JURASSIC ROCKS.

The Jurassic rocks, from their lying above the Triassic, suffered more from the denudation that affected both, and are now found in a few places only, below the outcrop of the plateau of Miocene dolerite in Antrim and Londonderry; the denudation having been greater towards the south-west than elsewhere; as appears from the fact that the Jurassic rocks are not to be seen in Tyrone, nor in Londonderry as far north as Limavady.

## Antrim.

In the south-east of County Antrim, according to Mr. Ralph Tate, the Jurassic rocks can be found below the White Limestone (Cretaceous) escarpment, from a little south of Collin Glen (SW. of Belfast) to White Head on the N. side of the entrance of Belfast Lough; also in the Carrickfergus Commons, and at Lough Mourne. They occur also on the east coast of Island Magee, along the shore of Larne Lough, at Larne, Glenarm, Garron Point, and on the north coast of Antrim at Ballintoy, White Park Bay, and Portrush.

Tate considers that the section at Waterloo, near Larne, "is the key to the reading of the Lias rocks of Ireland;" and the rocks in this section he thus groups:

5. Zone of the *Belemnites acutus*.
4. Zone of the *Ammonites Bucklandi*—compact blue argillaceous limestones, full of *Gryphæa incurva*.
3. Zone of the *Ammonites angulatus*—alternations of grey and blackish limestones with blue marls . . . 35 feet.
2. Zone of the *Ammonites planorbis*—black indurated shales 40 „
1. Whitish marl and black shales.

In the vicinity of Larne there is no well-defined boundary between the Jurassic and Rhætic; group No. 1 being considered by Tate as neutral ground; but the rocks in group 2 evidently belong to the Lias. The rocks of the latter group have been found at Collin Glen, White Head, Larne, Glenarm, Garron Point, and Portrush.

Group No. 3 Tate considers to be the representative of the *Infra-Lias* of the Continent. It attains its greatest development in thickness and organic remains in East Antrim, at Larne Lough, Waterloo, Glenarm, and a few other places. At Collin Glen it is represented by a calcareous marl a foot thick; while to the NW. in Londonderry at Craig, Gortmore, and in the Tircrevan Burn, by a calcareous grit.

Group 4 is found at Waterloo, Larne; at Glynn, two miles south of Larne, and beneath the Hibernian Greensand at Doon Hill and Tircrevan Burn, County Londonderry. Tate states "the *Gryphæa incurva* is the ever accompanying fossil to those characteristic of this zone."

Group No. 5, besides being supposed to exist at the Waterloo coastguard station, near Larne, is also found at Carrickfergus, and Castle Chichester, on Belfast Lough, and on the north coast near Ballintoy. In the latter place, the base of the "White Limestone," or indurated Chalk, which is here conglomeritic, rests on black micaceous clays with some calcareous nodules and numerous specimens of *Belemnites acutus*. But the majority of fossils, principally *Ammonites*, found here are cast up during the winter storms, having been extracted from submerged beds of this zone. According to Tate, "the fossils of these clays are indicative of an horizon on a level with, or newer than, that of the *Ammonites Turneri*."

A list of the fossils at Ballintoy is given by Portlock in his Geological Report on Tyrone, &c., and a list of the Lias fossils, by Tate, has been published by the Belfast Naturalists' Field Club, 1870, and also in the papers by Tate in the *Quart. Journ. of the Geol. Soc. Lond.*, vols. xx. and xxiii., while Baily's lists appear in the "Memoirs of the Geological Survey," Ex. sheets 21, &c.

Portrush is classical ground, as the altered Lias rocks were once supposed to be igneous rocks of the same age as the Miocene dolerites; they were cited by the Wernerians as a proof of the sedimentary origin of dolerite. Dr. Buckland, however, pointed out that the fossils were of Lias type; while subsequently Portlock showed that similar fossils occurred in the Lias to the west in Londonderry, and to the east and south-east in different places in Antrim. Portlock was of the opinion that the Lias at Portrush and that of Ballintoy were on the same horizon. Tate, however, from more minute research, has come to the conclusion that while the Ballintoy rocks belong to the zone of the *Belemnites acutus*, those of Portrush are older and belong to the zone of the *Ammonites planorbis*.

Various theories have been put forward to account for the alteration of the Portrush Lias into hornstone; some considering that it was due to the overlying sheets of Miocene dolerite. This, however, seems to be impossible, because, as will be mentioned in describing the Miocene rocks, those sheets were unable to produce change in the (alterable) beds of Lignite, only a few inches beneath them.

A far simpler explanation is suggested by what is found among the older rocks in various places in Ireland, especially among the Cambro-Silurians of Wicklow, Wexford, and Waterford. This class of metamorphism is fully described in the chapter on Metamorphism (Section II. Chap. X.), but here a short *résumé* may be given. Local metamorphism, or Paroptesis, occurs in the vicinity of the foci of Plutonic eruptions, or in places where gases and such products due to Vulcanicity, came up through the rocks, often giving to rocks over greater or less areas a baked appearance; and in such places there are usually protrusions or masses of elvan or other granitic rocks that mark the site of the ancient funnel or fissure of eruption. These conditions are complied with in the vicinity of Portrush; as a focus of eruption is marked by the granitic rocks (basic elvan) in the Skerries and in the Portrush promontory, while adjoining them are the metamorphosed Lias rocks.

The metamorphism of these Jurassic rocks may have taken place at any time after the beginning of the Cretaceous age. It is probable, however, that it was during the Miocene age when the great sheets of dolerite were poured out; as farther eastward under these sheets there are rocks which apparently were once tuffs, but are now in aspect like the Miocene dolerite. These altered tuffs (?) are more specially described among the Miocene rocks.

## LONDONDERRY.

From Down Hill on the shore of the Atlantic to Ben Evenagh to the north-east of Limavady, there seems to be a narrow band of Jurassic rock, but the sections are obscured by the detritus on the slope of the escarpment, as previously mentioned when describing the Triassic rocks. There are, however, a few detached sections at Down Hill in the boundary stream between Aghanloo and Magilligan, and in Tircrevan Burn, while in other places the débris of the rocks is found. In the Tircrevan Burn section is a thin seam of coal apparently in the zone of the *Ammonites Bucklandi.*

# CHAPTER VIII.

## CRETACEOUS.

PREVIOUS to the formation of the Irish Mesozoic rocks, the Palæozoic rocks were ruptured, upturned, and extensively denuded ; while subsequently patches of Permian rocks were deposited in hollows. On the Permian, and also for considerable distances thence on to, and over, the adjoining Palæozoic rocks, the Triassic rocks were laid down, and on the latter the Jurassic ; the deposition of the last being succeeded by disturbance and much denudation. This denudation, although it removed a large thickness of strata, was very differently circumstanced from that just before the Mesozoic age, the rocks during the second disturbance being very little displaced, and still lying nearly as horizontal as when they were deposited.*

By the denudation of the Jurassic and older rocks a surface was formed on which the Irish Cretaceous rocks were deposited, they, according to Tate, being of a somewhat similar age to the Upper Cretaceous rocks of England. In places the Cretaceous rocks overlap the older Mesozoic rocks and extend out over the adjoining Palæozoic rocks, as in north-east Antrim, and in the County of Tyrone, SW. of Lough Neagh. But the extent of the

* There does not appear to be more unconformability between the Cretaceous rocks and the Jurassic than there is between some of the inlying limestones of Cambro-Silurian age and the rocks below them.

area they once covered is now unknown, as the Cretaceous rocks have also suffered from considerable denudation, and are of greater thickness to the eastward than to the westward. The thinning out to the westward, however, may in part be due to overlapping, the lower members of the group not having been deposited over as large areas as the higher ones; in the east portion of the County of Antrim there are strata called by Tate *Hibernian Greensand* under the *White Limestone* (Indurated Chalk), while in Tyrone the White Limestone lies directly on the older rocks.

That there was denudation after the Cretaceous period is evident, as there is nearly invariably at the base of the Miocene rocks a stratum of flint gravel, or shingle; in some places this accumulation forming the only beds between the Triassic, or older rocks, and the Miocene dolerites. Some writers on the rocks of the north of Ireland have classed these flint gravels, or shingles, with the Cretaceous rocks, but Jukes has proved that they are of Miocene age, from the fossils found in the interstratified shale beds.

As with the Jurassic rocks so also with the Cretaceous; their classification is principally due to the researches of Tate, who has divided them into,—

2. Upper chalk ("White Limestone").
1. Hibernian Greensand.

The Upper Chalk he thus subdivided:

3. *White Limestone*, or the zone of *Ammonites Gollevellensis.*
2. *Spongarian zone.*
1. *Ananchites zone.*

The White Limestone Tate considers to represent the Upper Chalk of Norwich and the *Craie de Meudon* of the Continent, while some of the fossils point to a higher horizon, that of the *Maestricht chalk.*

His subdivisions of the Hibernian Greensand are :

4. Zone of *Exogyra columba.*
3. Zone of *Inoceramus Cripsii.*
2. Zone of *Ostrea carinata.*
1. Zone of *Exogyra conica.*

Tate is of the opinion that No. 1 represents the basement beds of the *Etage Cenomanien* of the French geologists, and is approximately equivalent to the Greensand of Blackdown, England ; No. 2 represents a portion of the Upper Greensand of England and the Lower Cenomanien of Normandy, while 3 and 4 (Chloritic Sands and Sandstones) have on the whole a fauna possessing an Upper Greensand facies, many species pointing, however, to higher zones. He also believes that the Gault and the Lower Chalk are absent in Ireland. From this it would appear that the oldest Irish Cretaceous rocks are in aspect like the Greensand of other countries, while the assemblage of fossils has an Upper Greensand character ; and that on these rocks in a regular sequence were deposited others that have characters similar to those of the Upper Chalk of England. It does not, however, follow that the Hibernian Greensand was accumulating at the same time as the English Upper Greensand. It would seem more probable that the Irish Cretaceous rocks have a type of their own, and that the Hibernian Greensand is on a higher geological horizon, its Greensand character being solely due to the conditions of the sea in which the strata accumulated.

In NE. Londonderry, east of Lough Foyle, the Cretaceous rocks are not seen *in situ*, their outcrop being concealed by the detritus on the slope of the dolerite plateau ; but to the north of the road from Limavady to Coleraine the White Limestone and Greensand appear ; the latter, according to Portlock, being very thin. Farther southward, east of Limavady, on the west slope of Keady Mountain, there is White Limestone about 33 feet in thickness, resting on 36 feet of hardened Greensand, or "Mulatto Stone," as it is called in Ulster. The lower portion of the chalk in one part of Keady Mountain is called "soft rock," as it crumbles into powder when exposed to the air, and can be used for manure without burning.

At Donald's Hill, to the SE. of Limavady, there are dolomitic beds averaging in thickness 2·5 feet in the White Limestone. In them are deep cavities containing crystals of quartz, chalcedony and bitterspar (?). The chalk is very flinty, and from 12 to 20 feet thick; what it rests on is not apparent. Farther south the Cretaceous beds thin away and possibly disappear; at Benbradagh, NE. of Dungiven, there is from 12 to 25 ft. of a visible thickness of the White Limestone; but to the south thereof it dwindles down to a few feet in thickness and disappears; its place being taken by a calcareous conglomerate, the basal bed of the Miocene rocks. The latter rock may easily be mistaken for one of those of Cretaceous age, being very similar in aspect, as it is made up of the *débris* of the White Limestone. On examination, however, it is evident that it is a rearranged rock; all the contained flints having been fractured and rolled prior to being deposited in a calcareous matrix, which was subsequently hardened into limestone by pressure and chemical action.

To the south-east of Dungiven and north of Moneyneany is an outlier of Miocene dolerite; to the south-west and south of which are the *débris* of the White Limestone. Some of this *débris* may be of the true "White Limestone," while other portions appear to be of the Miocene basal bed. In some places a flint gravel or shingle can be seen, but in the townlands of Damlaght and Dunmurry, about two miles north of Moneyneany, there appears to be two or three feet in thickness of a rock, in some places like the Upper Chalk, in others like a rearranged rock, but it is so obscurely seen that no definite opinion can be given on it.

To the north and east of the tract of Carboniferous rock in the neighbourhood of Draperstown, no Cretaceous rocks are exposed, neither do they seem to exist; but to the south, in the outlier on Slieve-Gallion-Carn, and to the south-east at Magherafelt, they again appear. On Slieve-Gallion-Carn, the Cretaceous rocks appear resting on Triassic rocks and capped by Miocene dolerite. They seem to be upwards of 20 feet thick, the upper portions being White Limestone, while the lower part is a very glauconitic and fossiliferous limestone, that is considered by Portlock to belong to the Greensand.

From Magherafelt the out-crop of the Cretaceous rocks extends southward by Moneymore and Coagh into the County of Tyrone; in every place they rest apparently directly on the Triassic rocks, and are principally White Limestone, although in places the lower beds are glauconitic and slightly sandy. At Tamlaght, near Coagh, at the base, is a remarkable pebbly or conglomeritic bed, that contains many fossils, such as *Ammonites Lewesiensis*, *Nautilus elegans*, *N. radiatus*, *Baculites Faujasii*, *Hamites*, *Inoceramus Cripsii*, *Cardium decussatum*, &c. Its total thickness is about 30 feet, and it rests on the Keuper marl.

South of Coagh is a tract of country in which the rocks are not seen. Jukes was of the opinion that it is occupied by Cretaceous rocks, while Portlock believed that in a considerable portion of it there were rocks that belonged to the Triassic and the Tertiary. At its north margin, a little south of Coagh, White Limestone is exposed, also farther southward, NE. of Stewartstown, and about a mile west of Stewartstown margining a small outlier of dolerite. Still farther south in the townsland of Lisnastrane, in the Coal-field near Coalisland, a small tract of a white limestone has been proved ; the rock, however, has many of the characters of the rearranged Miocene limestone, and possibly may not be of Cretaceous age.

To the SW. and S. of Lough Neagh, the Cretaceous rocks are concealed by the Lough Neagh Series ; but to the SE. of Lough Neagh, in the neighbourhood of Lurgan and from thence north-eastward to White Head, on the north of Belfast Lough, and from that NNW. to Ballycastle on the north coast, the Cretaceous rocks form a more or less continuous fringe to the dolerite plateau ; sometimes being seen only in detached quarries ; they often form but a thin band. In various places they and the associated rocks are displaced by faults, while in other places they are cut by dykes and protrusions of dolerite and other igneous rocks.

To the southward, according to Du Noyer and Warren, the Hibernian Greensand is from 70 to 80 feet thick ; below are dark green marls, passing up into flaggy pale bluish or greyish sandy limestones, over which are beds of greensand, the highest being the "Mulatto Stone," a massive hard calcareous pebbly grit or fine conglomerate, containing pea-sized rounded pieces of quartz and chloritic grains. According to Du Noyer, some of the sandy limestones found at Collin Glen have been used for lithographic stones.

To the NE. of Belfast, the Hibernian Greensand thins away, being from 15 to 25 feet thick, while north-west of Black Head it varies in thickness from 10 to 20 feet:

usually it is of different shades of light and dark green, but near Larne, at Waterloo, where it is well exposed, it is of a reddish colour. The Hibernian Greensand is very fossiliferous ; Baily's lists of the fossils is given in the Explanations to accompany sheets 21, 28, 29, and 36.

The Indurated Chalk or White Limestone is of various thicknesses, ranging from less than 50 feet to over 100 feet, a considerable portion having been removed by denudation. It is hard and compact, but breaks with an uneven surface. It usually contains numerous nodules of flint, of various shapes and sizes, which are generally arranged in parallel layers. In places, especially near Moira, are found the large more or less symmetrical flints described by Buckland as fossil sponges, and called by him Paramoudras. In these, traversing the longest axis, is a cylindrical core of white limestone : the name is said to have been coined by Dr. Buckland's guide, as the Doctor expressed a wish to obtain an Irish name for them. At Larne and Glenarm the White Limestone is manufactured into whiting. The stone is first broken into pieces about two or three inches in diameter, after which it is put with water into vats and ground by revolving blocks of granite ; the finer material is then run off into troughs, where it is allowed to settle, and the sediment is then pumped into drying rooms, and when dry is sent into the markets; principally to Glasgow.

A little to the east of the town of Antrim, where they are brought up by a fault, also in the neighbourhood of Larne, and farther to the south, are outlying exposures of Cretaceous rocks appearing in the Miocene rocks; while south, south-east, and east of Ballycastle are different fringes of Cretaceous rocks round outliers of dolerite, they lying on the Metamorphic (Cambro-Silurians) and the Carboniferous rocks. Farther north, in the south-west of the island of Rathlin, is White Limestone, appearing from under the dolerite sheets ; it also appears in detached places on the north coast of Antrim, between Ballycastle and Portrush, especially between Whitepark Bay and Ballycastle (where, in places, the underlying rocks are exposed) and between the Giant's Causeway and Portrush. A very elaborate description of the White Limestone along the north coast of Antrim is given in Portlock's " Report on the Geology of Tyrone and Londonderry." Baily gives lists of the White Limestone fossils in the "Geological Survey Explanations," just now referred to.

# CAINOZOIC PERIOD.

## CHAPTER IX.

THE Irish Tertiary rocks of Miocene age occur only in the Province of Ulster. There are also in Ulster and in other places, as near Cahir, County Tipperary, accumulations of Plastic clays and sands associated with Lignite beds, which by some are supposed to be of Pliocene age. These beds are best developed in the neighbourhood of Lough Neagh (Counties Antrim, Londonderry, and Tyrone), from which they are called the "Lough Neagh Series." The age of these beds has not been proved as yet; they may be classed provisionally as Pliocene; but it appears just as probable that they belong to the Præglacial drift, or are of Pleistocene age, and, possibly, that they ought to be described among the Superficial Accumulations in Section III., Chapter XIV.

*General Section of the Cainozoic Rocks.*

| | | |
|---|---|---|
| PLIOCENE (?). | LOUGH NEAGH SERIES.—Plastic clays and sands, with subordinate beds of lignite and layers of fossil wood *maximum thickness about* | 300 feet. |

| | | |
|---|---|---|
| Miocene. | Eruptive Series.—Principally bedded flows of dolerite, associated with tuffs and tuffose rocks. Locally there are flows of trachyte. In places, interstratified with the dolerites, there are Iron-ore measures *maximum thickness about* | 1,200* feet |
| | Basal Series.—Generally a flint conglomerate, but in places this accumulation is associated with, or replaced by, clay, tuffose rock, iron ore, or laterite (Bole) *from a few inches to over* | 20 " |
| | | 1,520 " |

## MIOCENE.

### BASAL SERIES.

Usually the lowest bed of a formation that lies unconformably on those below it, is, for the most part, a conglomerate, and this is the case with the Irish Miocene rocks, the lowest member of which is generally a flint conglomerate.

This conglomerate may be a flint shingle, or gravel, but more generally the flints are embedded in an ochreous, a calcareous, or an argillaceous matrix. When the matrix is calcareous, the rock is very like the White Limestone (Indurated Chalk), except that the contained flints were more or less broken, rolled, and abraded, prior to being included in the limy matter.

When a Lignite occurs, it nearly always lies on a thin bed of clay. The Lignites of Miocene age seem to have accumulated somewhat similarly to the major portion of the Irish peat, as they were formed in the places in which they are now found ; nowhere do they seem to have a

* As estimated by W. le S. Duffin.

sedimentary character, except, perhaps, in that of the upper portion of the bed at Ballintoy, County Antrim.

In the island of Rathlin, a conglomerate seems to occur in various places under the dolerite, and lying on the denuded surface of the White Limestone. On the opposite coast of Antrim, close to the harbour at Ballycastle, there is a calcareous conglomerate containing fragments of white limestone, flint, and dolerite; while in other places in the same vicinity, the matrix of the conglomerate is an ochreous bole containing flints. On the latter rock an indurated or altered tuff sometimes occurs. This last rock has somewhat the aspect of a dolerite, but it disintegrates freely and contains numerous flints. To the westward, at Ballintoy, there is an ochreous tuff or bole.

To the west of the Giant's Causeway, near Dunluce Castle, the basal conglomerate is of considerable thickness; and in the same neighbourhood, under the massive flows of dolerite, there is a series of thin beds ranging from a few inches to a few feet in thickness. These rocks are in aspect like dolerite, but can scarcely be flows of that kind of rock, as each bed is so thin, so even in thickness, and so extensive; probably they are beds of tuff or tuffose rocks, which were hardened by a metamorphic action similar to that which changed the Lias at Portrush into hornstone. That such a change can take place is pointed out elsewhere (Chaps. X., XI.); here, therefore, we need only direct attention to the previously mentioned indurated tuff at Ballycastle, on the same geological horizon.

To the west of Portrush, at Down Hill, County Londonderry, the basal rock is an ochreous flint conglomerate, which fills up the hollows in the surface of the White Limestone. To the SW., on the west of the dolerite plateau, at Keady Mountain, east of Limavady, there is a conglomerate under a peculiar indurated tuff, "very black like coal, and weathering into small cubical pieces." Farther south, at Donald's Hill, a thin bed of clay lies above the conglomerate. This clay is, in one place, fifteen inches thick; it is yellow above and red below, while the conglomerate is pinkish.

Following the boundary of the dolerite southward, on the south-east of Dungiven in the Eden hills, a calcareous and chalk-like conglomerate occurs resting on Triassic rocks. This thins away to a few inches in thickness. Farther south, in places, under the large outlier of dolerite to the north of Moneyneany, lignite was found. Due north of Moneyneany, immediately west of Craig-na-shoke, in the Ballynascreen hills, is a bed of Iron-ore nearly three feet thick, over about three feet in thickness of a chalk-like conglomerate. Under the latter there seem to be a few feet in thickness of Triassic rocks. A mile farther east, on the slope of Bohilbreaga, the iron-ore is replaced by a bed of lignite about eighteen inches thick. This lignite rests on a bed of clay, is highly bituminous, and contains small pieces of Amber. It is separated from the overlying dolerite by a few inches in thickness of steatitic stuff. At the "Coal Level" the basal calcareous conglomerate cannot be seen, but it occurs at a short distance to the east. Lignite is recorded by Portlock as occurring to the south-east at the Slieve-Gallion-Carn dolerite outlier, on from three to four feet in thickness of calcareous argillaceous conglomerate.

In Tyrone, the basal series is not well exposed, but in one of the coal-pits at Coalisland, a few feet in thickness of a white calcareous rock occurs, which is in aspect more like these basal beds than the White Limestone.

To the south-east of the dolerite plateau, the conglomerate is generally found where a section of the base of the Miocene rocks is exposed. West of Lurgan these rocks give as follows :—

| | | |
|---|---|---|
| Tuffose dolerite rock . . . . | 3 | feet. |
| Fire-clay . . . . . from | ·5 to 0·75 | " |
| Flint conglomerate, with yellowish marl matrix . . . . . | 1 to 3 | " |
| | 6·75 | " |

But farther north-east there is only a thickness of three or four inches of purplish marl between the dolerite and the white limestone. In the Knocknadona and Kilcorig quarries, there is a thin bed of very impure lignite on a dark fire-clay, from two to twelve inches thick; they overlie an ochreous flint conglomerate from six inches to three feet in thickness. It was the impure lignite (plant bed) in Limestone Lodge quarry, townland of Knocknadona, three miles NW. of Lisburn, that Jukes metioned in his paper published in the *Geological Magazine*, vol. v., in which he pointed out that the thick beds of dolerite are incapable of altering the underlying rocks, as the plant remains in this bed were totally unaltered, although only separated from the dolerite by a few inches of clay.

Farther north-east the conglomerate usually has a steatitic, clayey, or ochreous matrix, but in places it is described as a flint shingle, or gravel. It ranges from one foot to four or five in thickness. In the neighbourhood of Carrickfergus, over the conglomerate Du Noyer found beds of clay and impure iron-ore. In Muck Island, off the east shore of Island Magee, is iron-ore, which, possibly, may be in the basal series of the Miocene rocks, as close to it in Island Magee are Cretaceous rocks.

North-westward, from Island Magee to Cushendall, Traill has observed various exposures of the basal beds of the Miocene; they being usually exposed wherever the dolerite forms an escarpment. The best sections are seen in the several quarries to the south of Larne, on the road to Glynn, and in those near Magheramorne; to the north of Larne, between Waterloo Cliff and the Black Cave Tunnel, and further inland along the Sallagh Braes, and at intervals along the coast to the townland of the little Deer Park, two miles south of Glenarm; in the quarries adjacent to the harbour at Glenarm; also below the small waterfall inside the Glenarm demesne; and at the Carnlough quarries.

"The accumulation is principally a conglomerate with a ferruginous clayey base, containing angular and rounded pieces of flint, chalk, and dolerite, associated with a ferruginous clay and red ochreous bands or beds of laterite, which are more highly impregnated by hydrated oxide of iron. Portions of the clay are plastic, and others in weathering break up into small cuboids." Of these beds at Carnlough, Traill states that "there does not seem to be any consolidation of the *débris* of the White Limestone into a conglomerate."

These beds average from two to four feet in thickness, but when filling up fissures or hollows they sometimes attain a thickness of twenty feet. Some of the interbedded flints have bands of colour developed in them, and are fractured apparently by heat.

## Eruptive Series.

This is principally made up of extensive sheets of dolerite, with their associated tuffs or tuffose surfaces; but in limited areas there are tracts of trachyte. Duffin is of opinion that "the trachytes occur at the centres of eruption, and were probably poured out at the end of the outburst;" while Du Noyer has stated that the trachytes near Tardree were newer than the dolerites, and that in coming up they lifted with them masses of the dolerite; such as some of those on Carncarney. Professor Hull has surmised that the trachytes are probably of Eocene age; but this seems improbable. The basal beds of the Miocene rocks are known to be of Miocene age from the plant remains in them; and if the trachytes were older than these, fragments of the latter would most probably occur in the conglomerates—but this is never the case—moreover, the conglomerate should intervene between the trachyte and the dolerite.

In the vicinity of Templepatrick, some of the trachytic rocks evidently occur as intrusions, while in the Tardree area, although some of them are bedded and apparently below a portion of the dolerite, others are newer and evidently intrusive. As proved by Scrope, basic igneous rocks flow more readily and occupy larger areas than silicious ones, and it would appear as if in Ulster there had been small outbursts of trachytic rocks at different centres, not at the dawn of the Vulcanicity, but during its progress, as took place in Central France and elsewhere.

The very early eruptions of trachyte would only occupy very limited areas, and, subsequently, would be covered up by the more recent flows of dolerite. At a still later period there must have been outbursts of trachytic rocks at Tardree, near Broughshane, and perhaps also at Templepatrick; some of the isolated masses of the bedded dolerites seem to be portions severed from the rest during the more recent outbursts of trachytic rocks. At Ballyknock, four miles WSW. of Hillsborough, there are also eruptive masses of trachyte, to which attention was directed by Du Noyer.

The dolerite beds are massive and compact, but above and below there are amygdaloidal portions ; while between the flows are thin tuffs, or, perhaps more strictly, tuffose rocks, that is, re-arranged disintegrated portions of the surfaces of the flows ; there are also in certain localities subordinate series of IRON-ORE-MEASURES.

The partings and beds between the dolerite flows are called BOLE, and they seem to agree in a great measure with the argillaceous varieties of the Indian rocks called Laterite ; the latter being either the waste or disintegrated portions of the beds of Tertiary traps re-arranged and deposited by water or other atmospheric agencies, or such accumulations mixed with Tuff. Many of these rocks have undergone methylotic action, and are more or less steatitic ; they also contain a greater or less percentage of iron, and in places graduate into the typical Iron-ore-Measures.

Associated with the argillaceous laterite, or bole, is a compact variety known as LITHOMARGE : this is usually steatitic, and always contains iron ore and silica. Of it Traill states : "it is often locally called 'the pavement,' among the miners, contains a small percentage of iron, and in places is an undoubted tuff."

These beds are of various colours. According to Egan, they are "generally light reddish or brown, and sometimes variegated, frequently liver-coloured, and at times a lavender blue, more or less spotted with lighter tints ; they disintegrate freely, but do not form a paste in water." The bright coloured lithomarges are identical in aspect with some of the varieties of steatitic laterites collected by Wynne in Kutch, India.

The columnar structure in the dolerite at the Giant's Causeway, on the north coast of Antrim, has been described by numerous writers, and is very generally known. On the island of Rathlin, north of Doon Point, at a place called the "Little Causeway," there is also a great development of columns lying at various angles to the horizontal.

## Iron-Ore Measures.

These measures are an important feature in the Irish Miocene rocks. Although classed as one series, they seem to occur on slightly different geological horizons. They consist of beds of *Pisolitic-iron-ore*, *Aluminous-iron-ore*, or *red bole*, lithomarge and bole, with, in places, lignite. At some of the Iron workings the aggregate thickness of these measures is over 60 feet, but in other places they do not exceed a few feet.

The pisolitic ores, according to Bauermann, contain from 30 to 70 per cent. of iron, and the aluminous from 25 to 35 per cent. They are mostly free from sulphur and phosphorus, and are of great value in smelting other ores for malleable iron and steel, especially the "Bessemer steel." Some of the richer lithomarge can be worked with profit, as it is extensively used as a flux for the rich Cumberland hematite ores. Traill states: "The pisolitic structure seems to have been generated very frequently in the uppermost portion of the bole beds without necessarily forming good 'pebble-ore.' The true pisolitic portion, or first quality ore, is of variable thickness: in some places its presence is only indicated by the structural appearance, but in the localities where it is more largely worked it averages from 14 to 18 or 20 inches, occasionally expanding in thickness to 3 feet, or exceptionally to 4 feet. The second quality ore is also, to a certain extent, pisolitic, but the concretions are not so hard nor so well formed, and it does not contain as high a percentage of iron. It is often worked for a thickness of 2 feet or more with profit. The varying circumstances of transit, shipment, and trade considerably modify the extent to which this portion is worked."

The Iron-ore Measures appear to have been lacustrine accumulations, and to have been formed similarly to like deposits now accumulating in Central America, where on the uneven surfaces formed by successive but unequal flows of dolerite there are shallow expanses or lakes of water. In such lakes the first accumulations are necessarily the detritus or disintegrated portions of the surrounding rocks carried into them by rain and runlets or wind, which may or may not have been augmented by showers of volcanic tuff. A necessary accompaniment of the decomposition of the detritus of the dolerite was the formation of iron ores, which more or less impregnated the strata ; thus the lithomarge would be formed. The aluminous-ore appears to have been due to a longer water carriage, alumina and iron held in solution being carried and deposited during hot weather. Somewhat similar action takes place at the present day in many places in Ireland, as, during the summer heat, waters which at other times are perfectly clear, get thick and muddy as they become shallow, depositing argillaceous peroxide of iron. The pisolitic accumulations were probably due to the presence of organic matter that attracted the iron. These shallow lakes in some instances became marshes or even peat-bogs, the latter being now represented by the lignite.

In the section at Island Magee two beds of iron-ore are separated by a bed of clay, as if the deposition of the iron had ceased for a space of time, while subsequently it was again deposited ; but this cessation seems hard to explain. On Rathlin island, apparently low down in the dolerites, are several thin beds of ochre and steatite (Bole).

Over the Iron-ore measures there are different thicknesses of dolerite, but in no case have these super-imposed rocks altered the former. When they are altered they are traversed by dykes of igneous rocks.

The chief places in which the Pisolitic ores have been worked are along the outcrop of the ore beds from Knockboy and Ballylig, near Broughshane, to Glenravel, Cargan and Newtown Crommelin ; along the side and at the head of Glenariff (the shipments of it having been from Red Bay) ; near Carnlough and Glenarm ; at Shane Hill, to the west of Larne ; and on Island Magee ; at Ballypalady, where it may be said that this industry was first originated ; on the north coast at Portmoon, beside the Giant's Causeway, and a little inland from the White Rocks near Portrush, and also to a limited extent in a few other localities ; all the workings being in the country to the north or north-east of Lough Neagh.

In the south portion of the dolerite area, on the west of the valley of the Lagan, the thickness of the eruptive rocks is, according to Warren's estimate, about 800 feet. In this thickness, beds of bole are found, but no regular Iron-ore Measures seem to be represented. To the west of Lough Neagh the Eruptive Series is supposed to be from 400 to 500 feet thick, but no conspicuous Iron-ore Measures are known to occur therein.

On the east side of the County of Antrim, in the vicinity of Larne, the Iron-ore Measures are, according to

Duffin's estimate, about 800 feet above the base of the Miocene rocks, while in Island Magee the thickness of the lower beds of dolerite appears to be less. Between Larne and the town of Antrim there seems to be a thickness of about 600 feet below and about 400 feet above them. According to Mr. Gray, the general section of Iron-ore Measures is :—

| | |
|---|---|
| 4. Pisolitic iron ore. | 2. Ochre. |
| 3. Bole. | 1. Lithomarge. |

This section, however, varies in the different workings, as will be seen from the details published in the "Memoirs of the Geological Survey."

Lignite occurs in the dolerite near Crumlin, east of Lough Neagh ; Carnmoney, south-west of Carrickfergus ; Ballypalady, east of Antrim ; Shane's Castle demesne, north of Lough Neagh ; about halfway between Ballymena and Ballymoney ; at Glenarm ; at Ballintoy ; in the face of the cliff near the Giant's Causeway ; and at Dunagael, Rathlin island. In most of these places the lignite is more or less associated with the Iron-ore Measures, but in some of them it occurs between beds of dolerite ; at Ballintoy it seems to be best developed. At this locality, according to Traill, "it is 30 or 40 feet above the lithomarge and bole, and has an average thickness of about 2 feet, in some places swelling to 4 feet, and, exceptionally, to 5 feet, the upper stratum being solid, black, and glistening. It rests on a thick bed of dark clay, part of which is a fire clay, but rather gritty." To the west of Ballintoy, at Lemeneigh, the lignite contains blocks of wood which split readily, while still farther west it is still very much in the condition of recent wood, being very little mineralized. In the clay under the lignite are found plant remains, one being considered by Baily to be *M'Clintockia Lyellii*, a plant previously found only in Greenland.

Of the plant and lignite beds at Ballypalady Duffin gives the following section :—

| | |
|---|---|
| 6. Glacial drift | 12 feet. |
| 5. Conglomerate beds, occasionally having thin beds of arenaceous clay and plant remains | 10 to 12 „ |
| 4. Plant bed. Reddish-yellow ferruginous arenaceous shale | 5 „ |
| 3. Dark shale, with plant fragments and pieces of lignite ; the latter increasing in quantity downwards | 3 „ |
| 2. Lignite | 1 „ |
| 1. Amygdaloidal dolerite | 1 „ |
| | 34 „ |

The following is a list of plants observed by Baily :—*M'Clintockia trinervis* (Ballypalady), *M. Lyellii* (Lignite bed, Ballintoy), *Sequoia Couttsiæ, Cupressus* or *Glyptostrobus Europæus,* leaves doubtfully referred to *Ulmus, Quercus, Fagus, Salix* and *Andromeda* (Ironstone nodules, shores of Lough Neagh). Others found in different places are *Pinus Plutonis, Sequoia Du Noyerii, Cupressites McHenrii,* leaves of *Platanus* and *Rhamnus* of three species.

## PLIOCENE.

### LOUGH NEAGH SERIES.

The Plastic clays associated with lignite either of Pliocene or Pleistocene age, but provisionally placed as the former, have been found near Cahir, County Tipperary, and in other places in Munster, while in the province of

Ulster, near Lough Neagh, they are largely developed. Other deposits of plastic clay, which may be of the same age, have been found on Aran island off the coast of Donegal, near Menlo, County Galway, and elsewhere. These latter accumulations, as they do not contain lignite beds, will be described in the chapter on the Drift.

At Loughloheny and Ballymacadam, south-east of Cahir, is a small tract of pipe-clay with beds of lignite, in a hollow in the Carboniferous Limestone. The exact depth of the beds has not been proved. In some places the lignite is never found until a depth of fifteen feet has been reached. The clay above the lignite contains small black specks, which makes it crack in burning, while that below the lignite is perfectly pure, and has been exported to England to be manufactured into the finer kinds of pottery. Wynne is of opinion that these beds are the remains of a once extensive accumulation, as three miles north of Cahir, also farther northward, similar pipe-clay has been found. In the drift of the valley of the Suir, in the vicinity of Cahir, a few pieces of silicified wood similar to the "Lough Neagh hones" have been found.

In the vicinity of Lough Neagh these beds consist of plastic clays, sands, and subordinate beds of lignite and clay-iron-stone.

Griffith and Portlock considered these accumulations to belong to the newer Tertiaries, although the latter believed that some of the upper beds are possibly of the age of the drift of the surrounding country; Jukes, on his map, classes them as Pleistocene, and Baily agrees with this; while Hardman, in recent publications, has called them Pliocene; but none of these writers have brought forward any new or conclusive evidence as to their age.

The following section was proved in a pump shaft a mile due west of the mouth of the Ballinderry river:—

| | | |
|---|---|---|
| 5. Boulder clay . . . . | . 50 | feet. |
| 4. Light brown and white clay | . 5 | " |
| 3. Bluish hard clay . . . . | . 3 | " |
| 2. Brown "till," with landstones | . 10 | " |
| 1. Dolerite . . . . . | . 22 | " |
| | 90 | " |

Nos. 3 and 4 are very like some of the Lough Neagh beds near Salter's Castle, but in this section these clays are apparently in the drift.

The Lough Neagh Series is undoubtedly newer than the dolerite, having been deposited subsequently to the denudation of the Blackwater Valley, out of which were excavated all the Miocene and Cretaceous rocks and a considerable thickness of the Trias. The newer rocks rest in some places on the dolerite, in others on the white limestone, or on the Triassic rocks. They are necessarily of very unequal thickness, and the greatest depth to which they have been proved is about 270 feet, and probably in no place do they much exceed this depth, although the dip of the layers would give a thickness of between 1,500 and 2,000 feet. This laminated structure, however, is evidently false stratification, like that found in all deposits similarly accumulated.

To the east of Lough Neagh, at Sandy Bay, a bore-hole was put down, of which Griffith gives the records. It proved about 76·5 feet in depth, of which 60 feet are said to be lignite. Near this, in the Crumlin river, the beds are only a few feet thick, and lie on an eroded surface of dolerite. The Crumlin river beds are evidently high up in their formation, and come directly on the dolerite by overlap. In these, bivalves have been found by Hardman, who considers the fossils to be *Unio*, but Doctor Henry Woodward, of the British Museum, considers that they are more like *Mytilus* or *Modiola*, which would go to prove the Pleistocene age of the beds. The great quantity of lignite recorded by Griffith in the bore-hole would suggest that possibly a mistake was made in the returns. Still, however, it should be remembered that Sandy Bay must have been a bay during the accumulation of these strata, into which there may have been currents that carried in timber and left it there, which would account for the great thickness of lignite.

To the SW. of the lake, at Annaghmore, near Coal-island, a deep trial-bore was put down, proving 270 feet of clay and sand, without bottoming them. Further north other trials were made, which reached "rotten dolerite" or a conglomerate containing pieces of dolerite. Of these trials no records seem to be forthcoming, but they are said to have been between 50 and 100 yards deep near Arboe or Salter's Castle. While sinking one of these trial pits about the year 1860, shells and plants were found by Mr. Garvin.

Centuries ago the silicified wood found in Ulster attracted attention, and led to the belief that "the waters of Lough Neagh had the property of petrifying wood." In 1684 Smith pointed out that the power must be in the soil rather than in the water, but Barton, in 1757, was the first to show that the silicified wood was connected with the lignite. This observer made a sinking near Glenavy waterfall, Sandy Bay, and found—

| | |
|---|---|
| Red clay . . . . . | 3 feet. |
| Blue clay . . . . . | 4 " |
| Lignite . . . . . . | 4 " |
| Clay . . . . . . | |
| | over 11 " |

The lignite was in a black compact mass, that in general could be cut by the spade. Some portions, however, could not be so cut, and "it required the aid of some other tool to separate them from the mass." Such portions, when examined, were found to have been more or less completely changed to stone.

Scouler afterwards examined into this subject, and came to the opinion that the silicified wood was not "co-extensive with the deposits of lignite." This observer found the "deposits of lignite at different places around Lough Neagh from Dungannon to Glenavy, a circuit of about twenty miles," while the silicified wood occurs over the country, from Cranfield on the north in Antrim to Seagoe on the south in County Armagh; he also mentions that it is not found in the potters' clay and lignite at Verner's Bridge, south-east of Dungannon. For these reasons he suspected that the silicified wood came from some of the beds associated with the dolerite.

It is possible that some of the "Lough Neagh Hones," as the silicified wood is popularly called, may come from an unknown bed in the dolerite, but at the same time it is evident that most of them come from the lignite in the Lough Neagh beds. None of the lignite associated with the dolerite is found to be silicified, although part of it is impregnated with iron; while a piece of lignite like that described by Barton, if bleached, would be identical with the Lough Neagh hones. In most of the many pieces we have picked up the central portion had all the appearance of the lignite of the Lough Neagh beds. Egan, who has lately paid particular attention to this subject, finds that the dark brown and black portions which compose the interior of the Lough Neagh hones, when heated in the fire or before the blowpipe, give out a smoke possessing clearly the peculiar smell of burning lignite. From this circumstance, and from the resemblance in appearance between specimens of the two substances picked up along the north-west shore of Lough Neagh, as well as from the fact that the fragments of silicified wood are sometimes not at all waterworn, he thinks it is difficult to avoid the conclusion that this is connected with, and derived by a process of silicification from, the lignite. This observer also finds, as far as his experience goes, that the hones found near the lake are bleached only "skin deep," while at distances from it they are deeply bleached; also that under the latter circumstances they only occur in stratified gravels. We have previously mentioned that in the drift associated with the Cahir lignites, County Tipperary, pieces of similarly silicified wood are found.

The opponents of Barton's idea seem to ignore that portions of the lignite he raised were so hard "that it required other tools than a spade to separate them from the mass;" also the well-known fact, that all rocks before they lose their "quarry water" are softer than afterwards, some being so soft that they can be cut with a knife, or even be easily moulded, although afterwards,when dry, they may become excessively hard. In reference to the Lough Neagh hones occurring so far north, it has been stated that the ice would only carry them southward. Those who have made this statement quite forget that probably the Lough Neagh beds, prior to being denuded far exceeded their present limits, and, if their present surface once formed a horizontal or nearly horizontal plain, they would extend northward nearly, if not quite, as far as the places in which the Hones occur; also that, as the Hones occur in aqueous drift, they were probably carried northward after the great ice age.

# SECTION II.—METAMORPHIC AND ERUPTIVE ROCKS.

INGENITE ROCKS (Forbes).

## CHAPTER X.

### METAMORPHIC ACTION.

THE Metamorphic and Eruptive rocks have been classed under the name of Ingenite rocks by Forbes. They will be described in this section together, as they are intimately connected, all being indirectly due to Metamorphic Action. As that action is not generally studied, a short description of it is given in this chapter, and a classification which will prevent repetition when describing the rocks of the different localities. The classification of Metamorphic Action is like that adopted by Professor le Conte of the University of California, in his recently published Geology.

One kind of Metamorphism is *Regional*, or extends over large areas. The rocks affected by it seem to have been under the influence of intensely heated water or steam, which, as it were, stewed them, from which the action may be called METAPEPSIS. Another kind is merely *Local*, its effects being only found immediately adjoining intruded masses of rocks, or in the vicinity of vents where gases, steam, or other products of vulcanicity found egress. When typical, this kind of Metamorphism produces in the rocks an appearance as if they were baked, from which it may be called PAROPTESIS. It is not, however, always typical, as many of the altered rocks must have contained

Fig. 7.

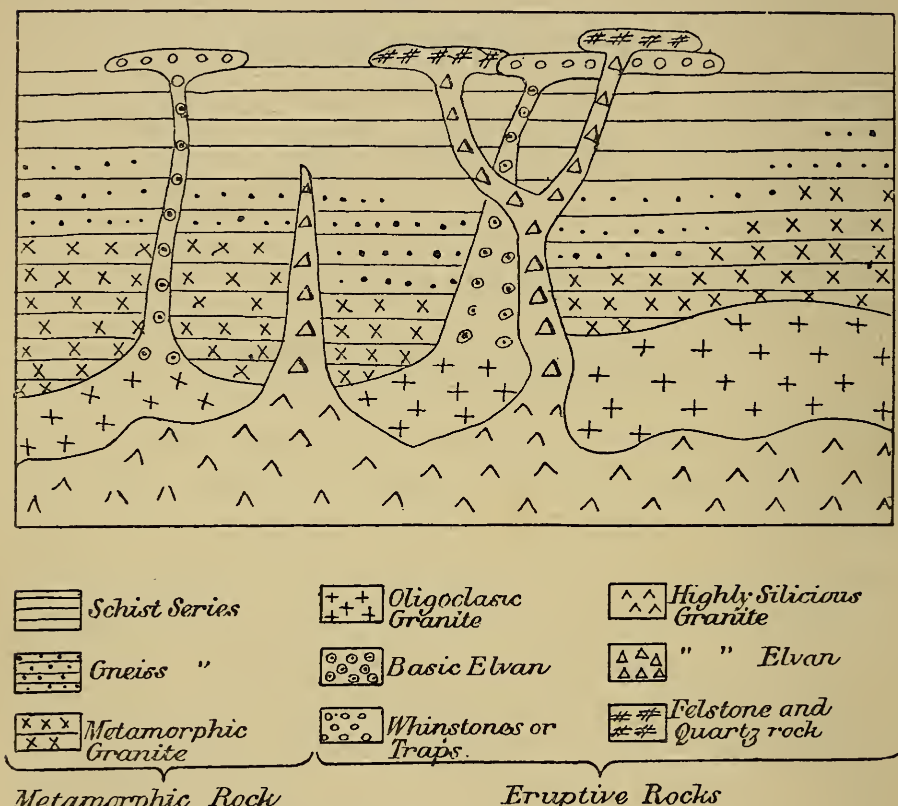



Diagram illustrating the formation of the Granitic and other Eruptive rocks.

moisture, which when heated into steam would give results more or less similar to Metapepsis, except that the action would be confined to limited areas. In both these classes of Metamorphism, chemical action has been, more or less, and sometimes, indeed, to a great degree, set up among the constituents of the rocks affected. There is a third class of

Metamorphism which is also local. It is due to the introduction and action of chemical substances from without; it has been called METHYLOSIS. The last is more often found among Metapeptic rocks than elsewhere. Metapeptic action is the metamorphism that is most interesting to the geologist, as it is by the extreme action of it that Eruptive rocks have been formed. These changes may be divided into stages, as represented in the accompanying diagram.

The originally unaltered rocks when subjected to a slight metapeptic action constitute the rocks of the first stage.

*First Stage.* SUBMETAMORPHIC ROCKS of the Indian Geological Survey Officers. These rocks are indurated, and the surface planes of the prominent structures are glazed or mineralized, while in most of them an incipient foliation has been produced. In others no peculiar structure appears, but only certain minerals have been developed. The principal rocks of this stage are the different varieties of *Argillite*, or Argillaceous-schist, *Phyllilite* or Phyllite-schist, and incipient *Quartzite* or Quartz-schist (Indurated grits). In some places, owing to the constituents of some rocks being more susceptible of change than those of the rocks with which they are associated, subordinate beds of well developed schists, gneiss, or even granite, may occur in close connection with rocks which have undergone very much less change, although they have been attacked by the same agent.

*Second Stage.* SCHIST SERIES. These rocks have their mineral constituents arranged in plates, or leaves, along which the rocks easily split, while in the direction transverse to that of the leaves or foliation they are tough and break with an uneven or hackly fracture. A typical schist consists of two well developed minerals, one of which is generally mica—various other minerals, however, may occur, sometimes merely as accessories, but locally as essentials, thus forming different varieties and sub-varieties. When mica is absent, quartz is nearly always present.

The principal varieties of schist are *Micalite* or Mica-schist, *Quartzite* or Quartz-schist, *Felsilite* or Felsite-schist, *Hornblendite* or Hornblende-schist, *Chlorilite* or Chlorite-schist, and *Talcite* or Talc-schist. The Metallic Schists, *Pyrilite*, *Pyrrholite*, and *Mico-iron-schist*, although not very common, may be also mentioned, as they are in some places worked as "sulphur ores."

*Third Stage.* GNEISS SERIES. Among these rocks gneiss predominates, but there are always subordinate beds, and groups of beds, of schist. Gneiss in its simplest form is a crystalline granular aggregate of quartz, felspar, and mica, in leaves or plates more or less parallel to one another. This is, however, rather uncommon, as gneiss usually contains various other minerals as well, sometimes as accidental accessories, but often as essentials forming numerous varieties and sub-varieties.

In ordinary gneiss the foliation follows the most conspicuous structure in the original rocks, but in *Granitic gneiss* the original structures are nearly always obliterated, and a more or less perpendicular foliation is substituted. Granitic gneiss is the nearest approach to the granites of metamorphic origin, and it is a question if it ought not to be included among them.

*Fourth Stage.* METAMORPHIC GRANITE. Granites of metamorphic origin usually have a more or less conspicuous foliation. They are necessarily very variable in composition, according to the mineral constituents of the different rocks from which they were formed. In Ireland most of them contain a large percentage of such minerals as oligoclase, a felspar that seems to be adularia, amphibole, titanite, and ripidolite; but in some places they are very silicious.

*Fifth Stage.* INTRUSIVE GRANITE. In the rocks of this stage there is a total change, the original rocks losing their identity and having become a molten mass. This mass, before cooling, generally separated into two zones, one more silicious than the other. Some portions of these zones cooled below the surface of the earth, forming the different Intrusive Granites and Elvans; while others were forced up to or near the surface of the earth to form the Plutonic* and Volcanic rocks.

The Intrusive Granites, with their associated Plutonic and Volcanic rocks, may be tabulated as follows:—

HIGHLY SILICIOUS INTRUSIVE GRANITIC ROCKS.

(*a*) *With Quartz in excess.*—GREISEN (Cotta); QUARTZ-ROCK;† a granular rock, almost entirely composed of quartz, but sometimes containing orthoclase or mica, or a little of both; petrologically a granite.

(*b*) *With Orthoclase in excess.*—FELSITIC GRANITE (King); FELSITE-ROCK (Cotta); a granular rock, almost entirely composed of felsite (an intimate mixture of orthoclase and quartz), but sometimes having a little free quartz, and rarely some mica; petrologically a granite.

(*c*) ORTHOCLASE GRANITE; when typical, a crystalline aggregate of orthoclase, quartz, and micas; usually also containing pyrite.

* The term Plutonic is used to denote the rocks formed during the times now long past, and consequently (if all the more recent strata were represented) at great depths below the rocks now forming. A few of these rocks may have accumulated similarly to the volcanic rocks of the present day, but in general their formation seems to have been vastly different, they having been ejected in great sheets, apparently from fissures, of which "fissure eruptions" there are now no representatives.

† *Greisen*, or *Quartz-rock*, here included among the Granitic rocks, and the *Quartz rocks* presently mentioned among the Plutonic rocks, are eminently Eruptive rocks, and must not be classed with *Quartzite* or Quartz-schist, which are metamorphosed grits, and other silicious rocks.

*(d)* ORTHOCLASE ELVAN; when typical, containing orthoclase, quartz, micas, and pyrite. Some of the minerals are not entirely crystallized out, but form a matrix, and some of the quartz always appears in distinct crystals, blebs, or globules. These rocks are the passage rocks between the typical granites and the felsitic Plutonic and Volcanic rocks.

## PLUTONIC AND VOLCANIC SILICIOUS ROCKS.

*(e) With Quartz in excess.*—QUARTZ-ROCK;* a granular rock, nearly entirely composed of quartz, but some varieties contain orthoclase or mica. By an excess of orthoclase, quartz-rock will graduate into petro-silex or a rock like fine felsitic elvan.†

*(f) Very Silicious.*—PETRO-SILEX, FELSITE-ROCK, and some TRACHYTES; usually a compact mass of felsite: sometimes, however, it is granular. It often contains free quartz in crystals, globules, or blebs. Some varieties are micaceous, others pyritous.

*(g) With Orthoclase in excess.*—FELSTONE, and some TRACHYTES; a granular or compact mixture of orthoclase and other felspars, the monoclinic felspar always being in excess. When one or more felspars appear as distinct crystals in the mass, the rock is called a PORPHYRITE, or PORPHYRY.

*(h) With Triclinic Felspar in excess.*—EURITE (Daubisson); BASIC-FELSTONE, and TRACHY-DOLERITE. These felstones belong to the *Hybrid-rock* of Durocher, and are the passage rocks between the Felstones or Trachytes and the Traps or Whinstones. If orthoclase is added to these, they graduate into the Felstones *(g)*, while with the addition of amphibole or pyroxene they will change into the Traps *(k)*.

## INTRUSIVE GRANITIC ROCKS, IN PART BASIC.

*(i)* OLIGOCLASIC GRANITE; a crystalline aggregate of orthoclase, triclinic felspars, quartz, mica, and pyrite. Amphibole, titanite, and such like minerals are usually present.

*(j)* BASIC ELVAN. These rocks are most variable in composi-

* See last note.

† Some of the Wicklow rocks mapped as "Granular quartz-rock" by Wyley were called "Elvan" by Jukes.

tion, they being the passage rocks between the Oligoclasic Granites and the different Eurites *(h)* and Traps *(k)*. They include such rocks as *Granitone*, some of the *Diorites* (amphibole + triclinic felspar), *Syenite* (amphibole + orthoclase), and various other basic granitic rocks.

PLUTONIC AND VOLCANIC BASIC ROCKS.

*(k)* TRAP OR WHINSTONE. — These embrace the different varieties and sub-varieties that may be included under the general names of gabbro, melaphyre, dolerite, diorite, and basalt.

The classes and divisions of the Metamorphic and Eruptive rocks are necessarily arbitrary, but not more so than the others adopted by geologists to classify the Sedimentary rocks ; and observers, after a little field experience, know in what division or class to place the different varieties. There is, however, a certain complication in the Eruptive rocks ; as between the highly silicious and the basic are others—the *Hybrid rocks* of Durocher, which in places are so prominent and important that they seem to form a class in themselves. There are many Granites and Elvans which it is impossible to put in either the highly silicious or the basic class. One part of a protrusion may have the characters of one, while another part may have the characters of the other, or the whole protrusion may have no definite character ; and similarly among the Plutonic and Volcanic rocks, as there are some Eurites and Trachy-dolerites, which in places have all the characters of one of the kinds of Whinstone, although the mass of the rock necessitates it being put among the Felstones.

In the descriptions of the rocks of different localities it will be seen that in one district rocks of one class usually predominate, although in some places all the classes are represented.

# CHAPTER XI.

## METAMORPHIC ROCKS.

### South-east Ireland.

In South-east Ireland the metamorphosed rocks are of Cambrian and Cambro-Silurian ages. In the promontory of Howth the Cambrian rocks are, for the most part, *sub-metamorphic*. They have already been described at page 11, in the chapter on Cambrian rocks.

From Killiney in the County Dublin to the south coast of Wexford the Cambrian and Cambro-Silurian rocks are in part altered. This metamorphism was evidently effected at four distinct times, at least; at the first and third regional metamorphism, or *metapepsis*, took place, and at the second and fourth local metamorphism, or *paroptesis*.

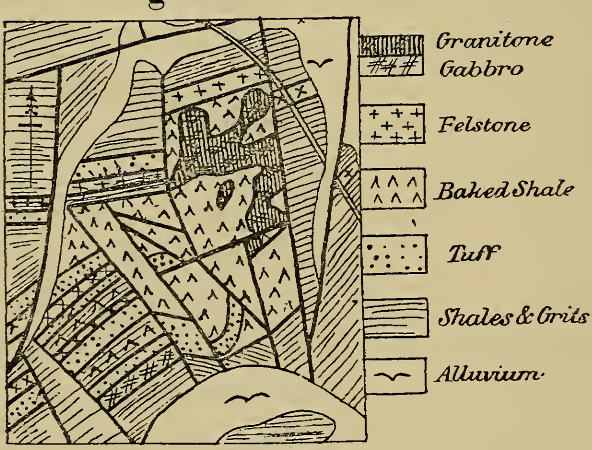
In south Wexford the Cambrian rocks are altered, the extent of change decreasing from the south, north and westward. In the Saltee Islands, and on the mainland in the neighbourhood of Carnsore, the action was so intense that the rocks are changed into granite. These granites graduate through gneiss and schist into the sub-metamorphic rocks of the Forth mountains; while farther westward and northward the Cambrians are unaltered. Still farther north, in the Counties of Wicklow and Dublin, the Cambrians are unaltered, except, perhaps, some rocks north of Aughrim. The age of these last rocks, however, is uncertain, and their alteration was subsequent to the metamorphism of the Cambrians in Wexford.

There are interesting points in connection with these metamorphosed Cambrians. At Carnsore and thereabouts the metamorphic granite is oligoclasic, while on the Saltees it is eminently orthoclasic and silicious. At Crossfarnoge, or Forlorn Point, north of the Saltee Islands, are orthoclasic granite or granitic-gneiss beds in sub-metamorphic rocks (incipient hornblendites and talcites). These granitic rocks of Forlorn Point seem to have been originally felsitic tuffs or tuffose rocks that rapidly altered, while the associated rocks were less susceptible of change. NW. of Greenore Point the quartzites are *metamorphosed grits*, while in the Forth mountains the quartzites are *metamorphosed quartz rock*. The latter are instructive, as foliation is well developed in them, while the grits in the associated Cambrian rocks are very little altered.

That the rocks which have been mentioned were metamorphosed prior to the Cambro-Silurian period is evident, because to the south-east of Wexford, east of Ballygeary Pier, and at Tagoat, are unaltered fossiliferous Cambro-Silurians resting on Cambrian schists. This occurs also to the south-west, on the shore south-east of Bannow, where a Cambro-Silurian slate conglomerate rests on Cambrian quartzite. This is the peculiarly confused locality, of which a section and map (pages 18 and 19) have already been given, showing the Cambrian and Cambro-Silurian rocks entangled together.

The second period of metamorphism was in Cambro-Silurian time. In the description of the Cambro-Silurian rocks of SE. Ireland it was mentioned that in the upper, ones, or those of the *Ballymoney series*, are sheets of bedded Eruptive rocks. In the lower, or the *Dark Shale series*, the granitic roots of these sheets occur. Some of these roots are silicious elvans; others are granitone, or some other variety of basic elvan; and invariably surrounding, and in the vicinity of, the protrusions of the basic elvans, the Cambro-Silurian rocks have been altered by paroptetic action. As the rocks in which these protrusions are situated are principally argillaceous shales, the altered rocks in general are hornstones, but some green tuffose rocks have been changed into rocks like whinstone, and some silicious rocks into a rock like quartzite, of a black or bluish colour. These tracts of paroptetic rocks are almost invariably margined by joint or fault lines, and traversed by others; as if the action was not so much due to heat given

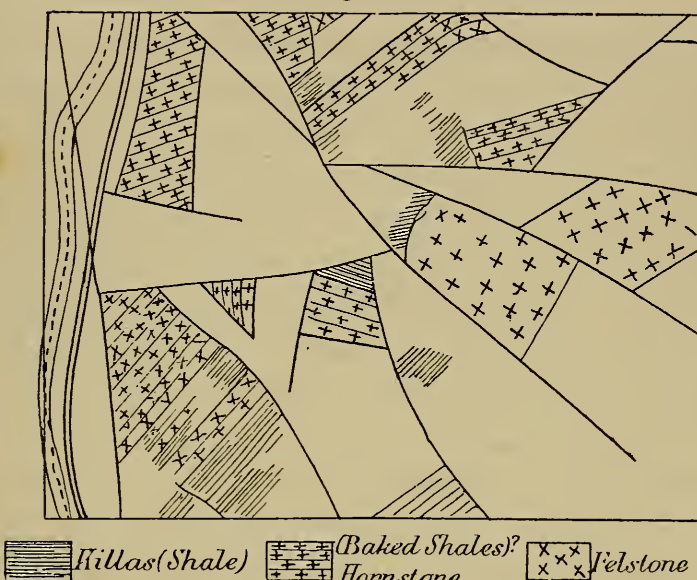
Fig. 8.




Map of "Baked Rocks" round vent of eruption, Owenduff, County Wexford.

off from the mass of eruptive rock as to the steam, gases, and such like products of vulcanicity given off during the time the eruptions were taking place, which percolated through the adjoining rocks and altered them, prior to the time that the present granitic rocks consolidated. That an alteration similar to that now described, and due solely to the gases and suchlike products of vulcanicity can take place, is proved in various localities where tracts of similar paroptetic rocks occur, although there are no protrusions of eruptive rocks associated with them.* The vents or passages of the Plutonic outburst are also found higher up in the formation among the lower rocks of the Ballymoney series. Here, since many of the altered rocks were originally felspathic and basic tuffs or tuffose rocks, the new

Fig. 9.




Map of isolated patches of Hornstone and Felstone, Tigroney (Ovoca), County Wicklow.

rocks are very puzzling; as these tuffs readily changed into rocks which are in places undistinguishable from felstones, eurites, and gabbros.

These paroptetic rocks form numerous small tracts in SE. Waterford, in Wexford, and in Wicklow. In the latter county those found in the vicinity of the Ovoca

* It was probably an action of this kind that altered the Jurassic rocks at Portrush, County Antrim, as described in the chapter on the Mesozoic rocks.

mines are very remarkable. Here, associated with the Mineral channel, are detached masses which by most writers have been called felstones. Weaver, however, in his description pointed out that some of them were hornstones, and that these, to all appearance, were originally shales. Usually each patch is abruptly cut off, as shown in the accompanying map ; but in a few places the hornstone graduates into fine felspathic shale or schist. The easiest way to account for these patches of hornstone is to suppose that small tracts, by means of joints or other fissures, were invaded by steam, gases, and such like, that altered them while the associated rocks remained unchanged.

The third period of alteration was after the Cambro-Silurian rocks were deposited. During it the metapeptic action was not universal, as it seems to have been most intense in certain lines that crossed the county obliquely, the rocks at these lines being more altered than those situated between them. It is also remarkable that while the rocks along the north-west margin of the great tract of the Wexford Cambrians are generally unaltered, the adjoining black Cambro-Silurian rocks are altered.

The metapeptic action seems in general not to have been very intense, as the rocks usually are *submetamorphic.* In the County of Wicklow, however, the rocks are more changed, some belonging to the *schist series*, others to the *gneiss*, while some seem even to be changed into *granite ;* these, however, appear to have been also subjected to a more recent change. In the county north of Aughrim some of the rocks seem to be of Cambrian age. These are the rocks previously alluded to; but, if Cambrians, they were evidently altered at this time, and not by the metamorphism that changed the Cambrians in Wexford.

It was evidently after the alteration of the Cambro-

Silurian rocks by metapepsis that the granite in the hills between Dublin and New Ross on the Barrow was intruded. Some of these granites seem to have been intruded immediately after that metamorphism of the Cambro-Silurians, but prior to the Carboniferous age; while there was a second protrusion of granite at a later period, the exact time of which is discussed in the next chapter. There may have been paroptetic action associated with the first protrusion, but it undoubtedly accompanied the second.

In the County of Wexford the rocks adjoining the earlier granite are less altered than those farther away; but to the north-east, in the Counties of Wicklow and Dublin, we find that alongside the granite the schists are more strongly mineralized and foliated. This, however, may possibly have been due to later vulcanicity, as some of the granite adjoining the schist seems also to be altered, while in many places a newer granite comes up at the margin of the older. To the west of the granite range in the County of Kildare the rocks are evidently altered by paroptesis into hornstone, jasperized grits, &c. Here, also, it is possible the change may be of a later date, as the adjoining granite looks like the newer kind, but no satisfactory section of the rocks can be seen. Farther southward, in the County of Carlow, west and south-west of Mount Leinster, the rocks are very much altered; but in this county there are evidently protrusions of the later granite coming up through the older.

The newer granite also occurs in isolated exposures in the Counties of Wexford and Wicklow, where the adjoining rocks are always affected by paroptesis. A striking accompaniment of the action produced by these later protrusions is the excessive ochreization of the adjoining rocks;

they, when weathered, having the same appearance as the metallic schists, but when broken the iron stains seem to be principally in the minute structural planes and other open lines in the rocks.

In the Metamorphic rocks of Wicklow and Wexford some of the beds have been subjected to *methylotic action*, and became steatitic and ophitic, but rarely is good steatite or ophite found. In the County of Waterford, associated with the sheets of eruptive rocks of the Ballymoney series, Willson has recorded steatites and ophites between Cheekpoint and Tramore, while west of the latter place, at Ballydouane Bay are fossiliferous seams of green ophialite in calcareous shales.

In the Carboniferous rocks of Wexford, Kildare, Carlow, and Kilkenny, and less frequently in some of the other counties, are dolomitic limestones and dolomites, some of which seem to be methylotic rocks. Those in Wexford, as also those lying on the granite and Cambro-Silurian rocks in Kildare and Carlow, seem to have been so deposited; while in Kilkenny there are peculiar masses and dykes of dolomite that have abrupt boundaries; and in these all traces of bedding and of fossils are obliterated, while the rocks adjoining are distinctly bedded and fossiliferous. These masses and dykes seem to be methylotic.

## Munster.

In the province of Munster, regional metamorphism or metapepsis has not affected the rocks conspicuously; although, as mentioned in the description of the Upper Carboniferous rocks, such rocks in Munster, as also in

Leinster, seem to have been subjected to an incipient metamorphism of this kind.

Paroptetic action can be observed in the vicinity of the protrusions of the eruptive rocks, but it is usually very limited, and rarely of much importance. Adjoining the granitic roots of the Limerick eruptive rocks, the rocks are altered, but for the thickness of a few inches only; the shales being changed into a kind of hornstone, while the limestones are hardened and ochreized, and have calcite strings developed in them.

In Beginish, Valentia Harbour, County of Kerry, the Silurian (?) slates adjoining the vent of eruption are altered into hornstone, and south-east of Killarney, adjoining the massive intrusion of felspathic rocks in Glenflesk and near Lough Gitane, the slates are similarly changed.

### Connaught and Ulster.

In these provinces there are more metamorphic rocks than elsewhere in Ireland, a great metamorphosed district extending from Galway north and north-eastward through Mayo and Sligo in Connaught, into Donegal, Londonderry, Tyrone and Antrim in Ulster.

In Galway and Mayo the altered rocks belong to the Cambrian, Cambro-Silurian, and Silurian formations, and in these counties there were three periods, at least, of metamorphic action. Here, as previously mentioned when describing the Cambrian rocks, the Cambrians and Cambro-Silurians form a continuous sequence, and after the latter rocks were deposited, all were more or less metamorphosed. The metapeptic action seems to have been most intense in a tract extending WNW. from Galway town to the Atlantic, but in this tract it diminished in intensity towards the WNW. and ESE. To the southward of this tract, in Lettermullen and the adjoining islands north of Galway Bay, the rocks are very little altered, while north of the tract, in the County of Mayo, some of the Cambro-Silurian rocks near Killary Harbour are unaltered. Farther north, however, in north-west Mayo, there seems to be another line of intense metamorphism, the action having been greatest near the coast at Black-Sod Bay, while it diminished towards the ESE. The rocks adjoining Clew Bay seem to be of Cambro-Silurian age, but some of those to the NW. are considered by McHenry to be Cambrians.

In west Galway the rocks can be examined in great detail, as they are so little concealed by superficial accumulations. In this area, to the north of Galway Bay, there is a vast tract of metamorphic granite, which is in places cut up and penetrated by protrusions of oligoclasic and of orthoclasic granites and by dykes of other eruptive rocks. In the most altered portion of the metamorphic granite, all of which is porphyritic, no foliation can be seen in hand specimens; but if the rock is viewed in mass, the prominent crystals of orthoclase are found to occur in lines, while slices of the rock under the microscope show distinct leaves. This granite graduates northward into distinctly foliated granite, and the latter, through granitic gneiss, in which there is perpendicular foliation, and ordinary gneiss, into schist, and the last, through submetamorphic rocks into unaltered Cambro-Silurian rocks. All these rocks, from the extremely metamorphosed to those of the Schist series, are exceedingly well exposed in the north and south section through the hill called Seefin, a little south of Oughterard; while the change from the rocks of the schist series to the unaltered rocks can be seen in the country north of Killary Harbour. All the various phases of metamorphism due to metapepsis can be studied in this area, and those displayed by the conglomeritic rocks are most interesting.

The second period of conspicuous metaphorphism occurs in Silurian rocks. Symes was the first to point out that the schists in the country south and south-east of Louisburg, between Clew Bay and Killary Harbour, are newer than those in the Croagh Patrick hills; and subsequent examination proved the newer rocks to be of Silurian age, containing fossils of Upper Llandovery and Wenlock types. The Silurian rocks above certain bedded sheets of eurite are unaltered by metapepsis, and the probable age of the metamorphism of those to the SW. of Croagh Patrick will be discussed hereafter, in Chapter XIII.

The sheets of eurite are connected with granitic roots which form protrusions in the country to the SW. of Kylemore lake; and in places in the vicinity of these protrusions there are distinct traces of paroptesis, especially on the south slopes of Bengooria or Diamond hill, where a columnar-like structure has been developed in the schist.

At a still later time, after the rocks of the Salrock Series had been deposited, another alteration of certain rocks took place. The rocks affected by this occur only as small patches and alongside joints and faults; the action may have been paroptetic; steam, gases, and such like, from internal sources, having found their way up through the joints and other shrinkage fissures in the rocks. This action is supposed to have taken place during the Carboniferous period, as will be mentioned in Chapter XIII.

The metamorphic rocks of Sligo, Donegal, Londonderry, Tyrone, and Antrim are supposed to be of Cambro-Silurian age. It may, however, yet turn out that some of them are Cambrians, or even Laurentians, as suggested by

Jukes. These rocks have not been fully worked out as yet; but Haughton, Jukes, Scott, and others have shown that they graduate from submetamorphic rocks, through rocks belonging to the Schist and Gneiss series, into metamorphic granite very similar to that of Galway. In Donegal are some very interesting and peculiar rocks, some of them being metamorphosed eruptive rocks.

Associated with the metamorphosed sedimentary rocks in these different areas are metamorphosed eruptive rocks. These are very variable in character, and would take a long time to describe; those, however, of most importance will be mentioned in the next chapter, along with the rocks from which they are derived.

Many of the metapeptic rocks in these portions of Connaught and Ulster have also been subjected to methylotic action, and methylotic rocks are found in various places, being most numerous in west Galway and Donegal; they include ophite, ophiolite, steatite, eklogite, onkosin, pyrallolite, magnesite, epidosite, sepiolite, meerschaum, and others.

In the Counties of Down and Armagh metamorphic rocks occur, associated with the granitic range (Slieve Croob granite) that runs NE. from Newry, and paroptesis in connection with the great protrusion of granite forming the Mourne Mountains. These metamorphic rocks are of Cambro-Silurian age, and, in places, were twice altered. In the vicinity of the Slieve Croob granite there is an additional alteration that formerly was thought to be due to the intrusion of the granite; but, as first pointed out by Traill, the granite adjoining these additionally altered rocks is itself altered, as also are the veins that extend from the granite into the metamorphic rocks, foliation being developed in them. It is therefore evident that the second action is of a much later date than the protrusion of the Slieve Croob granite, and it possibly took place during the vulcanicity in connection with which the Mourne granite was protruded, which is supposed to have been in post-Carboniferous times. The time of the first metamorphic action has not been determined, but probably these Cambro-Silurian rocks were first altered contemporaneously with the alteration of the rocks of the same age in the other portions of Ireland.

# CHAPTER XII.

## ERUPTIVE ROCKS.

Exotic Rocks (Sterry Hunt).

Extravasated Rocks (American Survey).

Intrusive Rocks.

Igneous Rocks.

### South-east Ireland.

The Eruptive rocks may be divided into *Catogene*, or Granitic, and *Anogene*, or Plutonic and Volcanic rocks. Both of these may have been metamorphosed after their original formation.

In south-east Ireland the various kinds now referred to are well represented. In the south of Wexford, in the Carnsore district, are very old rocks, which are interbedded with the Cambrian rocks and were metamorphosed along with them. They consist of hornblende rock, probably metamorphosed gabbro; conglomeritic, concretionary, and nodular hornblende rock, probably metamorphosed tuffs and agglomerate; with granitic and foliated felstones, the latter evidently being metamorphosed felstones. In the same district are protrusions of granite that are older than the associated Cambro-Silurians.

In the Cambrians at, and to the SW. of, Wexford town (Forth Mountains) are dykes and cake-like masses of quartzite that are metamorphosed quartz-rocks. Such cakes of quartz-rock appear to have been deposited from springs, or some such accompaniment of feeble vulcanicity, the cakes being surrounded and eventually covered up by the deposition of the contemporaneous sedimentary rocks, while the dykes mark the sites of the passages through which the mineralized waters found egress. To the northward and eastward of the Cambrian rocks are other masses of quartz-rock in the Cambro-Silurians. These are especially numerous to the south-westward near Bannow, where some of them are felsitic and graduate into rocks like petro-silex and fine elvan. In this neighbourhood some of the quartz-rocks in the Cambrians are altered, and are of the same age as the rocks of Forth Mountains; but others are unaltered and were probably intruded at the same time as those in the adjacent overlying Cambro-Silurian rocks. In the Cambro-Silurian rocks are also peculiar masses of steatitic rock; as if, in connection with the silicious springs, there were also calcareous and magnesian springs that deposited cakes around them.

North of Wexford, at Glenbrian and thereabouts, to the SE. of Enniscorthy, are small protrusions of granite that came up at a later age than the general granite of the Leinster range. Possibly they are of Carboniferous age, as will be hereafter mentioned.

To the N. and NW. of Arklow, and also SW. from Arklow, in a tract that extends to the valley of the Barrow south of New Ross, and from thence westward half across the County of Waterford, are Cambro-Silurian rocks, of the "Ballymoney Series," having in them eurites, gabbros, felstones, agglomerates, and other tuffs; and in the older underlying rocks belonging to the "Dark Shale-Series," are protrusions and dykes of granitic and other eruptive rocks. The protrusions and dykes are associated with the paroptetic rocks mentioned at page 184.

The protrusions, which evidently are the roots of the bedded eruptive rocks, principally consist of syenite, diorite, a rock like diorite, but containing orthoclase in addition to the triclinic felspars, hyperite, granitone and such like rocks.

There are, however, also felspathic elvans that in places graduate into typical granite. These are probably the roots of the felstones, while the basic elvanites are probably the roots of the eurites and gabbros.

Associated with these rocks, and probably of the same age, are dykes of gabbro in the "Dark Shale Series" and in the Cambrians. But there are also newer rocks, melaphyre, eurite, petro-silex, and other felstones, that are very similar in aspect to the Carboniferous eruptive rocks of Munster.

In the Cambrian rocks of the Counties of Wicklow and Dublin are protrusions, dykes, and cakes of quartz-rock. In the country north of Aughrim and eastward to the valley of the Avonmore are masses of quartzite, evidently metamorphosed quartz-rock, the age of which, as previously mentioned, is uncertain, but probably they are in the Cambrians. NW. of Wicklow town, especially in Carrick Mountain, are long, more or less continuous cakes of quartz-rock; near Kilcoole, and at Bray Head, and in the country to the west thereof, are dykes and protrusions of quartz-rock. One of the principal quartz-rock dykes in Bray Head runs SW. from the Brandy Hole, and the junction between it and the other rocks is well exposed at the path above the Railway. It breaks up through the Cambrian rocks, and those to the north of it seem to be altered, being very much mineralized, still not so much as to destroy the fossils, this being a locality for Oldhamia. Of the protrusions the largest and most remarkable constitute the Great and Little Sugarloaves. Another remarkable hill of quartz-rock is that called Shankill or Carrickgollogan, to the NW. of Bray. The quartz-rock in these portions of the Counties of Dublin and Wicklow clearly cannot be a *metamorphosed rock*, because it occurs as dykes and masses in *unaltered* grits, shales, and slates. The protrusions of quartz-rock in the Howth promontory have been mentioned in the description of the Cambrian rocks.

Extending SSW. from Dublin Bay through the Counties Dublin, Wicklow, Kildare, Carlow, Wexford, and Kilkenny, to the valley of the Barrow near New Ross, is the great granitic protrusion of Leinster, in which there are some marked peculiarities. Large tracts for great depths weather *in situ* into GROWAN or granitic sand. In nearly all there is a foliation-like structure, or *grain*, as it is locally called, although most of the rocks are intrusive. In some places portions appear to be of metamorphic origin; this, however, is very hard to be proved as sections are rare, the slopes of the hills being enveloped in deep drift, often a granitic sand derived from the growan.

In this range of hills there are evidently granites of two distinct ages partly jumbled up together, and hard to separate on account of the paucity of sections, also because some characters of the different rocks are so similar. In both there is the "grain" that makes them capable of being split easily into long blocks. The older granite, however, seems to be a better stone than the later, as the later usually weathers deeply, either getting rusty or changing into growan. Becoming growan is not solely a characteristic of the later granite, as in the main range some of what seems to be the older granite, is thus weathered. In the later granite at the Carrick quarry near Rathdrum, and also in other protrusions, albite is said to be one of the constituents ; to this we will refer when describing the newer granites of Connaught and Ulster, as it may indicate a Carboniferous or post-Carboniferous age for the rocks.

South of Mount Leinster, in the County Carlow portion of the valley north of Blackstairs (Scullogue Gap), there are in one place beds of green schist in foliated granite, the foliation of the granite and the bedding of the schist being parallel, which would seem to suggest that the granite in this place is metamorphic. But if we follow this granite southwards to the valley between St. Mullins and Ballywilliam, we find in it caught up patches of schist ; while a little north of Scullogue Gap, west of Mount Leinster, there is foliated growan and similar granite that is evidently intruded into the associated metamorphosed Cambro-Silurian rocks.

It may here be pointed out that in Ireland nearly all the intrusive granites have a grain along which, in two planes at nearly right angles to one another, the rocks will split more or less easily. In some places in the rocks which compose these masses of granite this grain is well marked, giving the rock a foliation-like structure ; while in other places it is so obscure that the "grain" cannot be detected by an ordinary observer until pointed out by the quarrymen. On the other hand, the metamorphic granites, although in general distinctly foliated, will not split ; and consequently, although often handsome stones, they are not as good materials for tool-work, as under the chisel and hammer they will not always cut in the required direction. Intrusive granite, which subsequently has been subjected to metamorphic action, seems to lose, in part, its "grain," or facility of splitting.

In rocks that seem to belong to the Ballymoney series (Cambro-Silurian), in the north of the County of Dublin; also north and south of the Boyne (Counties Louth, Meath, and Dublin), near Clogher Head, Balbriggan, and Lambay; in the Chair of Kildare; and in the Tipperary and Kilkenny hills to the north of Carrick-on-Suir, are gabbros, eurites, and felstones; while in the lower rocks are their granitic roots.

In the King's County, a few miles north of Philipstown, is Croaghan Hill, made up of melaphyres, eurites, felstones, and tuff, that are interbedded with the Carboniferous limestones at and above the cherty zone, at the junction of the Lower and Calp (Upper) Limestone.

## South-West Ireland.

In Munster there are no typical granites, but the Eruptive rocks displayed are instructive. Among the hills west of Lough Graney, County Clare, in Cambro-Silurians belonging to the "Ballymoney series," are beds and intrusions of gabbro and eurite. In the same hills, also farther south and south-east respectively, in Slieve Bernagh, the Cratlow Hills, and in Slieve Phelim (Counties of Limerick and Tipperary), forming the basal beds of the Old Red or Lower Carboniferous Sandstone, is a quartz-rock which in places is replaced by a silicious limestone. These silicious and calcareous rocks are evidently not sedimentary, but were probably deposited from springs due to feeble vulcanicity at the dawn of the action which was more fully developed later on in the Carboniferous period, at the time when the sheet of eruptive rocks like those at Croaghan

Hill, King's County, and those now to be mentioned, were forced up.

Among the Old Red Sandstones of Knockfeerna and Ballinleeny, in the County of Limerick, are eruptive rocks. Those in the first are evidently intrusive, and are of the hybrid kind of rocks, that may be classed either as eurite or melaphyre, while those in Ballinleeny were supposed by Jukes to be contemporaneous with the associated sandstones, as their outside portion has a tuffose aspect. Farther south, in the Old Red Sandstone of the Cork type to the south of Mallow, is a mass of agglomerate that seems to belong to about the same geological horizon as these Limerick eruptive rocks.

In the Carboniferous Limestone of South Clare, of Limerick, and of North Cork (NW. of Mallow) are great interbedded sheets of melaphyres, eurites, agglomerates, and other tuffs, with their associated granitic roots. In the County of Limerick, where the roots are seen, they graduate from elvan into porphyrites. They occur in some places as isolated protrusions among lower beds, but in many others they are joined on to the sheets. In all the isolated masses the rock is basic elvan, except one that forms Castle Hill, north of Hospital, in which the rock is very peculiar; hand specimens from some portions of the mass being similar in aspect to, and having been mistaken for, trachyte, although the rock probably is of Carboniferous age.

The agglomerates in Cork and Clare lie on the cherty zone at the base of the Calp (Upper Limestone), as do also the major portion of the eruptive rocks in the County of Limerick, but in the latter county they also occur at other horizons. To the ENE. of Limerick city, and a little south of Castleconnell, is a mass of agglomerate in which are two small protrusions of melaphyre. This agglomerate is in the Fenestella (Lower) Limestone, and on the same horizon is a local cherty zone. At Carrigogunnel, a few miles west of Limerick; under the south-east suburb of Limerick; a little southward of Limerick, in the Roxborough and Cahernarry hills; also further south-east, forming a more or less wide ring, having the Coal-Measure hill of Ballybrood in the centre, are great sheets of eurite, melaphyre, agglomerate, and other tuffs, which occur at or a little above the cherty zone at the base of the Calp. The melaphyres are principally found in the outer ring round Ballybrood above the eurite, although small tracts occur in some of the other places.

Above the rocks just mentioned, a little to the SE. of Shanagolden, at the cherty zone, which in West Limerick divides the Upper Limestone of the Calp type from that of the Burren type, is a bed of agglomerate; while inside the ring previously mentioned, east and south of the Ballybrood Coal Measures, are great sheets of tuff associated with sheets of rock in some places evidently melaphyres, in other places apparently eurites, and occasionally the lower portion of a bed will be one class of rock which changes upwards, so that the top of the bed is another. The lowest bed in this tract is on the same horizon as the Shanagolden agglomerate, but to the east of Ballybrood there is such a number and thickness of beds that the whole of the Burren type Limestone is cut out, and the Coal Measures seem to have been deposited on the eruptive rocks.

Some of these rocks are more or less columnar. In the Knockfeerna tract are small façades of columns; to the east and north of Ballybrood, at Linfield and Caherconlish, especially at the first, there are fine columns.

The tuffs to the NW. of Lough Gur are peculiar, as in them is a structure having all the appearance of columns when viewed from the south. This probably was caused by paroptetic action, due to the vent of one of the subsequent eruptions. It may be pointed out that each of these outbursts of eruptive rocks has in connection with it a series of cherty beds.

In SW. Cork, on Dursey Island, and to the NE. thereof, in the vicinity of Cod's Head, a little below the base of the Yellow Sandstone, are thick sheets and protrusions of a rock like gabbro. These rocks seem to be a little below the geological horizon on which the quartz-rock and silicious limestone occur, at the base of the Old Red Sandstone in the Counties Clare and Tipperary.

On the north of the entrance of Bantry Bay, in the Carboniferous Slate of Bear Island, and the mainland to west thereof, are felstones and gabbro (?). These first occur about half-way up in the group (at about the horizon of the base of the Calp), and from thence upwards to the highest beds seen. Most of the felstones are bedded masses, having on them tuffose rocks ; while, in general, the gabbros (?) occur as dykes running with the strike of the beds, except in the uppermost slate, where they appear to be bedded.

To the SW., at White Ball Head and in its vicinity, are a remarkable mass and dykes of agglomerate. To the north, in the Yellow Sandstone near Cahirmore, is a nearly N. and S. dyke of agglomerate; while south of it, in the overlying Carboniferous Slate, are two dykes, that at White Ball Head expands into a large mass, from which extend apparently bedded sheets of felstone and gabbro (?) ; while in the lower strata are interbedded sheets of agglomerate, one being in the Yellow Sandstone.

Jukes gave it as his opinion that this was the site of an ancient igneous vent, from which the eruptive rocks were ejected; while subsequently tuff fell in and filled the fissure, thus forming the dykes of agglomerate. The most remarkable fragments in the tuff are pieces of Silurian (?) limestone and numerous abraded large crystals of black Uralite (?).

In the Glengariff grits (Silurian) to the south-east of the Lakes of Killarney are great beds of felstones and tuffs, while associated with them in Bennaunmore, south of Lough Guitane, is an intrusive mass which to the eastward forms a grand façade of massive columns, in places over 200 feet high. In similar rocks in the vicinity of Valentia Harbour, principally in Beginish and in the mainland to the east, are thick beds of gabbro and agglomerate and lesser ones of felstone, while in Valentia island is a great dyke of gabbro. Farther north, in the fossiliferous Silurians of the Dingle promontory, are beds and protrusions of similar rocks.

### North-west Ireland. (Connaught.)

In Slieve Dart, north of Tuam, County Galway, is a mass of felstone first described by Mr. Bermingham, which Symes supposes to be associated with the accompanying conglomerates and sandstones (shore-beds of Upper Limestone age ?). The age of the felstone and its relations to the associated rocks, however, are obscure, and possibly it may be of Cambro-Silurian age, belonging to rocks below the Carboniferous.

In west Galway and south-west Mayo the eruptive rocks are very numerous and various. The oldest occur as dykes, protrusions, and interbedded sheets, in the metamorphosed Upper-Cambrians and Cambro-Silurians. These to the south, in the islands of Gorumna and Letter Mullen, and to the north in Murrisk or the tract north of Killary Harbour, are very little altered, and consist of gabbro, hornblendic-gabbro, eurite and felstones, while among the more altered sedimentary rocks they have been changed into hornblendic-granite, syenite (amphibole + orthoclase), diorite (amphibole + triclinic felspar), kersanton, or micaceous diorite, a rock somewhat like diorite but containing both monoclinic and triclinic felspars, hornblende rock, hyperite, granitic felstones passing into granite, granulite, gneissite, peculiar granular compounds of quartz and felsite (felsitic quartz-rock), massive quartzite (metamorphic quartz-rock), and various others; some also having been subsequently again changed by methylotic action. The felsitic quartz-rock occurs principally in the vicinity of the Corcogemore and Lackavrea mountains.

After the Cambrian and Cambro-Silurian rocks were altered, and probably in connection with the vulcanicity to which their metamorphism was due, oligoclasic and orthoclasic granites were intruded; while newer than these are dykes and protrusions of elvans, felstones, and gabbro, many of the felstones being petro-silex; while later on was the intrusion of the Silurian granitic and plutonic rocks, next to be described.

In the NW. of Galway in the country to the south of the Ballynakill and Kylemore valley are protrusions of granite and elvan, which are connected by dykes with the interbedded sheets of eurite in the Silurians, north and south of Killary harbour; the dykes gradually changing from elvan into quartzitic felstone, and from the latter into the eurite. The eurite is of purple and green varieties, the latter being the most basic, and in places by the addition of pyroxene it changes into gabbro. With these eurites, but especially to the eastward near Lough Mask, are great masses of agglomerate and other tuffs, some being calcareous, or even good limestones. These limestones come in peculiarly, some apparently as if deposited from springs; some of them are fossiliferous, the fossils being principally in the concretions. One of the eurites usually occurs as the base of the Mweelrea beds; but when it is absent its place is taken by a quartz-rock of the same nature as that previously mentioned as occurring at the base of the Carboniferous rocks in Munster (p. 71). It should be mentioned that to the north of the Silurians, in the Cambro-Silurians of the country SW. of Lough Moher, are intrusive masses of steatitic, dolomitic, and calcareous rocks, which are evidently newer than the associated rocks, and probably are connected with this period of Vulcanicity. In the neighbourhood of Clifden and Ballynahinch are dykes and protrusions of elvan and eurite that seem to be of a similar age to those just described.

Higher up in the Toormakeady rocks is a thick bed of melaphyre, while in higher Silurians (Salrock Slates) are dykes of uralitic-gabbro or diabase and eurites. These latter seem to be of the same age as the protrusions of granite that come up through the Silurian rocks at Corvockbrack to the SW. of Croagh Patrick, as the elvans extending from that granite mass graduate into rocks like these gabbros and eurites. Elvans of two kinds can be traced from the granitic mass SW. of Croagh Patrick—one kind graduates through quartzitic felstone into petro-silex, and the other through a hornblendic rock into a trap or eurite. If, therefore, the granite is of the same age as the dykes cutting the Salrock Slates it must be newer than all the Silurians of the country. The granite is said to be albitic.

Apparently the newest rocks in the area are dykes and protrusions of melaphyre. The dykes in general are very massive, but to the west in some of the headlands they are very numerous, and only from ·25 to 2 inches wide. This melaphyre also occurs in a mass to the north of the west end of Killary harbour. Here it is, on the outside, except in one place, a hard compact rock, while the central portion is friable, and, as this has weathered, the whole mass is formed like the crater of a volcano. As most of the melaphyres are newer than the Silurian, they are probably of Carboniferous age, and, as the rocks of the latter age lie nearly horizontal in the neighbouring country, it is just possible that this mass is the site of a Carboniferous igneous vent that still retains its original perpendicular position. The outside portion of the core that filled the funnel, being more compact than the inner, has remained, while the rest has weathered away.

Although some of the melaphyres are evidently newer than all the Silurian rocks, yet they are similar in aspect to the interbedded mass in the Toormakeady conglomerates; therefore, it is possible that some of the melaphyre dykes may be of Silurian age. Usually these dykes weather much more rapidly than the associated rocks, and leave deep perpendicular gashes through the hills, which are locally called Boher-na-callee (*anglicé* Witch's path), but some are of a harder nature, and stand out as dykes or ridges above the associated rocks. These latter are very like the Miocene dolerites of Ulster.

To the NE. near Castlebar, coming up through the Carboniferous limestone are long tracts of melaphyre, the rock weathering to a great depth, like the melaphyre in the Toormakeady (Silurian) conglomerates. Symes, however, considers the Castlebar melaphyres to be of Carboniferous age.

In north Mayo and the adjoining portion of Sligo there are igneous rocks similar to those that occur in west Galway. Here are basalts and dolerite, which, as they penetrate through the Carboniferous rocks, must be of newer age. Traill considers some of these to be Miocene rocks of the same age as those in Antrim: while it is highly probable that others of them may be of Triassic age. In the west of Sligo and in Roscommon there are rocks associated with the metamorphic Cambro-Silurians; some being altered, while others are newer than the metamorphism, but all seem to be more or less similar to those already described in west Galway.

## North-East Ireland (Ulster).

Associated with the metamorphosed rocks of Donegal, Londonderry, Tyrone, and Antrim, there are metamorphosed eruptive rocks, and intrusive granite, elvan, felstones, and whinstones, more or less similar to those in the metamorphic rocks of Connaught.

In Donegal the ages of the metamorphic rocks have still to be worked out. Some of them seem to belong to the Cambrian, or as suggested by Jukes, may be even of Laurentian age. In addition to the varieties of the metamorphosed eruptive rocks found in Connaught there are others which, as yet, have been discovered only in Donegal. These and the minerals of the area have been described by Mr. Robert Scott, F.R.S., in papers in the *Dublin Quarterly Journal of Science*, vols. ii. & iii. One of the most remarkable of the metamorphic eruptive rocks is called by this authority *Sphene-rock;* it consists principally of oligoclase and titanite.

In Antrim, Londonderry, and adjoining parts of Tyrone and Armagh, are the great sheets of Miocene dolerites already described among the Tertiary rocks. The roots of these sheets occur in various places as dykes and protrusions of elvan and other rocks in the underlying Mesozoic strata. Some of the most remarkable of these are the granitic rocks in the NW. of Antrim, in the Skerries, and at Portrush, associated with the metamorphosed Jurassic rocks, and the protrusion at Slemish, about seven miles eastward of Ballymena. This forms a bold ridge 3,000 feet long, about 1,000 feet wide, that rises abruptly from 300 feet to an altitude of 1,437 feet. It is a mass of dark greenish blue crystalline intrusive dolerite. Between Portrush and the Giant's Causeway, is a mass of breccia or agglomerate coming up through the White Limestone and the overlying dolerite, which apparently fills up an old fissure of eruption. North-east of Antrim town is a mass of Nevadite (Tardree trachyte porphyrite) which occupies a centre of eruption. To the south of Londonderry, at Tamlaght, near Coagh, is a wide columnar dyke margined by perpendicular layers of a substance that has a composition like meerschaum or magnesite; while at Ballyknock, about four miles WSW. of Hillsborough, County of Down, are masses of trachyte that were considered by Du Noyer to be the most recent eruptive rocks in Ireland. Traill states, "other undoubted old igneous vents occur, and many vertical dykes, cutting through the bedded dolerite and the older rocks. In some localities the dykes are so numerous that they present great impediments to the working of the beds of iron-ore.

Near Ardtrea, County of Tyrone, in the Triassic rocks, is a thick bed of dolerite. Two miles east of Moira, in the south of the County of Antrim, are dolerites in the Triassic rocks, but whether they are bedded or intrusive rocks has not been proved; while at Scrabo Hill, in the north of the County of Down, are the dolerites which Portlock considered to be interbedded with the associated Triassic rocks; some of the eruptive rocks in this locality, however, have been proved by Du Noyer and Warren to occur as protrusions.

In the vicinity of Carlingford Lough, in the Counties of Down, Armagh, and Louth, is a most interesting assemblage of eruptive rocks that have been carefully worked out by Traill. Perhaps the oldest rocks are some dykes of either gabbro or eurite in the Cambro-Silurian rocks, and next to them are the granites forming the tract that extends NE. and SW. from Newry (Newry or Slieve Croob granite). These intrusive orthoclasic granites are newer than the Cambro-Silurian rocks, as they were intruded into them after they were metamorphosed. The peculiar secondary metamorphism to which some of these rocks have been subjected was described in the last chapter. Associated with these rocks are elvans.

Next in order of age are pre-Carboniferous gabbros and eurites; and next, the post-Carboniferous "granitoid rock" of the Carlingford Mountain and Slieve Foye, called by Haughton "anorthite syenite" (page 212). This rock may be classed among the basic elvans, being a very basic granitic rock, but closely allied to the Plutonic rocks. It is of Post-Carboniferous age, as it intrudes into the Carboniferous Limestone, while it graduates into dykes which in some places may be called melaphyre, but in others eurite, some being more pyroxenic than others.

They belong to Durocher's group of "Hybrid rocks." This rock and its associated dykes, as seen near Carlingford, are very similar to, and apparently identical with, the dykes which, in the country to the north of the Lough, are cut out by the intrusion of the Mourne granite. The Mourne granite mass is associated with elvan, identical in aspect and composition with the Fathom mountain and Barnavave elvan, which in the country to the south of the Lough cuts out the dykes from the Slieve Foye granitoid rock. If the Mourne granite and the Barnavave elvan are of the same age, the Mourne granite must be Post-Carboniferous. At Slievebrack and Slievenabolea, SW. of Newry, are remarkable masses of agglomerate, which Nolan believes to graduate into a rock which seems to be of the same type as the Mount Fathom elvan.

Coming up through the Barnavave elvan, and apparently much newer than it, are dykes and protrusions of a spotted eurite or toadstone, while these later rocks are cut up and traversed by dykes of dolerite and basalt, in general very like the Miocene dolerites of Antrim. In places, however, the dykes of dolerite graduate into the spotted eurite, while the latter, when in wide dykes or in protrusions, merge into a granitoid rock or spotted elvan. The latter rock is of a bluish colour, spotted over with crystalline spheroids of whitish felspar, being identical in appearance with the margins of the large course of elvan at Goragh-wood station, now extensively quarried under the name of the "Goragh-wood granite." This elvan course comes up through the Newry granite, and evidently is much newer than it; and at its margin is the rock similar to the spotted elvan of the Carlingford promontory, all being of the same age, which is probably Miocene.

Fig. 10.

Slievemore (quartzite hill), Achill, County Mayo.

It has been shown that farther northward, in the province of Ulster, there are interbedded pyroxenic rocks of both Triassic and Miocene ages, the later being much more developed than the older. Carlingford Lough District seems to have been a centre of vulcanicity during the Mesozoic and Cainozoic periods, or perhaps even earlier, the eruptive rocks in it being of different ages ; it is therefore probable that the pyroxenic rocks of Triassic, as well as those of Miocene age, have their representatives. The dykes are exceedingly numerous, as seen in the Carboniferous quarries in the neighbourhood of Carlingford.

In reference to the "anorthite-syenite" of Haughton mentioned in page 209, Traill states, "this rock *en masse* would be more appropriately called Gabbro, graduating on the one hand into hypersthene-dolerite or hyperite, and on the other into diorite ; as the pyroxenic mineral changes from diallage, either into hypersthene or into hornblende." Such rocks may be included under the general name of Granitone (page 181).

In the County of Cavan, coming up through the Cambro-Silurian rocks, is a tract of intrusive orthoclasic granite, very similar in aspect and composition to the intrusive granites found elsewhere associated with the Cambro-Silurian rocks. In places there are also dykes and protrusions of gabbros, eurites, and felstones.

# CHAPTER XIII.

## THE ERUPTIVE AND METAMORPHIC ROCKS CHRONOLOGICALLY CLASSIFIED.

In the first chapter of this section (Chapter X.) it was stated that the Eruptive Rocks are products of Metamorphism, they being the result of extreme metapeptic action, by means of which the different sedimentary and other rocks of each formation were so variously and completely changed. In the chronological classification of the eruptive rocks, there is this difficulty, that in Ireland the great alterations took place after the rocks of one formation were deposited, and prior to the accumulation of those succeeding. Still, the eruptive rocks seem nearer in age to the older than the newer formations, as the metamorphism, of which they are the product, had not only ceased, but the altered rocks were more or less denuded prior to the later rocks being deposited on them. On this account the metamorphic and their accompanying eruptive rocks must be nearer in age to the rocks out of which they were formed than to those which succeeded them; and in the following table the eruptive rocks are grouped under the names of the formation with which they are thus connected.

CHRONOLOGICAL TABLE OF THE ERUPTIVE ROCKS.

| FORMATION. | GROUPS OF THE ROCKS. | SE. IRELAND. | MUNSTER. | GALWAY AND SOUTH MAYO. | NORTH MAYO AND SLIGO | ULSTER. | CARLINGFORD DISTRICT. |
|---|---|---|---|---|---|---|---|
| MIOCENE . . . | 5. Dolerite, eurite, and felstone (Trachyte) . . . . | ... | ... | ? | ? | * | * |
| | 4. Elvan . . . . . . | ... | ... | ... | ? | * | * |
| | 3. Intrusive triclinic felspar granite | ... | ... | ... | .. | ... | * |
| | 2. Intrusive monoclinic felspar granite . . . . | ... | ... | ... | ... | ... | ... |
| | 1. Metamorphic granite . . | ... | ... | ... | ... | ... | ... |
| TRIASSIC . . . . | 5. Dolerite, eurite, and felstone . | ... | ... | ... | ? | * | ? |
| | 4. Elvan . . . . . . | ... | ... | ... | ? | ... | ? |
| | 3. Intrusive triclinic felspar granite | ... | ... | ... | ... | ... | ? |
| | 2. Intrusive monoclinic felspar granite . . . . | ... | ... | ... | ... | ... | ? |
| | 1. Metamorphic granite . . | ... | ... | ... | ... | ... | ... |
| CARBONIFEROUS . | 5. Melaphyre, eurite, and felstone . . . . . | ? | * | ? | ? | ? | ... |
| | 4. Elvan . . . . . . | ? | * | ... | ? | ? | ... |
| | 3. Intrusive triclinic felspar granite | ... | ... | ... | ... | ... | ... |
| | 2. Intrusive monoclinic felspar granite . . . . | ? | ... | ? | ... | ... | ... |
| | 1. Metamorphic granite . . | ... | ... | ... | ... | ... | ... |
| SILURIAN . . . | 5. Melaphyre, gabbro, eurite, and felstone . . . . | ... | * | * | ... | ... | ... |
| | 4. Elvan . . . . . . | ... | * | * | ... | ... | ... |
| | 3. Intrusive triclinic felspar granite | ... | ... | ... | ... | ... | ... |
| | 2. Intrusive monoclinic felspar granite . . . . | ... | ... | * | ... | ... | ... |
| | 1. Metamorphic . . . . | ... | ... | ... | ... | ... | ... |
| CAMBRO-SILURIAN | 5. Gabbro, eurite, and felstone . | * | ... | * | * | * | * |
| | 4. Elvan . . . . . . | * | ... | * | * | * | * |
| | 3. Intrusive triclinic felspar granite | ? | ... | * | * | * | ... |
| | 2. Intrusive monoclinic felspar granite . . . . . | * | ... | * | * | * | * |
| | 1. Metamorphic granite . . | .. | ... | * | * | * | ... |
| CAMBRIAN . . . | 5. Gabbro, eurite, and felstone . | * | ... | * | ? | ? | ... |
| | 4. Elvan . . . . . . | * | ... | * | ? | ? | ... |
| | 3. Intrusive triclinic felspar granite | ? | ... | ... | ... | ... | ... |
| | 2. Intrusive monoclinic felspar granite . . . . | * | ... | ... | ... | ... | ... |
| | 1. Metamorphic granite . . | * | ... | ... | ... | ... | ... |

In this table the first column indicates the different formations that in Ireland are associated with eruptive rocks. In the second column is given the general classification of the eruptive rocks, to which metamorphic granite is added, so that it may be seen in what formations and localities the gradual change from unaltered, through metamorphic, into the eruptive rocks can be seen and studied. The rest of the columns are devoted to the districts into which it seems most convenient to divide the country. In them an * denotes the existence, a ? the probable existence, of the rocks in the place indicated ; while the columns are left blank when the rocks of the class are not represented, or are supposed not to be represented.

## Cambrian.

In the County of Donegal there may be very ancient eruptive rocks, but at present this is uncertain. The oldest ones in Ireland of which there is a certainty are the hornblende-rock and granitic-felstone (*metamorphosed gabbro and felstone*), found among the Cambrian rocks near Greenore and Carnsore, County of Wexford. In higher beds are cakes and sheets of quartzite (*metamorphosed quartz-rock*) in the country between Wexford town and Bannow to the SW.

After the intrusion of these rocks, and before the beginning of the Cambro-Silurian age, the Cambrian rocks were altered ; to the SE. the alteration was sufficiently intense to form metamorphic granite, and with the latter is associated intrusive Granitic and Plutonic rocks. This metamorphism must have taken place while the *Upper Cambrians*, or passage rocks between the Cambrians and Cambro-Silurians, were being accumulated in west Galway; interstratified with the latter are massive beds of Plutonic rocks associated with their elvan and other granitic roots; all of which are probably products of the metamorphism that altered the Wexford rocks.

In the Cambrians of Wicklow and Dublin are found cakes, sheets, and dykes of quartz-rock similar to those found in Wexford; while in the vicinity of Corcogemore Mountains, County of Galway, in the lower beds of the Upper Cambrians (Great Quartzite Series, page 21), are found masses and protrusions of quartz-rock now metamorphosed.

## CAMBRO-SILURIANS.

Among the lower beds of the "Dark Shale Series" of this age, are cakes and masses of quartz-rock, with dykes and protrusions that come up through the underlying Cambrians. In the upper beds, or the "Ballymoney Series," are great interbedded masses of Plutonic rocks, with which are associated their granitic roots (elvans and granites). These interbedded masses in the "Ballymoney Series" are best developed in the Counties of Wicklow, Wexford, and Waterford, but they also occur to the northward of Carrick-on-Suir in Tipperary and Kilkenny; near Lough Graney, County of Clare; in the Letter Mullen and Croagh Patrick beds, Counties Galway and Mayo; probably also in Donegal and Londonderry; and in the County of Louth, near Clogher, &c.

Toward the end of the Cambro-Silurian age was the greatest period of metamorphism of which there is evidence in Ireland. This more or less altered all the Cambro-Silurian rocks in Wexford and Wicklow; also, perhaps, portions of the Cambrians. In the Counties of

Galway and Mayo it altered all the Upper Cambrians (or the passage beds between the Cambrians and Cambro-Silurians) and nearly all the Cambro-Silurians; it did the same in Sligo and Donegal; in Londonderry, Antrim, and Tyrone it also prevailed, and partially in the south of the County of Down and in the County of Cavan.

Connected with this period of metamorphism are the metamorphic granites of Galway, Mayo, Sligo (?), and Donegal; the older intrusive granites of the Leinster range of hills; the intrusive granites with their accompanying elvans and Plutonic rocks, in west Galway; the older intrusive granites of Mayo and Sligo, with their accompanying elvans and Plutonic rocks; some at least of the intrusive granites, their elvans and Plutonic rocks in the County Donegal; the intrusive granites of Londonderry, Antrim (?), and Tyrone; the Newry, or Slieve Croob, intrusive granite, Counties Armagh and Down; and the intrusive granite near the town of Cavan.

## SILURIAN.

Among the lowest of the Irish Silurians (rocks containing Upper Llandovery fossils) are found interbedded Plutonic rocks, remarkable from the fact that in some places the more typical rocks are replaced by a sheet of quartz-rock; they are also accompanied by protrusions of dolomite and limestone. In north-west Galway some of the bedded rocks can be traced downward by dykes, to bosses of elvan and granite in the Upper Cambrian rocks at Lugnanoon, south of the Kylemore and Ballynakill valley.

In the Silurians of the Dingle promontory, County Kerry, Plutonic rocks also occur; and in the Glengariff

Grits (Upper Silurians, or the passage beds between the Silurians and the Carboniferous) there are interbedded eruptive rocks at Valentia Harbour, and in the hills to the SE. of the Killarney Lakes.

To the SW. of Croagh Patrick, County of Mayo, there is a considerable tract of metamorphic Silurians, associated with the intrusive granite of Corvockbrack; and an unaltered portion of these rocks at Creggaunbaun contains fossils of Upper Llandovery and Wenlock types. The exact time at which this metamorphism took place is uncertain. It is possible it was towards the end of the Silurian period, during the accumulation of the Glengariff Grits, and that the interbedded Plutonic rocks in them are products of this metamorphism. The Corvockbrack granite, however, seems very similar to the Carboniferous granite, and is said to be albitic; therefore it seems possible that this metamorphism took place in, or after, the Carboniferous age.

## CARBONIFEROUS.

In the Old Red Sandstone of the promontory of Bear, west Cork, are bedded eruptive rocks associated with dykes and protrusions; and, in the upper rocks, up to the highest bed of the Carboniferous Slate, others are found.

The basal rock of the Old Red Sandstone in the Clare, Galway, and Tipperary hills, margining on the north and east the plain of Limerick, is often a quartz-rock or a silicious limestone; while in the Carboniferous rocks of the plain, at different horizons up to the base of the Coal Measures, are great beds of Plutonic rocks with their elvan roots. At Croaghan Hill, King's County, there are eruptive rocks similar to those in the plain of Limerick.

The rocks that have been mentioned are undoubtedly of Carboniferous age, while the granites now to be referred to, may possibly be of the age of the Glengariff Grits (Silurian), as just now stated ; all of them, however, are said to be albitic, which is supposed to prove their Carboniferous or Post Carboniferous age. In Mayo, to the SW. of Croagh Patrick, are the Corvockbrack granite and metamorphosed Silurians, supposed to be of Carboniferous age. One kind of elvan from this granite graduates into a Uralitic gabbro, which possibly may render questionable the Carboniferous age of the granite. The granite, however, is said to be albitic. In SE. Ireland, forming isolated protrusions at Glenbrien, SE. of Enniscorthy, County Wexford ; in different small masses between Aughrim and Rathdrum, County Wicklow ; and in various places associated with the older granite in the range between Dublin and New Ross, are newer albitic granites. In connection with the formation of these newer granites in SE. Leinster, there seems to have been Local metamorphic action (paroptesis), which caused in places additional alteration in the Cambro-Silurian rocks, especially at the SE. margin of the older granite between Killiney, County Dublin, and Tinahely, County Wicklow ; also in the County of Carlow, to the westward of Mount Leinster.

In west Galway, in Mayo, Sligo, and Donegal, and also in SE. Ireland, are melaphyres, eurites, and felstones, newer than the Lower Palæozoic rocks, that must be of Carboniferous or newer age. The melaphyres and eurites are very similar to those of Carboniferous age, but in west Galway, associated with them, are rocks very like the Miocene dolerites of Ulster.

## TRIASSIC.

Reference has been already made (p. 209) to the bedded masses of dolerite which occur among the Triassic rocks near Ardtrea, County Tyrone; at Scrabo Hill, County Down; and on the east of Moira, County Antrim.

In N. Mayo are eruptive rocks that Traill has proved to be post-Carboniferous; it seems probable that some at least of them are Triassic, while others may be Cainozoic.

In the Carlingford Lough district are the Mourne granite, the Barnavave or Mount Fathom elvan, and the Slieve Foye granitoid rock, with their associated dolerites, eurites, and felstones; all of which are evidently of post-Carboniferous age, while they seem to be pre-Cainozoic and probably were intruded during the Triassic age; the Mourne granite and Barnavave elvan representing the monoclinic-felspar intrusive granites and elvans of the period of vulcanicity; and the Slieve Foye granitoid rock the triclinic-felspar elvans. Associated with the intrusion of the Mourne granite, there was probably metamorphic action, which additionally altered the Cambro-Silurian rocks alongside the Slieve Croob granite, and also an adjoining strip of the granite.

## MIOCENE.

In Antrim, and the adjoining portions of Londonderry, Tyrone, and Armagh, are the great sheets of eruptive rocks of Miocene age. They have their associated granitic roots near Portrush, at Tardree, and in other places. At Portrush, in the neighbourhood of th protrusions, the Jurassic rocks are metamorphosed, bably in connection with this period of vulcanicity.

In the Carlingford district are dykes and protrusions c dolerite, eurite, and felstone, newer than the Carlingford granitoid rock (Triassic ?) and all other rocks in the district; some of them are apparently identical with the Miocene rocks of Antrim. These rocks have their granitic roots in the country westward of Carlingford, and also, in a great course coming up through the Newry granite in the vicinity of Goragh Wood.

The vulcanicity to which the interbedded Cambrian eruptive rocks in south Wexford were due seems to have ended in springs that deposited great cakes and sheets of quartz-rock. In the Upper Cambrian of west Galway the vulcanicity appears to have begun in springs that deposited the quartz-rocks and masses of dolomite in the Corcogemore and Lackavrea mountains; while the dawn of vulcanicity in the Cambro-Silurian, the Silurian, and Carboniferous ages seems likewise to have begun in springs which deposited quartz-rock, dolomite, and limestone. Silicious and calcareous deposits seem also to have been deposited at other times while the different vulcanicities lasted, especially during the Carboniferous age, as large Cherty Zones occur at each horizon where the outburst of the eruptive rocks began.

The late David Forbes, F.R.S., in a communication in reference to a collection of different Irish eruptive rocks, stated that he believed he would be able by their felspars to divide into three groups both the Felstones and Whinstones; but at the time he wrote his classification perfected. In this communication the proposed ing of the Felstones was not given, although there a provisional one for the Whinstones ; viz.—

*Cainozoic and Mesozoic.*—Dolerite (pyroxene + triclinic felspar).
*Upper Palæozoic.*—Melaphyre (pyroxene + amphibole + triclinic felspar).
*Lower Palæozoic.*—Diabase (diallage + triclinic felspar).

The felspars of each division have distinct characters: these, however, were not given. The rock called diabase by Forbes has, in the foregoing descriptions, been named gabbro, as diabase seems to be used by most petrologists for a granitoid variety of pyroxenic-whinstone containing some quartz and amphibole. Forbes' classification of the Whinstones seems very applicable to the Irish rocks, as only in two places are there exceptions to it; namely, in the Carboniferous rocks of the Cork type, where the Whinstones seem to be allied to gabbro; and in the Toormakeady Conglomerate (Silurian), where there is an interbedded melaphyre like the Carboniferous Whinstone.

# SECTION III.—SUPERFICIAL ACCUMULATIONS.

## CHAPTER XIV.

### DRIFT.*

In Ireland the drifts may be classed as Glacial, Aqueous, and Meteoric. The Glacial has been divided into the *Boulder-clay-drift* and the *Moraine-drift.* The Aqueous may be *Marine*, *Estuarine*, *Lacustrine*, or *Fluviatile.* A marked variety of the Meteoric is the *Æolian drift.*

### Glacial Drifts.

The *Boulder-clay-drift*, called *Till* in the province of Ulster, has a more or less clayey—often limy—matrix, in which are imbedded irregularly striated, polished, and etched blocks and fragments, principally of the rocks in the vicinity, but also associated with many pieces of foreign rocks. In places it may contain irregular pockets, patches, and channels of fine sand or gravel. It is supposed to have resulted from the general glaciation of

* A considerable portion of this chapter was published in a paper read before the Manchester Geological Society; and to the Council of that Society I am indebted for the use of the accompanying diagram.

ıring the time of the Ice cap on the Northern ısphere. The *Moraine-drift* has a sandy-clayey matrix containing angular or sub-angular partially ice-dressed blocks and fragments of the local rocks, foreign rock fragments being of rare occurrence. It is only found in the groups of hills, or in their immediate vicinity; and when in ɹe latter position it often overlies the Boulder-clay-drift. Between these newer and older glacial drifts it is rare to find any aqueous drifts, and when they do occur they are generally not more than a few inches thick, and rarely exceed two or three feet. They are usually fine sand or laminated clay (*Book* or *Leaf-clay*). Of the Moraine-drift, there is a remarkable rocky variety, that occurs in irregular hummocks, having in it, and on it, large angular blocks of rocks, often tons in weight. The Moraine-drifts are supposed to have been formed by local systems of glaciers in the different groups of hills, whilst the *Rocky-moraine-drift* would answer to Clarence King's description of the drift he found on the dying-out glaciers of the West Pacific slopes. Local systems of glaciers seem to have existed among the hills during the time of the 300 feet sea beach (*Esker sea*), while in the west Cork and the Wicklow hills they seem to have lasted much longer, probably to the time of the 100 *feet sea beach.* To these we will refer hereafter.

## Aqueous Drifts.

The sea-formed or *Marine* drifts of Ireland are very interesting and important, as they are supposed to include the remarkable ridges (Celtic *Eskers*) so characteristic of the central plain of Ireland. Of the existence of pre-Glacial Marine drifts there are no positive proofs. Usually the Boulder-clay-drift is found resting on grooved, striated, polished, and etched surfaces of rock; but Pump-sinkers say that sometimes they find sands and gravels intervening. These must, however, be very local, as in the miles of railway and other cuttings that have been examined, they were only found on one or two occasions, and then in such positions that possibly they were *intra*-glacial, not *pre*glacial. Among and on the hills of the Queen's County, Tipperary, Clare, Galway, and Derry, are gravels apparently marine; sometimes under typical Boulder-clay-drift, but more often under Moraine-drift; in the latter case they are evidently intraglacial, while the others possibly may be preglacial.

A very common marine drift among, and in the vicinity of, the groups of hills, is a *Glacialoid-drift.* This is a boulder-drift, made up of very similar materials to one or other of the glacial-drifts, but always having a distinct stratification; the materials of which it is composed having been re-arranged by, and deposited in, water. This Glacialoid-drift seems to be marine, on account of its extending over large areas; in some places, however, it may be lacustrine. Usually it is made up of the mixed *débris* of the Boulder-clay and Moraine-drift, but in some localities as, in SW. Mayo, it is divided into two distinct members; the lower drift being the *débris* of the Boulder-clay, while above, over a denuded surface of the first, and often having a parting, of thin beds of fine sand or Book-clay between, is a drift made up of the *débris* of the Moraine-drift.

The marine drifts, that are undoubtedly post-Glacial, may be divided into the accumulations formed—when the sea was at about the 300 feet contour line (*Esker Sea*); when the sea margin rested for a time at about the 100 feet contour line ;* when the sea rested for a time at about the 25 feet contour line ; and more recent drifts. This brings us to the subject of "Raised beaches ;" but these will be discussed in the next chapter. The "Esker Sea" drifts are found in the country a little above or below the 300 feet contour line ; as the sea margin, similarly to that of the present sea, varied in height. The margin of the Esker Sea will be found in places in the hills ; sometimes as a shelf cut in their sides, at other times as a beach accumulation. It is extremely well marked in parts of Tyrone and Derry, forming circles of gravel and sand round the isolated drift hills so common thereabouts.

In some places on the low ground the Esker Sea drifts are spread out in undulating sheets, as in the County of Kildare. In places in these sheets there is fine gravel and sand under a shingly gravel. Such sections, however, are only to be found in narrows, like that in the Valley of the Nore, at the City of Kilkenny. This is easily accounted for. When the waters were deep and broad, there were fine deposits accumulating ; but as it shallowed and narrowed, the current became more rapid and the deposit coarser.

In many places in the central plains, between the 100 and 250 feet contour lines, sands, gravels, and shingles are piled up in ridges or Eskers. These are best exemplified in the plain between Galway and Dublin. The formation of the Eskers is a disputed subject, but it seems probable that they are modifications of the banks and shoals which accumulated at the colliding and the dividing of the "Flow" tide currents of the Esker Sea ; similar to those that are found in the seas round Great Britain and Ireland

* This margin is always above the 100 feet contour line, and sometimes up nearly to the 190 feet contour. The average would be about the 130 feet from the heights on the east coast of Ireland.

at the present day. In the Irish Sea, in the vicinity of the Isle of Man, there is a meeting of the north and south "Flow" tide waves, or a "Head of the tide." Here the tidal currents meet and neutralize one another in one place, forming a mass of currentless water, that simply "rises" and "falls," and deposits there silt and such like materials. The other "Heads of the tide" in these seas are south and east of England, in the Straits of Dover, and between Norfolk and Holland. But in these places there are different results, as the currents collide and pass one another, for greater or less distances; and at their edges, or the junctions of the different currents, long banks of gravel and shingle accumulate. It is also found that long banks of gravel and shingle may form at the dividing or splitting up of the "Flow" tide current. This is exemplified off the south-east coast of Ireland. From Greenore Point a main current runs northward up the Irish Sea, while secondary currents branch off into Wexford Bay; and at the junction of these currents with the main current, there are long banks between Greenore and Wicklow Heads. Similar results must have occurred in the Esker Sea.

The flow tide wave entering at Galway must have sent a main current eastward to the coast between Drogheda and Dublin; south of this current there would be a bay somewhat similarly circumstanced to Wexford Bay, off which banks would form between Galway Bay and the Dublin mountains, that is, in the line of country occupied by the principal Eskers.

By a similar process long banks and shoals would have accumulated in positions which the Eskers now occupy; but the typical Eskers are very unlike shoals and other sea banks, they being comparable to railway embankments, some being so narrow that you could nearly shake hands across them; and it has yet to be explained how shoals could be thus modified.

Although it cannot be positively affirmed, yet it appears possible, that as the sea shallowed and the shoals and banks became "awash" the current would have the power of changing the massive banks into narrow ridges. In favour of such a supposition it may be mentioned that at the half-tide or "awash" portions of banks, and in other shallow places where two currents collide, there are Esker-like ridges; as St. Patrick's Bridge between Kilmore and the Saltees, County of Wexford; and on the Dogger Bank off the mouth of Wexford Harbour.*

At the same time it has not been shown that, in any place, long continuous ridges like the Irish Eskers are anywhere being formed by marine action, although similar ridges, but more massive, occur at the "Head of the Tide" in the sea between England and Holland, as pointed out by Milne-Home.

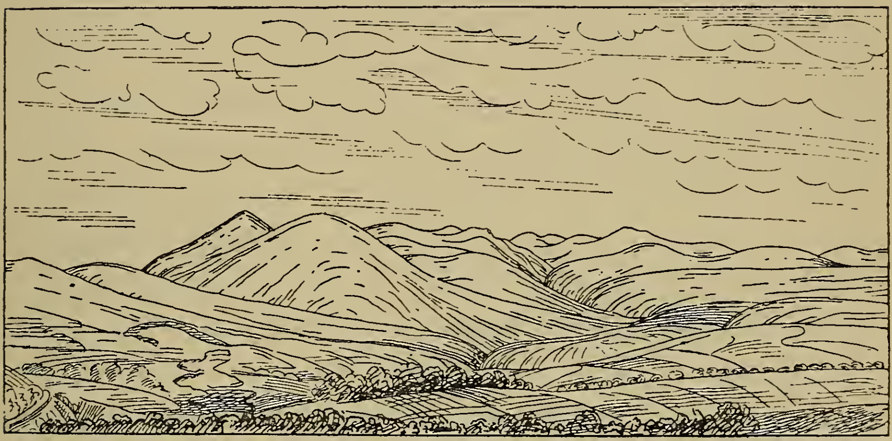
In favour of their marine origin it may also be mentioned that they are often in the higher parts capped with accumulations of fine sands like Æolian-drift, similar to those that, at the present day, are blown up into mounds and ridges by the wind out of reach of the waves; while in other places there are fine and coarser sands interstratified, like those in the recent ridges between Lady's Island Lake (County Wexford) and the sea; the fine deposits being Æolian, and the coarse ones sand driven up during high tides. Moreover, no action but marine, at the present day, forms ridges at all like the Eskers.†

* This was carried away with the bank in the winter 1876-77.

† In a previous writing on this subject, I suggested that the Eskers were produced directly by a "Head of the Tide" like that in the Irish Sea. Such

If the marine origin of the Irish Eskers is allowed, the various details and complications in the eskers in the Central plain of Ireland could be explained by the colliding, or the meeting of the "Flow" tide currents branching from the main, with those coming through the straits, now valleys in the surrounding hills; as also the different eskers in the country to the north of the main current; such details, however, would occupy too much space if fully entered into.*

Fig. 11.



Lugnaquillia and adjoining mountains, Co. Wicklow.

Drift deposits, which must have been formed at the "heads of tides," similar to those in the vicinity of the Isle of Man, can be observed in various places; as in SE. Wexford, where the esker drift is represented by large

a meeting of tidal currents would not produce ridges, but massive shoals. This supposition, therefore, has to be abandoned; and it appears more probable that to the colliding and parting of the tidal currents as above described such banks must be due.

* The eskers proper of Scotland seem to have had a similar origin to those of Ireland—not, however, all the drift now classed as *Kames*, as under that name have been included ridges of marine, lacustrine, fluviatile, and meteoric drifts

accumulations of fine fossiliferous sand, marl, and clay; also in some of the valleys further north; and in the County Dublin, where there are also thick beds of brick-clay in the esker drift.

Some observers question the marine origin of the eskers, on account of the paucity of fossils in them, and also on account of the number of contained ice-dressed fragments. But in many similar accumulations formed by the sea at the present day fossils are rare, as the nature of the deposits and the materials they are composed of are adverse to the preservation of fossils: the drifts they were formed from were principally glacial, consequently, many of the fragments in them, especially near the old drifts, ought to be ice marked; but in no esker will you find any fragments that have not also some marks of subsequent water action. It might as reasonably be said that all recent accumulations that contain ice-marked fragments are glacial; some of the present estuarine accumulations contain between 50 and 75 per cent. of glacially marked stones.

At the base of the Esker drift along the coast between Bray Head, County Wicklow, and the coast south of Bannow, County Wexford, remarkable recent conglomerates and sandstones occur, while higher up in the drift near Blackwater, County Wexford, are fossiliferous sandstones and friable conglomerates; as also in the Curragh of Kildare and elsewhere.

The marine drifts more recent than those of the "Esker Sea" period are very similar to the older drift, being rearranged glacial, marine, or meteoric drifts; consequently no definite rule can be laid down for distinguishing the older from the newer, except the heights at which they occur. But in the valley of Lough Corrib, north of Galway, there is a distinction, as the newer gravels are principally made up of granitic gravels, and sands, while the older are more or less limestone gravels. In this valley there is a long esker, which seems to have been piled up by the colliding of the tidal "flow" currents that entered respectively through Galway and Kilkieran bays during the time of the 100 feet sea. Terraces of the newer marine drift that accumulated when the sea stood for a time at about the 100 feet and at the 25 feet contour lines, are well marked in various places on all the east coast of Ireland and in the associated valleys; also in the valleys of the Slaney, Barrow, Nore, Suir, and Blackwater; and to the west, especially in the valleys of Galway, Mayo, and Donegal.

The peculiar drifts containing sea shells found at great heights in the Dublin and Wicklow mountains will be mentioned hereafter.

The *Estuarine drift*, although marine, is put in a distinct class on account of its partaking in part of the nature of lacustrine and fluviatile drifts; it often contains terrestrial and freshwater fossils, while it is very different from those accumulated in the open sea. The latter are always well washed, sorted, and water-worn, but the estuarine drifts may be nearly similar to the drifts of which they are the *débris;* some being scarcely distinguishable from glacial drifts, while many are more or less clayey or marly. No pre-Glacial estuarine drifts are known. In the Queen's County portion of the Castlecomer tableland, in the Newtown colliery, an intra-glacial peat was found by Mr. B. B. Edge, which is probably estuarine, as the gravel associated with it contained marine fossils. A peculiar blackish pre- or intra-Glacial drift has been lately exposed in the railway cutting near

Dalkey, County of Dublin, which possibly may belong to this division.

The post-glacial estuarine drifts occur in many valleys, being respectively of the ages of the 300 feet (Esker), 100 feet, 25 feet, and more recent, seas. Plains of estuarine drifts are often miscalled "river gravels," they being supposed to have been formed by the rivers that flow in them. A little consideration, however, will show the error in such a supposition. All estuaries, but especially those that are long and narrow, which seems to have been a very general character during the time of the Esker 100 and 25 feet seas, form two distinct deposits; one nearly horizontal, that marks the shore or margin of the estuary; and the other sloping more or less from the tidal strand at the head of the estuary to its mouth, the latter being the bottom accumulation. If the land rose the bottom accumulation would form a sloping plain (often called a terrace) with a river flowing through it. This plain is said to have been formed by the river, because it slopes with it and because the fossils may be, for the most part, terrestrial or freshwater. Rivers, however, rarely form a sloping plain, as the floods form ridges, hills, and other irregular accumulations. Furthermore, fossils are rarely deposited in river accumulations, as they are generally carried down by the floods to the lakes, estuaries, or other still waters. In Ireland fluviatile action has no doubt added to the surface of the estuarine plains during floods; or in the immediate vicinity of the river channel, parts of the flats may be cut away, and the materials be re-arranged, but all the extensive flats adjoining the rivers were originally formed by estuaries or lakes.

In the Slaney River valley these estuarine drifts are well seen; those belonging to the 25 feet sea being found up the valley to about half-way between Enniscorthy and Newtownbarry; the drift of the 100 feet sea to Clonegal, in the County Carlow; and those of the Esker sea to above Stratford, in the County Wicklow.* During the latter time a bar of drift formed east of Tullow, in the County Carlow, that diverted the waters into the valley through the Carlow and Wicklow hills at Clonegal; as, apparently, prior to that time, the portion of the valley of the Slaney north of Clonegal was included in the water-basin of the Barrow.

There are also estuarine accumulations, hereafter mentioned, that were deposited between the time of the 100 and the 25 feet sea beaches; these are now submerged 30 feet or more below the present sea levels. Such accumulations seem to consist principally of marl, clay, sand, and peat. Some of the estuarine deposits, like those in the estuary of the Shannon, are remarkable from the quantities of bones of *Cervus Megaceros* and other terrestrial animals found in them. Many of the estuarine accumulations that contain ice-worked fragments have been called "Upper Glacial Drift," the associated estuarine gravels being called "Middle Gravels."

Of the drifts due to lakes, or the *Lacustrine drift*, some are said to be pre-Glacial. In the province of Ulster, are the previously mentioned Lough Neagh clays and sands, which have been provisionally placed and described among the Cainozoic rocks. To the same may possibly be referred similar deposits that occur near Cahir, County of Tipperary. These, however, may more properly belong to the drift.†

* The peculiarity of the aqueous drift of Glen Imale or the upper portion of the valley of the Slaney is mentioned farther on.

† Baily states that the Lough Neagh beds are undoubtedly Post-Pliocene, and the fossils found in them are of that type.

South of the district of the Lough Neagh beds, at Knockagraffy, 3 miles west of Armagh, oak timber was found under 45 feet of drift; also in a railway cutting west of Armagh, and charcoal-like wood under 30 feet of drift near Aghavilly church, SW. of Armagh. In the Boleyneendorrish River valley, near Gort, County Galway, there are plant beds and clays under glacial drift; the latter are probably lacustrine, and evidently intra-glacial: and near Nenagh, County Tipperary, Mr. Wilkinson has found an intra-glacial peat that is probably lacustrine.

The sites of post-Glacial lakes are numerous, but most of them are now filled by deep accumulations of peat and marl.

In places in the glacial drift are sinuous channels with branches from them, filled with fluviatile shingle, gravel, and sand. Such channels were probably formed by rivers, which, as Dana suggests, flowed under or in the ice. The post-Glacial fluviatile drift occurs in the mountain valleys and in the low valleys associated with the ancient estuarine gravels.

Some of the fluviatile drifts occur under deep accumulations of meteoric drift; this seems to be the case with the "gold sand" of the County Wicklow. As before stated, the glaciers seem to have continued longer among the Wicklow hills than in most of the other Irish hill groups. This is surmised because in the tributary valleys of the Aughrim river the Esker sea gravels do not appear to exist, while in the cooms in the hills west of Glenmalure there are traces as if of very recent glaciers. While the last traces of the sea were disappearing off these hills, torrents rushed down the different ravines forming drifts, of which the very lower portion was composed of ferriferous auriferous sands (“*Black sands*”). After the ice had melted, the torrents left the ravines, and the sides weathered into slopes, thus covering the fluviatile for a greater or less depth with meteoric drifts. Whether the gold drift extends under the 25 feet estuarine drift of the Ovoca valley has not as yet been proved.

The Fluviatile drift now forming has produced deltas or “srahs” in many of the lake basins, also well-defined ridges and hills on the estuarine flats. The ridges seem due to sudden and great floods going through a narrow, or gorge, on to a flat. Such sudden floods must have been of frequent occurrence prior to the climate becoming as temperate as it is now. During the historical period they are from time to time recorded in the annals, and a small one occurred in the Ovoca river as late as March, 1867. This flood was not due to heavy rains, but to a heavy fall of snow in the highlands. This remained longer than usual, giving time for lakes or ponds of water to accumulate in the valleys behind the snow drifts. When the thaw came, all these lakes burst nearly at once, the water rising in the valley from 10 to 15 feet higher than the more ordinary violent floods.

## Meteoric Drift.

This includes the deposits due to weathering more or less *in situ*, and also the vast accumulations of *Æolian* or wind-formed drift.

The drifts due to weathering are of considerable extent in Ireland, although little notice has been taken of them. As the Ice-sheet, and subsequently the local systems of glaciers, melted away, the meteoric abrasion must have been excessive, not only on account of the surface of the ground being devoid of vegetation, but also on account of the excess of water trickling down every slope of ground.

In portions of the low lands in Ulster under the Till, and in a few places under the Boulder-clay-drift in Galway and elsewhere, there is a greater or less thickness of angular *débris* of rock, called *Broken shelf* by the miner, and *Foundation* or *Rubble* by the quarryman. These seem to be pre-Glacial meteoric formations. In the south of Ireland, especially in parts of Cork, Waterford, and Wexford, there are large, and in some places thick, accumulations of an angular drift, characterized in general by having most of the contained rock-fragments standing more or less on edge. If we examine drifts that are in process of formation, we find that at corners and curls in rivers the pebbles may be on edge; and also in estuarine deposits near the margin, in eddies, or where slips of the adjoining cliffs take place, the pebbles are on edge; and in marine drift if a slip take place from a cliff, the disturbed stones may be forced up on edge; and we may suppose that floating ice grounding on drift would have a similar effect. These, however, are all local or exceptional cases, while in meteoric slopes such an arrangement is not uncommon; we may, therefore, believe that the drifts just mentioned are meteoric, formed while the ice was disappearing. In the County Carlow, we find on the hills near Borris, that this drift is thin, but that it thickens as we go to the base of the hills, and that afterwards it again thins, as it is followed out on to the estuarine gravels of the valley of the Barrow. In this valley the meteoric drift has been called erroneously "upper glacial drift," and the estuarine gravels "middle gravels." In the same county, but on the north slope of Mount Leinster, there is a great thickness of meteoric drift, which in one place tails out over a recent bog, from a few inches to four or five feet deep. On the south coast of Wexford a lime-kiln has been smothered by meteoric drift, and the recent meteoric drift over it is identical in every particular with that which further west forms cliffs from twenty to nearly a hundred feet high.* A very puzzling variety of meteoric drift is found in the meteoric slopes that have been formed out of the weathering of ancient cliffs of glacial drift. In artificial works, such as those for railways, after the new ground has had time to consolidate, it is extremely difficult to point out the exact boundary between the old drift and the artificial work. Similarly with these meteoric drifts, it is hard to distinguish them from the old drift, except that the fragments in them, if flattish, have a tendency to stand on edge. The estuarine gravels of many of the Irish river valleys are more or less covered with such talus.

The accompanying diagrammatic section represents the 25 feet, the 100 feet, and the 300 feet sea terraces in the Valley of the Barrow, the distances between the different terraces being curtailed to allow them to fit into our dia-gram—the dotted lines representing the cliffs prior to their being weathered. The talus on the 300† feet terrace is extremely similar to glacial drift, it being the *débris* of glacial drift; while those over the 100 and 25 feet terraces are more or less a mixture of the *débris* of glacial drift and estuarine gravels, as usually the upper portion of the cliffs from which they were formed is gravel. The

* This drift, as also that over the limekiln, contains ice-dressed fragments, some of hard grit retaining the old polish and etching.

† The heights given are the average ones, as the terraces rise in height slightly as we proceed up the estuary.

meteoric drift in both of these slopes contains a large percentage of ice-dressed fragments, often polished and etched, and many observers have classed them as glacial drift. The depths of these meteoric drifts vary, their maximum depth being generally about half the height of the original cliffs. Such meteoric drifts capping gravels have of late years been called in many places "Upper glacial drift," and from such data we are asked to believe in the existence of a second Glacial period.

*Diagrammatic Section of the Old Sea-beaches in the Valley of the Barrow.*

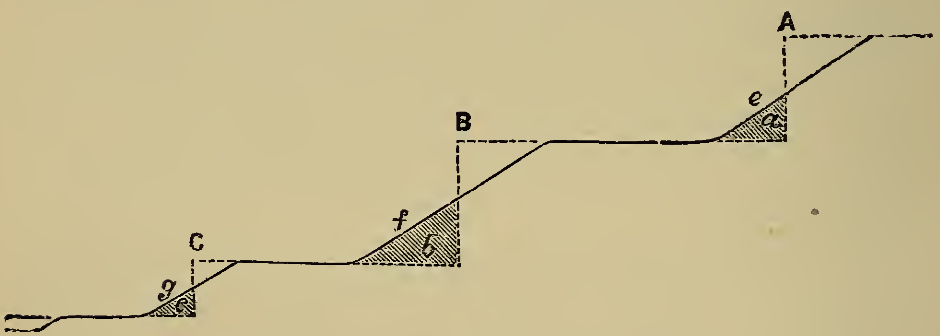



Fig. 12.

A. B. C.—Ancient Marginal Cliffs.
*a. b. c.*—Meteoric talus due to the weathering of the Old Cliffs.
*e. f. g.*—Meteoric Slopes.

The *Æolian drift* is conspicuous in many places. We cannot point to any undoubted pre-Glacial or intra-Glacial accumulations, but those of post-Glacial age are well represented. In places at the margin of the "Esker Sea," such as on the Cratloe hills, County Clare, north of the estuary of the Shannon, there are great tracts of fine sand, locally called in Ireland "rabbit sand;" also in places at the margin of the 100 feet sea, as at Birdhill, County Tipperary. These accumulations are usually found at, or near, the inver or mouth of a valley down which a glacial river probably flowed. We may, therefore, suppose that the sand was formed in glaciers, similar to what is going on at the present day, while subsequently, after it had reached the seashore, it was blown up into hills by æolian action. In other places, such as in the Eskers at high levels, and at the previously mentioned "Heads of the Tide," the sands seem to have been brought to, or near, their present positions by tidal action, and afterwards to have been drifted by wind. All these older æolian accumulations are now clothed with vegetation, as are also some of those that were formed at the margin of the 25 feet sea; but many of the latter, and most of those belonging to more recent times, are still shifted hither and thither by the wind. Those at present forming are of two distinct kinds—silicious and calcareous, or *Shell sand.* On the east and south-east coasts they are very silicious; and are very prevalent along the coast, in places forming bars enclosing lagoons, in places filling up bays that were formed when the sea was at about the 12 feet contour line. On the west coast many of them are calcareous, some of those at the mouth of Galway Bay containing more than 75 per cent. of limy matter. Along this coast, as the prevailing winds are from the westward, this drift is usually piled up at the heads of the bays, or on a low coast line backed by high land; while in some places it occurs as *Sand-streams.* In south-west Mayo the inhabitants near the shore have great difficulty in keeping the sand from travelling inwards and smothering up the arable and pasture land. In the north-west of the same county, adjoining Broadhaven, there were sandhills covered with Bent grass. This was burnt off, and the sand began to travel up the hill to the north-eastward.

It has gradually crept up the hill, about 700 feet, destroying all before it, so that the inhabitants have had to migrate to the other side of the hill. In Omey island, off the coast of Galway, the sand has covered up a village, and the inhabitants now come out of holes, like rabbits in a burrow. In the vicinity of Galway Bay, in Aranmore, and to the north in Errismore, the sands, within the last forty years, have taken to travel southward, and have nearly all disappeared out to sea; also on the east coast, between St. Helens and Greenore, County Wexford, the sand dunes formed during the time of the 25 feet sea (Plate V.) have within late years been nearly entirely carried away by the wind into the sea, and by the latter round Greenore point; and they are now accumulating and forming sand dunes to the east of the new pier of Ballygeary; at Arklow, County Wicklow, the great sand dunes that once existed have now nearly disappeared.

To face page 240.


SAND-DUNS (ÆOLIAN) ST HELEN'S, CO WEXFORD.

# CHAPTER XV.

## GLACIATION, ERRATIC BLOCKS, RAISED BEACHES, AND SUBMERGED LAND AND FORESTS.

CONNECTED with the Drift are—the Glaciation of the country, the Erratic blocks, and the Raised beaches or Ancient Sea Margins; and to some extent the Submergence of the land.

### GLACIATION.

It would appear, as has been elsewhere stated (*Journal Roy. Geol. Soc.*, vol. i., and "Memoirs Irish Branch Geol. Survey"), that at one time there was a general south-south-westward movement of a thick sheet of ice across Ireland, while in later times there were systems of local dispersion in connection with the different groups of hills, and still later, minor glaciers in the highland valleys; some of the latter have only disappeared in very recent times.

These conclusions, however, are different from those arrived at by the Rev. M. H. Close, who has paid particular attention to the study of the Glaciation of Ireland.* This authority believes "that during the glacial period the universal ice sheet had no general movement across Ireland, though it so happened that its longest flows on the surface of

* I would refer those interested in this subject to the various papers by the Rev. M. H. Close, as in many particulars our opinions differ.

the land were towards the SE.; that the most predominant centre of dispersion was near the hills of Fermanagh; and that there were others in Donegal, north Galway, and Kerry, but none on the east side of Ireland. The mountains of the Counties Dublin, Wicklow, and Wexford, were swept by ice from the less important hill group of Fermanagh. The Waterford Mountains also were swept by ice from the interior of the country; so that it was not always the greater height of the ground that determined the position of the centres of radiation."

The earliest movements of the ice will for ever be a subject for controversy. The later movements are more or less distinctly marked and can be followed, although some are very hard to be accounted for. But they have in places so changed and obliterated the earlier work that a great portion of the latter has to be guessed at. Furthermore the different observers often come to different, or even opposite, conclusions from the same phenomena; some believing that they belong to the older, others to the newer ice, or they may even not agree as to the direction in which the ice was moving.

In the Central plain the earlier movement to us seems to have been southward, as the rocks are planed in that direction, they sloping northward and cragging southward. The form of the grooves and striæ would lead to a similar conclusion. The hard limestones when freshly uncovered are generally beautifully rounded, polished, scratched, and etched; but the softer limestones and shales of the Calp rarely retain the marks. The general bearing of these striæ, especially in the western portion, seems to be from NNE. or NE. to SSW. or SW., the easting in these bearings being due to the form of the ground. As the axes of the lines of the Pre- and Post-Carboniferous Hills in general had such bearings, and as these hills must have formed prominent features during the glaciation, they would have influenced the direction of the streams of ice. The records of this general southward movement, so prevalent in the plain, are less frequent among the hills, the traces having been obliterated by the more recent local systems.

When ice first invades a country it effects great denudation ; rapidly wearing away and removing, except in protected places, all loose and soft portions of the surface. But when the solid rocks are reached the work goes on more slowly, till eventually the surface becomes so re-arranged, even, and polished, that the ice has very little power of denudation.*

We learn this from various circumstances. In many places over large areas are two sets of striæ on one rock surface, and in some places three or even four sets ; showing that ice-streams, all moving in different directions, had succeeded one another. If ice at all stages had the same denuding power this could not occur, as the older marks would have been obliterated by the newer ice ; but if the rocks had been hardened and polished by the passage of the first ice, all that passed subsequently could only record their passage by the scratches and other marks due to the protruding points and edges of contained pieces of rocks. Also in many areas, such as in west Galway, where two or more sets of striæ occur, large tracts are found without any drift on them ; as if the first ice effected the denudation, and when the later ice melted there was no detritus in it to form drift.

In the hills occupying west Mayo and west Galway the markings left by the system of glaciers are better

* This is similar to the process of artificially polishing a block of stone.

preserved than elsewhere; and it would appear that the dispersion was not from off the highest hill (Mweelrea), or from the greatest mass of highland (Formnamore table-land), but out of the valley between the Bennabeola and the Maumturk Mountains. Radiating from this centre glaciers flowed in every direction, more or less following the valleys, but to the north and north-east crossing the present watershed in places at considerable heights.

To the west is a remarkable newer glaciation, that had a NNW. movement: what was the cause of it is unexplained. The marks are very perfect and recent looking, much fresher than any of the others. As will be presently mentioned, similar recent-looking glaciations also occur near the coast of Ulster.

The great development of the ice in west Connaught was long prior to the Esker Sea period, as all the principal glaciers of the age occupied the valleys in which the Esker drift occurs; but during the Esker Sea period smaller glaciers existed in the hills, as large blocks of the Galway rocks are found perched on the Eskers. These cannot be a residue from a glacial drift, as suggested by some, being always on, and never in, the Esker drift, as pointed out by O'Kelly, Foot, and Jukes.

In the Counties of Cork and Kerry also, in which are found the highest Irish hills, Ice-marks are conspicuous, although not as prevalent as in west Galway. In the low ground in the neighbourhood of Kenmare there seems to have been a centre of dispersion somewhat like that of the Galway Mountains, and some of the striæ show that part of this ice went SSE. over the high mountain ridge that divides Kerry from Cork; but the best marked sculpturing is due to very recent glaciers.

Of these recent glaciers Du Noyer and Close record traces in the Dingle promontory and among the mountains west of Killarney, while in the promontory between Kenmare River and Bantry Bay they are of great interest. In the latter locality, in a ravine immediately south-west of Hungry Hill, striæ occur which are continuous from the commencement of the ravine down to the low land, when they end at a hill of drift that evidently was a terminal moraine. As this hill is on land only 140 feet above the level of the sea, it is evident a glacier existed here long subsequent to the Esker Sea period. But in the County of Kerry, to the north of the mountain ridge, as also farther NE. near the lakes of Killarney, and especially at the mouth of Glenflesk, are well-preserved marine gravels up nearly to the 300 feet contour line; suggesting that in these portions of Kerry no glaciers extended down into the low ground after the time of the Esker Sea.

In the mountains and hills near Skibbereen, and in the country to the E. and NW., Wyley and Willson have recorded the traces of glacial abrasion and moraines, and also numerous perched blocks. The undercutting and sculpturing in the transverse valleys near Mount Gabriel are most perfect and fresh-looking.

To the eastward, in the Knockmealdown, the Galtees, and the Commeraghs, there are, besides the general glaciation across them, the records of several small glaciers, that retreated gradually up the different valleys till eventually they were confined to the limits of the different cooms. In some of the valleys the ends of the different glaciers during pauses in their retreat, are marked by terminal moraines at different levels.

In the Leinster range of hills there seem to be traces of *mer-de-glace* in the low hills to the south and north, of Lugnaquillia. These sent glaciers N., NW., W., and

SW., into the valleys of the Liffey, Barrow, and Slaney, and E. and SE. into the valleys of the tributaries of the Ovoca. The glaciation in the valleys of the Aughrim river and Avonbeg is well marked, bearing about N. 40° to 45° W.

To us it would appear that during the general glaciation the southward movement of the ice was diverted in the County of Dublin, by the mass of the Dublin and Wicklow Mountains; part going SW. into the valleys of the Barrow and Nore, then nearly south across Kildare and Kilkenny to the County of Wexford, where it turned towards the SE. (N. 60° W.); part across the Dublin and Wicklow hills with the general bearing of Glenmalure (N. 40° W.), and the other main valleys; and part southeast till it passed the hills, when it turned south along the low ground in Wicklow and Wexford. A later ice went from west to east, across the north portion of the County of Wexford.

In the County of Kilkenny, on the high land between the Nore and the Barrow, striæ occur in different places with a general bearing of about N. 10° W. In south and west Wexford striæ are very rare, although, in places, the rocks have been planed over extensive areas. This is probably due to the glacial drift having been washed away over most of the county, and replaced by marine and meteoric drifts. In north Wexford and in Wicklow striæ are much more frequent, especially in the latter county.

The traces of the local glaciers connected with Lugnaquillia are interesting. In Glenmalure, the valley of the Avonbeg, the gravels belonging to the Esker Sea period are well preserved, they becoming very conspicuous at Ballinacor, and from that northward to Drumgoff, where they form a high mound or bar, on which the barrack is situated, across the valley, at a height of 440 feet. North of this bar, is the site of an ancient lagoon, and everywhere above the level of the surface of this lagoon are moraine drifts; while to the north of the valley and in the valleys coming down from Lugnaquillia are terminal moraines at successive heights, marking the gradual retreat of each small glacier up their respective valleys.

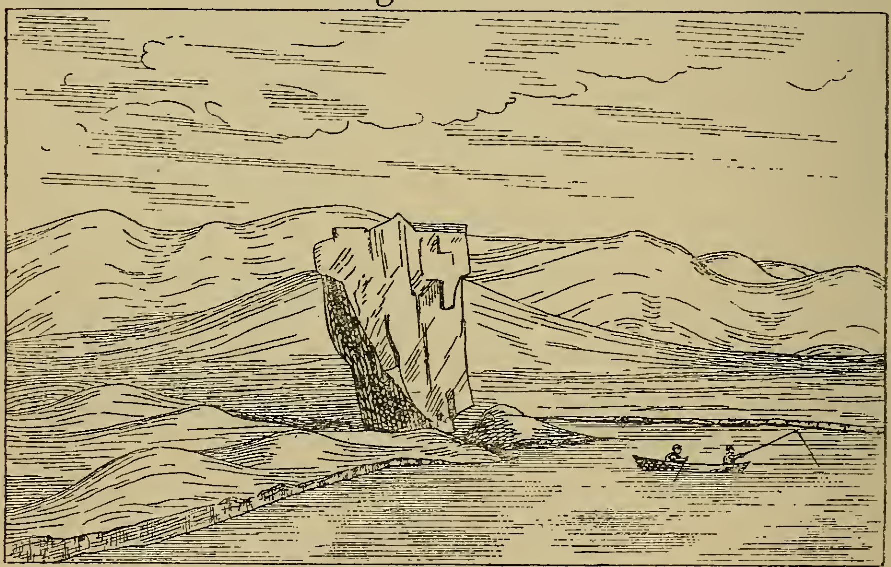
In the province of Ulster there seems to have been a general southward movement, as boulders and fragments of the Ulster rocks are found to the southward in Leinster and Connaught. Since then, however, there have been various local movements; in the eastward portion towards the south-east, and in the western part towards the west and south-west. There has also, in certain localities near the north coast, been a northward movement, like the recent glaciation already mentioned in West Connaught, which has left traces so perfect and fresh-looking that they must be the records of a much more recent movement than any of the others. In Ulster this northward movement evidently was due to the ice, when finally breaking up, slipping off the high lands; but it is hard to explain why there was a movement in a nearly similar direction in West Connaught.

## Erratic Blocks.

Erratic blocks are distributed over the whole of Ireland, but are more numerous and conspicuous in some places than in others. Ice as land-ice, icebergs, or shore-ice (*ice-foot*), seems to have been in all cases the motive power that carried the large blocks from their parent rocks to their present sites; but in some places smaller erratics may have been brought by strong oceanic currents.

In west Galway and Mayo, the erratics are more numerous and of greater size than elsewhere. In the mountainous country south of Galway Bay, most of the largest ones are found, some being very remarkable; the largest known in Ireland being a porphyritic granite block on the Carboniferous limestone at Ballagh, a few miles to the NNW. of Galway. Formerly it was larger, but a considerable piece was blasted off its side to form the pedestal on which the statue of William Dargan now stands in Leinster Lawn, Merrion Square, Dublin. Attention may be also called to Clogh-Currill, at the

Fig. 13.



Clogh-Currill, County Galway.

margin of the lake similarly named, in the flat country, between Recess and Kilkieran (Fig. 13). This stands on its end, and from a distance looks like one of the old castles so frequent in Ireland. Of this stone there is a legend that it was thrown by a giant (Currill) from the Corcogemore Hills at another, Moidaun, who was carrying off his daughter, and Currill's fingermarks are shown on the base of the stone. This seems to have been rather a far "push" for the stone, a distance of over twelve miles.

Among these hills there are large erratics on hummocks of Rocky-moraine-drift ; the latter apparently being the *débris* left by dying-out glaciers, similar to those described by Clarence King, on the West Pacific slopes ; while margining the hills in the flat country, between Killala Bay on the north and the estuary of the Shannon to the south, and also in other places, are numerous large and small erratics on the limestone crags, that seem to be the residue of the Boulder-clay-drift. The numerous blocks found on the Aran Islands, at the entrance into Galway Bay, appear to have had a similar origin.

Erratics of the west Galway rocks, principally of the porphyritic granite, are found at great distances to the eastward, south-eastward, and southward. To the east they are very numerous, in places, on the Eskers, especially between Woodlawn and Loughrea, also near Ballinasloe ; while smaller ones occur in the country about Eyrecourt, Portumna, Birr, Silvermines, Nenagh, and even on the slopes of the Slieve Bloom mountains. In the valleys looking west of the Slieve Phelim, to the NE. of Newport, Tipperary, are remarkable gravels and shingles, made up almost solely of fragments of these west Galway rocks.

To the southward, blocks and pieces of the west Galway rocks occur in the Galtee mountains, while Willson has found them farther south in the County of Cork. In Limerick, on the Coal Measures between Foynes and Glin, the Rev. Ponsonby Lyons pointed out that the blocks and pieces of rock in the drift, were chiefly portions of the Galway granitic and metamorphic rocks. These seem to have been brought south by the oceanic current that ran southward between Killala Bay and the estuary of the Shannon, when the sea was 100 feet higher than at present.

In the mountainous country that includes portions of Limerick, Kerry, and Cork, also in the hills of Tipperary and Waterford, erratics occur; but in none of these places are they as remarkable or as large as in west Galway; all the more remarkable of these erratics are mentioned, and some of them figured, in the Geological Survey Memoirs. The most remarkable are Cloughvorra, a block of limestone, figured by Du Noyer, lying on the Old Red Sandstone of the Kenmare valley; huge blocks of Limestone on the Old Red Sandstone near Ballingarry, County of Limerick; and large blocks of Old Red Sandstone conglomerate scattered over the country between Kilmacthomas and the sea, County of Waterford. The largest of these NW. of Stradbally, on the bank of the river Tay, is called Cloughlowrish, and a picture of it is given by Du Noyer in the Memoir.

In the hills of South Leinster large erratics are not very numerous, although small blocks are not uncommon. In the mountains of Wicklow and Dublin they are larger, some in Annamoe valley near Glendalough being of considerable size. On the ice-planed surface of Brockagh north of the Seven Churches they are plentiful, four conspicuous ones being perched on the eastern summit, 1,550 ft. There is a very great one close by Annagolan bridge, near the N.W. end of the Devil's Glen. In the valley of the King's River there is a remarkable assemblage, the blocks being so near together as to look like a pavement; while perhaps the best known of the erratics in the County Wicklow, is the Motto Stone, perched on Cronebane Hill, over the Ovoca mines. In the central plains of Ireland, the erratics, that have not been broken up, are of small size. In north-east Ireland, including Ulster and the neighbouring portion of Connaught, erratics are in general not very numerous, although in a few places many occur, some in Donegal being of large size.

## Ancient Sea Margins, or Raised Beaches.

A sea margin is not necessarily a horizontal line. It is lowest at the "Nodal" or "Hinge lines" of the tide, when such exist, higher at the "Head of the Tide," and often exceedingly high at the heads of narrow bays and estuaries. At the present day the mean height of the tide around Ireland varies eight feet, but the difference between the mean height at Courtown, County Wexford, the point of the lowest rise of the tide in Ireland, and that of the opposite coast at Cardigan Bay, the point of lowest rise on the west coast of England, is thirteen feet; while between the mean heights at Courtown and Chepstow, in the Bristol Channel, there is a difference of forty-five feet. These are the variations between the *mean* heights of the Spring tides, but the variations between the *maximum* heights are much more striking, and it is the latter that form the "foreshores" which represent the terraces of the Raised beaches.

The present variations in the rise of the tide are due to the tidal wave coming from the west dividing on the west coast, part going northward, and part southward round Ireland, to meet in the Irish Sea, as has been explained by Haughton.* It is found that the wave rises

* "Manual of Tides and Tidal Currents," by the Rev. S. Haughton, M.D., F.R.S., &c.

less on the islands off the west coast of Ireland than on the coast itself, and on the east coast of Ireland than on the west coast of England, and variations, due more or less to similar causes, occur in the heights of the ancient sea margins.

The most conspicuous and continuous of these ancient sea margins or raised beaches occur at about the following heights:—A little above high-water mark, or at about the Ordnance 12-feet contour line;* at about the 25-feet contour line; at about the 100-feet contour line; and at a little below the 300-feet contour line. Besides these, there are in the different groups of hills, cliffs, rock terraces, and shelves, that may possibly mark older sea margins; they being found at about the 450-feet, 650-feet, 750-feet, 1,000-feet, 1,200-feet, 1,500-feet, and 1,800-feet contour lines.

The 12-feet beach varies much in height, being a few feet above the present level of high spring tide. Some extraordinary tides rise to or above it; consequently in many places it has been obliterated, but traces of it can be found in most of the bays and estuaries. In the neighbourhood of Dublin Bay it seems to have formed the flat that joins the hill of Howth to the mainland, also the low ground on which Trinity College and the adjoining portions of Dublin are built. Formerly it was conspicuous as a beach with caves at Dunleary (coal harbour, Kingstown); these, however, were covered up when the hill at De Vesci Terrace was cut away. South-east of Dublin Bay until lately it could be seen at Bullock and Dalkey, and it is still preserved at the inver of the Shanganagh river, and was formerly

* The Irish Ordnance zero plane is 20·9 feet below a permanent mark on the Poolbeg lighthouse, Dublin Bay; and this has been found, from a system of levellings, to be 8·094 feet below the mean level of the sea round Ireland.

in the estuary of the Bray river. Between Bray Head and Carnsore, County Wexford, it is seen in many places. Between Greystones and Wicklow it is very conspicuous as a flat, wide gravel bank or murrough (*Anglicè* sea plain), behind which are lagoons and salt marshes; while farther south it has filled up portions of nearly all the bays, and on it there are now accumulations of Æolian drift, margined by the old sea cliffs. In the vicinity of Wexford Harbour it is seen in the ravines occupied by the Blackwater and other streams.

On the south coast it has been observed in the Ballyteigue lagoon (now an Intake), between Ballyteigue and Bannow; in the Bannow estuary, near Fethard and elsewhere; in the estuary of the Suir, where it has been described by Captain Austen (*London Geol. Soc. Proc.*, page 360); in Tramore lagoon; in the estuary of the Lee (Cork Harbour), especially about Inishmore, and in some of the smaller bays.

To the west it is conspicuous among the islands and promontories of west Cork, and it joins Crookhaven Island to the mainland; while it has been observed in places near the heads of the bays in Cork, Kerry, Galway, Mayo, and Sligo, it having formed rich land in the estuary of the Shannon (corcasses, or meadows), and on the middle island of Aran, Galway Bay, it occurs as a shell-gravel beach.

To the north it does not appear to be so well seen, as it has been more or less cut away by the encroachment of the sea; but on the N. and NE. coasts of Antrim it occurs as caves a little above high-water mark, as pointed out by Portlock. Near Larne it is very interesting, as mentioned hereafter. It also occurs on the east coast, between Belfast and Dublin, where its existence has been shown by Du Noyer, Traill, and others. Usually this beach is below the 12-foot contour line, but in some of the estuaries it rises to the 16 or even about the 22-feet contour line, as in Carlingford Bay, where the gravels contain flint implements; its rises and falls, apparently corresponding with those of the present sea margins. This beach is often confounded with the 25-feet sea beach, next described. They, however, are perfectly distinct, as between the formation of the two there was an upheaval of the land to between 30 or 40 feet above its present level. The low parts of most of the maritime towns in Ireland are built on portions of the estuarine flat of the 12-feet and 25-feet beaches, the *corcagh* (or low flat) after which Cork is called being part of the latter.

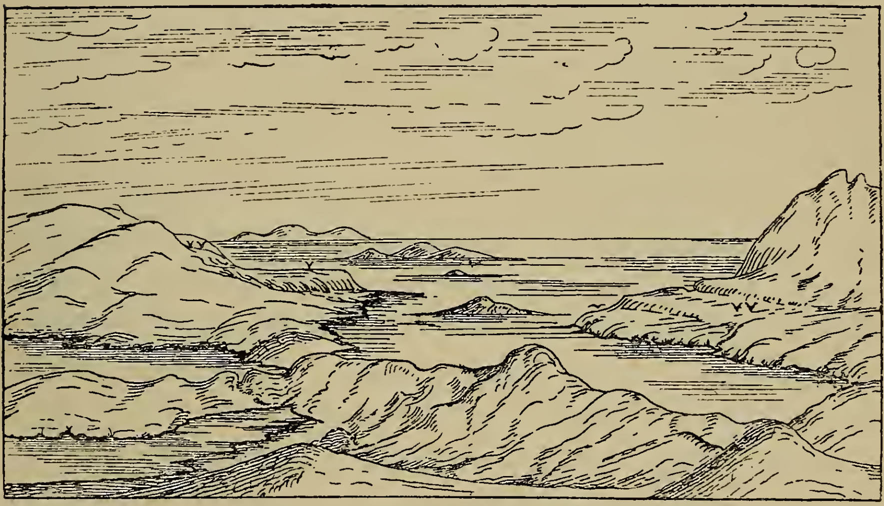
The 25-*feet beach* can be traced in the vicinity of Dublin Bay, rising from about the 25-feet contour line at the Heads (Dalkey and Howth) to over 35 feet at the west end of the ancient estuary, as traced out by Cruise. About thirty-five years ago, or more, it was very conspicuous along the cliffs from King George's monument, Kingstown, eastward towards Sandy Cove, but all traces of it have since been obliterated; also in places at Bullock, Dalkey Sound, and at the north end of Killiney Bay.

To the south of Killiney Hill there are gravels in the Shanganagh and Bray river valleys that seem to have accumulated at this time. From Wicklow southward to Kilmichael in the County Wexford this beach is perhaps more conspicuous than elsewhere in Ireland, in places forming a shelf in the cliffs at about the 22-feet contour line; and it can also be traced up the river valleys, the terrace rising slightly up the ancient estuary.

In the County of Wexford the old cliff, as it was cut in drift, has in part been removed by the encroachment of the sea; but in many places, at about the 25-feet contour line, there is a sloping escarpment that seems to mark its site, and its marginal gravels can be seen in many places in the valley of the Slaney to about half-way between Enniscorthy and Newtownbarry, while the old beach was well shown in the railway cutting at Park, near Wexford, prior to the slopes being finished off and soiled. In the estuaries of the Suir, Barrow, and Nore, it is well marked, especially north of Graiguenamanagh and near Dunmore.

In Waterford, Cork, Kerry, Limerick, and Clare, it has been observed and recorded by Capt. Austen, Wyley,

Fig. 14.

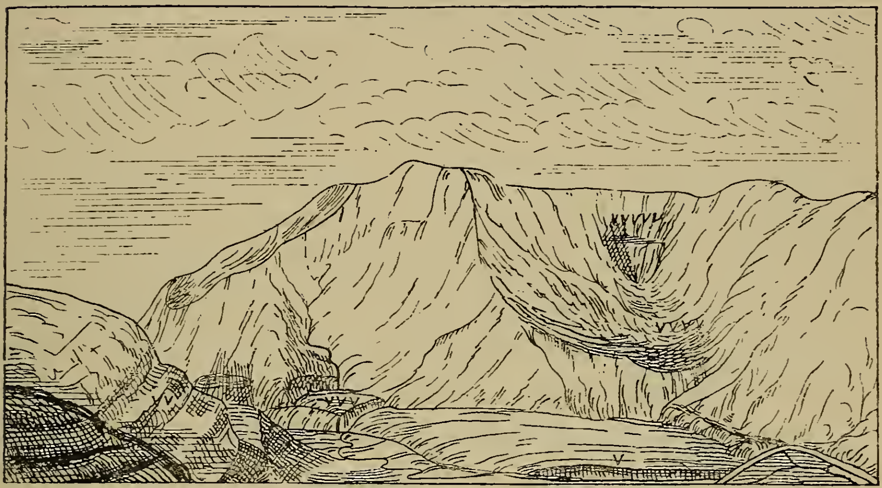


Ballynakill Harbour with Terraces, County Galway—Terraces, v, vv.

Willson, Du Noyer, Jukes, Foot, Wynne, and others, generally in the bays or on the eastern sides of the islands, as on the headlands and open seaboards it has been nearly invariably washed away by the storm waves of the Atlantic. In part of Kerry, however, and in the plain of Limerick, to the south of the estuary of the Shannon, it is well preserved in places as a low cliff in the limestone. In the Burren, County of Clare, it also occurs as a limestone cliff, while in the County of Galway it forms gravel terraces in the valley of Ballynakill Bay, and at Leenaun near the east end of Killary Harbour, where a height of 32 feet is marked on the terrace, although down near the open sea the terraces are below the 25-feet contour line. At Leenaun this beach and higher beaches are conspicuously marked, as shown in the accompanying sketch (Fig. 15). Farther northward, it has been observed in Clew, Blacksod, Broad-Haven, Killala, Sligo, and Donegal Bays, besides in some of the smaller inlets; also in the bays, especially Lough Foyle, to the west and north of Donegal and Londonderry; while Portlock has drawn attention to the caves cut in connection with it in the chalk on the north coast of Antrim, in some places there being even three sets of caves, marking the 12, 25, and 100-feet old beach lines.

On the east coast, between Ballycastle and Dublin Bay, this sea margin seems to be very generally marked by caves or beaches, attention having been directed to it by Du Noyer, Traill, and others. On the open coast it is below the 20-feet contour line to the northward, but southward rises gradually to above the 25-feet contour line in Dublin Bay. On the coast of Antrim, as pointed out by Du Noyer, it is of special interest, as at Larne, at Magheramorne, and Island Magee, east and west of Larne Lough, and at Kilroot, on Belfast Lough, flint arrow-heads and other implements occur in the marine gravels. Du Noyer considered that the implements found at Magheramorne are of an older type than those at Kilroot. The Kilroot gravels rest on bluish clays, and contain shells, some of which are stated by Dr. Grainger and Mr. Stewart to have now disappeared from the neighbouring seas. The upper beach at Larne belongs to the 25-feet sea. But it would appear probable that the Kilroot sands belong to the 12-feet beach, while the underlying clays are the estuarine deposits of the time of the 25-feet sea beach. Dr. Grainger and Mr. S. A. Stewart have published a list of the shells found, in the "Brit. Assoc. Report for 1874." The Curran, Larne, is apparently one of the best places for procuring them. Besides the raised

Fig. 15.



Lugs and Terraces at Leenaun, Killary Harbour, Co. Galway, v. gravel terrace; vv, sloping terrace; vvv 100 feet terrace; vvvv, 320 feet terrace; vvvvv flat bottomed coom.

beaches on this coast are the previously-mentioned caves, formed at the times both of the 12 and 25-feet beaches.

Near Greenore, Carlingford Bay, Traill records shell gravel terraces at a little above high-water mark and about 15 feet higher. In the gravels near Greenore coast-guard station are flint implements, and in other places Mr. D. J. Rowan found the remains of kitchen middens. Du Noyer has also directed attention to the beaches on the east coasts of Meath and Dublin, in which are found the bones of such animals as the sheep, pig, and ox, also

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numerous shells and the remains of fires, as if kitchen middens had existed prior to the formation of the beaches. Some of these ancient human relics seem to be in the 12-feet, others in the 25-feet sea beaches. The 25-feet sea beach all round Ireland rises and falls very similarly to the levels of the present sea margin. The "Head of the Tide," however, in the Irish Sea would seem to have been a little more south (opposite Dublin Bay) than at present.

The 100-*feet sea beach* is more inland than those which have been described, and it is not as conspicuous, as in many places it must have been cut in drift, whence weathering and the tillage of the land have often obliterated it.

In the valley of the Liffey its gravels occur, as also on the promontory of Howth, near the town, while formerly they were well seen in the neighbourhood of Dalkey. In the valley of the Bray and the other Wicklow rivers they are found, being very conspicuous in the Vale of Ovoca, especially in the transverse valley opposite Kilmacadam Church, in the vicinity of the Mines, and the upper Meeting of the Waters, that of the Avonmore and Avonbeg. Above Enniscorthy, in the valley of the Slaney, the gravels can be traced to beyond Clonegal into the County of Carlow; while in the valleys of the Suir, Nore, and Barrow it forms well marked terraces, as near Mount Loftus in the last. Similarly it is found in the valleys of the Cork, Kerry, and Limerick rivers; while near Galway town and the branching valleys from Lough Corrib are terraces at about 110 feet; the beach on the crags north of Galway looking as fresh as some of those at the present sea margin.

In the valleys of the hills of Galway and Mayo these gravels are very numerous and conspicuous, as in the

Kylemore valley and near Leenaun, Killary Harbour; while some remarkable bars, with associated terraces, occur in Gleninagh and other mountain valleys at about the 125-feet contour line. These seem to mark the bars of the terminal lagoons at the ends of the narrow bays.

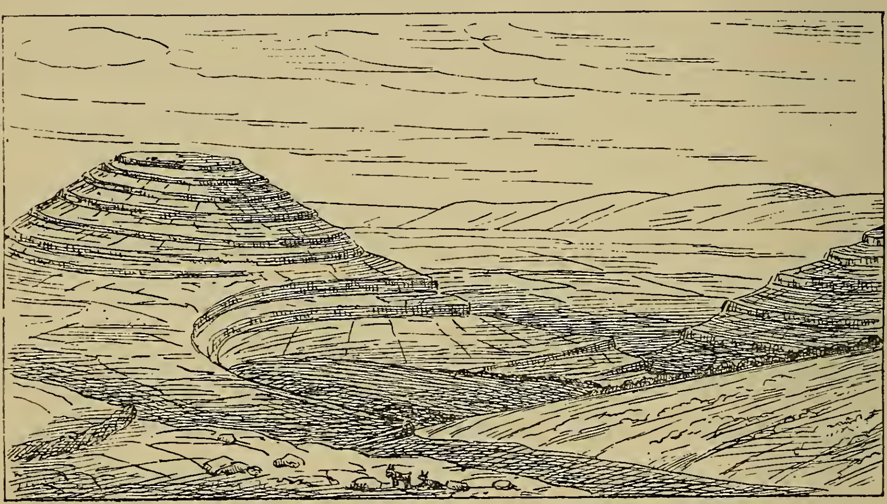
In north-west Mayo there are shell gravels that seem to belong to this beach, and in Sligo terraces; while in the valleys of Donegal are bars, terraces, and cliffs. In Antrim there are the caves mentioned by Portlock and the fossiliferous gravels described by Bryce and Hyndman; while many of the inland cliffs seem to have been cut at this time. In the County of Down this beach occurs in some of the valleys.

The *Esker sea margin* is the most important in Ireland, usually occurring between the 270 and 300-feet contour lines, but to the west, in the County of Galway, it is lower, though in some of the long, narrow valleys, like that of Killary Harbour, it rises higher; in some of the Dublin and Wicklow valleys it is very high.

In the valleys among the hills of west Galway it is in general well marked, rising up each valley, sometimes to above 300 feet, except in the Maum valley and its tributaries, where the margin is as low as 255 feet. Terraces are conspicuously marked on Leckavrea, the hill to the south of Maum. In the valley of Killary Harbour, to the westward near Salrock, the terraces are at a height of about 290 feet, and reach more or less continuously eastward, for twenty miles, to great terraces and flats of gravel in the Erriff valley, on which heights of 350 feet and more are marked.

Further northward and north-eastward, in the different hills above 300 feet high, some traces of this sea margin are sure to be found; it being very conspicuous, as before mentioned, in the County of Tyrone, forming rings of gravel and sand round the drift hills, at a little below the 290 feet contour line. In the eastern portion of the central plain of Ireland, the margin is usually a little above or below the 300-feet line, while westward, it decreases in height. A rock terrace and cliff due to this sea is very continuous all through the Burren hills in North

Fig. 16.



Terraces in Limestone Burren, Co. Clare.

Clare, while in the neighbouring hills of Galway it is also found; south of the Shannon in the plain of Limerick, to the west of Ballingarry, there is a remarkably perfect recent-looking beach, a little below the 290 feet contour line, and north of the Shannon on the slopes of the Cratloe hills, is a great accumulation of Æolian drift just above this height.

Among the Kerry hills, in the valleys that open northward and westward, these gravels occur a little below the 300-feet line; while to the SE. of Killarney, at the mouth of Glenflesk, at about the same height, is an enormous accumulation of shingle. In the west Cork hills, these gravels are absent or rare; but they occur in the valleys of the Waterford, Wexford, and Wicklow rivers, being very conspicuous in those of the Suir, Nore, Barrow, Slaney, and Ovoca.

In some of the Wicklow valleys, as previously mentioned, these gravels appear to be absent; while in others and in the Dublin hills they are very complicated. In the County of Wexford, to the south and south-east of the Leinster range of hills, the shell drifts containing flints and pieces of chalk have nowhere been recorded above the 300-feet contour line.*

Along the valley of the Slaney, through the range of hills into the County of Carlow, they keep at about the same height, but in that county to the north of Mount Leinster, chalk fragments occur at a height of 760 feet; in Glen Imale the upper portion of the basin of the Slaney, the valley of the King's River, and the valley of the Liffey, there are great terraces of aqueous drift up to, and above, the 750-feet contour line; while eastward of that Close has found them up to 1,200 feet. In Glenmalure, the valley of the Avonbeg, is the previously mentioned bar and terrace up to a height of 440 feet; while in the Vale of Clara, the valley of the Avonmore, terraces are conspicuous in the vicinity of Clara bridge, and can be traced up the valley till they terminate in the flat bar and terrace, on which the Seven Churches were built, at a height of 445 feet, or a few feet higher than in Glenmalure. South and north of the Glen of the Downs

* Sir H. James states that they occur on the Forth Mountain at 500 feet. This, however, seems a misprint for 300, as Wyley nowhere found them above the 280-feet contour line; neither could I, although I examined every section and carefully questioned the natives of the hills.

the surface of the gravel rises to 470 feet. The reason for this difference between the north and south of the Wicklow hills, has still to be explained.

In the Esker-sea, and newer, drifts of Wexford and Wicklow chalk flints are numerous; these are said by some to come from the County Antrim. This, however, seems improbable, as the quantity and size of the flints decrease northwards, when we leave the County of Wexford. To me it would appear that they were drifted from the Continent or England—or perhaps, as suggested by Wyley, from a tract that occupied a portion of the Irish Sea.

Above the Esker sea margin are the previously mentioned cliffs, shelves, and gravel accumulations, at heights of about 450, 650, 750, 1,000, 1,200, 1,500 and 1,800 feet. These occur in places among the Wicklow, Carlow, Waterford, Tipperary, Cork, Kerry, Limerick, Clare, Galway, and other hills; those at about the 450, 750, and 1,200 feet lines being best marked. At the 1,800 contour line on the Knockadober range, County Kerry, there is a remarkable beach of shingle. (Plate VIII).

As these marginal markings occur on nearly similar horizons in places so widely separated, it would appear that they must have been made by some wide spread denudant like the sea. But if the sea made them, at what time was it? Was it prior to, or after the glacial period? If prior, why were they not obliterated by the ice action? And if since, why did not the seas that cut the terraces, denude away the glacial drifts?

It seems more probable that such marks were formed subsequent to the accumulations of the Boulder-clay-drift; and that since the sea was 1,800 feet higher than at present, there has been no general glaciation of the country; that is, no second "Ice-cap," but only local systems of glaciers connected with the different groups of hills.

In favour of these suggestions, it is found that the glacial drift on the hills is usually Moraine; while in those places on the hills in which Boulder-clay-drift does occur, it is in isolated patches, and in situations where it could not have been easily denuded away by the sea. Local systems of glaciers could not remove all the old sea marks; they would have great power on the gravels and such accumulations, but could not easily destroy the rock-shelves, cliffs and cooms. Such records are now found best preserved in the hard rocks, as shown in the west Galway hills, where they are frequent in the hard quartzites, while in the adjoining slate rocks, nearly all of them are obliterated.

In the valleys among the hills, the marine gravels that were not carried away would be covered up by Moraine-drift, while in the vicinity of the hills, the gravels and Moraine-drifts would be mixed up together and deposited in the adjoining sea, forming the glacialoid drifts. This is what seems to have taken place; as only among, or in the vicinity of, the hills, but in such places often at low levels, are thick accumulations of gravel found under Moraine drift;* while it is only in the vicinity of the groups of hills that the glacialoid drifts, of the kind just mentioned, are found capping the Boulder-clay-drift.

* In various places on the Castlecomer table-land (Queen's and Kilkenny counties), patches of Limestone Boulder clay drift are found in hollows under the Moraine drift, while in one place, in an old ravine along the fault between the Modubeagh and Wolfhill Collieries, a great thickness of sand is preserved under the Moraine drift, although not a particle of it was found in the pits a little to the east and west.

## Submerged Land and Forests.

As there are indications afforded by raised beaches that the land formerly stood at levels lower than its present one; so on the other hand there are indications afforded by the peat bogs now submerged off our shores, that the land has been at one time, at least, higher than it is now. This time was certainly after the formation of the 25 feet beach; but whether it was before or after the time of the 12 feet beach is not so certain. In the west of Ireland, the sea-side bogs in various places, and the ancient habitations on Aran islands, Galway Bay, extend from above highwater-mark down below the level of low water of spring tides; this would seem to suggest that the submergence took place after the time of the 12 feet sea beach. But on the east coast, different beaches of this age lie on the submerged peat, proving that the 12 feet beach was formed more recently than the submergence.

In reference to this last subsidence of the land, there are statements in the ancient annals that may be important. We are given accounts of the formation (the "bursting forth") of different lakes; there are also traditions with regard to different bays, stating that at one time they were fresh water loughs. A tradition of the latter kind, states that Galway Bay was at one time a land-locked sheet of water, having a passage out of it to the NW.; but that subsequently the barrier between it and the sea sank. This tradition gets weight from the recent discoveries made by the Rev. W. Kilbride, Vicar of Aran, who has proved that at Tramore, on the largest island, human habitations and other structures can be traced down below low water of Spring tides. It has also been found that margining the bay are bogs below low water of

Spring tides, with oak corkers *in situ* at their base, being in places over 12 feet deep. In connection with Galway Bay is Lough Corrib. Of this lake tradition says that formerly it was but half its present size; and if it was now raised less than 15 feet, more than half the area would be drained through the subterranean passages in the surrounding Burren limestone.

Off the south-west of Ireland submerged bogs are common, one of the most interesting being that discovered by Dr. C. Farran at Clonea, near Dungarvan, after one of the highest tides known in the country. Here are the remains of an ancient pine forest, miles in length, now usually covered with many fathoms of water. At Dunworley Bay on the south coast of Cork, as recorded by Mr. Good, a bog was bored for 50 feet in depth without finding its bottom ("Geol. Surv. Memoirs").

Very little is known of the distance to which these peats extend seaward, but in a few places their outcrop has been recorded, between the four and five fathom lines; at about this depth peat is said to occur off Tramore, County Waterford; while adjoining the lagoon it can be seen at and below low water mark.

In the estuary of the Barrow the following are the beds passed through, when putting down the piers for the New Ross bridge:—

| | |
|---|---|
| 6. Hard marl . . . . | 12 feet. |
| 5. Debris . . . . . | 1 ,, |
| 4. Soft marl . . . . | 14 ,, |
| 3. Debris . . . . . | 1 ,, |
| 2. Soft marl . . . . | 6 ,, |
| 1. Gravel and shingle . . . | 7 ,, |
| | 41 ,, |

The surface of the marl No. 6 is 38 feet below high water mark of Spring tides, which gives a full depth to the rock of 79 feet. Higher up in the estuary, near the junction of the Nore and Barrow, the estuarine deposits have been proved to extend down for about 65 feet below high water of Spring tides.

When sinking the foundation for the engine-house in the north Intake of the slobs in Wexford Harbour, the following were proved :—

| | | |
|---|---|---|
| 4. Mud . . . . . | 16 | feet. |
| 3. Peat . . . . . | 5 | „ |
| 2. Grey muddy stuff . . . | 1·5 | „ |
| 1. Marl . . . . . | | |
| | 22·5 | „ |

This section was opened at the margin of one of the islands in the estuary, and cannot give the full thickness of the estuarine deposits ; its surface is 5 feet below the rise of Spring tides. In the peat were logs of oak, apparently "drift timber," and it is possible that they were drifted into their present site ; but, at the same time, peat is found on the same level, as to depth, to the NE. in Curracloe Bog, at the margin of the Intake, while the oyster dredgers find it outside the sand-hills in about 4 fathoms of water, also at the same depth farther northward, to the south of Cahore point.

# CHAPTER XVI.

## PEAT-BOGS AND PRE-HISTORIC REMAINS.

### PEAT-BOGS.*

PEAT may be classed as *Pre-* or *Intra-glacial* and *Post-glacial*, the latter including the *Submarine*, and that accumulating at the present day.

Pre-glacial, or perhaps Intra-glacial peat, was found near Nenagh, County Tipperary, under 43 feet of Boulder clay ; in the Boleyneendorrish valley, near Gort, County Galway, under 25 feet of glacial drift ; and at the Newtown Colliery, Queen's County, under 94 feet of drift. In the latter locality it was 3 feet thick, and more a lignite than peat. Pieces of peat occur in the Marine gravels in the country south of Oughterard, County Galway.

In the peaty accumulation of Boleyneendorrish, are the cones of *Pinus sylvestris*, *Abies excelsa* (De C.), fragments of wood, chiefly coniferous, portions of branches, scales of bark, hazel nuts, and the leaves and stalks of plants, which prove the presence of such trees in Ireland during intra-glacial times.

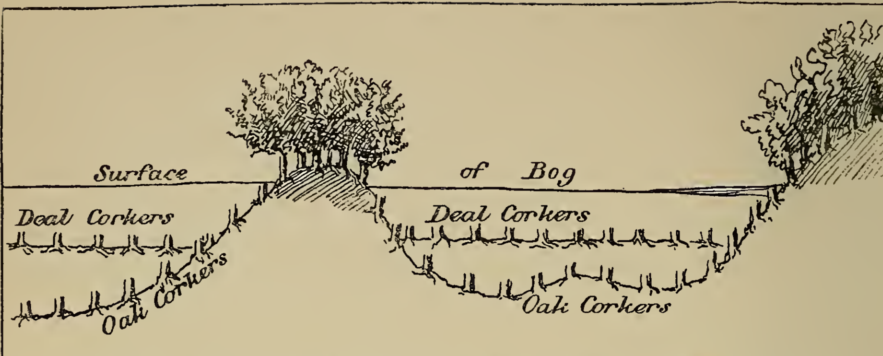
The submarine peat has been mentioned in the last chapter. At the present time very little peat is growing on the lowlands of East Ireland, yet submerged bogs are not uncommon ; those off the south and west coast seem

* A more popular description of the Irish Peat-Bogs has already appeared in the *London Quarterly Journal of Science*, No. xliii., July, 1874.

partly to have grown where now found, and partly to have been deposited from the denudation of bogs margining the sea. In the submarine bogs the roots and trunks of the oak, yew, deal, willow, and hazel, are found, similar to the tree remains that occur in the inland bogs.

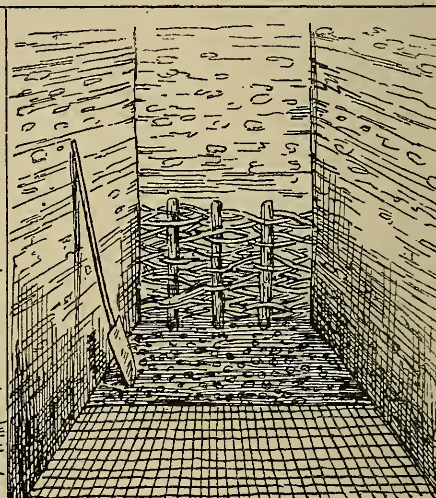
The normal lowland or *Red bogs* of the central plain of Ireland, usually have a marl or clay under them, which is more or less penetrated by the roots of the trees and larger plants that once occupied the land. Usually the roots and trunks of the trees under the peat, or in the lowest strata, are principally those of the oak and yew, as if prior to the growth of the peat, the low country was a vast forest of these trees. It would appear that subsequently mosses and other peat-producing plants began to grow and flourish, until eventually they stopped the drainage and formed an envelope of peat, thus killing the trees, which one by one toppled over and were buried in the succeeding growth of the peat. After the disappearance of the major portion of the oak trees, the bogs year by year gradually increased in depth, until, apparently, suddenly, for some as yet unexplained cause, their growth ceased, and on their surface forests, principally of deals, sprang up. During all this time, however, portions of the oak forests remained, which seems due to the oaks being destroyed only in those low places where the peat could easily accumulate ; while on hills the oak still flourished, forming oak groves. These hills, or "islands," in the bogs, although now destitute of trees, are still called *derries* (Anglicè *oak-woods*), the ancient name which has survived down to the present day, probably from the time when they were oak groves surrounded by forests of deal. In some of the wilds of Mayo, the oak may still be found growing on the drift islands in the bogs, it always being associated

PLATE VI.] [*To face page* 269.

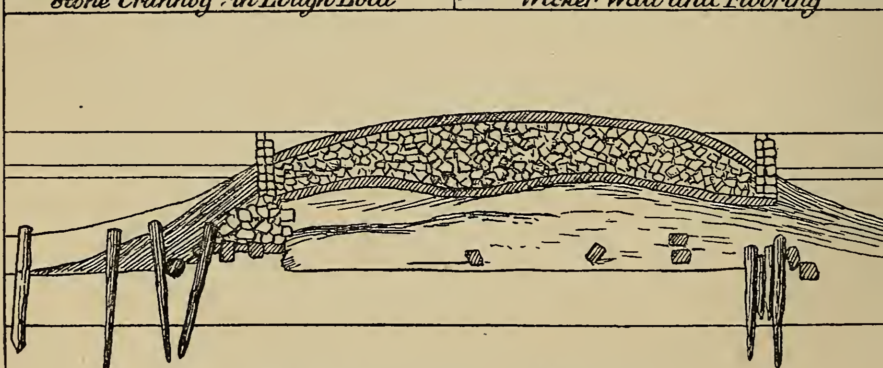



Diagrammatic Section of a Bog Shewing the Oak & Deal Corkers

Stone Crannog, in Lough Bola



Wicker Wall and Flooring



Section of Crannog (after Wilde)

with yew, hazel, birch, ash, and holly; probably the last three kinds of trees were also denizens of the Primary forests, but their timber has long since disappeared, they being of kinds that rot quickly in bog.

That such was the growth of the red bogs is proved by the different sections exposed, as beneath the peat in the under-clay, marl, or gravel, are found the "Corkers" or roots of the oak and yew, following the undulations of the ground, while above them in horizontal layers, and separated from them by from 4 to 12 feet of peat, are the roots of the deal forest, which at the sides of the hills, as shown in the accompanying section (*see* Plate VI.) join into the oak roots.

In a few lowland bogs in the west of the island, and in many of the bogs in the mountainous districts, the two systems of corkers belong to deal trees, as if in such places there were two distinct ages of deal forests.

Some of the red bogs are of great depth, being in places over 50 feet deep, but in general they do not exceed 20 or 30 feet, and often are of less depth. A typical red bog gives four kinds of peat; near the surface is the *clearing* of more or less living organic matter from 2 to 6 feet in thickness; under this *white turf*, then *brown turf*, and lowest of all, *black*, or *stone turf*. White turf is a nearly pure organic substance, very light when dried, burns quickly, giving out only a moderate heat, and leaves little or no ash. Brown turf is always slightly mineralized, while Black or Stone turf is a chemico-organic production, and may contain such minerals as pyrite or marcasite, it is often very compact and passes into lignite; it always, when burnt, leaves more or less ash.

A variety of Turf in Ulster is called "Flow bog," but in Munster "Monagay turf;" it is always full of the stems of reeds and flag-like plants, from which the latter name, and in places extends down through the Brown and Black turfs to the base of the peat. Monagay turf is evidently peat that grew either in a marsh or in the vicinity of a spring where water abounded, and facilitated the growth of water plants and grasses. A variety of Black turf when freshly cut is like soap, but of a pale greenish yellow colour. This turf, if entirely dried, "melts" or disintegrates under the influence of the atmosphere, but if stacked when half dried, it becomes a hard, compact, beautiful turf, that burns with a strong heat and brilliant light; this turf seems due to local circumstances, as it will be only found in a limited portion of a bog. An allied variety is "candle, or gas turf," of a dirty, yellowish-white colour, that has the consistency of soap, and when dried is very inflammable and burns with a clear, bright, steady flame. This kind is rarely found, and only in irregular veins.

The residue, or ash of Red bog peat, generally, but not always, is greater the more deeply the peat is seated. Some mineral matter must be carried up into the peat from springs and the underlying soil;* but usually the ash of peat, as suggested by Mr. Hugh Leonard, "appears to be due to the plants growing on the surface collecting their inorganic food from the atmosphere, and after their decay, to the collected mineral substances being continually carried downwards by the water percolating through the mass. In this way each lower stratum becomes more impregnated than the parts above it, and when burnt its ash is greater."

The mountain bogs in some respects are very different

* The vegetable soil on which the first plants grew, has been quite changed by the subsequent growth of the bog.

from those on the lowlands. The latter usually grow on more or less flat places, having a non-porous substratum, where they form extensive, nearly level plains; while mountain bog may grow on the hill tops or in the valleys, or they may creep up or down slopes over porous or non-porous strata. They are generally shallow, the peat growing much more slowly and more densely than on the low lands, and consist of a *clearing* or "sod," rarely more than 12 inches thick, *brown turf*, and sometimes underneath, *black turf*, the latter, however, is often absent. The great difference between the lowland and mountain peat is for the most part due to the different rates of growth; but not entirely, as in all mountain districts portions of the peat are subjected to denudation by rain, runlets and wind, which carry particles of peat from one place to another, adding to the surface of the growing peat, and keeping it compact and firm. In this way, after rain or wind, a stratum of sedimentary peat may be deposited, afterwards to become interstratified by a subsequent growth of the plants. In flat mountain bogs and also in the lowland bogs (when the latter are situated at the base of a hill or along a river, or in any other place where at times they are subject to floods) layers of sand, gravel, silt, or the like, may be found in the peat; such foreign materials having been deposited on the surface of the bog during freshets, for the peat afterwards to grow over them.

In the mountain bogs the prevailing timber seems to be deal, and some of the sticks are of lengths to which the fir rarely attains in this country at the present day. The absence of remains of the oak seems to suggest that it could not flourish above a certain altitude, which seems to have been about the 400 feet Ordnance contour line, from which it would appear that prior to the growth of the Red bogs, the low lands, and the hill sides to a certain height, were covered with oak forests, while above that height the hills grew deal; the deal trees then flourishing at greater heights than now, as large sticks are now found in some bogs at heights above 1,000 and 1,200 feet.

It is probable that since the Glacial period there have been, at least two ages of the most active growth of peat, *first*, after the great oak forest age; and *second*, subsequent to the deal forest period. That a considerable time elapsed between them on the lowlands is evident; but the cause of the change in the nature of the trees is unknown. There may, indeed, have been a third period, while the now submarine bogs were growing; but it seems more probable, especially in the south-west and west of the island, that the submarine bogs were accumulating at the same time as the lower strata of the subaerial bogs, although now found under such different conditions.

A great difficulty in reference to bogs is to procure reliable data by which to estimate the rate at which they grow. If drained, they will not grow; while undrained bogs do grow. This introduces various complications, as it is known that large areas of the Irish bogs were, at different times, drained, afterwards again to run wild. This specially refers to the lowland bogs, as in the mountainous districts Nature has been less interfered with, and there many facts in relation to the growth of bogs can be advantageously studied. In such places we find that the bogs naturally grow most readily on flats in the valleys and on flat hilltops; but they also creep up and down the slopes, creeping up faster than down. This is due to the bogs on heights being often denuded at their edges, especially in exposed situations, which prevents their creeping downward, while the annual growth and decay of the plants increase their thickness, thus forming low long cliffs in all exposed places; and it is only in sufficiently sheltered situations that the peat covering will extend continuously downward. But bogs creep rapidly upwards, even over porous materials; as the wind, rain, and runlets will add boggy stuff rapidly to the edge, in which heather, moss, and other peat-producing plants quickly grow; and this soil may accumulate on any porous substratum, so that in places in Connemara there is thick peat over deep coarse shingle slopes.

Many bogs are a more or less felt-like mass; but in others each year's growth is represented by a layer or lamina, and these laminæ in the *white turf* are about, on an average, one hundred to the foot; in *brown turf* two hundred to three hundred; and in *black turf* from six hundred to eight hundred; but their numbers are different in the different bogs, as one grows more rapidly than another.*

As yet no human relic is recorded from the Submarine peat; but such accumulations have only been proved by borings or small excavations, while vast extents are unexplored; but in the Subaerial peats they are very numerous. One of the most important was a two-storey log-house in an enclosure, found under 14 feet of peat in Drumkelin bog, Inver, County of Donegal. Each storey of the house was 4 feet high, while under it was 15 feet of bog, making a full depth of 37 feet, over 22 feet of which must have grown around and above the house since it was inhabited. On a level with the floor of the house were the corkers of sallow, ash, and oak; while in its vicinity a piece of a

* In a former estimate, in the already mentioned paper on Peat bogs, I made these numbers much less, but from subsequent research I would make them on an average as above.

leather sandal, a flint arrow-head, and a wooden sword were subsequently found. In 1824, a man's body, clad in woollen garments of antique fashion, was found at a depth of six feet in a bog, in the parish of Killery, County of Sligo ("Catalogue R.I.A.," vol. i., p. 326). In 1783, on the estate of the Earl of Moira, in the County of Down, a female body, clothed in a very antique hair-garment was found in two feet of gravel under eleven feet in thickness of peat. In a bog at Castlewilder, County of Roscommon, another female body was exhumed, having peculiar shoes (pampoota), antique gold ornaments and long black hair. Other human remains have also been found in the Irish bogs.

In Duncan's Flow bog, Ballyalbanagh, County Antrim, a cash (*casan*, a path) or wooden road, under about five feet of "flow bog," was found; and under it was about four feet of black turf. At the base of the black turf are oak logs and corkers, and, on the level of the cash, deal corkers. The road was seven feet wide, formed of round longitudinal oak beams, covered with transverse planking or slabs of oak. In the centre of the bog there were eight longi-

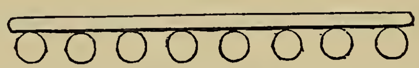


Fig. 17.—Section of Cash, "Duncan's Flow," County Anrrim.

tudinal beams (*see* Fig. 17), but in the north and south portions there were only three, one in the centre and one at each side (*see* Fig. 18); the great number in the centre evidently having been used to bridge over a soft portion, while in the firmer ground, near the margin of the bog, they were unnecessary. Three sections of the road were exposed when the bog was visited, and in that to the south one of the longitudinal beams was found to be deal timber. This roadway evidently was formed prior to the deal-forest age, as none of the associated deal corkers occur under it, but all are on the same horizon. The oak timber to form the road probably was procured from the neighbouring upland, as on such situations they are known to have existed

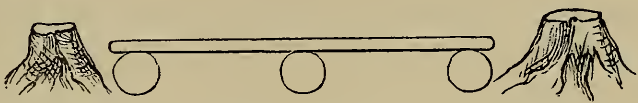


FIG. 18.—Section of Cash, "Duncan's Flow," County Antrim.

during and subsequent to the deal-forest age. The road probably was used as long as the deal forest existed, and during its occupation, holes in the oak sheeting were mended with deal slabs placed across them (*see* Fig. 19).

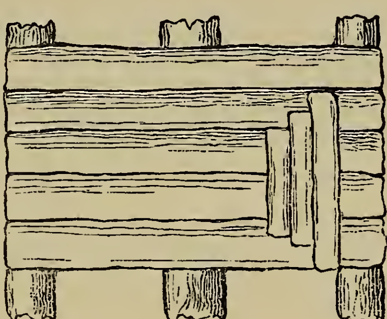


FIG. 19.—Plan of part of Cash, "Duncan's Flow," County Antrim.

After the four feet of lower peat had accumulated, which represents at least 16 feet of uncompressed peat, the climate must have changed for the place to dry, thus stopping the growth of the peat, and forming a surface, on which the deal-trees grew; or it may have been drained artificially. Probably both contributed, as it appears likely, when the road was formed, some drainage also was accomplished, to keep surplus water away. The road seems to have been abandoned and the deal forest destroyed at about the same time, which appears due to flooding, as the peat above both is "Flow bog" (Ulster), that is, peat full of sedge and flaggers, which only grow and accumulate in marshes or flooded bogs. On the roadway there are now 5 feet of uncut turf, while 10 feet of "good turf" are said to have been cut away. Over the good turf there must have been "white turf" and "clearing," which would add at least about 5 feet more to the thickness of the peat over the cash.

On the floors of, and the roads into, crannogs, we usually find cut reeds, ferns, or heather, sand, clay, or some such; but this roadway seems to have been swept clean, and the bog to have grown direct on the planking. In the bog, however, the following have been found—as I have been informed by Mr. J. Wilson, a farmer in the vicinity—near the south end of the cash: a stone hatchet, very large horns of a cow or ox, and four sticks like "walking-staves;" near the centre of the roadway, where Fig. 19 was taken, a shoe, in shape like a weaver's shuttle. It probably belonged to a woman or a small man, "it was near twelve inches long, and very narrow;" also a carved block of wood, which seemed to represent the head and shoulders of a man of ordinary size.

"Other submerged roadways in Ireland are as follows:—A roadway constructed somewhat similar to an American corderoy, in the bog between the old castle of the O'Connings (corrupted into Castle Connell) and the esker called Goig, County Limerick."—"Mem. Geol. Survey Ireland," Explanation of sheet 134.

"A roadway in the bog margining Loughnahinch, King's County, and Tipperary. This evidently was made for the convenience of the crannog in the lake."—*Dublin Quarterly Journal of Science*, vol. vi p. 69.

"A roadway in the 'North Intake,' Wexford estuary. This ran south from Begerin to Great Island. It was constructed of longitudinal oak beams, supported on two rows of oak piles."—"Jour. Roy. Hist. and Arch. Ass., Ireland," vol. ii. (4th series) p. 435.*

Stone huts, sharpened stakes, and methers full of lard or butter, have been exhumed from under bog 10 to 15 feet deep in the mountain pass NW. of Glenbonniv, parish of Feakle, County Clare ; and Jukes stated that the huts were similar to those built by the natives of Newfoundland to shelter them while waiting for the deer in their annual migrations. In the hills NW. of Clifden, West Galway, wattle fences were found stuck in the clay under bog from 8 to 10 feet deep. The ridge of these hills is very uneven, large flat places occurring connected by more or less narrow passes, in one of which this wattle fence occurred, formed of stakes driven into the ground and interwoven with horizontal rods or branches, gaps here and there being left open. This wattle fence answers to the description of the traps for deer in use at the present day in parts of Russia.

Near the already mentioned road at Castle Connell a mether full of a substance like whey was found standing by an oak corker, and five feet higher up is the horizon of the deal corkers, while a little above the latter was the corderoy road, over which was 12 feet of good peat, not including the white peat and clearing. Alongside the road were the remains of old bog holes in which the peat seemed to have been cut by a process similar to that at present in use. The roadway was made of round oak sticks, probably procured from the adjoining hill of Doig.

* Extracted from the "Proceedings of the Anthropological Society," to whose council we are indebted for the woodcuts.

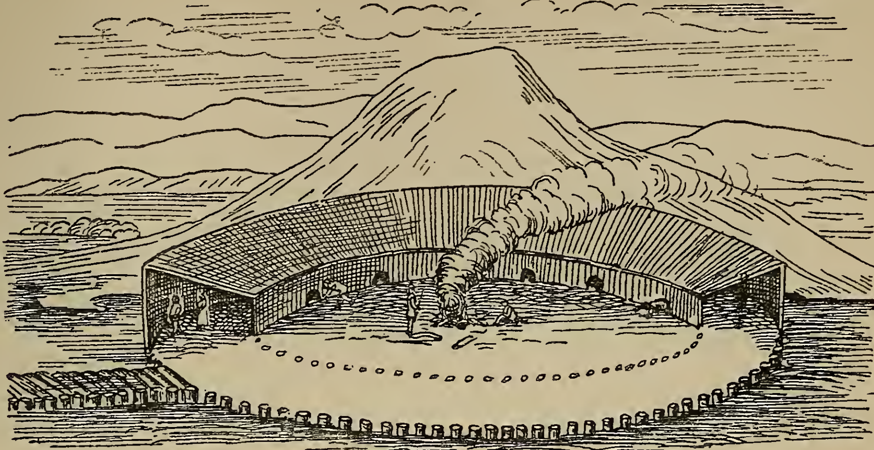
The finds of stone weapons and others, of woollen stuffs, also of butter or lard, are too numerous to mention,* the last occurring sometimes in lumps without the trace of any envelope—sometimes in methers, barrels, cloths, and in conical vessels made of hoops and straight sticks lined with cloth. Some of them evidently were purposely buried, while others seem to have been dropped and were subsequently covered by the growth of peat. There are also the remains of crannogs in accumulations of peat, apparently filling up shallow lakes or morasses; also the bones of the Megaceros Hibernicus and other deer, bears, cows, pigs, sheep, and other animals. A list of the principal Mammalia found in the Superficial Accumulations is given at the end of the next chapter.

Three varieties of pines, distinguished by their cones, are known, *Pinus sylvestris*, *P. pinea*, and *P. pinaster*: the first and last are said to be still indigenous to the country. On the crags near the ferry of Knock and west of Lough Corrib —also in other places—are the remains of very ancient yews, that probably are of a similar age to those in the bogs.

## CRANNOGS.

Crannog is now the generally accepted name for the ancient lake-dwellings in Ireland; it is, however, a modern term introduced to supply the place of the ancient one, which is unknown, or unrecognized. These habitations are invariably roundish or irregularly oval, and were built in lakes and morasses. When in lakes, they were usually constructed in shallow places, by the enlargement of islands, or the heightening of shoals; a few, however, are

* *See* "Catalogue of the R. I. Academy," by Sir W. R. Wilde.



*Elevation & Section of Crannog*

*View looking S. down Glen Coghan, Shewing Driftbar across the mouth of the Valley (about 250) feet.*
*Cashel in the Distance*

*Twelve Pins Mountains looking E (Bennabeola)*

found in deep water. Some were built entirely of stone others of wood, but most of them, of a combination of stones and piles. Some seem to have been made of basket work and sods, and a few stand on platforms like the Swiss lake-dwellings.

The *Stone Crannogs* have been recorded in Connaught and Ulster. The finest and largest is Hag's Castle in Lough Mask, opposite the mouth of the Robe river, County Mayo. This seems to have been built in connection with a small rock or island; outside its circular wall is very deep water. Those recorded in west Galway are, one in a lake in the island of Gorumna, a second in Lough Cam to the north of Roundstone, and a third (see Fig. Plate No. vi.) in Lough Bola, Irrisaniagh; to the SE. of Roundstone a few others also occur. In Ulster they occur in the lakes of the rocky districts of Antrim and Donegal. None of these have as yet been excavated, and their internal arrangement is unknown.

According to the sections of the more usual crannogs, it would seem that in general a portion of a shallow, or a circular belt round an island, was enclosed by one or more sheets of piles usually of split oak, or of piles in which rods and branches were entwined forming a circular wall. Inside these circles, branches of trees were placed on the mud, and over them stones, sods, and branches, until the structure was raised above the level of the water, when a platform was constructed, sometimes quite rudely of sticks, but at other times, carefully made; piles being driven, on which cross beams were laid, and over the latter, basket-work floors, while in other places, the floors were neatly paved (Plate VI).

On the large crannogs, the habitations seem to have been constructed round the edge, leaving an open space in the centre. The outside walls were of round piles, lined inside with sods; while the partition walls were of shingle or double wicker-work, or of sods. These seem to have been the earlier habitations, but in much later years stone structures were erected on the crannogs, and on some, as at Ballynahinch, west Galway, large castles. In the central open space, there are always the remains of one or more fireplaces with heaps of ashes, while outside in the lake is a kitchen-midden where the bones of the animals eaten and other refuse were thrown. Some of the crannogs are joined to the land by causeways; these, however, may not have been original appendages. After the crannogs were built, they were strengthened in such places as were exposed to the waves by stone ramparts and piles; and we learn from the annals that a condition imposed on the occupiers in later years, was the placing yearly of a certain number of boat-loads of stones outside the piling, to prevent damage from the waves of the lakes.

The crannog of Lough Cimbe, now Lough Hacket, County Galway, seems, from the descriptions, to have been originally a platform on piles. There are records of its having been twice destroyed during severe storms; after the second, an artificial island was constructed, stones having been brought from the adjoining land in boats. The large crannog in Lough Rea also in the same county, was in part on a platform adjoining an island—while a smaller crannog in the same lake, the crannog in Loughnahinch at the mearing of Tipperary and the King's County, also others, were platforms erected on piles.

Reed island, or the small crannog just mentioned in Lough Rea, except that it was round, was very similar in construction to some of the Swiss lake-dwellings. On piles driven in the lacustrine accumulation, two sets of horizontal beams at right angles to one another were placed, and on the upper, wooden structures were built. Subsequently, however, when the lake rose, the crannog seems to have been heightened and surrounded with stones brought from the adjoining land.

At the SE. of the large crannog in Lough Rea, are the remains of piles, on to which cross beams were rudely morticed. This crannog is interesting, as its section demonstrates that it was abandoned, and re-inhabited several times. The oldest habitations were built of pilings, basket-work, and sods ; the second of split timber, and sods ; and more recent ones of stones and sods. When the crannog was first erected, the water of the lake must have been about six feet lower than at present. The first habitations were burnt down, after this the lake rose, and before the subsequent habitations were built, the island was raised several feet in height.

After the last time the crannog was inhabited, it was flooded again. During recent years, the lake level has been lowered by two feet or more, yet the ordinary surface of the lake is now nearly four feet higher than the basket floor of the first habitations.

Some of the crannogs are now enveloped in peat ; this was the case with the crannog at Lagore, near Dunshaughlin, County of Meath, peaty matter having grown over it. This seems to be also the case with Crannagh Macknavin, parish of Tynagh, barony of Leitrim, County of Galway, the last crannog mentioned in history—for although it was destroyed by the English as late as 1610, its exact site is now unknown in the tract of bog in which it was situated. Sir W. R. Wilde was the first to direct public attention to the crannogs, in his description of that of Dunshaughlin, read before the Royal Irish Academy in 1840, but since then over 200 have been discovered, the accompanying section (Plate VI.) of a crannog is taken from one of his drawings in the catalogue of the Royal Irish Academy.

In the crannogs are found various kinds of articles, ranging from the rudest flint implements to highly finished golden ornaments.

These are very much mixed up together, but usually in the older habitations, implements of stone and bronze predominate. In the large crannog of Lough Rea, iron (?) implements, with rude stone implements, highly finished stone hammers and sling-stones, and a few rude bronze articles, were found on the floors of what seemed to be the oldest habitations; while near the surface were stone and bronze celts, numerous iron scissors or small shears, a straight sword with a cross handle, a bishop's crozier, a metal die for a medal, and the head and horns of a Megaceros, besides innumerable bones of the ox, pig, sheep, goat, and other animals.

## Kitchen Middens, and other Records of Ancient Man.

The Kitchen Middens have been principally found a little above the present shore line. Those to which attention was first directed, are in the vicinity of the bay called Kenmare River, County of Kerry. Some of these, about 25 to 35 feet above the present rise of the tide, are covered with from one to two or three feet of peat, although the late Mr. W. S. Trench has stated that the oyster shells of which they are principally composed, were put there within the last fifty years. Subsequently, Du Noyer recorded the middens previously mentioned on the coast of Dublin and Meath; while a little later, those at the east end of Galway Bay were described, and at about the same time, others on the coast of Donegal, by Mr. Harte, County Surveyor. Since then middens have been recorded on the islands of Aran, Galway Bay; on the shore of Cashla Bay and Omey island, County Galway; in Bannow Bay and other places in the County Wexford; and at Greenore, County Louth.

Of all of these Kitchen Middens, except those in the County Donegal explored and described by Mr. Harte, very little can be told. In general they consist, for the most part, of the shells of edible mollusks, ashes, and more or less burnt stones, with rude stone flakes which seem to be artificial.

In some places, as at Bannow island, County Wexford, bones of the ox, pig, sheep, and other animals predominate. In the same county, but farther eastward, at the "Bar of Lough," there are two peculiar middens; as seen in the low cliff, masses of ashes, about five feet wide and four deep, occur with bones and shells, in apparently artificial trenches, while over the ashes is from two to three feet of soil. On the shore of Cashla Bay, County Galway, is a remarkable, conspicuous, conical mound, over 30 feet high. It seems to be principally made up of shells, but as yet has not been explored.

Inland, the middens recorded are usually in the vicinity of ancient forts or other habitations, and contain metal implements, such as axes, arrowheads, pins, and such like. A midden occurs at a pre-historic *tuam* or sepulchral mound in Kennycourt demesne, County Kildare, remarkable for the quantity of ox teeth found in it, while other bones are scarce, or broken up into little bits. Perhaps the most important midden is that recorded by Mr. Thomas Plunkett, and discovered at the entrance into one of the Knockmore Caves, County Fermanagh, in which occurred burnt human bones, bones of other animals, iron implements, and other relics.

In the County Wicklow, townland of Knockmillar, to the SW. of Wooden bridge, in the river flat, immediately north of the hill called Lyra (*Anglicè* a fork formed by two glens), Mr. M. H. Jones states that about thirty-five years ago, the Placer-miners found under about 5 or 6 feet of meteoric drift, an oak frame about 14 feet by 10 or 12 feet. The oak beams were neatly squared, the shorter ones being morticed into the others about a foot from their ends. On the outside of all the beams, were rude figures of animals, some being mounted by men. These animals " were like mules with long bobtails, goats or deer, and nondescript animals." The sculpture on the beams was discovered when they were washed, to get rid of the sand and drift, previous to their being sawn into ground joists for the east wing of the Wooden Bridge Hotel.

## Caves (Lusca).

Natural luscas, or caves, are very numerous in Ireland, but fossils and pre-historic relics are not as common in them as might be expected. In Clare and Galway there are numerous caves that were explored by Foot and others without any results ; also caves in the County of Limerick and at the Banteer limestone quarries, County Cork. The last are apparently favourably situated for the haunts of not only wild animals, but also man ; yet, although they have been largely opened by the quarries, nothing important has been found in them.

The first "find" of importance was in the cave of Shandon, near Dungarvan, County Waterford, by Mr. James Brenan. This, as far as the excavations have been carried, has given rich returns in the remains of mammalia; but it may be eclipsed by the caves of Knockmore, County of Fermanagh, lately discovered, and now being explored by Mr. Thomas Plunkett, who has given the following list of the mammalia and other relics found:—*Homo* (remains of thirty-two individuals), *Sus scrofa* (portions of forty animals), *Equus fossilis* (representing about twelve animals similar to those found fossil in France and India), *Cervus*, *Lepus cuniculus*, *L. timidus* (of very large size), *Canis vulpes*, *C. lupus*, *C. familiaris* (representing over thirty dogs), *Bos longifrons*, *Capra hircus*, *Ovis aries*, *Sturnus vulgaris;* also a quantity of flint flakes, sea-shells, some of them wrought into the form of spoons, pottery, and bone pins. Some authorities believe that the remains are quite recent; Plunkett, however, thinks in reference to the deposits, that "there is strong evidence pointing to the presence or operation of ice in this region since these remains were deposited." If Mr. Plunkett is correct it would appear that the *Luscans* or Cave-dwellers of Fermanagh were a race somewhat similar to the Lapps of the present day, who lived portions of the year in places that at other seasons were enveloped in snow and ice.

Caves that have still to be explored are Dunmore Cave, County of Kilkenny; the historical caves of Aille, County Mayo; a cave in the middle island of Aran, Galway Bay, and others in different localities. It has been stated that there is a cave somewhere near Omagh in Ulster from which large bones were taken, but where it is situated is uncertain.

In the Dunmore Cave human remains occur, but this place, as also the Caves of Aille, history tells us, were scenes of various massacres of the Irish by the English; hundreds of the natives being driven into the caves and there smothered. At Aille the mouths of the caves were blown up, so that now they cannot be entered, or even their exact position pointed out.

On the coast of Antrim at Ballintoy, and on Carrick-arede, there are caves in which Drs. Bryce and McDonnell found ox, deer, horse, sheep, and other bones. The cave in the first locality is about sixty-six feet from high water line and about ten feet above it, while the Carrickarede cave can only be entered at low water.

Before concluding this brief notice of the caves, those near Mitchelstown, County of Cork, in the hill to the north of Ballyporeen, may be mentioned. Although it appears probable that they were never inhabited by any Mammalian, yet they are remarkable for their size and the beauty of their interior; the latter due to the variation in form and size of the Stillactites in the different grottos or chambers.

## CHAPTER XVII.

### SOIL; POST-PLIOCENE MAMMALIA.

THE Irish soils may be generally classified as Local and Transported; the former being subdivided into Vegetable and Mineral. *Vegetable Soil*, as the name expresses, is composed nearly solely of vegetable remains; it is the first subdivision of the Local soils. Certain classes of plants grow and die on the surface of the land, forming an envelope which, under favourable conditions, will increase in thickness until it forms a deep bog. In many places, however, this vegetable decay only forms a thin stratum, naturally poor and unproductive, but usually capable of being much increased in value by culture. Such soils are very common in some of the mountain districts, especially in those where "cold" rocks, such as granite, gneiss, quartzite, grits, and some kinds of clays, come to the surface; also over hard subsoils similar to bog-iron-ore. In the lowlands they are also found, occasionally, on the Calp and on clays in the Drift; bog often occurring on the Calp and ceasing at its boundary. An artificial soil similar to this vegetable soil has been formed over considerable tracts by the cutting away of bogs for fuel, and leaving the waste on the subsoil.

The second subdivision of Local Soil, as defined by Kane, is the product of the decomposition of the minerals of which the surface rocks consist. "The water which flows over the surface is absorbed into the pores and fissures of the rocks, and in frost it expands with such irresistible force as to crumble down even the materials of the densest and hardest stone. Independent of the mechanical action of water, the constitution of numerous rocks is such as to cause their gradual decomposition by its chemical action, as in the case of felspar and other minerals, and by the direct action of the atmosphere. All rocks which contain protoxide of iron rapidly decompose and crumble away. As the soils originate from the decomposition of the rocks of a country, those in the areas in which the rocks vary in composition are necessarily the richest."

Areas of quartz-rock and quartzite, unless drift overlies the rocks, are nearly always destitute of soils, except the portions of peaty stuff which form in the hollows and crevices. Other silicious rocks like grit and sandstones produce a small quantity of soil or a poor unproductive sand. On this account areas of the Old Red Sandstone, or similarly constituted rocks, produce tracts of wild heathery land, except where the sandstones are interstratified with argillaceous rocks, the débris of the latter mixed with the sand causing strips of country to be fertile, while the débris of subordinate beds of limestone or calcareous shales will have a similar effect.

In the Old Red and Yellow Sandstones of the Cork type, also in the Carboniferous Slate, there are many beds or series of beds of slate or other argillaceous rocks and some calcareous beds, and although the general aspect of the country is rocky, yet among these rocks there are innumerable small patches of deep rich soil, formed from the mixed silicious, argillaceous, and calcareous detritus that has collected in the hollows. Most granites, like the sandstones, are bad soil producers, but some disintegrate into a coarse sand, as in many places in the granitic range of Leinster. Granitic sand by itself is poor and unproductive, but when mixed with shale or limestone débris the result is often a highly productive soil.

In a metamorphic area the quantity and quality of the soil bear a certain proportion to the intensity of the action which has affected the rocks. Rocks belonging to the gneiss and schist series are usually bad soil producers, except when containing inliers of limestone and other calcareous rocks. In West Connaught and the metamorphic districts of Ulster the beds of calcareous rocks can be detected miles away by the strips and patches of green or arable land upon them.

The submetamorphic rocks, if consisting for the most part of varieties of argillite, are fair soil producers, giving land rather light for pasture, but excellent for tillage; and the hills of these rocks in the Counties of Wicklow and Wexford are productively cultivated to considerable altitudes. Similarly the Cambrian, the Cambro-Silurian, and Silurian rocks, if the argillaceous rocks predominate, form productive but light soils;* and the richness of these soils is much augmented by the detritus of calcareous inlying rocks, or of beds, dykes, or other protrusions of basic eruptive rocks. Among the Silurian conglomerates in the hills west of Toormakeady, County Mayo, is a thick bed of melaphyre, and its débris has formed a belt of rich land. Similarly in the Counties of Wicklow, Wexford, Waterford, Tipperary, Clare, &c., the inlying beds and

* Slate and other argillaceous rocks usually have between them and the soil a shingle that acts as a drain and carries off the manure applied to the land. This, in a few districts, is broken up by the cultivators and mixed with the soil, greatly adding to the value of the latter. Unfortunately, however, this practice is only adopted by a few; while, if it were more general, the value of these slate soils would be greatly increased.

protrusions of basic eruptive rocks among the Cambro-Silurians produce rich soils in their vicinities.

On the limestones of Carboniferous age the soils are very variable. This is, in a great measure, due to the limestone tracts lying low, the consequence being that materials are transported to them from the higher lands and become mixed up with the limestone débris. Such soils, however, belong to the third or transported class hereafter mentioned.

The Calp limestone in general forms a "cold" or a wet retentive soil. It has, however, good qualities, and if treated properly may be made very productive. In the central plain of Ireland the bogs are more deep on the Calp than on the Lower and Burren limestones ; this seems due to its non-porous nature. Bogs, however, are not uncommon on the Shore-beds of the Lower Limestone shale type, their nature being very similar to that of the Calp.

The Burren and Fenestella limestones seem incapable of forming a deep soil by themselves, but the thin soil on them produces rich herbage with great fattening qualities ; lands in Clare, Tipperary, and other counties, on these limestones, being famous for the meat they produce, although the cattle grazing on the land have to push the surface stones about to get at the grass. These limestone soils in places are vastly enriched by the débris of eruptive rocks. To this, in a great measure, is due the richness of the soil of the plain of Limerick and the land in the vicinity of Croghan Hill, King's County ; as in both localities the débris of the associated eruptive rocks is mixed up with that of the limestones.

The *Transported soils* are the richest and most important. The materials forming them may be carried for miles during floods, to be deposited on the flats along the rivers, or by the tide in the estuaries, and in other places by the wind. The most extensive flats in Ireland due to floods and tides, are the Callows along the Shannon and its tributaries, and the Corcasses, or salt marshes in connection with its estuary. The soil in most of these is of great depth, and year after year produces a vast weight of meadow, and, when tilled, of other crops. The Callow alluvium is composed of particles of the various rocks and accumulations forming the land drained by the tributaries of the Shannon and their head waters, calcareous and peaty matter predominating; while in the Corcass alluvium, a large admixture of the débris of shells and other marine products are added to them.

There are considerable Corcasses and Callows associated with other river systems, although these are small compared with those of the Shannon. Of these the most extensive in South Ireland are those connected with the Suir, Nore, and Barrow; and in North Ireland, those in connection with the river Bann. The alluvium of the rivers mentioned is collected from various rocks, but in cases where the water-basin of a river is principally or entirely confined to rocks that are bad soil-producers, the alluvium in the flats is poor, in places a nearly barren shingle, gravel, or sand. The remains of Mammalia are not uncommon in some of these alluvial depostis.

The pulverulent materials generated in the hills or highlands, are carried down by rain, floods, and wind to the lower grounds, to be there mixed with the local detritus, thus causing great variations in the composition of the soils, and in most cases increasing their productive qualities. This is exemplified in the valley of the Lagan, in Ulster, and in the tract called the "Golden Vein," in

Munster; the latter extending from Cashel, in Tipperary, to near Limerick. These tracts are known to agriculturists as the richest in Ireland.

Both the Lagan Valley and the "Golden Vein" receive detritus from numerous and various rocks. The Lagan Valley is on the Triassic rocks, but on one side, in the County of Antrim, are the Miocene dolerite, the Cretaceous limestone, and the Jurassic rocks; while on the other side, in the County of Down, are the Cambro-Silurian rocks, principally argillaceous and granitic. The "Golden Vein" has in connection with it, different Carboniferous rocks, but principally varieties of limestone, with which are associated melaphyres, eurites, tuffs, sandstones, shales, and clay-rocks, sufficient in themselves to form rich soils; but in addition to these is the débris of the Cambro-Silurian slates, shales, and grits, and of the Old Red Sandstone, from the Galtees and Slieve Phelim, combined with the detritus of the rocks of the East Munster Coalfield.

In some places the soil is due to the decomposition of the drift, and has no relation to the rocks of the country. This is the case in parts of Leinster, as in considerable portions of Wicklow and Wexford, where there are marls and shell sands that were transported into their present position by the seas of the Esker and subsequent periods. But in parts of Dublin, Kildare, Carlow, and Kilkenny, although the soil is derived from the disintegration of the underlying limy drift over the granitic rocks, yet it appears highly probable that many of its rich qualities are due to matter carried down in solution by the water draining off the adjoining high granitic ground.

The animals that form soils are earth-worms, ants, rabbits, rats, mice, foxes, badgers, and others that burrow in the ground. Of these, the most important is the earth-worm, and next in order the ant. This is an interesting study, but too extensive to be entered on here; but those interested in it will find the work of these different soil-producers fully discussed in the appendix to my book on "Valleys, and their Relations to Fissures, Fractures, and Faults."

## POST-PLIOCENE MAMMALIA.

The list of these mammalia found in Ireland is at present in a very unsatisfactory condition. In the latest papers published on the subject, by A. Leith Adams, M.D., F.R.S., (*Journal Roy. Geol. Soc. Ireland*, vol. iv. (new series) p. 246) the list is reduced to ten species; while if we add to the lists given by previous writers, the mammalia found in Knockmore Caves, County Fermanagh, by Plunkett, the number is over twenty. In the following list all the mammalia that may possibly be not recent, are included; but as previously stated, the character, in this respect, of the remains found in the Knockmore Caves is questioned.

HOMO? Knockmore Caves. Peat Bogs (page 274).

LEPUS TIMIDUS (*variabilis*)? Knockmore Caves, and elsewhere.

L. CUNICULUS? Knockmore Caves, and elsewhere.

ELEPHAS PRIMIGENIUS. Teeth and bones in Shandon Cave, near Dungarvan, County Waterford. Teeth at Maghery, 8 miles from Belturbet, in Ulster. Reported to have been found in brick clay, near Drogheda, County Meath; also, bones in the County Wicklow?

EQUUS FOSSILIS. Knockmore Caves; Port Ballintoy Caves, County Antrim, and elsewhere.

SUS SCROFA. Knockmore Caves; also not uncommon in the river and lake accumulations. These pigs were of the long-faced variety, somewhat like the old Irish pig, now nearly extinct, but they seem to have had very long tusks, more than twice the size of those of the pigs of the present day. This mammal is not included in Dr. Adams's list, but its presence in a naturally-fossil condition can scarcely be disputed.

HIPPOPOTAMUS. Dr. Moore states that a tusk of a hippopotamus was found in gravel a mile NW. of Carrickfergus, County Antrim. What has become of the tusk is now unknown.

BOS FRONTOSUS—B. LONGIFRONS. The long-faced ox occurs in the Knockmore Caves; while both varieties occur in the lake and river accumulations, as also under the bogs. Bones of the ox occur in the Ballintoy Caves and numerous broken bones in the Crannogs and Kitchen-middens. The finding of the remains of the ox associated with those of the *Cervus elaphus* and *megaceros** in the Crannogs, would seem to prove they were animals indigenous to the country, while some of the bones found in the gravels are evidently fossil.

CERVUS ELAPHUS var. *fossilis Hibernicus.* According to Haughton, the Ancient Irish Red Deer, or *Marsh deer,* as it is often called, was different from those of the present day, having fourteen instead of thirteen dorsal vertebrae.

CERVUS TARANDUS (*Tarandus rangifer*). The first discovery of these of which there is any record, was in the bog of Ballyguiney, near Dungarvan, this occurred in 1761, but the fossils were not determined until they were brought under Dr. Carte's notice in 1863. Other localities are, Curragh bog, near Ashbourne, and Ballybetagh, near

* Lough Rea Crannog.—*Dublin Quarterly Journal of Science*, vol. vi. p. 113.

Golden Ball, County Dublin (in the latter locality they were associated with the remains of *C. megaceros*); Coonagh, County Clare, three miles from Limerick; Lough Gur, County Limerick, and in the County of Meath.

CERVUS MEGACEROS (*Megaceros Hibernicus*). Of all the fossil mammals, the remains of the *C. megaceros* and *C. elaphus* are the most common, large numbers of their bones having been found in some places. It is stated that near Dunmore, County Galway, and in the County Meath, bones of the Irish Elk have been found in the Esker gravels, but the remains of that animal and of the Red Deer are more often found in the clay and marl under the bogs, or in lake and river deposits. It often happens that the skulls and horns are away from the rest of the skeleton; this may be due to the deer having been lost in marshes, as happens to horses at the present day, the body sinking while the head remains above the surface to be eventually carried away, perhaps by floods which would be likely to leave a number together in a sheltered place; thus many heads and horns are often found together without any other bones.

The plain of Limerick seems to have been a favourite, or rather, perhaps, a dangerous place for these different deer to graze in, as so many of their skeletons are found there, entombed in the alluvial deposits. Other places where large finds have occurred are, Turloughmore, near Tuam, County Galway; also, in a boggy tract in the same county, close to Mount Shannon, on the margin of Lough Derg. In reference to the last place, there is a tradition that the hunters in ancient times used to drive the deer into a marsh there situated, for the purpose of capturing them. In the "Elk hole" at Killowen, near the north of the County of Wexford, the remains of man and of from twenty to thirty skeletons of the *C. megaceros* were found. Many other large finds were made during the different drainage and other works, but the most remarkable was that at Ballybetagh, near Kiltiernan, County of Dublin, where in a boggy tract, the remains of over 105 individuals of *C. megaceros* were found associated with bones of Reindeer and other animals.

The late J. R. Kinahan, M.D., made the following suggestions to account for so many remains of *C. megaceros* being found in Ireland. At the present day the Moose and other deer in subarctic and arctic regions migrate during the winter across the ice to pasture on the islands, returning to the mainland before the ice breaks up. If the Megaceros acted similarly during the age when Ireland and England were joined by ice to Europe, more of the deer when weak from want of food would die in Ireland than elsewhere, many being drowned in the marshes and swamps. Also after the climate began to change, and the seasons for the ice remaining on the intervening sea became shorter, many of the deer would be too late in returning; while eventually many of them would be pounded in the island on the final breaking up of the ice.

Capra hircus. The goat is not included in Adams's list, but its remains, besides being found in the Knockmore caves, occur also in the rivers and lake accumulations; while broken bones are common in the crannogs.

Ovis. These also are absent from Adams's list. The sheep, whose remains are generally obtained in the crannogs, although some are also found in the alluvial deposits and in the Ballintoy caves, usually belong to the horned varieties, some skulls having even four or more horns. Hornless skulls also occur in the crannogs.

Cetacea. In the marl of Wexford Professor Scouler found the rib of a whale. A bone supposed to be that of a whale was found in the marl in the Railway cutting at Ballygeary in the same county, but was lost before it was submitted to any competent authority. The bones of different cetaceans are found in various places near the coast in the accumulations of the Æolian drift; but in nearly all cases they seem to be recent.

CANIS LUPUS, C. VULPES, and C. FAMILIARIS. The bones of the wolf, the fox, and the domestic dog, occur in the Knockmore caves and various other places; they are also found in the crannogs.

URSUS ARCTOS, U. SPELÆUS and U. MARITIMUS (?). Dr. Carte records three kinds of bears as being found in Ireland, while Dr. Adams states that only one, *Ursus spelæus*, or *Ursus ferox fossilis*, has been found. Adams's reasons for this conclusion are given in his paper just now referred to. The bears' skulls are so very like those of large dogs that they may have often been found without being particularly noticed. Bears' remains have however been discovered in the County Longford; near Leinster bridge, barony of Carberry, County Kildare, where they were associated with a quantity of heads and bones of deer; in Shandon cave; in Loughgur, County of Limerick; while a skull and tusks supposed to be those of a bear were found near Broadford, County Clare.

The remains of the hare found in the Knockmore caves belonged to larger animals than those at present in Ireland. The breed of cattle with mouse-coloured muzzles met with in West Connaught previous to the famine (1850) were very like the *B. longifrons*; these are now nearly if not entirely extinct. The red deer still exist in Kerry, but they have been extensively crossed by foreign blood. Whether the Megaceros existed into the historical period is still a disputed question, but the evidence seems to be in favour of its having become only recently extinct. At the present day there are wild goats on some of the Antrim cliffs margining the dolerite plateau; while according to the records the last wolves killed in Ireland were in Kerry in 1700, and in west Galway in 1710.

In addition to these mammalia, Dr. Bryce recorded as found in the Ballintoy caves remains of the badger, otter, and water-rat. It is possible, however, that these may be quite recent. Associated with the other bones in these caves were those of several kinds of birds; but as yet there are no authentic records of fossil bird remains in Irish recent deposits.

# SECTION IV.—PHYSICAL FEATURES.

## CHAPTER XVIII.

### ESCARPMENTS, CLIFFS, HILLS, AND COOMS.

It is evident that the sculpturing of the Irish hills is due in a great measure to marine and ice action aided by meteoric abrasion; under the latter being included the work done by the sun, cold, heat, wind, rain, rivers, and surface chemical action; but none of these denudants could have effected much work but for the aid given them by faults, fractures, and other shrinkage fissures in the rocks and the surface accumulations.

We shall not now confine the term escarpment, as some do, to the class of cliffs formed by the outcrop or basset of strata. Such escarpments are not very common in Ireland, on account of the greater portion of the country being occupied by the Lower Palæozoic rocks that have been greatly faulted, contorted, twisted, and denuded. The Upper Palæozoic, the Mesozoic, and the Cainozoic rocks in general have not been much contorted, and as some of the first and all of the others lie more or less horizontal, escarpments occur in connection with them.

On the hills at the junction of Clare and Galway, also in other places, the basal beds of the Old Red Sandstone cap horizontally, or nearly so, the hills of Cambro-Silurian rocks, their boundaries being escarpments, in places continuous for miles. In the Burren, County Clare, the Limestone beds lie nearly horizontal, the escarpments being most remarkable in a tract of country about 20 miles long and 18 wide. Here the rocks are generally bare, and form systems of huge steps, which surround the entire group of hills, from base to summit, in lines that are continuous in and out of all the valleys. In connection with the Coal Measures of Leinster, Munster, and Connaught, there are more or less continuous escarpments at their base.

In connection with the Mesozoic and Cainozoic rocks of Ulster the escarpments are very conspicuous, especially the cliff that margins the great plateau of Miocene dolerite, while the bassets of the different flows or beds of the dolerite form minor escarpments. It seems nearly impossible these great escarpments were, as supposed by some, originally formed by meteoric abrasion; as this denudant at the present time, and ever since the Esker sea period, seems to have been employed in changing the original cliffs into slopes; perpendicular cliffs now being rarely found except where the sea washes the base of the escarpment.

These cliffs in Ulster seem to have been formed at two distinct periods; the base of the slope of the older ones being at about the 270 feet contour line, and the base of the newer cliffs a little above or below the 110 feet contour line. That the former are much older than the latter is proved by the former being damaged by meteoric action, which is well exemplified at the NW. margin of the plateau in the County of Londonderry, where landslips have so obscured the strata between the

Shingle beach at a height of about 1800 feet

Knockadober from Aghada

Burren Hills C° Clare, View looking S. across Galway Bay

Cooms at the margin of the Formnamore table-land C° Mayo.

dolerite and the Carboniferous rocks, that rarely are the Mesozoic rocks found *in situ*. On the other hand, although slopes have been formed below the newer cliffs, yet they are only very partially modified, and the rocks under the dolerite can be easily studied and their positions traced out.

The escarpments of the Cainozoic rocks in Ulster are on nearly similar horizons to cliffs among the Palæozoic rocks in Munster and Leinster. A cliff at the 270 feet contour line occurs in the north-east of the Leinster Coalfield, passing from the Coal Measures into the hills of limestone near Stradbally; while in NW. Munster there are other cliffs on the same horizon that pass from one set of beds in the Coal Measures to higher or lower, or from the Coal Measures to older rocks. Similarly in the Burren, County Clare, at the faults the cliffs will pass from one set of beds to another.

In the Burren the rocks have usually a low westerly dip, rarely exceeding 5°; but in a few hills to the south-east near Corrofin the dip is about SW. at from 10° to 20°. The escarpments or terraces round most of the hills are extremely regular, some being completely circular, (page 260) the best marked examples occurring at about the 100, 275, 450, and 700 feet contour lines, but not in the same beds, as a terrace will leave one to go to a higher or lower according as the beds sink or rise. On a careful examination, it is apparent that all the valleys and fissures in these hills occur along lines of breaks, some of which have considerable displacement, so as to cause quite different beds to be on the same horizon. This is more conspicuous in the adjoining Aran islands, Galway Bay, where there are certain beds of shale and clunch interstratified with the Burren limestone.

As the principal terraces in the Burren are on nearly the same horizons as those of the other Irish hills, it would appear they were formed in the first instance by some universal denudant like the sea, but at the same time it is apparent that meteoric abrasion has greatly modified them; while it is also changing them at the present time. Heat opens the joint lines, and chemical action, combined with wind, rain, and runlets, deepens and widens them, thus gradually breaking up beds into very coarse shingle : or if the joint lines are few and far between, more or less large surfaces are eaten away, part being removed in solution, and the insoluble particles by the wind. Erratics of granite and other hard rocks in places record the amount of weathering since the rocks were uncovered; this is in general about 2 or 3 inches in thickness, but near the sea from 4 to 6 inches.

The perpendicular faces of the terraces appear to be weathered backwards by the wind driving the rain against and into them ; and this, combined with the effects of changes of temperature and chemical action erodes them away. These denudants act more at corners than elsewhere; consequently, all angles are rapidly worn away and replaced by curves, so that they only occur now at recent falls. The falls are due to master-joints opening and getting filled with water, which by freezing, and by means of its weight, gradually wedges out masses of rock. The wind driving along the terraces sweeps them quite clean, and thus prevents slopes from forming; it also acts as much on the base of the cliff as higher up, thus keeping it perpendicular. The few localities in which slopes occur in the Burren, are sheltered nooks or other places in which the wind cannot act. Plate VIII. and Fig. 16, p. 260, gives sketches of some of these hills.

## Hills.

In the introduction it was mentioned that across the central part of Ireland is an undulating plain, while to the north and south are hilly districts. In general the nucleus of the hills is of granitic or Lower Palæozoic rocks, while under the central plain are Carboniferous rocks. There are, however, exceptions to this general rule, as most of the Coal Measures form high ground, while the hills of Antrim are of Cainozoic rocks.

The hills may be generally classed as follows ; those in which the rocks are contorted and crumpled up, they having been elevated by a more or less lateral crushing of the strata ; and those in which the rocks lie comparatively horizontal, being formed either by the strata having been lifted evenly, or by the continuation of the strata having been denuded away, and portions only left.

Everywhere in Ireland the Lower Palæozoic rocks are much crushed, crumpled, and dislocated ; while the Upper Palæozoic and newer rocks in general lie more or less horizontal. In Munster, however, there is a marked exception to this rule, as in that province the Carboniferous rocks in Waterford, Cork, Kerry, and part of Limerick, have been crushed up into sharp folds, the strata standing in places perpendicular, or being even inverted. This marked crushing up, dislocation and overturning of the Carboniferous rocks, occurs principally to the south of the valley and fault running from Dingle Bay to Dungarvan ; although immediately north of it, in the south portion of the West Munster Coalfield, the rocks are also inverted, while farther northward they form marked anticlinal and synclinal curves ; but these undulations die out to the northward in Clare and eastward in Limerick. In the vicinity of the great nearly east and west dislocations north of the lower portions of the Shannon, the rocks have high dips due to their suddenly rising or falling to faults.

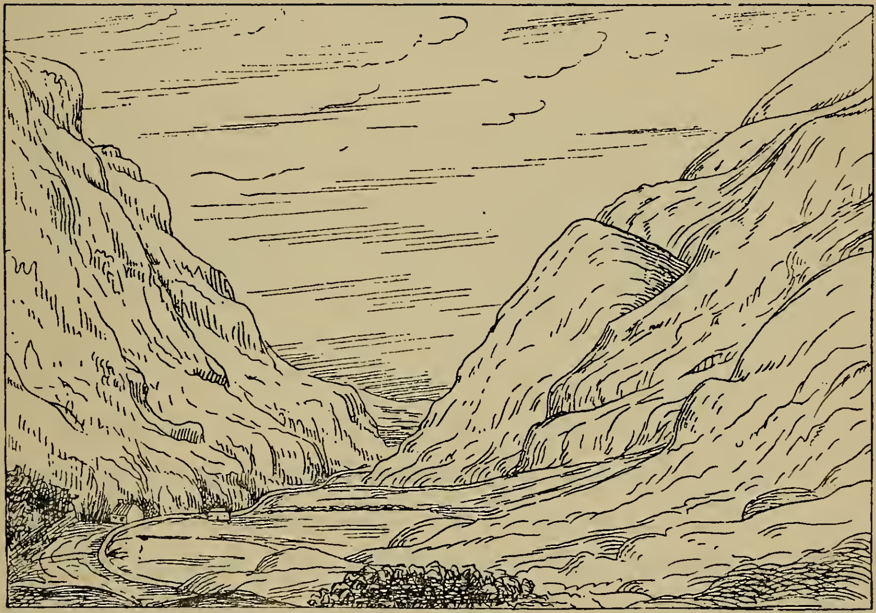
It is evident that prior to the Carboniferous rocks being deposited, except in South-west Munster, and perhaps, also, in South-west Ulster, the Lower Palæozoic rocks were elevated by lateral pressure into hills and ridges, round and among which the Carboniferous rocks were deposited; accumulations of conglomerate, sandstone, and suchlike, margin the hills, and these in general dip away from them. But it is probable that in some places during subsequent movements to which the land was subjected, the ridges were elevated more than the adjoining plains, thus giving a high dip to the arenaceous rocks; in many places, however, the dips of these rocks are not greater than those of shore accumulations at the present day.

The Leinster range of hills south-west of Dublin was elevated prior to the Carboniferous period, as probably were also the hills of West Connaught and the Ulster hills formed of Lower Palæozoic rocks.

In the south-west portion of the central plain there must have been pre-Carboniferous hills, but, the present hills seem, in part, at least, to have subsequently acquired their elevations above the surrounding country (Clare, Limerick, and Tipperary).

In South-west Munster, especially in Cork and the adjoining portion of Kerry, during the end of the Silurian period the land was gradually sinking, while elsewhere in Ireland, except in South-west Ulster, the older rocks were being elevated into hills and ridges. This sinking in South-west Munster seems to have continued until after the accumulation of the Coal Measures, when all the rocks of the country were subjected to violent convulsions that squeezed them up together, and formed ridges and hollows afterwards to be modified into the present hills and valleys. Among the hills thus formed is Carrane-tual (3,414 feet) the highest in Ireland. In this area is the greatest extent of ground above the heights of 1,000 and 2,000 feet; although the high land does not form a continuous mass, being traversed and cut up by deep valleys, one of which, the well-known Gap of Dunloe, is sketched in Fig. 20.

Fig. 20.



Gap of Dunloe, County Kerry, looking north.

The crumpling and distortion of the Cork rocks took place after the end of the Carboniferous period. In Ulster and Leinster, in the country in the neighbourhood of Carlingford Lough, are hills of granitic rocks that were elevated since the Carboniferous period, and probably during the Triassic age. It is therefore not impossible that the vulcanicity to which they were due may have had some connection with the crumpling up, dislocations, and other disturbances of the Cork rocks.

The Coal Measure hills of Leinster and Connaught, the Limestone hills of north Clare (Burren), Queen's County, and Sligo, and the Dolerite hills of Ulster, are principally due to denundation, that cut away portions of the strata, leaving other portions to form the hills. It, however, was not the sole agent, as in many places the same bed or series of beds are now at very unequal heights, proving that they were either elevated or depressed. The numerous minor elevations and depressions, although of local importance, cannot be here mentioned.

The granitic rocks form roundish massive hills about Lugnaquillia (3,039 feet) in Wicklow and Dublin (page 229). This is the most continuous highland in Ireland, a considerable area being over 1,000 and 2,000 feet in altitude. To the NE. of this tract, near Bray, protrusions of quartz-rock form several conspicuous sugar-loaf shaped hills.

Extending obliquely across Wicklow, Wexford, and Waterford, are conspicuous although low hills due to interstratified masses and protrusions of eruptive rocks of Cambro-Silurian age. The Coal Measures of Leinster and Tipperary form more or less regular tablelands, while the isolated exposures of Lower Palæozoic rocks, with their associated Old Red Sandstone conglomerates and other Lower Carboniferous rocks, occur as massive hills; sometimes table-topped, when capped by a horizontal outlying portion of conglomerate; but often peaked, when a sheet of conglomerate dips away from the summit of a hill at a high angle. Keeper or Slieve

Kimaltha (2,278 feet), SW. of Nenagh, County of Tipperary, is a good example of the first, and Galtymore (3,015 feet), south of Tipperary, of the second. In connection with both of these summits may be mentioned the low-seated narrow valleys immediately north of each; called respectively Glencolloo and the Vale of Aherlow. Both of these summits are so conspicuous that they, especially Keeper, were important stations in the trigonometrical survey of the country.

The Glengariff grits and Carboniferous rocks of Cork and Kerry form ridges from which proceed broken

Fig. 21.

Iveragh Mountains, County Kerry, from Ballinskelligs.

lateral spurs, usually rather flat-topped, but in places peaked like Carrane-tual, Macgillicuddy's Reeks, and others farther westward. Most conspicuous among these hills, as viewed in travelling by rail from Mallow to Killarney, are The Paps, a pair of equally high, isolated peaks (2,268 feet), appropriately described by their name. The sketch, Fig. 21, represents the Iveragh Hills as seen from Ballinskelligs.

In west Galway and Mayo there are different characters in the different hills. Those of granite form more or less rounded masses that contrast with the rugged outlines of the hills of hornblende-rock (metamorphic eruptive rocks), such as those in Errisbeg, near Roundstone ; while quartzites form the peaks so characteristic of the Bennabeola mountains ; and the Silurian sandstones, masses like Mweelrea and the tableland of Formnamore. On the latter in places are patches of Carboniferous conglomerate, showing that the denudation which formed the present tableland has just removed the great mass of Carboniferous strata which once covered it. Croagh Patrick on Clew Bay, Slievemore in Achill (of which a sketch is given in Fig. 10, p. 211), and various other peaks in north-west Mayo, are other examples of conical hills formed of either quartzite or quartz rock.

The hills in Erris or north-west Mayo, north of Clew Bay, have their greater slopes southward and their cliffs falling northward. This is also a character of many of the Sligo and Donegal hills ; the latter, like those of Erris, are principally composed of metamorphic rocks, while those of Sligo are for the most part Carboniferous rocks, but all seem to have been scarped by marine action. Some of the latter are shown in the sketch Fig. 6, p. 91.

In Londonderry and Tyrone the general character of the higher hills is massive, and in Antrim and adjoining portions of Londonderry is the great dolerite plateau already described. Down, as the name expresses, consists of numerous low hills, except to the south, where the previously mentioned post-Carboniferous granites protrude to form the Mourne mountains.

The Conical hills that have been already mentioned, are formed of arenaceous or silicious rocks ; the highest being Carrane-tual, formed of Glengariff grits ; while the Old Red Sandstone forms such hills as Galtymore ; quartz rock the Sugar-loaves near Bray; and quartzite the peaks of the Bennabeola mountains. In the grits and the conglomerates, the peaks seem principally due to a combination of a high angle of dip with jointing; but in quartz rock and quartzite, to the rocks weathering into shingle. There are also peaks of other kinds of rocks, but of much lower altitude. The metamorphosed eruptive rocks, sometimes form peaks, like Cashel hill, NE. of Roundstone, west Galway (Plate VII.); while in various places rising from the limestone plains are peaks like Tory hill, NW. of Bruff, County Limerick, which, although small, are conspicuous, rising suddenly from the surrounding plains. The limestone in such hills appears in general to have been subjected to some kind of metamorphic action, as previously described; and to be less fossiliferous, and more hardened than the limestones of the adjoining country; but in some places it would appear as if it was a mass of Fenestella limestone, that had originally been surrounded by another type of limestone, the latter being now denuded away from it.

## Cooms or Corries.

In connection with the hills are the cooms or corries; which are more or less rounded, bowl-shaped hollows or valleys enclosed on all sides but one, by steep, and in some cases perpendicular, cliffs. In SW. Kerry the cooms are very numerous and of great dimensions, some of their bounding cliffs being over 1,000 and 2,000 feet high, and in nearly all of them there are lakes, sometimes in rock-basins, but more often the lake-basin is partially due to a drift accumulation. One of the best known of these cooms is Glen-na-gappul or the Horses'-glen, on the north of Mangerton (2,756 feet), and to the south of Killarney; but farther westward in the mountains of Dunkerron and Iveragh they are very numerous. These cooms are in general on the east or north sides of the hills.

In the neighbouring hills of the County of Cork there are a few cooms, but generally small and insignificant when compared with those of Kerry; in the Comeragh mountains, County of Waterford (so called from that circumstance), there is a conspicuous assemblage of cooms, some being to the south and west, although the larger ones look north and east. In the County of Wicklow, grouped round the summit of Lugnaquillia (3,039 feet) are some very instructive cooms: the two largest are called the South and North Prisons, which open respectively due south and north-west; while other large cooms face to the east and north-east. There are also a few other cooms in the Wicklow mountains, in the tract north of Glendalough and south-west of Glencree, including those at Lough Bray.

In west Galway and Mayo only a few of the cooms can be compared in dimensions with those of Kerry, but small ones are numerous. Among them are two remarkable groups, one forming a line along the north slopes of the hills south of Croagh Patrick, and the others along the north-west margin of the Formnamore tableland. (Plate VIII.) In both localities the cooms are on nearly one horizon, about 750 feet, and among the latter, is Glennawooa, the premier coom of the country, occupied by a lake and having nearly perpendicular sides; others of the corries in the west Galway and south-west Mayo hills, are also at about the same level. The corries in the quartzite hills are remarkable for not having lakes in them, their floors sloping slightly outwards. To the east of Mweelrea (2,688 feet), the highest hill in Connaught, there are two cooms with lakes at about the 1,200 feet contour line; while farther east on the south slope of Benlugmore there is a coom on the same level without a lake. Near the east end of Killary Harbour south of Leenaun is a large coom having floors at about the heights of 320, 750, and 1,200 feet (Fig. 15, p. 257), the latter being very small. There are several well-marked cooms on the northward side of the Maum-Thomoish range of mountains north of Clew Bay.

According to Ramsay, cooms are eminently characteristic of all glacier countries, past and present; while the Rev. M. H. Close points out that in Ireland they are principally found in glaciated hills, and that the majority of them face northward and eastward, and affect high altitudes. For these reasons they are supposed to have been scooped out by small glaciers that occupied the different cooms, the drift accumulation or bars across their mouths being the terminal moraines of the glaciers.

All the cooms in Mayo, Kerry, Cork, Waterford, and Wicklow, appear to have been occupied by small glaciers, some of them up to very recent times. In those of Lugnaquillia, with their associated valleys, there seem to be the remains of three or four of these supposed terminal moraines at different levels, the lowest being at about 450 feet, while the highest, composed solely of blocks, may be seen forming at the present day. In some years, as in the winter of 1876-77, great snow-drifts form in these cooms, and occupy them for three or four months. These drifts, being due to the wind, are generally of about the same size in each coom; and when the surface of the snow becomes frozen, all blocks that fall from the adjoining cliffs on to these snow-drifts slide off them, and form at their margins moraine-like accumulations, which are very conspicuous in the North-Prison, Ballinaskea, and Corrasillagh.

The cooms of the different hills, miles apart, have their floors on somewhat similar horizons; which would suggest, that at first they were cut by some universal denudant like marine action, although subsequently their forms may have been more or less modified by ice. In west Galway there is a gradation from the smallest to the largest cooms; and on the neighbouring coastline are found bays being cut by the sea similar to the small cooms; while larger coom-like bays are being formed, in places, on the coasts of Kerry and Cork.

At the present day snow drifts like those in the Lugnaquillia cooms preserve the cliffs; and the ancient coom-glaciers ought to have acted similarly. Therefore, high up in the hills, especially to the northward and eastward, where such glaciers would remain the longest, the cooms should be most numerous; not because they were formed by the ice, but because they were preserved by it. On the south and west the snow and ice would melt first, thus leaving these portions of the hills exposed to all the vicissitudes of the atmosphere. In nearly all the Irish hills the slopes are longest to southward and westward; while northward and eastward they are steep, or even form cliffs. These south and west slopes seem due to solar influences (perhaps aided by the hot sea winds), the repeated changes from heat to cold, weathering and wearing them away; while the north and east slopes have more equable atmospheres. Thus the old sea cliffs and cooms on the south and west slopes would be weathered away and more or less obliterated. It may also be observed, that all the coom-like bays that are being now cut by the sea are associated with faults or other shrinkage fissures, and similarly faults or other shrinkage fissures are connected with the cooms in the hills. These sea-formed cooms in most cases are not quite as round as the corries or *cirques*, to give the French name. It must, however, be remembered that the corries were, not long since, occupied by glaciers and masses of snow; also that a very slight modification of the cooms now being cut by the sea, would make them similar to the more ancient corries.

# CHAPTER XIX.

## VALLEYS AND SUBTERRANEAN RIVERS.

It is a popular belief that Rivers and Streams have excavated the valleys in which they flow. This may be the case in reference to some valleys no doubt, but in Ireland, in general, the rivers are due to the valleys, not the valleys to the rivers ; the valleys occupying dykes of fault-rock or lines of breaks or other shrinkage fissures in the strata or accumulations in which they are situated.*

West Galway is well adapted to study the connection between breaks and valleys, as large areas of the rocks are bare, or only covered with a few feet of peat, and the breaks in the strata show as if on a map. In this area it is found, with rare exceptions, that even the smallest streams occupy lines of breaks, whether faults or only joint lines ; while, in the exceptional cases, where a stream

* Although most valleys may have originated with breaks, yet it does not follow that all breaks must form valleys. In the older rocks there are more breaks than in the newer. In the Lower Palæozoic they are much more numerous than in the Upper Palæozoic, in the Palæozoic than in the Mesozoic and Cainozoic, and in the latter than in the Drift. Sometimes the newer breaks occur more or less along the lines of older ones, but always each newer formation obliterates most of the older breaks and the valleys due to them. Accumulations of drift, or even bog, may have even surfaces while they are of variable thicknesses. In some mining districts, both for coal and metals, the great faults of the country have been found to run obliquely, or even at right angles to the river valleys, but in such cases the main faults of the country are breaks that are not developed in the highest accumulation of the country.

has been found to cross over a continuous bed of rock, the stream has had very little effect, in some cases not having been able even to efface the striæ and polish due to the ice of the glacial period.

In SW. Cork and Waterford, the rivers sometimes leave the valleys that run along the synclinals in the strata, and cross the bounding anticlinal ridges in transverse breaks. Jukes, in his paper on the River Valleys of SW. Ireland, suggested that the transverse valleys were first formed by nearly N. and S. streams coming from much higher land to the northward, and that, subsequently, the longitudinal valleys were formed by meteoric denudation.* However denuded, it is evident that the transverse valleys run along lines of breaks; while, farther westward, similar valleys are being cut at the present day along breaks by marine action. Westward there are also maums or gaps across the ridge of hills south of Ballydonegan Bay, that have nearly level floors a few feet above the surface of the sea, which must have been cut by marine action; for if these maums had been excavated by meteoric denudation, their floors would slope in some direction. As these maums, and the gaps at present being cut, are similar to the transverse valleys that the rivers occupy, it appears extremely probable that marine action must have had something to do with the excavation of them, more especially as all of them were fiords during the time of the Esker sea. If, however, these were formed by meteoric abrasion, it must have been previous to the Glacial period, as since then meteoric action has not been able to empty

* Jukes, at the time, considered that the "Cork rocks" were once covered by the Carboniferous Limestone of the central plain. Subsequently he had to allow that this was incorrect, and his theory, formed on the supposed Limestone hills, therefore falls to the ground, although it is still quoted.

them of the drift, which is partly glacial, but for the most part marine or estuarine, belonging to the Esker 100-feet and 25-feet seas.

The largest of these rivers is the Blackwater, which rises in the Coal Measure hills at the boundary of Kerry and Cork to the east of Castleisland, and flows south till it enters the nearly E. and W. valley of the great fault line between Dingle and Dungarvan. In this valley it flows eastward to Cappoquin, where it turns at a right angle, and, in one of the transverse fissures, passes through the ridge of Old Red hills to empty into the sea at Youghal. The western portion of the east and west valley is occupied by the Flesk, which empties into Dingle Bay. This river passes by transverse valleys, which, apparently, it ought to have occupied, if such valleys were those which were first excavated. The second river in size is the Lee. This rises to the north of Bantry in the mountain ridge that divides Cork and Kerry, and runs nearly east to Cork, where it falls into its nearly N. and S. estuary, that occupies one of the transverse valleys. This river also in its course passes-by some transverse valleys.

In Kilkenny, Wexford, and Wicklow, the rivers occupy valleys which for the most part are oblique, or at right angles to the strike of the rocks of the country. The Suir, the Nore, and the Barrow, have their sources nearly together in the isolated mass of hills (Devil's Bit Mountains and Slieve Phelim) at the Junction of the King's, Queen's, and Tipperary Counties, and after taking different courses through the south portion of the central plain, join together in the fiords that enter the open sea at the Hook Point. The fiords or estuarine portions of these rivers are in deep gorges cutting transversely across the Cambro-Silurian rocks, in which are many bedded eruptive rocks which, by their displacements, prove the gorges to occupy lines of faults. In the valley of the Barrow there seem to have been successive displacements in different geological times, one having been later even than the Esker sea period, as the gravel of this sea on the west of the valley appears not to reach as high levels as those on the east.

There are some remarkable peculiarities about the valley of the Suir. In the upper portion the course is about NNE. and SSW., as far south as Golden, from which it runs in a south-easterly direction past Caher to Newcastle, where it enters a nearly N. and S. fissure; unable to cross the southward hills it runs north along this fissure to Old Bridge, where it takes an east course past Clonmel to Carrick in the soft Lower Limestone Shales. These, however, it shortly afterwards leaves, and winds along breaks, in and out of the Old Red Sandstone and Lower Palæozoic rocks in the neighbourhood of Waterford, till eventually it joins the estuary of the Barrow, which extends nearly N. and S.

As previously mentioned, the estuary of the Barrow must have been a valley at the beginning of the Carboniferous period; while, during the Esker sea period, the valleys of these three rivers were straits joining the sea in the central plain of Ireland with the sea to the south; at that time, and much later, there was also a channel running south from Waterford to Tramore. At the present day these rivers are tidal for many miles; in the Suir the tide extends a mile and a half above Carrick, in the Nore to above the village of Innistioge, and in the Barrow a mile above St. Mullins, thirty-seven, thirty-one, and thirty-two miles, respectively, from Hook Point. The sea at the present day is effecting scarcely any denudation in these estuaries, its principal work being to carry in sand, and to spread out on the slobs the detritus brought down by the rivers.

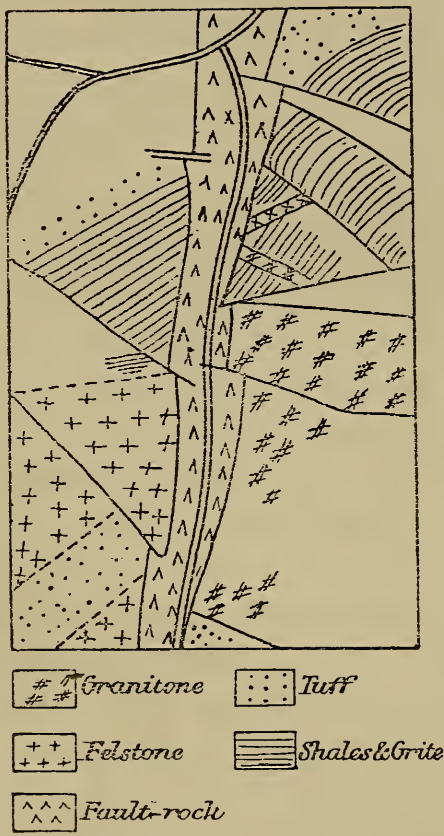
The Slaney river valley is remarkable, as the upper portion is to the westward of the Leinster range of hills,

Fig. 22.

Aughrim River Valley, County Wicklow.

and, apparently, ought to belong to the basin of the Barrow. To this it probably did belong before the Esker sea period, as in the neighbourhood of Tullow, County of Carlow, there is a bank of Esker gravel which deflects the river into the gap through the hills. The Slaney keeps altogether to the W. and SW. of its water basin, and all its large tributaries flow into it from the county to the east, some of them into its estuary, it being tidal up to Enniscorthy, about nineteen miles from the open sea. Wexford Harbour, on the lower portion of the estuary, is a spacious lagoon, margined

Fig. 23.




Map of the Fault-rock in Kilmacrea Pass, County Wicklow.

to the east by long ridges of Æolian sand, called the Raven and Rosslare banks, the length of the two being nearly eleven miles. Nowhere in this valley till it reaches the mountains around Glen-Imale do rocks appear, the river course being cut in estuarian sands and gravels belonging to the Esker, and the more recent, seas. Spencer calls the Slaney the "Sandy Slaney;" this may refer either to the sands at the mouth of the Estuary, or to the sands through which the river flows.

The Ovoca and its tributaries, which drain the greater portion of the County of Wicklow, occupy deep narrow valleys excavated along lines of faults, that of the Aughrim river being shown in Fig 22. Along these fault-lines dykes of fault-rock seem to occur, as can be seen at the Ovoca mines, in Glenmalure, and in some of the neighbouriug fissures, like that called Kilmacrea Pass, of which the accompanying is a map (Fig. 23). Here the fault-rock is shaly flucan with hard ribs, having a stratification transverse to the strike of the rocks of the country.

The following valleys; the Vale of Ovoca, the Vale of Clara (Avonmore), and Glenmalure (Avonbeg), were fiords during the time of the Esker sea, the terminal bars in the two last being very conspicuous at the Seven Churches and Drumgoff, where they separated the sea from lagoons. In Glenow (Aughrim river) the Esker sands are not conspicuous, and the drift presents peculiarities, which would seem to suggest that during this time ice occupied the valley. The Avonmore and Ovoca, from their source at Crockan Pond (1,770 feet), on the NNW. of Lough Tay, have all their principal tributaries coming from the hills to the westward; and nearly all the basin of the Vartry seems to have been at one time included in that of the Avonmore, as the water of the Vartry is deflected out of the upper part of the valley into the gorge of the Devil's Glen by a drift bank only a few feet high; one of the tributaries of the Avonmore rising on this bank a few perches distance from the NW. end of the gorge.

The Liffey rises near Sally Gap in the Wicklow mountains, only a few miles south of Dublin; and after a circuitous course of over sixty miles westward, northward, and eastward, through the County of Kildare, it enters the sea at Dublin. The mountainous portion of this river valley, as also the valleys of all the small rivers and the tributaries of the larger ones, in the Dublin mountains and the adjoining portion of the County of Wicklow, are of a different type from those in the south of Ireland; for although in most portions of their courses they follow breaks, yet in many places they cross continuous masses of rock, that cause cascades and waterfalls, a thing rare among the southern rivers, except in some of their mountain headwaters. The principal waterfalls are Glenmacanass, on one of the tributaries of the Avonmore; Powerscourt waterfall, on the Dargle river; and Poulaphuca on the Liffey, at the boundary of Wicklow and Kildare.

It seems remarkable that the Liffey should cross the rocks at Poulaphuca, as its course was previously in a direct line a little farther south. To the NE. of the fall there was an extensive lake or other sheet of water, and apparently it would have been easier for the stream to deepen its old bed than to cut the present ravine. If a dislocation formed the ravine, it must have been a very irregular one, as it has not much the appearance of a line of fault; still residents state that chaff thrown into the river above the bridge finds its way by a subterranean passage to the pools below the fall. There are here and farther south, at Holly-wood, traces of very recent faults and displacements, to one or more of which the diversion of this portion of the course of the Liffey may be due. Westward and south of Bray are the two great maums called the Scalp and Glen of the Downs. These lie in lines of fault, and were probably excavated by marine action, aided by ice, along dykes of fault-rock. The last was a fiord during the Esker sea period, and possibly the Scalp also; if it is allowed that since the Esker sea period the country north of the valley of the Dargle has been raised more than that to the south thereof.

The Boyne commences in the bogs of central Ireland, and flows north-east to Drogheda. Its valley has not much the appearance of a fault line, yet, when sinking the foundation for the viaduct at Drogheda, it was found that the Calp limestones are thrown down northward over sixty feet.

The Bann has its source in the Mourne Mountains, County of Down. It first flows northward, then NW. to Gilford, where it joins the great valley and fault between Coleraine and Carlingford Lough, in which it runs northward; but it appears that if the drift were cleared out of the valley S. of Gilford it would run southward into Carlingford Lough. This accumulation of drift and the deflection of the river seems to have occurred in recent times. The river Foyle and its tributaries, as also the rivers to the north-west in the County of Donegal, manifestly follow dislocations in the strata, some of them apparently being very recent faults.

The Shannon, the premier river of Ireland, is considered to have its source at the "Pot of the Shannon" in Cavan, a great gushing spring out of the limestone under the Coal Measures of Cuilcagh. The stream from the Pot is not, however, the largest stream flowing into Lough Allen, out of which, at the south end the Shannon flows as a considerable river. South of Lough Allen, the Shannon and its tributaries, some of which are very large, such as the Inny, the Brosna, the Suck, and the Maigue, drain a very low tract of land, most of it, except some of the land adjoining the head waters, being below the 250 feet contour line. From Carrick-on-Shannon to Doonass at Castle Connell, County of Limerick, the river is characterized by being margined by extensive flat bogs and callows (alluvial flats), as if the valley had once been a series of lakes which were subsequently for the most part filled up by bog and alluvium; some of the lakes, however, still remaining, such as Loughs Derg, Ree, Forbes, and others.

It is evident that the valley of the Shannon in general coincides with lines of breaks, although in some places continuous rocks cross it. A little NNE. of Portumna a bench of rocks crosses the bed of the present river; at Killaloe it breaks across a ridge of Cambro-Silurian rocks, and at Doonass are limestones making the fall. That the river crossed the rocks in the last two places seems to be due to diversion, caused by drift accumulated during the Esker sea period, as before that time the channel would seem to have run SE. from the bay of Dromineer, Lough Derg, towards Nenagh, and thence SW. by Birdhill to Annacotty. This channel, however, was filled up by accumulations of drift to the NE. of Birdhill and to the east of Castle Connell, which forced the water to find a new channel. If the river had kept to the ancient course, the surface of Lough Derg would be about 60 feet lower than at present. This fall from Lough Derg to below Doonass is the greatest in the main river. The eskers of the central plain cross the valley in a tract extending from Meelick to Athlone. These ridges of gravel, although cut through by the river, are not obliterated. Besides, as they narrow the valley in places, they raise it from 108 feet, the height of Lough Derg, to 122 feet, the height of Lough Ree; from this it rises gradually to about 160 feet in Lough Allen.

The eskers crossing the valley of the Shannon, the "Rock of Killaloe," and the limestones at Doonass, show what small power a river has to deepen its bed. This mighty river has been running over these gravel ridges and these rocks ever since the Esker sea period; yet it could not cut to the base of the eskers; while at Killaloe it was only able to remove the drift off the rocks, and similarly at Doonass the limestones are but slightly worn except along the lines of joints.

## Subterranean Rivers.

In some of the mountainous districts such as those of Cork, Kerry, Galway, and Clare, streams are for short distances subterranean, or lakes have subterranean outlets. These seem in most cases to be due to dykes of incoherent fault rock through which the water flows as through shingle; and such often get choked, especially in a boggy country, by particles of matter being carried into them; thus causing the waters to rise and form surface channels. In Slieve Aughter, County of Clare, there are subterranean passages that have been dissolved out along the joints in the peculiar limestones which in places form the basal bed of the Old Red Sandstone. In the Upper Limestones, however, are found the great systems of subterranean rivers, with which are associated lakes, Turloughs or Blind lakes, and holes, locally known as Sluggas, Swallow-holes, or Pot-holes.

The *Turloughs* and *Sluggas* are remarkable features. The latter are due to portions of the rock falling into the underlying vacancies made by the subterranean rivers; sometimes the courses of the rivers can be traced by them; in some localities they are dotted irregularly over a tract of ground as if the ground was traversed by numerous subterranean streams. Some are abrupt deep holes, others open into shallow hollows ; and when the water during floods rises in the latter, it overflows the adjoining land, forming the turloughs, which are usually lakes in winter and callows in summer. The subterranean channels seem to have commenced by the water dissolving out vacancies along joints and other weak portions of the rocks, more in some places than in others ; as the channels and the streams increase in size, vents (sluggas or pot-holes) break in from the surface, and stones and such like find their way into the stream, thus causing the currents to act more like surface ones, abrading as well as dissolving away the rocks.

A slugga is usually shaped like an hour-glass, although some have perpendicular sides ; they seem always to be formed from below. The water of the underground rivers and streams during floods acts upwards, in the joints and other weak portions of the roof, till eventually openings are formed, connected with the surface, while afterwards the holes are more or less increased in size by meteoric abrasion.

In the limestone country between the estuary of the Shannon, and Killala Bay in Sligo, the rivers and streams are more or less subterranean, the best developed system being in the neighbourhood of Gort. Lough Cooter, near Gort, receives the drainage from most of the north-west portion of Slieve Aughter. The Beagh river flows out of Lough Cooter, having for about two miles an open course, when it disappears in the limestone under a drift cliff. But its course can be traced by sluggas, called the *Devil's Punch-bowl*, the *Black Weir*, the *Ladle*, and the *Churn*, to *Pollduagh*, a cave, out of which it again comes to the surface. After this it is an open river for about three miles, when it sinks again SE. of Killarten, but rises west of that village to again sink and rise several times, till eventually it finds its way into Coole Lough; into which the Boleyneendorrish river and Owenshree also flow. These are similar in their passage across the limestone, being in places subterranean; and the combined waters of these rivers, during floods, form an extensive turlough, over five hundred acres in area, in connection with Coole Lough. From Coole Lough the water finds its way by subterranean passages to the sea. Part seems to flow into Galway Bay at Kinvarra, in the vicinity of Dungory Castle, a distance of six miles as the bird flies; but the water does not all come out here; some may have vents in Galway Bay, but it is popularly believed that a considerable portion of it goes south into the lakes that join with the Fergus; thus flowing into the estuary of the Shannon.

In connection with this river system are Caherglassaun Lake, the small turloughs in its vicinity, and a small lake west of Gort, which rises and falls with the tide in Galway Bay. This rise and fall cannot be observed during floods, on account of the expanse of water, when it is so small as to be scarcely perceptible; but at other times it is most marked.

To the south of this area is the water basin of the Fergus. The main stream bursts, as a fully formed river, out of a limestone cliff under the Coal Measures a few miles north-west of Ennis; to the north and north-east are numerous lakes that have an underground connection with the Fergus, and also, probably, with Coole Lough. To the east of the basin of the Fergus, at Kiltannon, are the celebrated Tomines, or immense natural vaulted passages in the Limestone, through which the river Ardsolla winds an extraordinary course. These present a scene of magnificence never to be forgotten by those who have viewed it. South and west of Galway Bay, in the Burren and in the County of Galway, nearly all the rivers and streams are more or less subterranean. In the latter district there were formerly most extensive turloughs; now, however, surface canals have been made throughout all the area; these only act in winter, and prevent the turlough forming, while in summer the underground passages are sufficient to carry off the water.

In the Upper Limestone country of the Burren type, to the north of Galway, especially in the water-basin of Loughs Corrib and Mask, the rivers were formerly, for the most part, subterranean, here also the land has been relieved from the winter floods by artificial cuts. This is especially the case in the neighbourhood of Tuam, where there were formerly extensive turloughs, in which the water now never rises. The Aille river, however, has not been opened up, and at the Caves of Aille (Upper Aille) the winter floods often rise over 50 feet. Farther northward there are subterranean streams connected with the water-basin of the Moy, although the main channel, from its source near Ballaghaderreen to Killala Bay, is open. In the County of Fermanagh, in connection with the water-basin of the river Erne, are many subterranean rivers and streams, more or less of similar character to those already described; some fine arches and caves occur in places.

## CHAPTER XX.

### BAYS, LAGOONS, LAKES, AND ISLANDS.

THE bays round the coast occur, more or less, in systems, due to breaks or other peculiarities of the rocks in which they occur. On the south coast all the bays have a tendency to run north and south; but in their upper parts they nearly always turn and run westward. Their directions are due to prominent breaks in the rocks.

On the west coast of Cork and part of Kerry they bear about N. 60° E., having in general been excavated in the troughs of the synclinal folds of the rocks, except, perhaps, Dingle Bay, in which there is a great line of fault. From Dingle Bay northward to Donegal Bay all the principal inlets run eastward. But in Connemara or west Galway there are lesser bays that run north, south, and north-east; while in north Mayo they have N. and S. bearings. In north Ulster (Donegal and Londonderry) the bearings at first appear to be very irregular, but when examined, they seem in general to be associated with two systems of breaks that bear nearly N. and S., and NE. and SW.

On the east coast bays are not very numerous. Those in Ulster run in different directions, while those south of Carlingford Lough have a tendency to extend east and west. All of the latter, except Dublin Bay, are more or less filled up with sand, or have become lagoons. To the north o Dublin there are the estuary of the Boyne and the bays at Rush and Malahide, the entrances to which have been blocked by great accumulations of Æolian drift, and in part formed into lagoons; but the most typical lagoons occur south of Dublin Bay, viz., at Wicklow, where the long lagoons to the east of the railway are now more or less filled by peaty and alluvial accumulations; at Wexford Harbour, where a considerable portion of the mudlands are now Intakes; on the south coast of Wexford at Lady's Island lake, Tacumshin, and Ballyteigue, the latter being now an Intake; and on the coast of Waterford at Tramore: there are also minor lagoons associated with these, which are now all more or less filled with peaty deposits. There are lagoons on the west coast of Mayo, south of Clew Bay; these, however, are very shallow, and have low dividing bars between them and the sea. Above the upper part of Dublin Bay there seems to have been once a considerable lagoon; but improvements to the port have nearly obliterated the enclosing bar, while the estuarine muds and salt marshes have been enclosed and built upon. The lagoon, however, not very long ago extended up to Dublin Castle. In south-east Ireland the sea is encroaching considerably on the land, and the lagoon bars are being gradually pushed inwards.

All the bays, except, perhaps, those of west Cork, are intimately connected with lines of dislocation in the rocks; but in some places the denudant that excavated the original valley left one break to occupy another; a good example being the fiord of Killary bay, which, beginning at its lower end, runs first along a SE. break, then along an E. and W. break, and at its upper end along a NE. break. The relations between the breaks and bays are very manifest in west Galway, in Donegal, and other places, but to give the details would occupy too much space.

## Lakes.

In connection with lakes the greatest point of interest is the basins in which they occur. These may be classed as *Rock basins*, *Drift basins*, and *Bog basins*. Many, however, partake of the nature of two, or even of all three, of these classes.

Rock basins are hollows in the rocks. In many cases the bed of the lake may not be now a simple rock basin, but it is evident that the basin originally had that character, and that its present conditions are due to subsequent accumulations. On examination it is seen that the basin of Lough Neagh, in Ulster, the premier lake of Ireland, was originally a hollow or valley bounded by rocks ; afterwards it was filled more or less by accumulations of plastic clay, sand, and vegetable matter, which subsequently were in part denuded away, and a new basin formed, which is again being filled up by alluvial deposits.

Lough Corrib, the second lake as to size, is now nearly entirely margined by rocks, except some of its bays and the south end. It appears to have been, before the glacial period, a rock basin, but during that time it was partly or wholly filled up by glacial drift, which in some way or other has since disappeared, leaving a few mounds forming islands as records of its former existence. The other large lakes of Ireland, most of them at least, are clearly in rock basins.

The mode of formation of rock basins is a disputed question. As pointed out by Ramsay, they are characteristic of all glaciated regions, past and present, whence it would appear that ice helped to form them. In west Galway, where they are numerous, they are found to be connected, in most cases, with lines of breaks; their greatest length and breadth, and the bays which branch off from them, always coinciding with prominent dislocations of the strata; but in a few rare instances it is possible that they may have been scooped out of softer strata; furthermore in the Errisbeg hills, near Roundstone, and in Lettermore north of Ballynakill Bay, since the glacial period, rocky basins, or deep rocky dells, due to the drying and contraction of the rocks, have formed at the crossing or junction of two or more faults. These are not, and probably never will be lakes, as all the water escapes from them on account of the dykes of fault-rock being loose and incoherent.

As the rocks in most of the small rock basins of west Galway are ice dressed, it appears probable that after the basins had in part been formed by the breaking up and shrinkage of the strata, the glaciers as they passed along lifted up and carried away all loose blocks and *débris*; at the same time wearing off the angles and projections, and in part modifying the rock basin. Similarly, in the large basins, the dislocations of the strata produced the original basins, while ice cleared out all loose materials, and more or less modified their forms.

Ice, however, could not alone have formed the large basins; as the charts of them show that they are not of the forms which could be produced by a denudant working similarly to ice, as pointed out by Mr. J. Ball, in his paper "On Soundings in the Lake Como." * The Irish lakes of which there are charts are Loughs Neagh, Corrib,

* *Geol. Mag.*, vol. viii. No. 8, August, 1871.

Mask, Derg, and the other lakes connected with the inland navigation. Of these Lough Derg, on the Shannon, especially shows the connection of its form and of its bays with the faults in the rocks of the adjoining county.*

Drift basins are situated in hollows in the drift. Some seem to be due to original hollows in the deposit, but others have been formed by the subsequent growth of bars or other accumulations. In some places, but especially in parts of Wexford, are peculiar small lakes and ponds that have no surface outlet; some of them may be due to original hollows in the drift, but many seem to have been formed by portions of the ground sinking; this may be owing to the underlying rock giving way, as previously mentioned when describing the sluggas, or from a pocket or lenticular mass of sand in the drift having been gradually carried away by a subterranean stream, forming a hollow into which the overlying beds sank. That they are due to some such causes is suggested by the fact that they occur in more or less regular systems, and are often connected by slight hollows on the surface of the ground as if over subterranean streams.

In many other places hollows in the original surface of the glacial and newer drifts are now filled with water. This is frequently the case in mountain valleys, but there are many hollows in the Esker and newer gravels, which on account of their porous nature will not hold water. In some of them, however, vegetable accumulations have formed a layer of non-porous matter, and in such as these shallow lakes occur.

Among the hills some of the drift basins appear to have been due to agencies described by Hooker, Forbes, and other mountain explorers; moraines, avalanches, and

* "Valleys, and their Relations to Fissures, Fractures, and Faults," p 153.

other *débâcles* of rocks, stones, clay, and mud, damming up the water; others are formed by streams creating a bar across a valley, and some are due to recent landslips. A stream or glacier may descend into a lake, forming a stragh or delta; if subsequently the lower barrier be diminished in height, two lakes form at different levels. This is well exemplified at the classical Glendalough, County Wicklow; the original lake or lagoon that extended from the Seven Churches westward was, near its centre, barred across by *debris* that was carried by a torrent or glacier out of the ravine called Lugduff; while subsequently, when the sea retreated out of the adjoining valley, the bar, on part of which the Seven Churches stand, was cut across, and the lower part of the lagoon almost entirely drained, only a small lake now remaining. The surface of the lagoon was a few feet higher than the present Upper Lake, as shown by the marginal terrace on the slopes of the hills to the north.

Bog basins are surrounded by peat, and often have no surface outlet. They are supplied by springs, which in general come from breaks in the underlying strata. As the peat grows it cannot cover up the springs, but forms a a wall round them, thus ponding up the water and forming a lake. When one of these lakes is situated on low ground it is often associated with a morass or swamp: but if on high ground, its margin is well defined, and usually higher than the surrounding bog. This high prominent margin is due to the spring-water equalizing the temperature during all the year; so that even in the heat of summer or the frost of winter, vegetation is going on in the vicinity of the lake, in some cases extending over considerable spaces, and raising the bog so fast that the lakes eventually are on the watersheds of the bogs.

Some of the bog lakes have perpendicular sides, or they may even cove in; others, however, have boggy sloping sides. This difference seems due to the springs being perennial in some lakes, and dry during summer in others. The drainage from a bog lake is usually by soakage through the surrounding peat, but in some cases cracks form in the peat during the dry weather, through which the water flows and converts them into open streams; or, as is often the case, an artificial cut has been opened. In the mountainous districts the lakes of this kind are usually small, some being mere pools; but those in the low lands, in the Red bogs, are more or less considerable in size.

A remarkable bog lake occurs in west Kerry on the north of Killmakilloge harbour. This is situated in the centre of a grassy flat, and is margined by a fringe of reeds; on this flat, a Patron or Saint's festival, is held on St. John's Eve (June 24), and the reeds move out into the lake. This movement is evidently due to the weight of people on the flat, its soft subsoil pressing out towards the lake while the people are on it, but returning to its original position when the weight is taken off.

In Ireland lakes are more numerous in the more strongly glaciated tracts than elsewhere, and in west Galway they are innumerable, varying from small ponds or *loughauns* in bog basins up to the large sheet of Lough Corrib. In this area all the different kinds of basins occur, and can be easily studied. In the low portions of Mayo, Galway, and Clare, are the lakes previously mentioned in connection with the subterranean rivers. In Kerry are the well-known lakes of Killarney, with other similar ones, and besides, there are numerous and remarkable tarns embosomed among the hills, in the previously described cooms. In Cork, besides the lakes at Inchageelagh and Gougane Barra, there is a host of small ones on the high ground immediately west of Glengariff.

In the central plain of Ireland there are not many lakes. Those along the Shannon Valley have already been mentioned, when describing that river; but there are also the beautiful Westmeath lakes that feed its tributaries, the Inny and Brosna. In Cavan and Monaghan there are many small lakes, the largest being Virginia Water; and in Fermanagh the principal ones are the two Loughs Erne, with their innumerable islands; while in Sligo and the adjoining portion of Roscommon are the picturesque Loughs Gara, Kay, Arrow, Gill, and Melvin. In Donegal the lakes are somewhat like those of west Galway, but smaller, and less numerous.

## Islands.

Off the West Coast, especially in Donegal, Mayo, and Galway, islands are numerous. Of these the largest is Achill, but the sound between it and the adjoining part of Mayo is fordable at low water. The islands in Clew Bay are noticeable for their number and their consisting of drift, and those off the Coast of Galway, as being the peaks of the western continuation of the ridges from the Bennabeola Mountains. To the north of the entrance to Galway Bay is a remarkable archipelago; and at the mouth of the bay are the three islands of Aran, which tradition says were formerly joined to the Burren, in Clare. Off the coast of Kerry are some remarkable stacks of rock, including the Skelligs. These are generally the first land sighted by home-bound ships from America. A little to the NE. of them is Valentia, separated from the mainland by a narrow channel and harbour.

On the W. coast of Cork is Dursey Island, severed from the mainland by one of the transverse valleys mentioned when describing the rivers, and off Dursey Head are three remarkable sea rocks called the Bull, the Cow, and the Calf. On the south coast of Cork is an archipelago, the most southern island being Clear, but the most southern land is the rock called the Fastnet, which lies four miles south-west of Cape Clear. It is also striking for its aspect, as it rises with nearly perpendicular sides to

Fig. 24.

Skelligs, County Kerry.

a height of about 95 feet from the water, with not much more than room for the base of the lighthouse that stands on it. It is represented in the vignette on the cover of this Book, from a sketch by Wyley taken during one of my first field lessons. The different N. and S. straits between Clear and the other islands are parallel to the already described transverse valleys of south-west Cork.

It is remarkable that there are no islands, except the Tuskar rock, off the E. coast of Wexford and Wicklow, as the masses of interstratified eruptive rocks in the Cambro-Silurians might have been expected to form prominences there as on the land ; yet it would appear from the charts that they do not do so anywhere E. of the coast line. Off the Dublin coast are Lambay, a considerable sized island, Ireland's Eye, the Skerries, and the remarkable sea-rock called Rockabill.

# SECTION V.—ECONOMICAL PRODUCTS.

## CHAPTER XXI.

### MINES AND MINERALS.

INDICATIONS of the ores of minerals are frequent in Ireland, but only in comparatively few places are the minerals found in large quantities ; in some promising places, however, no deep trials have been made as yet. The ores oftenest found are those of iron, copper, lead, sulphur (iron pyrite), and barytes ; while others are antimony, manganese, cobalt, arsenic, and tin. Native gold, silver, copper, and sulphur, auriferous copper ore, argentiferous lead ore, and nickeliferous pyrrhotite (magnetic pyrite), also occur. Other useful minerals are salt, gypsum, steatite, magnesia, pipe-clay, etc.

### GOLD.

Gold has been got principally by *Streaming*, or *Placer-mining*, being found in diluvium near Slieveanorra, County Antrim, in the Moyola river, County Londonderry, in the Dodder, County Dublin, and in different tributaries of the Ovoca, County Wicklow. Of the finds in Antrim and Londonderry little is known. In reference to the first, gold was found in the streams from Slieveanorra into Glendun, prior to 1820; while in other streams from the same hill, into Glenshes and the valley of the Bush, there are ferriferous sands. The gold of Londonderry is mentioned in Gerard Boate's "Natural History of Ireland," written about the time of Charles II.; since then no gold has been recorded from the latter locality; but in some of the head waters of the river near Moneyneany there is ferruginous sand very like that which accompanies the gold in auriferous regions. Small pieces of gold have in late years been picked up in the gravel at Glennasmole, part of the valley of the Dodder; while, quite recently, a small nugget of gold was found in St. Stephen's Green, Dublin, in a load of gravel brought from the valley of the Dodder.

That the gold in the mountains of Dublin and Wicklow was worked by the ancient Irish seems proved by the annals. One of the names by which the people of Leinster were called was *Laighnigh-an-oir*, or the Lagenians of the gold; and we are told that the king, Tighernmas or Tiernmas, who reigned about 1000 years B.C., was the first that smelted gold in Ireland, and that the mines were situated in the Foithre, or woody district east of the Liffey (the Dublin mountains). The name of the artificer is said to have been Uchadan, and his residence in Fercualan, or the present barony of Powerscourt. Although no gold has lately been found in the valley of the Liffey or those of its tributaries, yet in some of the valleys are rugged places that may possibly be ancient "diggings," or placer-mines; while at the hill of Lyra, nearly a mile SW. of Woodenbridge, County Wicklow, ancient workings were discovered 35 years ago, and about the same time the oak frame described at page 284, which was supposed to have had some connection with the ancient miners.

Other kings also are mentioned who introduced certain golden ornaments, or made the custom of wearing them common. In proof of these traditions and records are the quantities of ancient gold ornaments found in various parts of the country, many of which are now in the Royal Irish Academy's collection, Dublin. Near the village of Cullen, on the borders of Limerick and Tipperary, there is a bog long celebrated for the quantities of golden ornaments found in it. For the last 100 years they have been dug up at the bottom of the bog associated with crucibles, ladles, and other implements necessary for working the gold; as if—as pointed out by O'Curry—this place was anciently inhabited by a race of goldsmiths who carried on the manufacture of gold ornaments in the woods that existed prior to the growth of the bog. O'Curry suggested that these goldsmiths were those whose genealogy is given in the Book of Lismore; they would be, if so, descended from Olioll Olum, King of Munster, and according to the annals they followed the trade uninterruptedly for seven generations, from about A.D. 300 to 500 (O'Curry, Lecture III., 205); the depth of the bog, however, suggests they may have been more ancient. This bog is alluded to by Crofton Croker in his "Enchanted Lake"—

> "And her wealth it far outshines
> Cullen's bog or Silvermines."

In recent times gold was not generally known to exist in Wicklow till about ninety years ago, when it was observed that the Wicklow people from time to time brought in pieces of gold to sell in Dublin. When a nugget, nearly

22 oz. in weight, was exhibited, inquiries were made, and it was found to have been got in the small river running eastward from Croghan-Kinshella to join with the Aughrim river, a tributary of the Ovoca, at Woodenbridge. This caused a rush to the place in 1795, and a good deal of gold was picked up by the diggers for about six weeks, after which time Government took possession of the Gold-mine Valley ; while the country people carried on works in the neighbouring streams of Knockmiller and Clonwilliam, Ballintemple, and Coolballintaggart, the latter running north from Croghan-Kinshella. Besides those, in these streams, placer-mines were also worked farther northward in the streams at Mucklagh, Ballinagappoge, and Ballycreen, tributaries of the Aughrim river or the Ow.

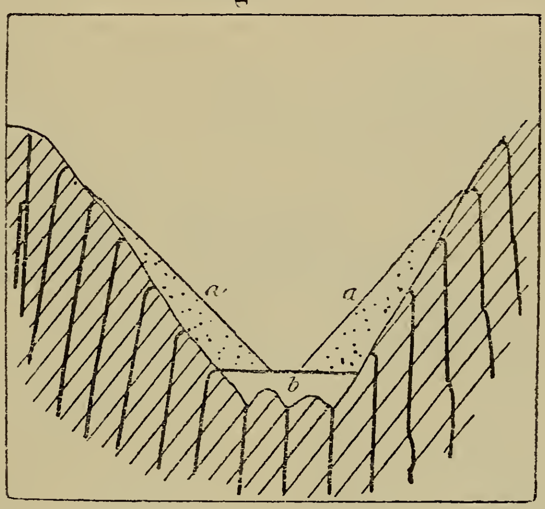
The Government works, under Messrs. Mills, King, and Weaver, were carried on till May 1798, when they were interrupted by the Rebellion, and were not resumed till 1801, when, beside placer-mining, a tunnel or level was driven into the east side of Croghan-Kinshella, and miles of trenches (open casts) were cut down to the rock around its summit. In these works numerous irregular veins of quartz were found, but not a particle of gold *in situ*. After these works the Government abandoned the undertaking.

The Government placer-mines are said to have been remunerative ; 944 ounces of gold were procured, the ingots being, according to Weaver, from 21⅜ to 21⅞ carats fine, the alloy being silver, and of a total value, at the time, of £3,675. Alchorn's assay gives an alloy of silver and copper. The money made by Government was all spent in looking for the "mother-rock" of the gold. According to Sir R. Kane, the gold collected and sold by private individuals was worth over £10,000.

Since then, placer-mining has been carried on by companies and private individuals, but without any great success. Professor W. W. Smyth suggests, "partly on account of the small amount of gold in the Placer, and partly from the difficulty experienced, in all gold-streaming or gold-digging regions, of obtaining from the workmen full produce of their labours."

Professor Le Conte states, in reference to the placer-mines of California, that the gold gravels always occur on, and at the bottom of, the slopes in which there is an out-

Fig. 25.




Diagram, showing the Section of a Placer Mine, County Wicklow.
*a*. Meteoric drift slopes.
*b*. Diluvium with black auriferous sand at its base.
The strong nearly perpendicular lines represent breaks and master-joints.

crop of an auriferous quartz-vein. The gold gravels of Wicklow always occur below the outcrops of certain iron and copper ore veins from which it is supposed to originate. In California, gold is found in the quartz-veins; while no gold has been found in the mineral veins of Wicklow above the placer-mines; although a little has been proved farther NE., in the Ballymurtagh, Cronebane, and

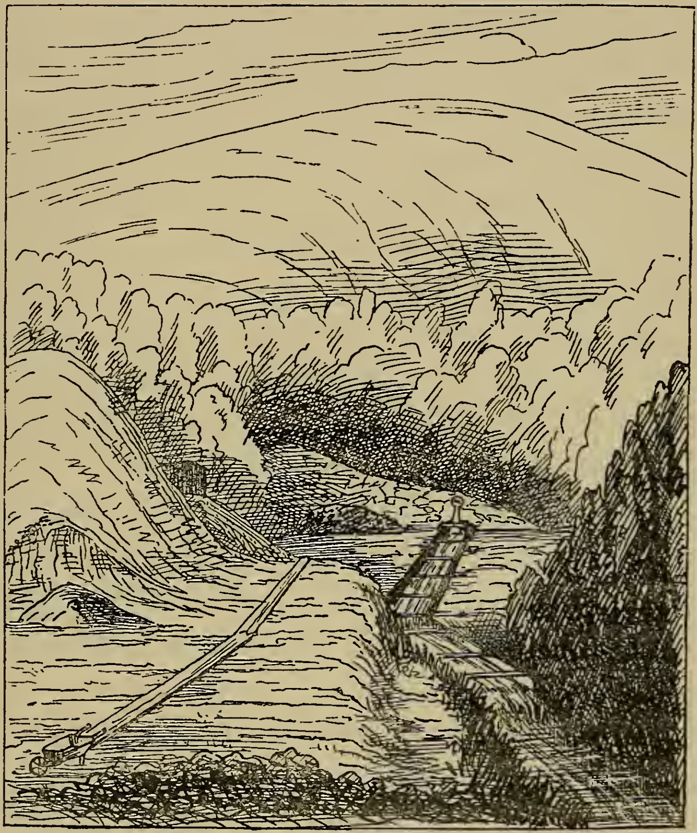
Connary mines, to the west and east of the valley of the Ovoca. Still it would seem as if these mineral veins, especially the iron ore veins, must have a connection with the gold, as pieces of these iron ores are always found with the gold, while above all the placers are iron-ore veins. But some of the nuggets are attached to quartz, as if a quartz-vein carrying gold must somewhere exist. Numerous experiments, however, have been made on the quartz blocks so common in the country; and hundreds of tons of them were reduced at Ballintemple without a particle of gold being got in return for all the labour.

At Mr. Acheson's mines, in the Gold-mine Valley, meteoric drift occurs over water drift; the latter containing many rounded* blocks and fragments of various stones; at the base of the water drift is sand and gravel, containing the auriferous or "black sand." The "runs" of the "black sand" occur in parallel lines which coincide with hollows denuded along the master joints and faults in the "bed rock" (Cambro-Silurian); and the miners can tell when they are coming to a "run" of "black sand," as the rocks are "crumpled," as they designate the twisting and bending of the lines of lamination to the fault lines. When one of these fault lines meets cross joints, hollows occur, in which there is more gold than elsewhere in the run; as these cross joints are more or less systematic, the spots in which the gold is found form regular patterns, somewhat like the corners of the squares on a chess-board. The gold usually occurs as *Eyesills* or minute scales, but in some localities as "large gold," or grains; while "nuggets" or

* In places the bed rock is rounded and smoothed, evidently by water, as no trace of ice striæ could be found on the rocks or on the blocks contained in the overlying drift.

large lumps are found from time to time; the heaviest nugget weighed 21·5 ounces, while others have been found of 18, 11, and less weights. The sand in the "runs" is barrowed out and washed in "Long Toms," or narrow, shallow, wooden troughs, at the streams, and the residue

Fig. 26.



Gold washing, Gold-mine Valley, Wicklow.

"panned;" formerly cradles and wide buddles were used, but the small quantity of gold in the stuff made the operation tedious and but little profitable.

According to Weaver the following minerals occur with the gold: magnetic iron, sometimes in pieces of half a hundred-weight; titaniferous iron; specular, red and brown ores; pyrite; tin ore associated with wolfram; manganese ore; garnets; quartz; and ripidolite. To this list Mr. Mallet has added (*Jour. Geol. Soc. Dub.* vol. iv. p. 271): platinum; galenite; chalcopyrite; molybdenite; sapphire; topaz; zircon; and spinelle. Mallet gives a very large return of tin ore (3·5lbs. from 150lbs. of sand), while all others observers have found very little of it.* In the old working (Ballinasilloge) more tin occurred than higher up (to the SW.) in Ballinavally.

Most of the gold seems to be abraded and more or less worn by attrition, but some of it is frosted and has an appearance as if it grew in the drift, similar to some of the gold that occurs in the *deep placers* in California. All the Wicklow mines are *shallow placers*, the deepest working being less than 50 feet. As the gold occurs in so many of the small tributary streams, it ought, also, as is the case in other gold regions, to be found under the deep alluvia of the rivers. Those, however, have never been mined, but it does not appear at all improbable that a quantity of gold may exist in *deep placers* beneath the river and estuarine gravels at Woodenbridge and other places in the vale of Ovoca.

A little gold has been found in the gaussen at Ballymurtagh and Cronebane, adjoining the vale of Ovoca; also farther eastward in the Silver-blend (*Kilmacoite*) of Connary. In the County of Cork, south of Bantry Bay, it has been found in the gaussen of the copper lode at Carrigat or Dhurode.

* Possibly Mallet's experiment was made on 150lbs. of the washed sand at the mouth of the buddle, in which the tin ore had collected.

## Silver.

Silver, similarly to gold, is mentioned by the old historians. Enna Airgtheach, who reigned about eight centuries and a half B.C., is said to have been the first who made silver shields for his chieftains. They were made at Argetros or Silverwood on the Nore, County Kilkenny. In that neighbourhood, at Ballygallion and Knockadrina, are very ancient mines in which native silver associated with argentiferous lead occurs. Silver is also said to have been found near Toomavara, County of Tipperary, at a place called Rosargid, which also means Silverwood. This name has not reached our day, but a little southward of Toomavara, at Kilnafinch, are the remains of of very ancient "Silver Mines," as they are locally called.

This old mine, southward of Toomavara, lies on the great fault line that can be traced SW-ward, to near Six-Mile Bridge in Clare, and on this fault to the south of Nenagh are the village and mines of Silvermines. The mines at this village were worked so long ago that the attal (pyrite and sphalerite or blende) in the stulls and old levels have undergone a complete chemical change into peroxide of iron, with carbonate and silicates of zinc; a little impure carbonate of lead (*cat's tooth ore*), filiform veins and botryoidal incrustations of binoxide of manganese, and a fibrous or stalactitic oxide of iron like decayed wood, are also found, besides other minerals.

Of recent years the principal workings have been to the west of Silvermines at Shallee, and in adjoining mines; where some native silver occurs, while the lead ore has given in places as much as 80 ounces of silver to the ton. Farther west on this great fault line, tumblers of argentiferous lead have been found in the hills SE. of Six-Mile Bridge, County Clare, but here a lode is not known.

Native Silver is also recorded from Milltown, near Tulla, County Clare, a locality that was worked in very ancient times; while there is a tradition that it was found at Carhoon, near Tynagh, County Galway. This mine was worked so long ago that nearly all traces of it are gone, and nothing is known about it but the above tradition and pieces of argentiferous lead found on the sites of the old burrows or attals. Other localities for native silver are Ballysteen, County Limerick; Lissooleen, near Tralee, and Clogher, near Castleisland, County Kerry; Boulysallagh, near Crookhaven, County of Cork; Cronebane, (Ovoca) County of Wicklow; Ballycorus, County Dublin, where a large mass occurred; and Lugawarry, County Sligo. Argentiferous lead occurs in many other places; a very ancient mine being at Garrykennedy, on the Tipperary shore of Lough Derg, in which were found ancient tools of wood and stone.

### Lead and Zinc.

The ores of lead seem to occur in more places than those of any other metal. It usually is the sulphide (*galenite*), and very generally it is accompanied by sulphide of zinc (*sphalerite*), and sometimes with those of iron (*pyrite*) and copper (*chalco-pyrite*); in many localities it is argentiferous. It also may be associated with *baryte* (sulphate of baryta), *strontianite* (sulphate of strontium), fluor spar (*fluorite*), and other minerals.

Some of the veins of galenite in the micalite and granite of the Leinster range are associated with baryte, the *cawk* of the miner. In this range more lodes have been discovered in the vicinity of Glendalough than elsewhere, that of Camaderry being the largest; it was generally five feet wide, and sometimes twelve, the principal gangue stone being quartz; under Weaver from 3 to 4·5 tons were got per cubic fathom. Associated with it were cerussite (*white lead ore*), sphalerite, chalco-pyrite, and pyromorphite (*phosphate of lead*); the galenite yields 70 per cent of lead. The Glendalough veins and those in Glenmalure, contained some baryte and siderite (*sparry iron ore*).

In many localities in the unaltered Lower Palæozoic rocks, the galenite is alone, or the ores accompanying it are in such small quantities as to be inappreciable. In the metamorphic Cambrians and Cambro-Silurians of West Galway, the sulphides of copper, lead, and iron, are often mixed up together. In some veins, however, the copper or iron (the latter being often in the form of *Pyrrhotite* or magnetic pyrites) predominates, but when in the limestone, the galenite. The richest lead lode in this district that has been discovered, was in East Glengowla, near Oughterard, where the ore was of the variety called "Plumber's lead." In vugs in this lode, large and beautiful crystals of quartz were very numerous; also crystals of very pale green or yellowish fluorite.

In the Carboniferous limestones, the lead ore in general is argentiferous, and is usually associated with zinc and sulphur (*pyrite*) and a little copper ore. When a lode extends down through the limestone into the sandstone, the lead is replaced by copper. This also takes place in the Lower Palæozoic rocks, the lead lodes in limestone and slate often changing into copper in the sandstone.

In the Counties of Limerick, Clare and Galway, some rich pockets of silver-lead ore have been discovered and worked out. It seems probable, however, that there are others, as a rich vein was cut between Rathkeale and Shanagolden, when making the Limerick and Foynes Railway. In the working at Monanoe (Kilbreckan) was discovered the peculiar compound of lead and antimony, called *Kilbreckanite.* The galenite here gave 76 per cent. of lead, and 120 ounces of silver to the ton. Other new localities for lead-ore in the Carboniferous limestone, as yet untried, are Gibberpatrick and Killiane, County Wexford. Remarkable lead ores occur at the Ovoca Mines, County Wexford, to be mentioned presently.

## Copper.

Copper ores were worked at a very early period in the Bonmahon district, County of Waterford, as Mr. Pederick records, very ancient wooden tools being found in the Stage-lode, Knockmahon. Since then, mining operations have been carried on, at intervals, with greater or less activity; sometimes with great success, at other times with loss. The lodes are of præ-Carboniferous age, as they are cut out by certain red conglomerates and sandstones, probably belonging to the Old Red Sandstone. The ore is principally chalco-pyrite; native copper has been found in these lodes sometimes in geodes.

In the County of Wicklow there were considerable workings for copper; also said to have been worked in very ancient times. At the beginning of the last century extensive works were carried on, and the mining operations have been continued ever since; at that time copper was raised in all the mines, while lead was also worked in the eastern ones (Cronebane and Connary). In 1840 the raising of the copper ores was neglected, and attention was turned to the pyrite or sulphur ore to supply the English market, on account of the interruption of the sulphur trade with Sicily. For some time a great quantity of the pyrite was raised, but now the demand has fallen off, and very little mining is going on.

The copper ore in the western mines is principally "yellow ore" (*chalco-pyrite*), of a very low per centage, on account of the admixture of pyrite, quartz and other impurities, rarely reaching eight, and usually being between four and six per cent.

In East Cronebane and Connary the ore is principally black copper (*melaconite*) associated with lead ore, but in one of the Connary lodes, especially near the surface, there was a good return of "yellow ore."

Usually in these lodes under the gaussen was lead ore, lower down sulphur and copper, and in depth sulphur ore only.

In the eastern portion of Connary (Kilmacoo), is the remarkable ore Kilmacoite ("silver-blende," or "blue-stone"), a combination of silver, lead, and zinc ores, associated with the sulphides of iron, copper, antimony, silver (?) and arsenic, with a trace of gold. Native silver has been found in Cronebane, and native copper in Connary, Cronebane, and Ballymurtagh. The waters from all these mines are rich in copper, and the metal is extensively collected by precipitation on iron, in landers, through which the water is conducted.

Copper ore has been found in various other places in the Lower Palæozoic rocks, but not in very large quantities. An untried district, however, is West Galway; but in this area the ore usually seems to be associated with pyrite or pyrrhotite, quantities of which have to be raised with it; in a few places pockets of rich "yellow ore" have been discovered and removed.

Rich lodes unknown to the ancients were discovered about the year 1810 by Col. Hall at Allihies, to the west of Bearhaven, and since then were worked most successfully, and vast quantities of ore raised. It was principally the yellow ore (*chalco-pyrite*), but in the north mine there was a large pocket of the carbonates (*Malachite* and *Azurite*) which is said to have given over 60 per cent. of copper. These lodes occur at the junction of the Yellow and Old Red Sandstones of the Cork type.

To the south, in similar rocks in the Mizen Head and Muntervary promontories, numerous small lodes occur; none of them, however, are equal to those which were worked at Bearhaven; with these are associated coppery beds. In the lodes the yellow ore is principally found, while in the beds the grey ore (*tetrahedrite*) predominates; but there is great mixture of minerals in the lodes; in some of the largest, barytes is mixed with the copper, rendering the ore nearly valueless; a little native copper has been found.

## Iron.

The Iron ores of Ireland were extensively worked, and iron mills were numerous prior to the introduction into England of the smelting of iron ore by coal. The last iron furnace, which seems to have been either that situated at Woodford, in Galway, or that at Portroyal, in Mayo, was put out more than 100 years ago. After this time all iron mining seems to have ceased until within the last few years, when an extensive trade sprang up in the Antrim

Miocene ores (*Belfast Aluminous ore*), which is now very briskly carried on. Other ores are also being looked after, and lately a vein of red hematite has been discovered in the Cambro-Silurian rocks at Deehommed, 8 miles from Banbridge, County of Down. The Miocene Iron-ore Measures have already been described among the Caino-zoic rocks.

The iron ores of the Coal Measures have also been mentioned previously; they are in the greatest quantity in the Connaught field; but in old times they seem to have been most worked in the Queen's County, near Maryborough; in the County of Limerick adjoining the Shannon; and in Fermanagh. In the Upper Limestone of the Burren type, limonite occurs at Desart, near Mary-borough; and in the County of Limerick at Kilcolman and Shanagolden. In the Calp the best ores are found in the Ballycastle Coal-field, but nearly similar stone was anciently worked in the Calp near Draperstown, County of Londonderry. Other localities are Baldongan Hill, and near Donabate, County Dublin, and Woarway Bay, County of Wexford.

In the Counties of Cork and Waterford, the red hematite was extensively worked about 200 years ago, as in Smith's History of the County of Cork, written 1750, iron works are mentioned at Araglin, near the eastern extremity of the County of Cork; at Aghadown, near Roaringwater Bay; and at Coomhola, near Glengariff. The sites of the mines are not mentioned, but veins of the ore are not uncommon in different places; near the west end of Bear Island is a thick untried vein of red hematite. At Drumslig on Slieve Grian, near Dungarvan, are the mines discovered and worked by Sir Walter Raleigh. Near Glandore, on the south coast, is a remarkable mineral channel, three distinct formations occurring together, manganese-ores, hematite, and fault-rock. The hematite occurs as a lode that crosses and sends veins into the fault-rock, while there are pockets and veins of the manganese-ores cutting through both. The hematite seems to be the "back" to a copper lode. Farther eastward the existence of this mineral channel has been proved under the town of Rosscarbery.

In the Cambro-Silurian rocks there are various iron veins and deposits, most of which were worked in old times. In the County of Down are the previously mentioned red hematite veins, at Deehommed, others at Carnreagh and Slievecroob; in Londonderry are veins at Benedy, Carndaisy and other places; in Tyrone at Lissan and Unagh; in Donegal at Welchtown, and Marfagh; in Fermanagh at Rossbeg; in Leitrim at Gortinee; in Longford in Cleeragh and Enaghan; in Clare at Glendree, Ballymalone and Bealkelly, where there were also extensive iron works, and on Knocksnaghta a vein associated with graphite; in Tipperary at Scotchmen's Cooms and Gortnamilla; in Kilkenny at Grenan; in Wexford at Ballybrennan, where there were very ancient workings, while at Ballynastraw, near Gorey, and farther eastward at Courtown, and along the coast at Ballymoney, are beds of iron ore in which it seems to occur principally as chalybite or siderite (carbonate of iron); none of the beds, however, have been opened into.

In Wicklow, in connection with the great mineral channel between Wicklow Head and Croghan Kinshella, are large deposits of iron ore. To the north-east there were formerly extensive works at Ballycapple, where specimens of limonite containing manganese, and chalybite, have been picked up. To the west of the Ovoca, at Ballymurtagh, a great deposit of ochre and iron was discovered about 1850; it is the back of a great sulphur or (pyrite) lode. Farther SW., at Ballymoneen (Hodgson shaft), a great mass of magnetic iron ore has been discovered that gives 55·5 per cent. of iron. To the SW. of Hodgson shaft, extending for half a mile, into Knocknamohill, are very old iron workings, magnetic iron having been lately raised at Knocknamohill. To the south of the Aughrim Valley, in the NE. spur from Croghan Kinshella, iron occurs in Ballycoag, Ballinasilloge, and Moneyteige, a large deposit of magnetic iron having been proved in the latter. In the hills north of Aughrim and west of Glenmalure, traces of iron and the remains of old sinkings have been observed in different places. In Glenasplinkeen, Cloghleagh and Knockatillane, near Blessington, there is red hematite associated with manganese ore, which, according to Haughton, gives 59 per cent. of metallic iron. On Lambay Island, County Dublin, Du Noyer records iron ore.

### Graphite (Plumbago).

This mineral has been recorded from Knocksnaghta, County Clare, where it occurs with iron ore; Upper Church, County Tipperary; Doonooney, County Wexford.

### Manganese.

This is usually associated with the iron ores; it has been recorded from Clay, County Armagh; Cappagh in the Burren, and Glendree, County Clare; Glendore mine, County Cork; Malinbeg, County Donegal; near Dromore, County Down; Sutton, County Dublin, where a large quantity was raised; Corduff, County Monaghan; Aherlow, County Tipperary; Glenasplinkeen, County Wicklow; and a few other places.

### SULPHUR ORE (Pyrite and Pyrrhotite).

Sulphur-ore, as has already been mentioned, was raised largely in the Ovoca mines, County Wicklow; there seems to be a considerable quantity in west Galway, but here a great deal of it is pyrrhotite, an ore hard to be reduced. Native sulphur occurs as concretions in the limestone at Oughterard, County Galway; at Lough Carra and Westport, County Mayo; near Finoge Bridge, County Wexford; and small quantities have also been found in some of the copper mines.

### ANTIMONY.

This mineral is recorded from Rabbit Island, near Castletownsend, County Cork; Jonesborough, County Louth; Lisglassan, Tullybuck, and Clontibret (where there is a vein of stibnite four inches thick in clay slate), County of Monaghan; Munterlony, County Tyrone; at Monanoe, County Clare, in the form of Kilbreckanite, a mineral having the sulphides of lead and antimony united in the same proportions as they are in manufacturing printing type; at Connary, County Wicklow, in the remarkable mineral kilmacoite, or "bluestone," as it is locally called.

### ARSENIC.

This occurs at Lackamore, County Tipperary; Adrigole Bay, County of Cork; and at Connary, in the kilmacoite.

## Tin.

This important mineral is recorded by Griffith as occurring with lead and zinc in a lode in Dalkey, County Dublin. It also occurs in the "black sand" with the gold in the diluvial workings or "placer mines," County Wicklow, but no lode of it has been discovered in that county.

## Cobalt.

Cobalt has been found in small quantities in the copper lodes at Knockmahon, County Waterford; while at Muckross, Killarney, it was found in great profusion as a granulated metallic-looking hard mineral of a dark blue colour tending to pink. All of the deposit was thrown as rubbish into the lake, except about twenty tons which had been taken away by one of the miners, who recognized it to be *Erythrite* (Arseniate of Cobalt). Dr. Stokes found Cobalt ore at Sutton Howth.

## Molybdenite.

This not very common mineral occurs in considerable quantities disseminated in a wide endogenous vein of granite in the townland of Murvey, near Roundstone, County Galway.

## Barytes.

The Sulphate of Barytes (*Baryte*) occurs very abundantly in various parts of Ireland. In Ulster it is found in veins in different parts of the Carboniferous sandstones (Old Red Sandstone and Shore-beds), also in some of the lead mines situated in the granitic range of Leinster. It occurs at the North Intake, Wexford Harbour, and in Cork; some of the deposits in the latter county near Clonakilty, Bantry, and Skull, being of great size. It is also found in various places in Connaught; a transparent crystalline variety occurring at Cregg, near Oughterard.

## Magnesia.

The mineral from which the earth Magnesia and its sulphate, Epsom salts (*epsomite*), are prepared, occurs abundantly in the dolomite so common in the Upper Carboniferous Limestone. It is also found at the base of the Mesozoic rocks near Ardtrea in Tyrone, and at Cultra near Belfast; from the latter place it was formerly largely exported to Glasgow to be manfactured into Epsom salts. In the County of Cork the Carboniferous dolomites are said to have been used for similar purposes and in the making of fluid magnesia.

## Alum and Copperas.

Alum shales are very abundant in the Lower Coal Measures, especially in Munster, while pyritous shales suitable for the manufacture of copperas occur among the Upper Measures. To these shales special attention was directed by Kane as long ago as 1844, but as yet no one seems to have endeavoured to utilize them.

## Salt and Gypsum.

Salt has been found only in Antrim in the neighbourhood of Carrickfergus and Larne; this has been described among the Triassic rocks at page 137. Gypsum has been found associated with the salt, and in the Triassic rocks of the valley of the Lagan in the same county; at Coagh, County of Tyrone; and at Derrynasrobe and Knocknacran, near Carrickmacross, County of Monaghan, where the deposit is said to be over 60 feet thick. Here it is probably a deposit allied to the Salt Measures at Carrickfergus, and somewhat similarly accumulated. The gypsum does not appear to be of the variety called Alabaster, suitable for architectural and ornamental purposes; but as a manure its practical value is indisputable. Its composition is sulphuric acid 46·5, lime 32·5, and water 21; and its peculiar value, as a manure, according to Kane, "consists in supplying lime for the rapid growth of clover and other papilionaceous crops, which its moderate solubility in water enables it to effect better than any other compound of that earth." It is also invaluable in the manufacture of artificial fertilisers.

## Steatite.

This rock occurs in mass on Bofin and Shark Islands in the County of Mayo, but off the coast of Galway; also on Achill Island, and in a tract of country running nearly E. and W. south of Clew Bay and Westport, same county; and at Church Hill, County of Donegal. Smaller deposits and veins are found in various places in the Counties of Galway, Waterford, Wexford, and elsewhere; a red or orange steatite occuring in Killahurla, County Wicklow. Fault-rocks in eruptive rocks, especially if they are melaphyres or eurites, are often more or less pure steatite. This mineral is worked a little on Bofin Island, to the extent of one or two small cargoes yearly, but more largely in Donegal.

## Clays and Sands.

At Kilranelagh, near Baltinglass, County Wicklow, kaolin of a fine quality has been obtained; and at Tullow, County of Carlow, is a porcelain clay, but partly impregnated with iron. A little SE. of Westport, County of Mayo, a decomposed petrosilex forms a dyke of kaolin; while, as previously mentioned, in the same neighbourhood, and near Roundstone, County of Galway, are dykes of petrosilex capable of being manufactured into kaolin; also in other places. At Belleek, County Fermanagh, kaolin is manufactured from a pink orthoclase, an endogenous granitic vein rock.

The clays of Lough Neagh, County Tyrone, and those near Caher, County of Tipperary, have already been mentioned at page 168. Besides these, there are a deposit of pipeclay on Arran island, County of Donegal; along the shore of Lough Ree, County of Roscommon, but especially near St. John's Point, are similar clays that are locally manufactured into tobacco pipes; these clays Foot considers to be in the drift. Pipeclay also occurs near Blackball, north of Brosna, King's County, and in addition to its being made into tobacco pipes it was used by the late Earl of Rosse for lining his furnaces. Near Ardmore, County of Waterford, is a clay very suitable for coarse pottery; while in the neighbourhood of Menloe Castle, County of Galway, an excellent clay is said to have been lately discovered.

In places in the Esker-sea drift, especially in the Counties of Wexford, Wicklow, Dublin, and Carlow, are good brick and tile-clays, formerly very largely worked; while in various places, as in the valley of the Shannon, are coarser clays in the alluvial deposits.

The best clays are in the Coal Measures, especially the Coalisland portion of the Dungannon field, County of Tyrone, where the supply is very abundant.

Silicious sands, and pure silicious rocks from which they could be made, are not uncommon, although very little used for manufacturing purposes. Formerly sand was exported from Donegal, Ballycastle, and elsewhere. Vast quantities of pure quartz-rock and quartzite could be obtained in the Counties of Donegal, Sligo, Mayo, Galway, Wexford, Wicklow, and Dublin. Silicious sand is found in various places among the Æolian drift; a large deposit of excellent sand occurs in Achill Island, County Mayo.

## Mineral Localities.

These are arranged in counties; each of them is indicated by the name of the townland and of the nearest post town, those localities in which ore has been worked being printed in italics. The different minerals are designated by the following letters:—G., Gold; S., Silver; C., Copper; L., Lead; Z., Zinc; I., Iron, if Hematite or Limonite, and C-I. if clay-ironstone; M., Manganese; As., Arsenic; P., Sulphur-ore (Pyrite); Py., Pyrrhotite; (magnetic pyrites); S-L., Silver Lead; A., Antimony; B., Barytes; T., Tin.

### Antrim.

Ballycastle coal field, C-I. In numerous places in the Miocene dolerite (see page 164), I. Rathlin Island, I. Slieveanorra, Glendun, G.; near Cushendall.

## ARMAGH.

*Carrickgallogly*, L.; *Drumnahoney*, L.; near Belleek. Dorsy, L.; Tullyard, L.; Tullydonnell, C.; near Crossmaglen. Aughnagurgan L.; *Clay* L. and M.; *Doohat* or *Crossreagh*, L.; *Drummeland* (Derrynoose), L.; near Keady. *Tamlaght*, L.; near Middletown. Drumbanagher (Churchglen), L.; *Kilmonaghan* (Jerret's or Tuscan Pass), C.; near Newry. *Ballintemple*, L.; near Newtown-hamilton. *Ballymore*, L.; near Poyntzpass.

## CARLOW.

Coal Measure Hills, C-I.; near Leighlinbridge. Carricklead Mountain, C.; near Graiguenamanagh.

## CAVAN.

Farnham Demesne, C., near Cavan. *Cornanurney*, L.; near Cootehill. South-east of Shercock, L. *Cuilcagh Mountains* (Coal Measures), C-I.; near Swanlinbar.

## CLARE.

*Cappagh*, C., S-L. and M.; *Moneen*, L.; *Glenulla*, C.; *Mogoahy*, L.; Glencrawne, L.; *Sheshodonnell*, Z. (botryoidal calamine); *Lough Aleenaun*, L.; Lisnanroum, L. and C.; Doolin Castle, L.; near Ballyvaughan. *Glendree*, L., I. and M. (the last as diallogite in the drift); Corrakyle, C.; Leaghort, C.; near Feakle. *Carrownakilly*, S-L.; Rathlaheen West, L. and P.; Newmarket. L.; near Newmarket on Fergus. *Ballyhickey*, S-L., C. and Z.; *Castletown*, L.; *Moyreisk*, S-L.; Monanoe (Kilbreckan), S-L. and A.; near Quin. *Ballyvergin*, L., C. and P.; *Knockaphreagaun* (Crowhill), S-L.; *Miltown*, S. and L.; near Tulla. *Crumlin*, S-L.; *Doolin*, S-L.; *Ballykelly*, I.; Shannaknock, C. and P.; near Broadford. Rathlaheen, L. and P.; Knocksnaghta, I.; near Sixmilebridge. *Ballyhurly*, Cahir and Ballynagleragh, L.; Ballymalone and Bealkelly, I.; near Tomgraney.

## Cork.

*Allihies*, C.; *Cahermeeleboe*, C.; *Caminches*, C.; *Cloan*, C.; *Coom*, C.; *Kealoge*, C.; *Kilkinnikin*, L.; Bear Island, I. (red hematite); Killaconenagh, L. and C.; near Bearhaven. East of Adrigole Bay, As.; disseminated in the rocks, C.; near Adrigole. Esk Mountain, C.; near Glengariff. *Carravilleen*, C.; *Clashadoo*, C.; *Derreengreanagh*, C. and B.; *Glanalin*, C.; *Gortavallig*, C.; *Gortacloona*, L.; *Hollyhill*, C.; *Killeen*, C.; *Killoveenoge*, S-L.; Roorksa, S-L.; *Derryginagh*, B.; near Bantry. *Ballycummisk*, C., L. and B.; *Cappaghglass*, C.; *Foilnamuck*, C.; *Horse Island*, C.; *Rossbrin*, C.; *Ballydehob*, C.; *Boleagh, Cooragurteen*, C.; *Kilcoe*, C.; *Skeaghanore*, C.; *Derreennalomane*, C.; Kilkilleen, C. and L.; Laheratanvally C. and L.; Leighcloon, C.; near Ballydehob. *Castlepoint*, C.; *Castle Island*, C.; *Coosheen*, C. and I.; *Gortnamona*, C.; *Long Island*, C.; *Skull*, C.; *Leamcon*, C.; *Mount Gabriel*, C. and B.; near Skull. Altar, C.; Ballydivlin, C.; Ballyrisode, C.; *Balteen*, C.; *Carrigacat* (Dhurode), G. and C.; *Boulysallagh*, C., S. and L.; *Callaros*, C.; *Cloghane* (Mizen Head), C.; *Crookhaven*, C.; *Kilbarry*, C.; *Mullavoge* (Brow Head), C.; *Spanish Cove* (Kilmoe) C. and S-L.; *Lackavaun*, C.; Toormore, C.; near Crookhaven. *Bawnishall*, C.; near Skibbereen. Cosscroneen, C.; Rabbit island, C., L. and A.; near Castletownsend.

*Aghatubrid*, I., M. and C.; *Derry*, C.; *Drom*, C.; *Keamore*, C.; *Kilfinnan*, C.; *Rourey glen*, I. and M.; Rosscarbery, I. and M.; *Gortagrenane*, C.; Little Island, C. and B.; near Rosscarbery. *Duneen*, L., C. and B.; near Clonakilty. Demesne, P.; Derreens, C.; *Coom* (Lackue wood), C.; *Inchanadreen*, C.; near Dunmanway. *Knockadoon*, C.; near Youghal. *Minane*, L.; Ringabella, S-L.; near Nohaval. Rathpeacon, C.; near Cork. *Vicinity of Carrigtohill;* L. and Z. *Vicinity of Mill Street*, C.

### Donegal.

*Welchtown*, L. and I.; near Ballybofey. *Abbey island*, S-L., Z. and C.; *Abbeylands*, S-L., Z. and C.; *Ballymagrorty*, L.; *Finner*, S-L., Z. and C.; *Tonregee*, L.; near Ballyshannon. Vicinity of Bundoran, L. and C. *Carrowmore* or *Glentogher*, S-L., Z. and P.; Clonca, C.; near Carndonagh. Ards, L.; *Keeldrum*, L.; *Marfagh*, L., C., P. and I.; near Dunfanaghy. *Drumnacross*, L.; *Fintown* (Loughnambraddan), L.; Gweebarra river, L.; *Kilrean*, L.; *Mullantiboyle*, L.; Scraig Mountains, L., Z. and P.; near Glenties. *Malinbeg*, S-L. and M.; near Killybegs. *Eighterross* (Castlegrove), L.; near Letterkenny. Inniskeel, L. and C.; near Naran.

### Down.

Glassdrumman, C. and L.; near Annalong. Ardtole, L.; Gun's Island, L., C. and B.; near Ardglass. *Fofanny*, L.; near Bryansford. Ballyleidy, L.; near Crawfordsburn. Lisnasliggaun, Tanvally, and Finnisbridge, iron-spas; *Deehommed*, I. (red hematite); near Banbridge. Spa cottage, iron-spa; near Ballynahinch. Slieve Croob (Begny, Gransha, Leganany, Moneybane, &c.), I.; near Dromara. Vicinity of Dromore, L. and M. *Moneylane*, L.; *Wateresk*, L.; near Dundrum. Carnreagh, I., near Hillsborough. Leitrim, L.; *Mourne mountains*, C. and L.; near Kilkeel. Ballydargan, L.; *Killough*, L.; Rathmullen, L. and B.; Rathdrum, L.; St. John's Point, C. and P.; near Killough. *Corporation*, L.; near Killyleagh. *Whitespots* (Conlig), L.; near Newtownards, in a pure amphibole gangue, according to Haughton. *Tullyratty*, C. and S-L.; *Castleward*, L. and Z.; near Strangford.

### Dublin.

Ashtown, L.; *Castleknock*, L.; *Cloghran*, L.; *Clontarf*, L.; *Killester*, L.; Crumlin, L.; *Dolphinsbarn*, L. and Z.; Kellystown, L.; Kilmainham, L.; Phœnix Park, L.; Dodder Valley, G.; near Dublin. *Ballycorus*, S-L., Z. and S.; *Rathmichael*, L.; *Shankill*, L.; near Golden Ball. *Howth*, L.; *Sutton*, M. and Cobalt; near Howth. *Dalkey*, L., Z. and T.; *Mount Mapas* (Killiney Hill), L.; Seapoint, C.; near Kingstown. Vicinity of Malahide, C.; Baldongan Hill, C-I.; near Skerries. Railway cutting, C-I.; near Donabate. Lambay, C. and I.; *Loughshinny*, C.; near Rush.

### Fermanagh.

Rossbeg (Castle Caldwell), C. and I.; near Belleek. Maheraboy district (Coal Measures), C-I.; near Enniskillen.

### Galway.

*Crannagh*, L.; *Carhoon*, S-L. and L.; Quarry Hill, L.; near Tynagh. *Ballymaquiff*, S-L.; *Muggaunagh*, L. and

C.; *Parkatleva,* L.; near Ardrahan. *Caherglassaun,* S. and S-L.; near Kinvarra. Killeely, L.; near Kilcolgan. *Rinvile West,* L., Z. and P.; near Oranmore. Galway dock, P.; Lenaboy, L.; near Galway. Spiddle, L.; *Kilcoe West,* L.; *Inverrin and Minna,* L., P. and C. (fluor spar gangue); Derrynea (Loughaunweeny), L., C. and P.; *Lettermuckoo* (Carrafinla), L. and P.; Clynagh (Crumpaun), L.; Booroughaun, L.; *Derroogh South,* L.; *Rossaveel,* L., P. and C.; Tully, L.; *Carrowroe South,* L.; *Maumeen* (Gorumna Island), C. and P.; Teeranea, C. and P.; Keeraunbeg, L.; near Spiddal. *Wormhole* (Gortmore), L.; near Moycullen. Knockroe, L.; near Monivea. Curraghmore, L. and P.; near Headford. *Ballygally,* P.; *Canrawer,* L., C., B. and P.; *Cregg,* L., C., B. and P.; *Claremont,* L. and P.; *Glengowla East and West,* L., B., Z., P. and C. (Crystals of green fluor-spar); *Tonweeroe,* L.; *Ardvarne,* L.; Illaunnacreeva, L. and P.; Moyvoon East, L. and P.; *Lemonfield,* P. and L.; *Portacarron,* L.; *Barratleva,* L., P. and C.; *Derroura,* L., P. and C.; *Curraghduff West, Middle, and South,* C., L. and P.; *Gowlaun,* P.; *Gortnashingaun,* P.; Farravaun, P.; *Gorteenwalla,* C. and P.; *Ballygally,* C. and P.; *Drumminnakill,* P.; *New Village,* P.; *Barnagorteen,* L. and P.; Eighterard, Carrowmanagh, and Fough, concretions of native sulphur in the Carboniferous Limestone; Eighterard, L. and P.; Derryeighter, P.; Leam East, P.; Letterfore, P.; *Derreennagusfore,* Py.; *Derry,* Py.; *Currane,* P.; near Oughterard. Ashford, P.; Doorus, P.; near Cong. *Doughta,* P.; *Drumsnauv* (Doon), C., M., L. and I.; *Maumean,* Py.; *Lackavrea,* Py.; *Maumwee,* Py. and C.; Teernakill, P.; near Maum. *Leenaun,* L. and C.; *Griggins,* S-L.; near Leenaun. *Ardbear,* C.; *Boolard,* C.; *Cloon,* C.; *Derrylea,* L.; *Doon,* C.; *Dooneen,* C.; *Fakeeragh,* C.; High island, C.; *Dawrosmore*, P.; *Cloonlooaun*, P.; *Cashleen*, P.; *Bofin*, C. and P.; *Barnaoran*, L.; near Clifden. Kylemore and Gleninagh, Py.; near Recess. Roundstone, L.; *Murvey*, C.; *Dogsbay*, C.; near Roundstone.

## Kerry.

*Vicinity of Ardfert*, L. *Clogher*, S., L. and C.; near Castle Island. *Annagh East*, S-L. and Z.; Meanus, L. and C.; Ballybrack, S-L.; near Castlemaine. Ballinglauna, L.; Coast east of Cashen river, L. and C.; *Lixnav*, L.; near Causeway. Vicinity of Dunquin, C. *Greenlane*, C.; *Cromwell's fort and Mucksna*, C.; *Ardtully* (Cloontoo), C.; *Caher West* (Shanagarry) S-L. and C., Caher East, C.; Gortnacurra, C.; *Killowen*, L.; west of Kenmare, C.; Public gardens, L.; near Kenmare. *Cahernane*, S-L.; *Muckross*, C., P. and Cobalt; *Ross island*, C., L. and Z.; near Killarney. *Behaghane*, C.; *Garrough*, C.; *Staigue*, C.; near Sneem. Ballybeggan, L. and C.; Ballymullen, L. and C.; *Lissooleen*, S., L. and C.; Oak park, L.; near Tralee. Tinnies Upper, C.; Oughquick, C.; Clynacartan, C.; Garranearagh, C.; near Cahersiveen. St. Crohan, C.; near Westcove.

## Kildare.

Ardclogh, L.; *Wheatfield Upper*, L. and Z.; near Celbridge. *Freagh*, L.; near Edenderry. Punchersgrange, C.; near Newbridge.

## Kilkenny.

*Castlecomer Coal-field*, C-I.; near Castlecomer. Ballygallon, S-L.; near Inistioge. Dunkitt, L.; near Kilmacon. *Knockadrina* (Flood Hall), L. and S.; Knocktopher, C.;

near Knocktopher. Grenan, I.; (red hematite); near Thomastown.

### King's County.

*Monasteroris*, C.; near Killan. *Blundell mine*, L.; near Edenderry. Slieve Bloom, L. and C.; near Kinnity.

### Leitrim.

*Creevelea district* (Coal Measures), C-I.; near Drumkeeran. *Gortnaskeagh*, C.; *Pollboy*, C.; Barrackpark, S-L.; *Twigpark*, S-L.; near Lurganboy. *Gortinee*, I.; near Dromod.

### Limerick.

*Ballycanauna* (Ballysteen), S-L. and S.; *Graiguelough*, L., Z. and P.; Askeaton, I.; *Kilcolman*, I.; near Askeaton. *Ballydoole*, C. and S-L.; Charter School, C.; near Pallaskenry. Ardgoul South, S-L.; Freagh, L.; Boolaglass, L.; *Ballingarrane*, S-L., Z., P. and C.; *Cloghatrida*, S-L., Z., C. and P.; *Ballinvirick*, L.; near Rathkeale. *Mahoonagh*, L.; near Newcastle. Oolahill, S-L., C., B. and P.; near Oola. Carrigbeg, L.; near Doon. *Glin and Loghill* (Coal Measures), C-I.; near Foynes.

### Londonderry.

Carrick-mountain, I; near Dungiven. Moydamlaght, I.; Ballynascreen mountains, I. and P.; Gortnaskea, C-I.; near Draperstown. *Slieve-Gallion-Carn*, I.; *Tirgan* and *Carndaisy*, I.; near Moneymore. Moyola river, G.

LONGFORD.

Two miles ESE. of Longford, S-L. *Cleenragh*, I.; near Scrabby. Enaghan, I.; near Arva.

LOUTH.

Clogher, C. Oldbridge, L. and C.; near Drogheda. Crumlin, L.; Fairhill, L.; near Dundalk. Vicinity of Jonesborough, A. Salterstown, L. and C.; near Togher.

MAYO.

Beldergmore, C.; Geevraun, C.; near Ballycastle. Ballynastockagh (Bellaveel) L.; near Ballyhaunis. Vicinity of Louisburg, C. and P. Achill island, P.; Clare island, P.; *Bolinglana*, C., P. and S-L.; Srahmore, C., P. and S-L.; near Newport. *Tawnycrower* (Sheefry), S-L.; near Westport. Ballymacgibbon, L.; Ballycurrin, P.; Gortbrack, L. and P.; Bunnacunneen, B.; near Headford.

MEATH.

*Cloghan*, L.; near Ardcath. *South of Athboy*, L. Dollardstown, C. and L.; *Painestown*, C.; near Slane. *Brownstown*, C.; *Cusackstown*, C.; *Kentstown*, C.; near Walterstown.

MONAGHAN.

Corbrack, L.; Cornamucklagh South, L.; *Dernaclug*, L.; *Derrylusk*, L.; Sra, L.; near Ballybay. *Derryleedigan Jackson*, L. and Z.; near Bellanode. Corduff, M.; near Bellatrain. *Carrickagarvan*, S-L. and B.; *Cornalough*, S-L. and B.; *Dromore,* L.; near Castleblayney. *Annaglogh,* L.; Annayalla, L.; Avalbane, L.; Avalreagh, L. and Z.; *Carrickaderry,* L.; Carrickanure, L.; *Coolartragh,* S-L., Z. and B.; Cornamucklagh North, L.; Croaghan, L.; Crossmore, L.; Glassdrumman East, L.; Kilcrow, L. and Z.; Latnakelly, L.; *Lemgare,* L.; *Lisdrumgormly,* L.; *Lisglassan,* L. and A.; *Tassan,* L.; Tonnagh, L.; *Tullybuck,* L. and A.; *Clontibret,* A.; near Monaghan.

### Queen's County.

*Dysart,* I. and L.; *Cullinagh,* C-I.; near Maryborough. *Coal Measure hills,* C-I.; near Crettyards. Coolbaun and Ballickmoyler, L.; *Wolf Hill,* C-I.; *Moyadd,* C-I.; near Ballickmoyler.

### Roscommon.

Lough Allen Coal-field, C-I.; near Keadew.

### Sligo.

*Abbeystown,* L. and S.; *Lugawarry,* L.; near Ballysadare. *Glencarbury,* C., L. and B.; Tormore, C. and L.; near Sligo.

### Tipperary.

*Clonmurragha,* C.; *Gleenough Upper,* C.; *Lackenacreena,* C.; *Reafadda,* C.; Scotchmen's Cooms, I.; near Cappaghwhite. *Garrane,* S-L.; near Toomavara. *Lackamore,* C., P., B. and As.; *Tooreenbrien Upper,* C.; near Newport. Coonagh Castle, L.; near Doon. Tower hill, L.; near Pallasgreen. Corbally, L.; Derry Demesne, C.; *Garrykennedy,* L.; *Laghtea,* L.; near Portroe. Cooleen, L.; near

Borrisoleigh. Rathnaveoge, C.; near Dunkerrin. *Gortnahulla*, I.; *Upper Church*, Graphite and Anthracite; near Thurles. *Ballygowan*, S-L.; *Cloonanagh*, P.; *Cooleen*, L.; *Coolruntha*, C.; *Garryard East and West*, *Gorteenadiha* (Gurtnadyne), and *Gortshaneroe* (Ballynoe), S-L. and argentiferous C.; *Knockanroe*, L., Z., C. and P.; *Lacka*, S-L.; *Shallee, East and West*, L., S. and C.; *Ballyhourigan*, C.; near Silvermines. Glenough, Turraheen Lower, and Hollyford, B.; Aherlow vale, S-L., C. and M.; *Ballycohen* (Hollyford), C.; near Tipperary. *Earls Hill Colliery*, C-I.; near Killenaule.

## TYRONE.

*Annagher*, C-I.; near Coal Island. *Lissan*, I.; Unagh (Slieve Gallion), I.; near Cookstown. Crockanboy, L.; Munterlony Mountain, A.; Teebane West, L.; near Gortin. Crannogue, C.; Bardahessiagh, I.; near Pomeroy.

## WATERFORD.

Knockane, C.; *Woodstown*, C.; near Annestown. Ballydowane, C. and S-L.; *Ballynagigla*, C.; *Ballynarrid*, C.; *Ballynasissala*, C.; *Kilduane*, C.; *Kilmurrin*, C.; *Knockmahon*, C., S-L., Z. and Cobalt; *Tankardstown*, C.; *Templeyvrick*, C.; *Seafield*, C.; near Bunmahon. Carrigroe, C.; *Knockatrellane* (Ballymacarbry), C.; near Ballynamult. Killerguile, I. (red hematite); Monminane, L.; near Carrick-on-Suir. *Dumslig* (Slieve Grian), I.; near Dungarvan. *Killelton* (Lady's Cove), C.; *Kilminnin*, C.; near Stradbally. Ballykinsella, C.; near Tramore. Coast opposite Youghal, L. *Camphire*, S-L.; near Lismore.

### Wexford.

*Clonmines*, L.; *Barrystown*, S-L., Z. and I.; near Carrick-on-Bannow. Gibberpatrick, L.; St. Tenants, C.; near Duncormick. Killiane, L.; South Intake, Wexford harbour, L. and B.; Forth Mountain, P. and C.; Kerloge, C.; vicinity of Finoge bridge, native sulphur in Carboniferous Limestone; near Wexford. Woarwoy bay, C-I.; near Fethard. *Balybrennan*, I.; *Aughathlappa*, S-L.; Bree, P.; *Caim*, S-L., Z., C., I. and P.; *Killoughrum*, L.; Mangan, L.; near Enniscorthy. Ballynastragh, I.; Courtown harbour, I.; Ballymoney, I.; near Gorey.

### Wicklow.

Bray Head, C.; near Bray. *Douce Mountain*, L. and C.; Powerscourt, L. and C.; near Enniskerry. *Glen* of Hollywood, L. *Lough Tay*, L.; *Lough Dan*, L., Z. and C.; near Roundwood. *Ashford*, C.; *Ballymacahara*, C.; near Ballinalea. *Cloghleagh* and Knockatillane (Glenasplinkeen), I. and M.; near Blessington. Boleyley (Moatamoy), L.; near Baltinglass. *Vicinity* of Shillelagh, L.; *Carrigroe*, L.; near Tinahely. *Brockagh* (Luganure and Glendasan), L.; *Lugduff*, L., C. and I.; *Camaderry* (Seven Churches), S-L., C. and Z.; near Glendalough. North Prison, Lugnaquillia, L.; *Ballinafunshoge*, L. and Z.; *Ballinagoneen*, L., Z. and C.; Ballyboy, L.; *Baravore*, L., Z. and B.; Camenabologue, L. and C.; *Clonkeen*, L., Z. and I.; Clonvalla, L.; *Corrasillagh*, L. and Z.; *Cullentragh Park*, L.; Ballinacarrig Lower, C.; Ballinaclash, L.; Ballinagappoge, G. and T.; *Ballycreen*, G.; *Muc lagh*, G. and I.; near Rathdrum. Aghavannagh, L. and C.; Aughrim Lower, C.; *Coolbawn or Coolballintag-*

*gart,* G. ; Moneyteigue, C., I. and G. ; near Aughrim. *Ballinagore,* C. and G. ; *Ballintemple,* L. and G. ; *Ballycoog,* C., P. and I. ; *Ballinasilloge,* C., I., P. and G. ; *Ballinvalley,* P. and G. ; *Gold mine river,* G. and T. ; *Knockmiller,* G. ; Clonwilliam, L. and G. ; Kilacloran, G. ; Templelusk, P. ; *Knocknamohill,* C., P. and I ; Ballinapark, I. ; *Killeagh,* C. and P. ; *Ballymoneen,* I., C. and P. ; *Ballygahan Upper* and *Lower,* C. and P. ; Tinnahinch and Kilqueeny, C. and P. ; *Ballymurtagh,* C., P., I. and auriferous gaussen ; *Kilcashel,* C. and P. ; *Knockanode,* L. and P. ; *Tigroney,* C. and P. ; *Castlehoward,* C. and P. ; Avondale (Meetings), P. ; *Shroughmore,* P., C. and L. ; *Connary Upper,* P., C., S-L., L. and Z. ; *Cronebane,* P., C., S-L. and S. ; *Kilmacoo,* C., L., Z., P., A., As. and S-L. ; near Ovoca. Kilmacrea, C. and P. ; *Templelyon,* I., C. and P. ; Ballykean, C. and P. ; near Redcross. *Ballycapple* and *Ballard,* I., M. and C. ; near Wicklow.

# CHAPTER XXII.

## QUARRIES, MINERAL MANURES, AND WATER SUPPLY.

THE stones that are utilized in Ireland for building and other economical purposes, may be generally classed as Slate, Slabs, Flags, Marbles and other Limestones, Sand and Gritstones, Granites, Felstones, Whinstones, with others of less importance.

### SLATE.

Slate is either cleaved shale or cleaved clay-rock. If the first, there is always a riband in it ; the cleaved clay-rocks are therefore usually the best slates, or, to use the quarryman's term, are the best "metal." The cleavage of slate in Ireland, as in most other countries, degenerates when the rock is weathered ; and usually a greater or less thickness, or "head" must be removed before the best slates are reached ; consequently considerable capital is required to open a slate quarry and make it profitable. This may account in a great measure for the Irish slates not being more general in the market ; as many undertakings on veins of good slate have failed solely because there was not sufficient capital forthcoming to push on the works to a prosperous termination.

Usually in the Irish slates the more nearly perpendicular the cleavage, the more pure and argillaceous the rock; to this general rule there is an exception, as in the arenaceous rocks belonging to the Glengariff Grits group, the angle of the cleavage is high, while in the argillaceous rocks it is low, as exemplified in the slates and other rocks on the island of Valentia, County of Kerry.

The slates are found in rocks of different ages, but all belonging to the Palæozoic; numerous small workings are found scattered over the country, but principally in the province of Munster. In Munster the largest and more numerous quarries are in the *Killaloe district*, or those portions of Clare and Tipperary west and east of the south extremity of Lough Derg, between Broadford in Clare and Portroe in Tipperary.

Of these quarries the largest is that at Corbally, near Portroe, where there seems to be a nearly inexhaustible supply of excellent slate; but the quarry is too confined to be worked to the best advantage, and a great deal of what ought to be profit, is spent in raising the slates and rubbish out of the workings. Some of the slate veins in this county have a curve or "wind" in their cleavage, which makes the slates, otherwise excellent, nearly valueless. The slates in this district are in the "Dark Shale series," the lowest division of the Cambro-Silurian.

The second district in regard to the number of quarries in work, is that generally called the "*Ormond Slate quarry district*," in the valley of the river Lingaun, at the boundary of not only the Counties of Tipperary and Kilkenny, but also of the provinces of Munster and Leinster, the nearest town being Carrick-on-Suir; the rocks, as in the Killaloe district, belonging to the "Dark Shale series" of the Cambro-Silurians.

The veins of slate are numerous; but unfortunately they are greatly cut up, shifted and displaced by faults, which adds considerably to the expense of working them; and when a quarry is in full working order the vein of slate is found to be cut out, necessitating all the work of opening up a quarry to be gone over again. At the present time, all the large workings are in the valley, where the strata must be most broken and displaced. If, however, the works were on the hills, they ought to be more remunerative; for even if the veins are as much displaced as below, which is not probable, the quarries could be worked by levels and tunnels, which would save the present vast outlay for lifting and pumping.

In the slate vein at the Victoria quarries, also on the hills to the SW., Mr. Hughes, Junior, one of the agents of the Company, has lately found most interesting fossils, of which the following is a list supplied by Mr. James Budd, of Tramore, County Waterford:—*Graptolites Hisingari, Diplograpsus pristis, Didymograpsus? Fucoids, Buthotrepis antiquata.*

In the County Cork, in the Silurian rocks of the Glengariff Grits type, various trials have been made on the slate veins, but the only ones that have been prosecuted with vigour are those belonging to the Knight of Kerry in the island of Valentia. The veins in this island do not give good roofing slates, but they are famed for the slabs made from them; all the larger sizes of slabs supplied to the London market coming from this locality. The best roofing slates are in a vein in the townland of Coole, and in another in the adjoining island of Beginish.

In the "Yellow Sandstone" of the same county, or in beds immediately below it, good red slates have been raised in different places, as at Crookhaven and on Sherkin Island, but no extensive works have been opened.

Some of the bright green slates at the base of the group ought to supply a good slate for ornamental purposes; as yet, however, no quarries have been opened in them. Blackish grey slate veins occur in the Carboniferous strata, and have been worked in places in the County of Cork, the largest quarries being at Benduff near Rosscarbery, at Clonakilty, and the Old Head of Kinsale.

In the County Tipperary, in the vale of Aherlow, are slate veins, on one of which in olden times an extensive quarry was opened. The rocks here however, are of an uncertain age, as this is one of the tracts that may possibly belong to the Cambrians. One of the veins is of very superior quality, and capable of producing excellent roofing slates and slabs, but the quarry is distant from either water or railway carriage. The cleavage is nearly perpendicular.

In the County of Waterford, in the "Dark shale series," slates have been worked east of Kilmacthomas, and farther northward, in different places in the Rathgormuck district, some of these veins seem to be of good quality.

In the County of Wexford, near Newtownbarry, there is a vein from which fair slates for local use are raised; the works, however, as yet are shallow.

In the County of Wicklow, at Clonwilliam, a little S. of Wooden bridge, is a vein of slate from which is being raised a material excellent for the manufacture of "school slates;" also a handsome green roofing slate. In the same neighbourhood, north and south of the Aughrim river, is a vein easily wrought into large slabs. This was, to a small extent, worked in the townland of Ballycoog, principally for tombstones. In the same county, in different places south and south-east of Rathdrum, there have been trial openings and workings on slate veins. Those in the

Kilmacrea hills, north of Redcross, were the most extensive, and good slates seem to have been got in places, but the veins are narrow; as, however, they could be easily worked, they ought to be remunerative. At Glanmore, to the north, but in Cambrian rocks, a quarry was opened by Mr. Synge, from which were procured slates stated by Kane to be "of a quality and appearance fully equal to those imported from Bangor."

In the County Mayo, in the Cambro-Silurian rocks near Westport, and probably on the same geological horizon as those already mentioned, slate veins have been worked a little, but as they have not been followed in depth, their quality cannot be stated. Farther south-westward, in the country north of Killary Harbour, in the neighbourhood of Doolough, and also margining the bay, are slate veins, some apparently of good quality, which are as yet untried, except at Derrygarve, where an excellent slate is found, but here the vein is too insignificant to be followed. In other places in the same group of Cambro-Silurian rocks, slate veins occur; it is, however, unnecessary to enumerate them. In the "Salrock beds"—Silurian age—at the farm-yard of Salrock, there seems to be a good bed of purplish slate; as, however, most of the rocks of this age in this portion of Galway are much affected by "concealed joints," it is possible the vein may not be of much value.

## Slabs. Flags.

The slabs made from slate rocks have been mentioned; others are the thick slabs into which the foliated granites are capable of being split, which are excellent for the flagging of pathways in towns; those procured from the Leinster granite being extensively used in Dublin. In places in the Old Red Sandstone, and in the similarly constituted shore beds of Carboniferous age, parallel systems of fine jointing occur in some sandstones, rendering them capable of being split into slabs; this is also the case in some of the limestone of the Burren type. The slabs due to fine jointing are usually of less value than flags, as they are liable to be easily broken across.

In the "flagstone-series" at the base of the Middle Coal Measures there are even-bedded thin but tough flags, on an average about two inches thick, which can be raised either in small or large sizes; the principal places in which they occur have already been mentioned in Chapter VI. on the Coal Measures.

In the Lower Carboniferous there are local series of flags, those of most value occurring in the Old Red Sandstone, the "Shore-beds," and the Calp. Near Kinnitty, King's County, are thick flags, capable of being easily worked to a beautiful even surface and edge; and the same class of stone is found in the Old Red Sandstone and the "Shore-beds" in other localities.

In the Calp, except in Ulster, the flags are usually limestone, and thick bedded, but in places they are arenaceous and thin bedded; the latter occuring near Loughrea, County of Galway, at Rathgar, County of Dublin, and in other places. In the Carboniferous Slate of the County of Cork good flags have been noted, as near Adrigole, Bantry Bay; but in no place have they been extensively worked. In places in the Triassic rocks of Ulster there are coarse flags, but not to be compared with those of the Palæozoic rocks.

In the Lower Palæozoic rocks good even flags are not very common; but they are locally worked, as at Mylerspark quarry, to the SE. of New Ross, County Wexford; also in other localities.

## Marbles and Limestones.

The Irish marbles are not only very varied, but some of them are handsome, and even beautiful. To Messrs. Sibthorpe of Dublin, and Colles of Kilkenny, who are best acquainted with those in the market, we are indebted for valuable information about them, which has been incorporated in the following descriptions; information has been derived also from Kane's "Industrial Resources of Ireland."

The marbles principally worked are black, grey, red, mottled, green, and white, in colour. The Upper Limestone gives more marbles than any other group, but the best red varieties occur in the Lower Limestone; while the white and green marbles are different kinds of metamorphic Lower Palæozoic calcareous rocks. Those quarries enumerated by Messrs. Sibthorpe and Colles will be described first, the others afterwards.

In Donegal, near Church Hill, is a white marble (metamorphic), value unknown, as it has not been opened up. SSW. of Armagh is the well-known red Carboniferous limestone, formerly much worked, but its colour is light and unsatisfactory, and of late its place has been taken by the Cork and Belgian marbles. Near Belleek, County Fermanagh, is a fossiliferous marble of a very peculiar colour, but the beds are thin. In Partry, Mayo, there is a fair black marble, but not in sufficient quantity to form a large quarry. SE. of Oughterard, County Galway, are black stones that can be raised in great lengths; they have not been, however, favourably received in the market. In the same vicinity, but nearer to Oughterard, in the townland of Billymore, is a "shelly black" stone like that of Kilkenny.

A little NE. of Galway, at Angliham, are the world-famed black marbles. The bed locally called "the London bed," which, according to Mr. Sibthorpe, is the best black marble known, unfortunately has now a great "clearing" over it, and has dipped considerably below the level of Lough Corrib, so that it is nearly impossible to keep the water out. In the same neighbourhood is an excellent grey stone, but only as yet worked for tombs and other local purposes. At the Merlin Park quarries is a bed of black stone, considered by Mr. Sibthorpe to be nearly equal to the Angliham "London bed."

The fossiliferous crinoidal marble of Clonmacnoise, near Athlone, is well known and much used, but the beds are thin. Near Bagenalstown and elsewhere in the County of Carlow are black marbles; but the colour is not so good as that of the Angliham stone. At Kilkenny are the well known marbles. Of these there are three varieties; "shelly black," "pure black," and "dark grey."

The shelly black was one of the first marbles worked in Ireland. Nearly two centuries ago it was worked by the great-great-grandfather of the present proprietor, Mr. Richard Colles, into chimney-pieces, picture frames, and various other articles, by machinery of his own invention, worked by water power. There is a very old and popular belief that this stone when raised is perfectly black, and that afterwards by degrees the white fossils become apparent. Mr. Colles, however, states that he never knew an instance in which this occurred, as the fossils are always to be seen from the first. The pure black is hard and fine grained, a very fine slab being in O'Connell's tomb at Glassnevin, Dublin.

In the south part of Clare, and in the County of Limerick, in various places in the Lower Limestone, are red and mottled limestones. Specimens of nearly all the Limerick "reds" can be seen in Adare Manor, the seat of the Earl of Dunraven. During its erection a considerable quantity of stone, in fact all the red marble, was taken out of the Clorane quarry, to the north of Adare; but since then the lower beds have become red, which proves that the red colour is due to a chemical change in the rocks. All the red marble quarries in Limerick and Clare are enumerated in the Geological Survey Memoirs.

A pinkish-grey stone, in places yellowish, was used for the beautiful pillars in the cloisters of Askeaton abbey, said to have been built by the Great Desmonds (Fitzgeralds) in the fourteenth or fifteenth century. The exact place where the stone was procured is unknown, but from the fossils it would appear to have been from the Lower Limestone of the adjacent county. At Thomond Gate, Limerick, a black marble was formerly worked; and in the Railway Terminus quarry, but at a great depth, an excellent bed of black stone was found, while a similar stone was discovered by Mr. William Barrington in the Railway cutting between Adare and Rathkeale.

The red and other coloured marbles are rather numerous in the County of Cork, as near Fermoy, Little Island, Buttevant, Midleton, and other places. The Little Island "red" has been used in the Liverpool Exchange, in Manchester, &c. The Fermoy red at the R. C. Church, Thomas Street, Dublin; and the Cathedral, Queenstown. The Midleton stone is very different from the ordinary Cork type, as it varies from a warm dove colour to a rich variegated marble, while in other places the colour is equal to jasper; it is now much used, although only very lately known. In Kerry, trials have been lately made on whitish, pinkish, and greyish stones, but as yet with no practical results.

The Galway marble (*ophiolite* and *ophicalcite*), known as the "Connemara greens," occurs in various places, but at present the only quarries worked are at Streamstown, near Clifden, by Mr. Colles; and at Lissoughter, near Recess, by Mr. Sibthorpe; while numerous articles of *vertu* are carved out of it by Mr. Macdonnell, a self-taught artist in Clifden. "The buildings in which this stone has been used, are very numerous, but the largest column yet obtained is at St. Ann's, County Dublin, the princely residence of Sir Arthur Guinness, Bart. This marble is a good stone for inside decoration, but for outside work it is nearly useless, as it weathers so rapidly. A short time since, it and some of the other Irish marbles were much used by English architects for outside work, the consequence being that all alike acquired for a time a bad reputation."

A rock allied to the ophiolites is a handsome greenish-brown speckled stone (*eklogite*), found at Currywongaun, near Kylemore Castle, in north-west Galway, and at Tonaderrew, south of Ballyhean, Co. Mayo. There is also a white stone at Craggs, to the south of Letterfrack, on which a quarry has been opened by Dr. Ritchie of Belfast. This stone is of "excellent quality, equal to the Italian, but it rises in small blocks." The latest accounts state that the size of the stones increases in depth, and it is hoped that good sized blocks will eventually be raised.

Other localities for marbles are; in the County of Dublin, red at Johnstown, and black at Celbridge; in the County Tipperary, black near Portumna bridge, and at Castle Biggs; in the County of Galway, an excellent grey stone near Ballinasloe; this can be raised in large sizes, and was extensively used in Lady Coutts's Markets in London; in the County of Clare, a fine bourdella marble at Clondeslough; in the County of Kerry, black, and white variegated stone near Listowel and Tralee; from the latter locality it used to be largely exported; a striped red and white marble at Killarney, and near Dunkerron marble of various colours, black, white, purplish, yellow, and veined; in the County Longford, brownish red, mottled grey, at Ballymahon. Black stones of different qualities occur at Castlebar, County Mayo; near Glasslough, County Monaghan; Rathmullen, County Donegal, and Carrickahedy, County Londonderry.

Good limestone for general building purposes occurs nearly everywhere in the Upper Limestone, those of the Burren type giving the best material. It is found in numerous places in Clare, Galway, Mayo, Roscommon, Sligo, Longford, &c. Many of the quarries have already been mentioned, but there are others of note. At Ross and Ardbraccan, in Meath, are well known stones, and much used; at Sheepshouse, County of Louth; at Edenderry and Tullamore, King's County, there are very superior stones, some being marbles; at Ballyduff, one mile NW. of Tullamore, the stone can be raised in large blocks; the tracery, windows, and dressing, of St. Patrick's Cathedral Dublin, are from this quarry; also columns, &c. in various public dwellings in Dublin.

At Moate, Westmeath, there is a very good quality of stone, which was largely used in the new Exchange, Manchester, and at other places in England. There are also good stones in the neighbourhood of Carlingford, County Louth, that have been largely exported to England.

The well known Milverton quarries near Skerries, County of Dublin, should also be mentioned.

The White Limestones of Cretaceous age in Ulster have been largely used for building stones, as in Belfast and Moneymore ; they do not, however, cut with as even faces as the Carboniferous rocks. These rocks at Larne and Glenarm, as previously described, are manufactured into whiting.

Formerly, all the limestones of the different formations were extensively used to burn into lime for agricultural purposes. This, however, unfortunately for the country, has been greatly done away with since the introduction of guano, and now there are thousands of limekilns that have not been alight for over twenty years. The lime produced from the Cretaceous rocks is usually "rich," and although good for land, it is not the best for mortar. The Metamorphic and other Lower Palæozoic limestones in general contain impurities, and many of them are difficult to burn without their slagging, while when burnt, they give a small return of lime; some of them, however, produce hydraulic limes ; this is also the case with many of the limestones belonging to the Calp. In general, the Fenestella and Burren limestones are good lime-producers, but in places they are magnesian, which takes away from them their value for building purposes.

Pure limestones make good road metal, when the traffic is not excessive, but the argillaceous or Calp limestone always makes dirty roads, and the former extensive use of it for metalling its streets has given to the capital of Ireland the *sobriquet* of "Dirty Dublin."

## Hydraulic Limestone.

A list of the Irish stones capable of making hydraulic limes was drawn out by Sir Richard Griffith, who went into the subject; but unfortunately it was never published, and cannot now be found; only a few localities therefore can be mentioned. Hardman records an hydraulic limestone at Drumreagh, County Tyrone; Egan one on Shelling hill, Benburb, County Armagh; Major-General Scott, eminent for his researches in this subject, mentions "a good hydraulic limestone, at Castle Caldwell, County Fermanagh," and Mr. John Kelly records a stone below high water mark in Lough Swilly, near Farland point, capable of producing a lime that will set under water.

Other localities are, Robertstown, east of Foynes, County Limerick; Courtown, County Wexford, a limestone in the Cambro-Silurian rocks; south of Wexford in the Carboniferous limestone there are beds having hydraulic qualities in different quarries; and in the Silurian rocks at Toormakeady, County Mayo, there is a limestone said to have similar qualities.

In connection with the hydraulic limes may be mentioned "a viscid greyish substance, which, when dried and mixed with lime, makes an hydraulic cement." According to Mr. J. Nolan it occurs in the drift to the north-east of Ballynamona, on the north of Lough Corrib, County of Galway.

## Sand and Grit Stones.

Stones of these kinds occur in all the groups from the Triassic downwards; but the best for fine tool-work are found among the Triassic and Carboniferous rocks.

The Triassic rocks are usually of red or reddish colours, but some are white, yellow, and brown. The most extensive quarries in them seem to be those in Scrabo Hill and Dundonald, County Down, but there are various others in different places in the province of Ulster.

The best Carboniferous sandstones worked at the present time, are in Tyrone and Londonderry; some of them, as, for example, near Draperstown, Londonderry, are in the Calp, while those in the County of Tyrone are in both the Calp and the Burren Limestones. According to Mr. Sibthorpe, the best of the Tyrone stone has been substituted for Portland stone. Formerly these stones were largely exported, but many of the old quarries are now closed, as the "clearing," or "head" of drift, became too expensive to remove.

In the Connaught Coal Measures there are superior stones for tool-work, but they have not as yet got into the market, principally on account of the expense of carriage. Some of these stones seem to be as good as those of Tyrone and Londonderry. Fair stones are also found in the Coal Measures of Leinster and Munster. For general work there are excellent stones in many places in the Old Red Sandstone, and in the Carboniferous "Shore Beds," some being of superior quality; such a vein is said to exist at the boundary of Clare and Galway, near Mount Shannon. The conglomerates, such as those in the promontory of Hook, County of Wexford, can be raised in large blocks, very suitable for piers, and other marine structures. The value of most of the stones belonging to the Old Red Sandstone, and the Shore Beds, for ornamental purposes, is much deteriorated on account of the instability and variations in their colours. In the Glengariff or Dingle Grits, massive blocks can be raised:

they have not, however, been used in any of the extensive sea works, as it has been found cheaper to bring materials by sea from other places where quarries are already open.

Some of the Cambrian, Cambro-Silurian, and Coal Measure grits, make good road metals; also the quartzites and quartz-rocks. The hard quartzose grits of Cambrian age at Bray Head, County of Wicklow, are now being extensively quarried, and carried to Dublin to mend the streets; a similar quartzose grit was cut through near Newtownmountkennedy, in making the tunnel for the Vartry Water Works. Quartzite and quartz-rocks are much used in the County of Wexford, for road metal, and grit-stones in other places.

## Granite and Elvan.

The granitic rocks of Ireland are very variable in character. Some are good handsome stones, easily worked, and of great durability, but excepting the quarries near Dalkey to build Kingstown-harbour, no extensive quarries have been opened in them.

In the Dalkey quarries the stones are of different qualities; they also seem to be of different ages, masses of the newer granite coming up through the older. The better class of stone cannot be surpassed for texture, for hardness when free from its quarry water, and for the readiness with which it could be squared and dressed. From other places in the Leinster range the granites have been largely procured for columns and other works in the public buildings of Dublin and places in England. Most of the stones thus used have been procured from surface stones. These surface stones are peculiar, for although they have lost all their quarry water, yet they are easily worked. This seems in a great measure due to the "grain," or structure like foliation, which, as previously mentioned, is found in all these granites. They are, however, of two distinct qualities, the older granites (*Pre-Silurian*) being for the most part good stones; while the newer (Post-Carboniferous?), although they work readily, become discoloured and weather more or less rapidly. Very good stones are procured at Ballyknockan quarry to the SE. of Blessington.

At Carnsore, in the extreme south of Wexford, are perhaps some of the oldest granites in Ireland, they being of Cambrian age. Most of them are of metamorphic origin, and consequently not the best for tool-work, but in the immediate vicinity of Carnsore there is a very superior vein of granite with floors, end, and backs (horizontal and perpendicular joints), that render the rock capable of being easily raised in large blocks very suitable for sea-works; this granite has not as yet been worked.

In the County of Galway the granites and Elvans are most varied, many of them being extremely handsome stones. The great mass of the granite is of metamorphic origin, but in different places, especially in the neighbourhood of the town of Galway, there are numerous veins and protrusions of granitic rocks (granites and elvans), many of them being both handsome and suitable for tool-work; yet none of them have been brought into the market. Some are red, others grey, or of mixed red and yellow; or red, yellow, and green; also purplish mottled or porphyritic, and of other varieties; one very handsome variety is a rapakivi porphyry, another being of a rich chocolate colour, spotted with deep red and green, similar to some of the continental porphyries that are so much prized. In Illaun Dara, and in places on the mainland in the neighbourhood of Roundstone Bay, are granites which are easily raised in large squared blocks, and are very suitable for piers and such works.

The newer basal elvans (Post-Silurian), such as that near Waterloo Bridge, Clifden, dresses readily; but the older ones (granitone and allied rocks), also the metamorphosed Plutonic rocks, including all those that may be classed under the general name of Hornblende-rock, almost invariably are bad for tool-work; but they cannot be excelled for rough sea-walls on account of their great weight and their capabilities of bearing nearly any amount of wear and tear.

At Bessbrook, near Goraghwood, County Armagh, a quarry has been lately opened in a pale bluish-grey granite, and one at Goraghwood in a porphyritic granitoid elvan. These quarries are now in active work, and the stones are shipped largely for monuments and public buildings, finished in every style up to the best polished work. At Ballymagreehan, near Castlewellan, County Down, great expense was gone to in opening a quarry, from which the steps and plinths of the Albert memorial, Hyde Park, London, were procured, but shortly afterwards the works were closed. In the County of Donegal, where there is as great a variety as in the County Galway, works were established near Buncrana, but "the stones manufactured were very variable in colour, probably from being top stones, which got them into bad repute, and the work did not turn out a commercial success."

The granites and elvans in places are used for road metal; the granites and silicious elvans make a good dry clean road, but in general they are unsuitable for any road on which there is an excessive traffic; the basic elvans, however, are usually excellent road metal, but as they are so hard and expensive to break, the contractors rarely use them, except when compelled. In the places in the Counties of Wexford, Waterford, and elsewhere, where they are used, the roads are very superior to those of the neighbouring localities.

### Felstones and Traps (Whinstones).

As building stones the rocks of these kinds are usually not very suitable for tool-work, although excellent for general building purposes. Some of the felstones, however, especially the porphyrites, are good and handsome stones, such as those in the neighbourhood of Glenflesk, near Killarney. Of the County of Down rock Traill writes, "There are a number of porphyritic dykes which penetrate the Cambro-Silurian rocks, many of which would form highly ornamental building stones; such as the dolerites and porphyrites occurring along the shore south of Newcastle, at St. John's point, and in the Ard promontory, also some inland near Ballynahinch."

They do not as a rule yield blocks of great size, and are as yet almost wholly unworked, but are "capable of producing very beautiful stones of sufficient dimensions for polishing and for architectural purposes." Remarks similar to these, on the felstones of other localities, will be found in the reports of Du Noyer and others of the Irish geologists. Some of the eurites and dolerites of the County of Dublin and elsewhere, as years ago pointed out by Oldham and Jukes, are suitable for paving stones, similar to those now being imported from England for the Dublin streets and tramways.

A rock allied to felstone is extensively worked at Belleek, County Fermanagh, to manufacture into kaolin or porcelain clay. It is possible this rock belongs more properly to the granitic rocks, but in various other places there is petrosilex similar to the rocks that in China are manufactured into kaolin. Dykes of petrosilex are specially numerous in Errisbeg, the country westward of Roundstone, County of Galway; while Warren recorded many dykes in the area to the north of the Erriff valley, County of Mayo. They have also been observed in Wexford and neighbouring counties in the neighbourhood of the granitic districts. The rocks suitable for the manufacture of kaolin have already been mentioned in the last chapter.

## Manures.

There are various mineral substances that can be used as fertilizers of the ground; some, however, have to be artificially treated. These (often local) manures were formerly in great request, but now foreign products, greatly to the detriment of the land, and the resources of the country, have nearly altogether superseded them.

*Lime* as a manure has already been mentioned. It is beneficial to all classes of drained land;* but to those of a calcareous nature too much must not be added. It may be used when fully burnt (quick lime), when half burnt, or when ground up unburnt—when half burnt it is very effective, if immediate results are not required, as the stones "shell," and the lime is imparted to the land by

* All the limy manures if applied to undrained land which is impregnated with iron are deleterious, as they make the iron soluble, and thus liable to be absorbed by the plants growing on the land; but when such soils are properly drained these manures are most beneficial.

degrees. In only a few localities is the ground limestone used; yet it is a highly valuable manure, especially on light peaty soils, because while fertilizing the land it adds to its weight and substance It ought to be more generally adopted, especially in those places where fuel is dear, as ground limestone will give nearly as quick, and much more lasting, returns than "quick lime." The use of *Gypsum* as a manure has been mentioned in Chapter XXI. page 359.

Another former favourite was marly gravel, or "Corn gravel" as it was called in Munster, as a coating of this material on wheat land greatly increased the crop. This gravel is very useful on upland, if not used in excess; while on drained bogs and moors it is nearly invaluable. In the latter cases scarcely too much can be used if added gradually, and time be given to allow it to blend into, and mix with, the peaty soil. The marl that occurs under many of the bogs was also used similarly to the "corn gravel." At the present time most of the gravel pits of Munster are levelled in; while the marl under the bogs is rarely raised.

In parts of Wexford and Wicklow there are marls and shell-sands (manure gravels), which were extensively used as manure. The marl was raised and allowed to "melt," or disintegrate, under atmospheric influences, during which process the injurious ingredients were dissipated into the air, or carried off by rain and runlets; while the manure gravel was raised and used as bedding or "soil" for the cattle, prior to its being applied to the land. The use of the marl is now almost obsolete, although the manure gravels are still used a little. The marl has similar qualities to those of ground limestone, and corn gravel, while the manure gravels are good except on light soils.

The Æolian drift and other sands were much used formerly, in Ireland, as manure. Those with sufficient limy matter have very similar effects to lime, but are more effective on stiff retentive soils. The silicious varieties are invaluable on marls, and very useful in stiff clays. Off the south-west coast of Cork are large banks of "shell-sand," and twenty-five years ago a large fleet of "sand boats" was employed in dredging this up and boating it to the different harbours and piers, from which it was carted for miles into the interior; while in some localities, where the banks were exposed at low water, innumerable carts and boats were loaded during ebb tide. This trade has now nearly ceased, although the "shell sand" was a most useful manure on all classes of land, especially if at a distance from the sea.

"Dolerite sand" is in many cases a natural fertilizer. Much of the rich land in the plain of Limerick is due to the *débris* of the melaphyres, eurites, and tuffs; the same thing occurs in the vicinity of Croghan Hill, King's County, and near Castlebar, County Mayo; while in the latter county, west of Toormakeady, the effects of this sand are most conspicuous, the *débris* of a bed of melaphyre forming a rich belt of pasture land in the Silurian conglomerates.

"Growan," or decomposed granite seems also to be a fertilizer under certain conditions, as seen in the County of Carlow, the *débris* of the granite mixed with the limestone gravel making rich soil. The disintegrated melaphyres, dolerites, and granites, furnish limy gravels and clays, alkalies, and soluble silica; and they are calculated to sufficiently supplement most of the deficiencies in the composition of any soil solely derived from merely calcareous rocks.

Sulphur ore (pyrite), although not in itself a fertilizer, is extensively used for making sulphuric acid (Vitriol), so valuable in the manufacture of artificial manure. The Sulphur ores of the Ovoca mines are thus utilized in the chemical works at Arklow, at Wicklow, in Dublin, in Cork, in Belfast, and elsewhere.

Apatite (phosphate of lime), also used in the manufacture of manures, occurs in the Counties of Dublin, Down, Antrim, Galway, and elsewhere; but as yet no vein of sufficient size to be worked economically is known.

## Water Supply.

The supply of water in a district, especially of that part of the water which issues from springs, is largely dependent upon the petrological character of the rocks, and the geological structure of that district. Sir Robert Kane, F.R.S., in his "Industrial Resources of Ireland," gives an estimate of the rainfall and an exhaustive account of the surface water and the uses to which it can be put. He also points out that the water power might be much more utilized than it has been. The Upper Bann only, "is fully economized in Ireland ; its banks presenting a picture of industry, of comfort, and intelligence which is a pattern to other districts." Observations since made, show that the average rainfall is greater than was estimated by Kane ; but, otherwise, what he states is applicable to Ireland of the present day. We shall here, without going into much detail, give a short discussion of the various rocks of Ireland, beginning with the Eruptive rocks, in reference to their absorbent powers, and the probability of procuring water from them, either by sinking wells or by driving levels across them.

The eruptive granitic, felspathic, and such other rocks, except the tuffs, and perhaps some of the traps, have small absorbent powers. Most of the water falling on areas of such rocks runs off rapidly, and pounded or collected water is rarely found, except in the surface accumulations (drift, alluvium and bog), or in breaks in the strata, such as dykes of fault-rock and growan, or the fissures adjoining newer eruptive rocks, and in mineral veins.* Dykes of fault-rock and growan, if in valleys or extensive flats, often give a large and continuous supply of water, due, not so much to percolation through the rocks which they traverse, as to the drainage into them from surface deposits. However, as such dykes always contain more or less metallic or other extraneous matter, and in some cases, even, can be profitably worked as lodes, the water derived from them is often tainted by their mineral contents.

Springs are frequent along the margins of tracts and courses of eruptive rocks; also in the tracts, when beds or other masses of tuffs are inter-stratified with the other rocks. Thus Pallas Hill, County of Limerick, which is composed of Carboniferous melaphyres with some beds of tuff, is famed for the numerous springs on it; these, however, are not solely due to the beds of tuff, as many of them are on lines of fault that dislocate, and sometimes shift, the rocks.

The metamorphic rocks generally have but small absorbent power, and this is in an inverse ratio to the

* A remarkable supply of water was found in the syenite of Town Hill near St. Helier, Jersey, in sinking the well laid out by Major Humphry, R.E., for Regent's Fort. In the above description *growan dykes*, although in general a variety of fault-rock, are mentioned separately, as they possess very distinctive characters.

intensity of the action to which they have been subjected; the metamorphic granite absorbing less than the gneiss, and the gneiss than the schist, while the "sub-metamorphic rocks" act very like the unaltered ones. There is, however, an exception in the quartz-rock, whether unaltered or altered, which, as mentioned at page 12, gives off copious springs; while quartzite (metamorphosed grits and sandstones) does not do so; this is markedly instanced at Howth, County Dublin, in the Forth mountains, County Wexford, also in the Bennabeola Mountains, County Galway, and in other places; where the principal springs issue from the quartz-rock or the lines of fault connected with it. This is due, not to the permeable character of the rock material itself, but to the innumerable regular and irregular joints in the mass, through which the water percolates. There are also in many of the metamorphic districts, permeable beds of limestone and other calcareous schists, that collect water to be afterwards returned to the surface in springs.

The general character of all the older Palæozoic rocks, excepting the limestones and such like, is to be impermeable; but the Cambrians and Cambro-Silurians are so traversed and broken up by faults, that they are generally capable of containing a vast quantity of water, which finds its way to the surface in innumerable springs, but some of these, especially in the Cambro-Silurian Mineral Districts, are chalybeate or cupreous. In many of the districts, supplies of water are stored in small lakes, whose basins have been produced by the rupturing and shrinkage of the rocks. It is, therefore, always possible when a town is situated at a lower level than ground formed of these rocks, to supply it with water, either by taking it from one of such lakes, or by tapping springs by a level driven across two or more lines of faults. Villages or small towns situated on these formations and not requiring a large and continuous supply of water, can usually be more cheaply supplied by pumps, if the wells be judiciously sunk; their sites being so chosen that the sewage of the town cannot percolate into them. To prevent this, it is usually necessary, only, that the dip of the beds of rock should be from the well towards the town; but in some cases, other precautions are also necessary.

The older Silurian rocks of Mayo, Galway, and Kerry (Llandovery, Wenlock and Ludlow types) are somewhat similar to the Cambro-Silurians, but are not as much broken up by faults; still they are capable of holding a considerable supply of water, especially when they contain beds of limestone and tuff, or permeable sandstones. There is no large town in Ireland situated on or near such rocks; the question therefore of their water-bearing character is not one of much practical importance.

The newer Silurians of Cork (Glengariff grits) and Kerry (Dingle beds) are usually impermeable; there are, however, exceptions to this rule, as certain calcareous and tuffose rocks collect water, as do also some of the slates. There are also many faults, not however as numerous as those in the Cambro-Silurian, in which the surface water collects to be conducted to the lakes and springs. Hereafter, if necessary, water could easily be procured from these areas, but at present the towns situated in them are inconsiderable. These remarks apply also to the tract between Pomeroy and Lough Erne, and those in the vicinity of Boyle and Ballaghaderreen where the rocks are probably of a similar age, as mentioned at page 82.

As pointed out when describing the sedimentary rocks, those belonging to the Carboniferous formation underlie a large portion of Ireland; they, therefore, are, as regards the matter in hand, the most important rocks in the island. For our present purpose they may be conveniently divided into the "Old Red Sandstone" of the Cork type, the ordinary "Old Red Sandstone" and the "Shore-beds," the "Carboniferous Slate," and the different Limestones and Shales.

The Old Red Sandstone of the Cork type constitutes but an indifferent water-bearing formation, if we except its upper beds, the "Yellow Sandstone" of Griffith. These are permeable rocks, especially certain slates that are usually found at the bottom of the group, from which the inhabitants procure excellent and constant water by cutting in them wells, only one or two feet in depth. These are important beds relatively to the present question, as so many towns in SW. Ireland are situated on them or on the overlying Carboniferous Slate or Limestone. In most cases, as at Queenstown, Cork Harbour, the "Yellow Sandstone" forms higher ground than the newer Slates and Limestone, and in such cases the water should be procured by driving levels from these into the slates belonging to the "Yellow Sandstone." This is to be preferred to sinking, if the place be situated near the sea, and especially if it be on the limestone, as this rock is so porous that the sea water often percolates through it for considerable distances.

The "Old Red Sandstone," of the ordinary Irish type, and the similarly constituted "Shore-beds," do not require much consideration, as they are usually not of great thickness, except in Kerry, and perhaps in Fermanagh and Tyrone, while in general, the necessary quantity of water of a better quality can be procured from older or newer rocks. If water, however, is required from them, it can be procured, as most of the rocks are permeable, while at their base in places in the County Clare is a peculiar limestone that yields good water.

"The Carboniferous Slate," the County Cork representative of the Carboniferous Limestone, is made up of grits and slates somewhat similarly to the Cambro-Silurian formation; it is, however, less affected by faults, and does not hold as much water, nor produce as many springs.

The Carboniferous limestones similar to the older ones, are more or less permeable, some groups being more so than others. These groups are named and described at page 65. The lower "Shaly Limestone," is in itself a permeable rock, but there are often between the beds impermeable shale and clay partings. In these rocks there is always a considerable supply of water, so that springs are common in the areas occupied by them. The "Fenestella Limestone," is very permeable, and the water rapidly sinks into it, generally not coming to the surface except at the outcrops of its basal beds ("Lower Cherty Zone"), or along lines of faults; but in some places there are peculiar thin seams of shale that traverse the mass irregularly, and these nearly invariably stop the passage of the water, pounding it up or bringing it to the surface. At the "Lower Cherty Zone," springs are not uncommon.

The Upper Limestone is very variable in character. In the Calp of Ulster, arenaceous rocks of an impermeable character often occur; but associated with them are others, also limestones and shales, all more or less permeable, which supply the springs in such areas. Elsewhere the Calp rocks, although always argillaceous, are more or less calcareous, often good limestones, and they can absorb water in a greater or less degree; but the shale partings and the beds of shale and arenaceous rocks, and, in some districts, of tuff, or even melaphyre or eurite, prevent it from descending; therefore, in these Calp areas water is generally easily found near the surface by sinking for it. There are, however, some districts, as in portions of Limerick and Clare, where the rock is called Calp on account of its dark, blackish colour, although a very pure limestone, without shale partings or beds, and in such areas water sometimes cannot be procured, except at considerable depths.

The Upper Limestone of the Burren type is generally inclined to be cavernous, and in it occur all the great systems of subterranean rivers; while on its surface are situated most of the Turloughs or Blind-lakes. It often has, however, beds or continuous layers of chert, and in some places, of shale, clay, or clunch, which prevent the water from sinking, and bring it to the surface, either at the outcrops of these impermeable beds, or along lines of fault. In portions of Clare, Galway, Mayo, and other counties, there is too much water in the winter and a want of it in summer; as during the former the turloughs are full, while in summer they are dry, and in places the cattle have to be driven miles, morning and evening, to water. This summer scarcity could be remedied in many cases; as each turlough is fed from one or more vents, while the rest of the basin is coated by impervious clay, the insoluble argillaceous residue of the limestone deposited by the water; if, therefore, impermeable walls or dams were constructed round the vents, a certain depth of water could be impounded for summer use.* This could not be done on hills, like those of Burren, County Clare, but in this and similar areas there are many places

* Such dams would in most cases require flood-gates or sluices to regulate the water supply.

where tanks or small reservoirs could be easily constructed, in which to collect the water given out during the winter by the springs at the fault lines, or along the outcrops of the partings and beds of shale and chert. Chalybeate and other mineral springs are not uncommon in the Upper Limestone, especially in the Calp. Many of these "wells" were formerly much frequented, and used on account of the medicinal properties of the water, but at present they all seem to be out of fashion.

The Upper Carboniferous or Coal Measures are made up of both permeable and impermeable rocks, and contain a large store of water that in general is easily procured. In the Queen's County Coal-field, numerous bore holes were made some years ago in search of coal, and the area is now dotted over by artificial springs; some being chalybeate, but most of them clear, good-looking water. Nevertheless, it seems probable that the water from some of the rocks have pernicious qualities; as in the Coal Measure areas, the inhabitants are often liable to ailments not prevalent outside their limits. Others of the waters, however, are eminently curative, such as the iron, sulphur, and magnesia springs of Lisdoonvarra, County Clare, which have been resorted to from time immemorial. These issue from the basal shales (Lower Measures), and in the same beds in other localities are somewhat similar springs.

The Mesozoic and Cainozoic rocks, which in England contribute largely to the water supply, occur in Ireland only in the province of Ulster, except an insignificant tract of Triassic rocks, which extends into Meath; and even in Ulster they are sparingly developed and of small thickness. They are represented by rocks belonging to the Permian, Triassic, Jurassic, and Miocene groups.

The Permian rocks are so rare, and occupy such limited tracts, that they are of no account; while the Triassic and Jurassic rocks usually emerge only as a fringe round the Cretaceous and Miocene rocks; consequently their waters in general can only be procured from deep wells. The Cretaceous rocks and the Basal beds of the Miocene supply numerous springs, but the other Miocene rocks are principally impermeable beds of dolerite. The latter rock, however, covers a large surface, from which a considerable quantity of water can be collected; besides, there are subordinate inliers of argillaceous rocks, which produce two or more zones of springs.

As a rule, the Mesozoic and Cainozoic rocks of Londonderry yield a good supply of water, but in some parts this is very variable. It has hitherto been chiefly obtained only by having recourse to the expensive process of sinking deep wells. These in the Triassic might in some cases have been advantageously avoided by utilizing the springs that occur in the Cretaceous strata margining the dolerite, as well as those in the superincumbent dolerite itself. The water from the latter, is, however, sometimes objectionable, because of the large quantity of oxide of iron contained in it, but when free from this impurity it is usually to be preferred to that springing from the Cretaceous rocks, owing to its comparative softness.

Perhaps one of the best examples of a constant, cheap, and easily available water supply, exists at Moneymore, where, at a distance of less than half a mile from the town, and at about 100 feet above it, the water springs in an unfailing stream from the lower part of the chalk; while the wells in the Triassic, from which the town at present is supplied, are expensive to sink.

For the following details we are indebted to Mr. W. A. Traill.

"Cretaceous, Jurassic and Triassic rocks underlie the greater portion of Antrim and Londonderry and in this respect these counties are favourably situated.

"The Miocene dolerite of the central plateau cannot be considered as water-bearing strata. However, the top surface of the trap rock, immediately below the drift, is to a small extent, but limited in quantity, and liable to pollution. The trap rock allows the percolation of water through cracks, fissures, and jointage seams to the underlying beds.

"The Iron-ore-measure, at an horizon about 600 feet above the base of the dolerite, containing impervious clay, forms a water-bearing stratum, evident by the great number of springs which mark its outcrop. However, the water from this source is not the best, being more or less contaminated by the hydrated oxide of iron.

"The lower aluminous beds yield better water, but to a less extent.

"The Chalk and its underlying bed of Hibernian Greensand, are pre-eminently the water-bearing strata of NE. Ulster. These permeable rocks for the greater part are underlaid by the plastic clays of the Lias, or by the Keuper Marls: and many confirmatory evidences exist which prove their constant supply of water. Along the entire outcrop of the Chalk, from above Belfast to the Giant's Causeway, the number of perennial springs is very great; and in many places this continued outflow of water is a constant source of local landslips, and the displacement of the Coast road.

"The Triassic Rocks—more especially the Bunter series—are also water-bearing, but to a less extent. The comparatively limited area over which these beds are exposed, renders the localities few where borings could be made with a prospect of success. In some cases, however, such Artesian borings have given most satisfactory results, as from the so-called Cromac Springs or Artesian well in Belfast.

"The newer rocks of the greater part of the Counties of Antrim and Londonderry form a geological basin, the dolerite area occupying the centre, with the Chalk and Greensand cropping out almost continuously along its margin, underlaid by the plastic clays of the Lias, or those of the Keuper Marls. The outcrop of the Chalk is found at considerable elevations on Slieve-gallion-carn and Ben Evenagh to the westward, Knocklayd, Lurigethan, and the Sallagh Braes to the north and east; Cave Hill, the Black Mountain, and Collin to the south-east; attaining in some cases to over 1,000 feet in altitude; while throughout the centre of the basin it is below the surface, and covered by variable thicknesses of dolerite. Its depth below the surface for many localities can be readily estimated from its relation to the Iron-ore-measures at the base of the Upper Dolerite.

"Other strong evidences in support of large quantities of water being pent up in the porous strata below the dolerite, are the great number of perennial springs which occur throughout its area.

"The following localities along the central axis of the basin may be cited as places where Artesian borings would probably be successful; near Antrim, Ballymena, Ballymoney, and Coleraine. The requisite depths of course would vary in the several localities, but some being situated in the Lower Dolerite, would not require very deep bore-holes before the Chalk and Greensand would be met with. The Mesozoic and Cainozoic rocks of Ulster would thus appear to possess several strata suitable for yielding water-supplies by Artesian borings.

"The Cambro-Silurian formation, which comprises the greater portion of the County Down, must be looked upon as an unpropitious field from which to expect a water supply by boring. However, in places where the Trias overlaps that formation, by boring into the junction a water-bearing stratum would probably be found. Near Newtownards, Knock and Lisburn are localities where boring under such circumstances might be successful."

As mentioned when describing the Triassic Salt-Measures, Saline springs occur in the neighbourhoods of Larne and Glynn, County Antrim.

The superficial accumulations, principally drift, are so extensive in Ireland, that they add considerably to its water supply. In some districts, such as portions of Kilkenny, Carlow, Kildare, Wicklow and Dublin, where they overlie granitic rocks, they are very important, as without them very little water could be retained, and in summer it would be very scarce. The glacial drifts usually are permeable, the water sinking in them until it reaches layers or lenticular deposits of sand or gravel. Water, however, is often found at no great depth, but in other cases the whole accumulation will have to be sunk through, or it may be even necessary to cut a "well," in the underlying rock, as a cistern to collect the water percolating between the drift and the surface of the rock. But when sinking these wells, if one or two sandy seams or partings have been cut through, a good and permanent supply of water sufficient for ordinary farming purposes may be procured.

In gravel and sand accumulations a permanent supply of water is rarely obtained unless a bed of clay is reached. If this impermeable stratum be pierced, the water will often disappear and may not be again recovered except at great expense. There are however, exceptions, as these sands and gravels may be accumulated in hollows margined by impermeable drift or rock, and under such circumstances the gravel and sand may be saturated with water close up to the surface of the ground. When sinking for water in a hill of glacial drift, the depth at which water will be found can usually be calculated from the heights at which the springs appear on the hill slopes.

Water is also procurable in some places, at the junction of the drift and the overlying alluvium or peat accumulations, this water, however, is often of indifferent quality; but, in places in the mountainous districts and even elsewhere, springs may occur at the junction of the peat and underlying drift or other rocks, and in most cases, if the outfall is kept open and a regular stream flows from the well, the water will be perfectly good and free from organic matter. Peat bogs have great absorbent powers; after a dry summer it takes weeks of heavy continuous rain to saturate the bogs in the basin of the Shannon, and raise the river at Killaloe.

# APPENDIX.

## GLOSSARY OF GEOLOGICAL AND CELTIC* TERMS.

ACICULAR.—Needle-shaped.

ADIT.—A horizontal gallery or tunnel, to drain or enter a mine.

ADULARIA.—*Ice-spar*, a variety of felspar.

ÆOLIAN-DRIFT.—Fine sand drifted and heaped up by the wind.

AERIAL.—Of, belonging to, or produced by, the air.

AGGLOMERATE.—A term introduced by Lyell to designate the unstratified accumulations of rock fragments produced by volcanic action.

AILLE.—A *Celtic* term for a cliff.

ALBITE.—A soda felspar having some lime.

AMORPHOUS.—Having no regular or determinate structure.

AMPHIBOLIC.—Rocks containing a large percentage of amphibole (hornblende).

ANOGENE.—Formed above or near the surface, *see* page 194.

ANTHRACITE.—Stone-coal; coal destitute of bitumen.

ANTICLINAL.—Applied to strata which dip in opposite directions, from a common ridge or axis.

APHANITE.—The compact varieties of the Traps or Whinstones, such as *gabbro-aphanite*, *melaphyre-aphanite* and *dolerite-aphanite*, in which the mineral constituents are in a pasty condition and undistinguishable.

ARD (*Celtic*).—A hill; properly a height.

* Many of the miners' terms are from Celtic (Cornish) roots.

Arenous, Arenaceous.—Sandy; composed of particles of sand (*arena*).

Argillous, Argillaceous.—Clayey; composed of clay (*argilla*).

Argillite.—Clay-schists; metamorphic argillous rocks.

Atalia or Ahalia (*Celtic*).—Brackish or slightly-salt water.

Avon (*Celtic*).—A river, *see* Owen.

Assay.—The determination of the quantity of mineral in an ore.

Attle or Attel (*Celtic*).—Waste, deads; the useless stuff taken out of a mine.

Axis.—Applied to the line about which rocks are bent or turn, or to which they have some common relation. "Axis of Elevation," "Anticlinal Axis."

Back, "The Top of;" Back-of-Lode.—The chemically changed portion of a lode, near the surface of the ground.

Basalt.—Aphanite; a compact variety of dolerite.

Basin.—In reference to a river, all the area draining into it; in reference to rocks lying in a limited depressed tract in older rocks, the area occupied by them; and in regard to rock strata, the beds dipping towards a common centre or short line.

Basset.—The outcrop of a bed of rocks, or the line at which it comes to the surface of the ground.

Bastard Limestone.—Impure limestone; a rock having a perceptible percentage of lime, but not sufficient to make a limestone. In some localities this term is applied to magnesian limestone and dolomite.

Bed.—A geological and quarryman's term. A stratum of rock of greater or less thickness of a uniform or nearly uniform composition or structure; or of a composition or structure different from that of the associated rocks. Correctly, the term applies only to the surface of a rock, and in this sense it is sometimes used.

Ben or Bin (*Celtic*).—A peak.

Bind.—A collier's term for shale.

Blebs.—Small globular aggregations.

Blind-lake.—A small lake or pond in drift, or bog, without a surface outlet, also called Turlough.

Bog (*Celtic*, soft).—An accumulation of peat.

Bog-Butter.—Masses and lumps of mineralized butter and fat found in the Irish bogs.

Bole.—A ferruginous argillaceous rock associated with the Miocene Traps, *see* page 163.

Bore-Hole.—A hole put down by an auger to prove the nature of unknown strata.

Botryoidal.—Resembling a bunch of grapes.

Boulder.—A block of stone that has been carried about by water or ice. In general it is more or less rounded and the angles worn off.

Boulder-Clay.—Drift containing boulders. When unstratified it seems to have been formed by ice, and is called Glacial Drift, or in Ulster, *Till*. Many boulder-clays are not glacial. In all the older glacial or *Boulder-clay drifts*, most of the boulders are rounded, while in the newer or *Moraine-drift* many are angular or subangular.

Break.—Used to denote a want or absence of strata, or a group of strata, in a geological sequence. Also used synonymously with *fault*, to indicate that a bed or series of beds have been broken across and displaced.

Breast.—The extreme "end," in a level or drive in a mine; very similar to *Face, q.v.*

Breccia.—A rock made up of angular fragments.

Brick-Clay.—A clay from which bricks or tiles can be made.

Brown-Coal.—*See* Lignite.

Buddagh (*Celtic*, useless).—Very impure dirty coal.

Buddle.—A trough used in tin mining for washing the ores, and in streaming for separating the gold and tin from the sand.

Bunch.—A miner's term for ore occurring in a small mass.

Burrows, Borradh (*Celtic*).—Synonymous with *Attle, q.v.*

Callow (*Celtic*).—An alluvial flat liable to be flooded.

Calp or Calpe.—A name used by Kirwan for the black Carboniferous Limestone, and subsequently adopted by Griffith for one of the lithological divisions of the Irish Carboniferous rocks.

Cam, Caim.—Winding, *see Kaim*.

CANNEL COAL.—In the Leinster and Ulster collieries this term indicates a compact laminated anthracite. In the Leitrim and Tyrone coalfields, the same term is applied to a compact laminated bituminous coal.

CARRICK, CARRIG (*Celtic*).—A prominent mass of rock *in situ*.

CARRIGEEN.—A little rock.

CATOGENE.—Formed below at some depth, *see* page 194.

CATS HEADS.—A Leinster collieries term for nodules of grit in shales.

CATS-TOOTH ORE.—Crystalline white calamine.

CAWK, CORK.—A miner's term for Barytes or Heavy spar.

CEMENT.—A lime that hardens quickly.

CHALYBEATE.—Containing iron in solution.

CHALCEDONY.—A variety of quartz.

CHERT.—A flinty substance prevalent in some Carboniferous Limestones.

CHINA CLAY.—*See Kaolin.*

CHLORILITE, CHLORITE SCHIST.—A metamorphic rock.

CLAY-IRON-STONE.—Impure earthy carbonates of iron.

CLAY-ROCK.—A term introduced by Jukes to designate unstratified clay indurated into a hard rock.

CLAY-STONE.—A compact variety of *Felstone*.

CLEARING.—In coal mining, the soft parting between the coal and the associated rocks; in quarrying, the surface that has to be cleared away before valuable stone can be procured.

CLEAVAGE.—An induced structure in rocks, which gives them a tendency to split into slates.

CLOGH (*Celtic*).—A block of stone, an erratic block.

CLUNCH.—Gritty or stony fireclay.

COAL.—Geologically, any rock capable of forming a fire.

CONCHOIDAL.—Like a shell.

CONCRETION.—Any mineral or matter that separates from the rest of the rock and forms more or less well-defined lumps or nodules.

CONE IN CONE.—A peculiar structure in some rocks as if the mass was made up of a number of cones placed one inside the other.

CONGLOMERATE.—A rock made up for the most part of rounded pebbles.

CONNEMARA.—A local term in the Cork colleries for a dirty clayey impure coal, *see Buddagh.*

CONTEMPORANEOUS.—Formed or deposited at the same time as the associated rocks.

CONTORTED.—Used of strata twisted up or folded after they were deposited.

COOM, COUM, CWM, COMBE.—A valley, also a *Corry, q.v.*

COPROLITES.—Fossil dung, often erroneously used for phosphatic nodules.

CORCAS, CORCAGH (*Celtic*).—An alluvial flat, usually tidal.

CORKER (*Celtic*).—Roots of trees found in the bogs.

CORRY (*Celtic*, a cauldron).—A "punch-bowl" or coom; a valley like a *cul-de-sac.*

COSTEAN (*Celtic*).—Searching for minerals or lodes under diluvium or other drifts; *Streaming*, which *see.*

CRANNOG.—The name used for the Irish lake dwelling. *See* p. 278.

CRAG AND TAIL.—Hills or rocks that slope gently in one direction and are steep or abruptly terminated in the opposite.

CROP.—The basset or outcoming of a bed of rock at the surface of the ground.

CROSS-COURSE.—A miner's term for a dyke of fault-rock or mineral vein crossing the lodes in a district.

DEADS.—*See Attals.*

DEBÂCLE.—A violent rush or outburst of water or mud.

DELTA.—The alluvial bank that often forms at the mouth or *inver* of a river.

DENDRITES.—Arborescent or moss-like forms occasionally assumed by some minerals.

DENUDANT.—A force that denudes or wears away and removes a substance.

DENUDATION.—Laying bare by removal.

DETRITUS.—The materials arising from the waste or distintegration of a rock mass.

DIABASE.—A variety of Gabbro containing quartz.

DIGGINGS.—A Colonial term for *Streaming*, or mining for ores or minerals in or under drift deposits.

DILUVIUM.—Gravels and such like, supposed to have been formed or accumulated by a sudden rush or some extraordinary stream of water.

DIORITE.—Triclinic felspar + amphibole.

DIP.—The inclination or angle of slope of the surface of a bed of rock, necessarily at right angles to its Strike, *q.v.*

DIRT-BED.—A local term in the Queen's County coalfield for a remarkable bed made up of fragments of plants.

DISLOCATION.—A rupture, *a fault*, a displacement of strata.

DOGSTOOTH SPAR.—Crystallized white *dolomite.*

DOLERITE.—Triclinic felspar + pyroxene.

DOLOMITE.—Limestone containing carbonate of magnesia as one of its essential minerals. Also a mineral.

DRIFT.—All accumulations that owe their position to having been drifted or driven by water, wind, ice, &c.

DRUM (*Celtic*).—A ridge-shaped hill.

DRUMLIN (*Celtic*).—A long narrow ridge mound, applied by the Irish geologists to the long regular hills of Boulder clay.

DRUSE, DRUSY-CAVITY.—Hollow spaces in ores or rocks lined with crystalline minerals.

DYKE.—A wall-like mass of rock cutting across other rocks ; now generally applied to narrow protrusions of eruptive rocks.

EKLOGITE.—A magnesian rock allied to serpentine (*Ophite*).

ELVAN, HELVAN (*Celtic*).—White-rock, *see* page 179.

END.—A miners' term similar to *Breast*, *q.v.*

ENDOGENOUS.—Produced within. A name applied by Sterry Hunt to the mineral veins deposited from solution in cracks and fissures.

ERRATIC-BLOCK.—A transported or carried block.

ESCARPMENT.—A cliff or abrupt slope on a hill, or the edge of a plain, *see* page 299.

ESKER (*Celtic*).—Literally a ridge ; applied to the long ridges of gravel so prevalent in some parts of Ireland. In some few places these are called *cams* (winding) on account of the ridges winding about ; in Ireland cam, however, is more often applied to a winding river.

Esker-sea.—The sea that covered the portion of Ireland in which the Eskers accumulated.

Estuarine.—Belonging to an estuary or a wide tidal river mouth.

Eurite.—Basic felstone, *see* page 180.

Exfoliate.—To disintegrate into scales.

Exotic rocks.—*See* page 194.

Face.—A miner's and quarryman's term for the front of a lode or quarry. When perpendicular joints cross a quarry it is said to have a good face. The dip of the beds is often also called *the face*, and the quarry or cutting is said "to face the wrong way" if the rocks dip away from the workmen.

Fault.—A break or displacement of strata.

Fault-rock, Fault-dyke.—The dyke or mass of broken rocks or rock débris filling up a fissure along a line of *fault*.

Felsilite. Felsite-Schist.—A metamorphic rock.

Felsite.—Defined by Cotta as a mixture of Orthoclase and silica. Another name for Petro-silex, *see* page 180.

Felstone.—*See* page 180.

Fjord.—A long narrow estuary or bay.

Fire-bricks.—Bricks that resist the fire.

Fire-clay.—Any clay capable of being made into fire-bricks.

Fire-stone.—Any stone that stands heat without injury.

Fissile.—Capable of being split into thin plates or laminæ.

Flag, Flagstone.—Thin bedded rocks that are easily split.

Flint.—Silicious nodules and layers found in the Cretaceous rocks.

Flucan or Floocan (*Celtic*).—Literally, a soft moist substance. Clay, rotten shale and such like.

Fluvio-marine.—Strata having a mixed river (*fluvius*) and sea (*mare*) origin.

Foil (*Celtic*).—A cliff.

Foliation.—The leaf-like structure of some rocks produced by metamorphic action.

Forcque; Fork (*Celtic*).—Unwatered; a mine is *in forcque* when all the water is pumped out of it.

FREESTONE.—Any rock that can be easily cut and dressed. In the Co. Dublin, however, the same term is applied to *growan.*

FRESHET.—A river flood.

GABBRO.—*See* page 181.

GANGUE, GANG (*Celtic*, worthless).—Veinstone, *q.v.*

GEODES.—Nodules having internal cavities.

GEOLOGICAL HORIZON.—The position of a stratum relatively to geological age.

GLACIAL.—Formed by or belonging to ice (*glacies*).

GLACIAL DRIFT.—Drift that was deposited directly from ice.

GLACIALOID DRIFT.—Drift like Glacial drift, but which has, nevertheless, been re-arranged by water, *see* page 225.

GNEISS.—A metamorphic rock, *see* page 178.

GORGE.—A ravine, a deep open fissure.

GOSSEN, GOSSAUN.—The ochreous Back (*q.v.*) of a lode.

GRANITE, GRANAT (Gran, *Celtic* a grain).—The name is now usually confined to a crystalline Ingenite rock (*see* page 178), but in many places in Ireland it is a general name for any silicious hard granular rock.

GRANITONE.—One of the basic Elvans, *see* page 181.

GRAPHIC GRANITE.—A granite with its minerals so arranged as to have an appearance like writing characters. In west Galway the graphic granite nearly always occurs in veins which cut across beds of limestone.

GRAPHITE.—Plumbago, "blacklead;" carbon, with an admixture of iron and sometimes other impurities.

GRAVEL.—An accumulation of generally water-worn fragments—when such accumulations are made up of fine particles it is called *sand;* if the fragments are large it is called *gravel*, but if very large, above the size of hen's eggs, it is called *shingle.*

GRIT, GRITSTONE.—Hard and compact arenaceous rocks, in which the grains of sand are not visible to the naked eye, or are so firmly compressed or cemented together that it is impossible to separate them.

GROWAN (*Celtic*).—Decomposed or disintegrated granite.

HACKLY FRACTURE.—Breaking with a jagged surface like the fracture of wrought iron.

HADE, HADING.—A miner's term for the dip or underlie of a lode.

HALVANS.—Heaps of *Deads* which still contain a little ore.

HAUGH.—An alluvial flat flooded in *Freshets.*

HEAD OF TIDE.—The meeting of two tidal waves which have entered a channel at opposite ends.

HEAVE.—A miner's term for the horizontal displacement of a lode.

HORNBLENDITE, HORNBLENDE-SCHIST.—A metamorphic rock consisting chiefly of hornblende.

HORNSTONE.—A rock like compact felstone. Baked slates or shales.

HORSE.—A miner's term for a mass of rock included within, or suddenly coming in and cutting out a lode.

HUMMOCK.—A small knoll or mound.

HYALINE—Glassy, glass-like.

HYDRAULIC CEMENT, HYDRAULIC LIME.—Lime capable of setting or hardening under water.

HYPERGENE-ROCKS.—*See* foot-note, page 4.

HYPOGENE-ROCKS.—*See* foot-note, page 4.

ICE-CAP.—The mass of land-ice which is supposed by some to have covered the northern hemisphere.

IMBRICATED.—Overlapping, after the manner of roof-tiles.

IN SITU.—In its original or natural position.

INDURATED.—Hardened by heat or other causes.

INLIER.—Applied to a bed or beds of rocks interstratified in rocks of quite different character.

INTERCALATED.—Interposed or inserted between.

INTERCOLLINE SPACES.—A term applied by Lyell to valleys or hollows in volcanic regions between erupted hills, to distinguish them from ordinary ones produced by denudation.

INVER (*Celtic*).—A river mouth.

INVERTED.—Turned over; as when a series of beds is folded, until part of it lies upside down.

IRE-STONE (Ire, *Celtic* brown.)—A Cornish and Irish name for whinstone, sometimes corrupted into *iron-stone.*

Iron Pyrites.—A general name for the different varieties of sulphide of iron—*pyrite, marcasite,* and *pyrrhotite.*

Ironstone.—A general name for the oxide and carbonate ores of iron.

Jasper.—A general name for coloured compact silicious compounds.

Jasper Rock.—A red-purplish or greenish quartz-rock occurring in regular dykes.

Joints.—Division planes, different from those of bedding, which cross rock masses in parallel sets and make them capable of being divided into smaller regular masses. A *Master joint* passes through a number of beds.

Kam, Kame, Kaim.—Winding. *See Cam* and *Esker.*

Kaolin (*Chinese*).—Literally "Low Ridge," the name of the hill on which *China clay* was originally manufactured. The name is now generally used for china or porcelain clays.

Kelve.—A local term in the Leinster collieries for carbonaceous slates and shales.

Killas.—A miner's term for slate and other argillaceous rocks.

Knock or Cnock (*Celtic*).—A hill.

Lacustrine.—Of or belonging to a lake (*lacus*).

Lagoon.—A sheet of water divided from the sea by a barrier of sand, a coral-reef, &c.

Lamellar, Lamellated.—Composed of very thin plates.

Lamina.—A thin leaf or stratum formed by deposition.

Landslip.—A portion of ground that has slipped from its original position to a lower level.

Laterite.—A name given by the Indian geologists to a variety of tuff or tuffose rock which can be cut up, when soft, into blocks, which, on drying, become hard enough to be used as bricks. It is often an impure steatite, sometimes conglomeritic. Some of the Antrim tuffs (Bole and Lithomarge) are identical with varieties of laterite from Kutch, India.

Launders (*Celtic*).—Wooden gutters for carrying water over hollows, or from one place to another.

LENTICULAR.—Shaped like a lens.

LIGNITE.—Wood-coal, brown-coal.

LITHOLOGICAL.—Relating to the physical characteristics of the *material* of a rock. "*Petrological*" properly refers to the structure and character of a rock in the mass, though it is sometimes used synonymously with "Lithological."

LITHOMARGE.—A tuff or tuffose rock, more or less ferriferous.

LITTORAL.—Belonging to the shore of a sea or lake.

LOAM.—Vegetable soil; a mixture of clay, sand, and vegetable remains.

LOOBS (*Celtic*).—The remnants, or remains of a mineral ore.

LOOSE SHELF.—A miner's term for the broken rock between the drift and the solid rock.—*See Rubble.*

LOUGH.—An English corruption of the Celtic *loch*, a lake.

LOUGHAUN.—A little lake.

LUG (*Celtic*, a prison).—A deep hollow or recess among hills.

LUSCA (*Celtic*).—A cave, a dwelling in the earth; which may be either natural or artificial.

LYDIAN-STONE.—A black earthy variety of chert, or of Baked-shale, used as touchstone for testing gold.

MAGNESIAN LIMESTONE.—Limestone containing magnesia.

MAGNESITE.—A rock formed of compact carbonate of magnesia.

MANURE GRAVEL.—A local term in Wexford for a shelly gravel.

MARL.—Calcareous clay.

MARLSTONE.—Indurated marl.

MATRIX.—The mass or body of matter in which minerals or other substances are contained.

MAUM (*Celtic*).—A connecting gap in a mountain range between two valleys.

MELAPHYRE.—Triclinic felspar + pyroxene + amphibole. *See* page 181.

METAMORPHIC.—Changed in form or character.

METAPEPSIS.—Change produced in rocks by moist heat. *See* page 175.

METEORIC.—Formed by atmospheric action.

METHYLOSIS.—Change produced by chemical action. *See* p. 177.

MICALITE, MICA-SCHIST.—A metamorphic rock.

MONAGAY TURF.—*See* page 269.

MONOCLINAL.—Strata undulating, but having a dip only in one direction. *See Anticlinal* and *Synclinal.*

MONOLITH.—A pillar formed of one block of stone.

MORAINE.—The mound of detritus heaped by a glacier at its side, or at its end.

MORAINE DRIFT.—The name adopted for the glacial drift supposed to have been formed by or deposited from glaciers.

MUDSTONE.—A term introduced by Murchison for the argillaceous rocks that disintegrate easily and become mud.

NACREOUS.—Having a pearly iridescent lustre, like mother-of-pearl.

NEOGENE.—Newly formed—a term applied by some geologists to a group including the Pliocene and Miocene.

NODAL LINE.—The hinge line of a *stationary* oscillating tide in a channel, or the line where the direct and reflex tidal waves neutralize each other.

NOVACULITE.—Whetstone (*novacula*, a razor).

NUMMOID.—Like money (*nummus*, a coin).

NUMMOID SCHIST.—A variety of micalite containing thin roundish pieces of quartz, giving the rock an appearance as if studded over with small pieces of money.

OBSIDIAN.—A glassy variety of felstone.

OCHRE.—Earthy ores of iron, yellow, red, or brown in colour.

OLD MEN'S WORKINGS; DANE'S WORKS.—Terms applied to old mining operations, the traces of which remain, but of which there is now no other record. "Dane" in many cases is a corruption for Tuatha De Danann, an enterprising tribe or colony that settled in Ireland about 1,000 years B.C. They were engaged in various great works.

OLIVINE.—A mineral common in dolerite; a silicate of magnesia and iron.

OOLITIC.—Composed of rounded grains like smalls eggs (*oon*).

OPALESCENT.—Resembling opal in lustre.

Ophiolite.—Sterry Hunt's name for the serpentines that are methylosed calcareous rocks.

Ophite.—A name for the serpentines that are methylosed igneous rocks.

Outcrop.—The edge, or outgoing, or basset of a bed of strata, or of a mineral vein.

Outlier.—A detached or disconnected portion from the main mass of any stratified group of rocks.

Overlap.—The extending of a bed or beds beyond the underlying beds.

Owen, Ow (*Celtic*).—River.

Palæontology.—The study of fossil animals and plants.

Paramoudra.—A name invented by Dr. Buckland's guide for the fossil sponges in the Antrim white-limestone (indurated chalk) and adopted by that geologist.

Paroptesis.—Change produced in rocks by dry heat. *See* page 176.

Partings.—Thin films of clay or shale between beds of strata; thin soft films under and over beds of coal.

Peach.—A miner's term for chlorite and chloritic minerals.

Peat (*peait* or *puit*, *Celtic*, soft or miry).—*See* page 267.

Pegmatite.—A very coarse variety of granite occurring in endogenous veins.

Petrological.—*See Lithological.*

Petro-silex.—Felsite; very silicious felstone.

Phyllite.—A mineral allied to mica.

Phyllilite, Phyllite-schist.—A metamorphic rock.

Pin-mine.—Clay ironstone.

Pindy.—A Munster name for carbonaceous shale.

Pisolitic.—Composed of small pea-like concretions (*pisum*, a pea).

Placer.—An American term for mineral mining in diluvial accumulations; similar to the English term *Streaming*, *q.v.*

Plutonic.—A name applied to igneous rocks not formed on the surface of the earth, though now, perhaps, appearing there by denudation.

Pluvial.—Of or belonging to rain.

Poikilitic.—By some geologists the Permian and Triassic rocks are placed in one formation under this name.

Porcellanite.—Baked or burnt and very slightly fused earth.

Porphyrite, Porphyry.—An ingenite rock containing distinct and well developed felspar crystals.

Pot-hole, Slugga, Sluggy.—Round holes that are formed in the ground from the subtraction of underlying rocks. *See* page 324.

Poul, Poll (*Celtic*).—A hole.

Psammite.—Fine-grained ferruginous clayey sandstone having, when mixed with lime, hydraulic properties.

Pseudomorphism.—A process by which a mineral, &c., assumes a form not properly belonging to itself; as where one mineral replaces another, particle by particle, and thus acquires the crystalline form of that other.

Pyrite, Pyrites.—Sulphide of iron, worked as a sulphur ore.

Pyrrhotite, Pyrrhotine.—Magnetic pyrites, worked as a sulphur ore.

Quaquaversal.—Tending in every direction.

Quartz.—Crystallized silica.

Quartz-rock.—*See* pages ix. and 180.

Quartzite, Quartz-Schist.—A metamorphic rock.

Quicksand.—An unstable running sand—some surface sands become *quicksands* when wet. In tidal places some sands are quite firm while the tide is *ebbing* or going out, while they are quicksands when the tide is *flowing* or coming in.

Raddle, Reddle.—A red argillaceous ore of iron.

Raised Beach.—A term applied to the old sea margins that are now at a higher level than its present margin.

Redfree.—An Ulster name for the Triassic sandstones.

Reticulated.—Like net-work.

Ripple-mark.—The low small ridges formed on the surface of sand by currents of water or wind (not by the water ripples). These are often preserved on sandstone.

River Basin.—The area drained by a river.

ROCK.—Geologically, any substance more or less solid forming part of the crust or external portion of the earth.

ROCK-BASIN.—A hollow excavated in the solid rock.—*See* p. 330.

ROCK-SALT.—The form in which common salt occurs as a rock mass.

ROCK-SOAP.—A soft variety of steatite.

ROOF.—A miner's and quarryman's term for the rock immediately over a bed of coal, or a quarry.

ROTTEN STONE.—Decomposed silicious limy argillous rock—used for cleaning and polishing metal.

RUBBLE.—The broken-up rock between the drift and the solid rock. In some places called *foundation*, and by the miners *loose* or *broken shelf*.

SAND.—*See* GRAVEL.

SANDSTONE.—An arenaceous rock having a distinct granular structure, having been composed originally of grains of sand.

SCALP (*Celtic*).—A cleft.

SCARPED.—Having a steep face.

SCHIST.—Metamorphosed rocks. *See* page 177.

SCORIACEOUS.—Composed of scoriæ, the small fragments like cinders blown from a volcano.

SEAM.—A subordinate bed in a series, as a *seam of coal*.

SEAT, SEAT-CLAY.—The fireclay under a coal.

SEAT-ROCK.—The hard rock under a seat-clay.

SET, SED (*Celtic*, a measure of value).—The area included in a mineral take or lease.

SHALE.—An argillaceous rock deposited in thin laminæ.

SHELF.—The miner's term for the surface of solid rock.

SHELL MARL.—A shelly marl found under the bogs and in lakes.

SHELL MINE.—Clay-ironstone that splits off in shells.

SHINGLE.—*See* GRAVEL.

SILVER-BLENDS.—A peculiar ore at Connary, Co. Wicklow.

SINTER.—Deposits from calcareous or silicious springs.

SLAB.—Plates of rock formed either by cleavage or jointing.

SLATE.—Argillaceous rocks affected by cleavage.

SLIDE.—Miners' term for a down-thrown fault.

Slieve (*Celtic*)—A mountain.

Slig, Sliggen (*Celtic*).—Loose shingly slate or shale.

Slugga, Sluggy (*Celtic*).—*See* Pot-hole.

Soapstone.—Steatite.

Soil.—The decomposed surface of rocks mixed with vegetable and animal substances.—*See* page 287.

Steatite.—*See* page 192.

Stellate.—Starlike.

Stone-bind.—Local term for arenaceous shale.

Stone-mine.—Boate's name for the iron ores occurring as rock masses (Hematite, &c).

Stratigraphically.—According to the order of the super-position of strata.

Stream Gold.—Gold obtained from drifts by streaming.

Stream Tin.—Tin obtained from drift by streaming.

Streaming, Streamwork.—Washing drift for gold or tin.

Striated.—Marked with fine lines.

Strike.—A term introduced from the German by Sedgwick· The line of the level bearing of a bed of rock, perpendicular to the dip of the bed.

Stull (*Celtic*).—A mine working, or *deads*, supported by timbering.

Syenite.—Amphibole + orthoclase, with or without quartz.

Synclinal.—A bed, or a series of beds, making a U or V-shaped fold, both portions, or the two sides of the U or V, dipping at each other.

Tachylyte.—A glassy variety of dolerite or melaphyre.

Talcite, Talc-Schist.—A metamorphic rock.

Talus.—A sloping mound of detritus accumulated at the base of a cliff or very steep slope.

Tesselated.—Divided into squares or chequers.

Thinning out.—A set of strata becoming thinner and thinner till at last it may disappear.

Throw.—The displacement of strata or veins by a fault.

Tieve (*Celtic*).—One side of a mountain or hill.

Till.—The Ulster name for boulder-clay drift.

Toad-stone.—A spotted variety of dolerite.

TRAP.—Basic igneous rocks.

TROUGH.—A comparatively narrow synclinal fold of rock strata.

TUFF.—The fragmentary products of volcanic eruptions.

TURLOUGH (*Celtic*).—*See* BLIND-LAKE.

UMBER.—An argillaceous peroxide of iron and manganese.

UNCONFORMABLE.—Used of strata lying on the upturned ends of older strata.

UNDER-CLAY.—The clay under a coal.

UNDERLIE, UNDERLAY.—A miner's term for the dip of a lode.

VARIOLATED.—Spotted.

VEIN.—A fissure or rent filled with minerals.

VEINSTONE, GANGUE.—The unproductive stony matter that occurs in a mineral vein associated with the ores.

VERD ANTIQUE.—Ophi-calcite, serpentine mixed with calcite.

VESICULAR.—Full of cavities.

VOLCANIC.—Belonging to a volcano. Igneous rocks that have been formed on or near the present surface of the earth.

VOLCANIC BOMB.—A mass of molten matter shot up into the air by a volcano.

VOLCANIC FOCUS.—A subterranean centre of igneous action.

VOLCANIC THROAT.—A volcanic vent or pipe.

VUG, VUGGY.—Holes or cavities in minerals and mineral veins.

VULCANICITY, VULCANISM.—Terms introduced by Humboldt to include "the entirety of those telluric phenomena which are to be ascribed to the constant active reaction of the interior of the earth upon its external crust or surface."

WAD.—An earthy oxide of manganese.

WALL.—A miner's term for the side of a lode. That under the lode is called the *Foot-wall*, and that above it the *Hanging-wall.*

WATERSHED.—The line that divides the water of one valley or area from that of others.

WHIN, WHINSTONE.—Name for Trap.

WHITE LIMESTONE.—The Ulster name for the indurated chalk of that province.

WHITE STONE.—The English name of ELVAN, which *see.*

WOOD-COAL.—Lignite.

# INDEX.

A.


ACHESON'S (F.) Gold mines, 344.
Achill, 335.
ADAMS (Dr. Leith) on mammalia, 293; on Ursus, 297.
*Adiantites Hibernicus*, 61.
Æolian drift, 223, 228, 235, 238, 319, 394.
Agglomerate, 200, 201, 202, 205; Valentia, 203.
Aghavilly, County Armagh, fossils, 234.
Aille, County Mayo, cave, 285; River, 327.
Albitic granite, 198, 206, 218.
Allihies mines, 352.
Alum, 358.
Aluminous iron-ore, 164.
Ancient sea margins, 241, 251.
Annaghone, colliery, 127; faults, 129.
*Anodonta Jukesii*, 7, 8.
Anogene rocks, 4, 194.
Antimony, 356.
Antrim, Cambro-Silurians, 35; caves, 286; eruptive rocks, 207, 208; hills, 303, 308; Jurassic rocks, 144; metamorphic rocks, 189; mineral localities, 361; raised beaches, 253, 256, 259.
Apatite, 395.
Aqueous drift, 223, 224.
Aqueous rocks, 4.
Aran Islands, Galway Bay, 240, 249, 253, 285, 301; Donegal, 360.
Archipelagos, 2; Galway, 335.
Ardagh rocks, 94.
Ardsolla river, 327.
Ardtrea, eruptive rocks, 209.
Arenicolites, 13.
Arklow, Æolian drift, 240; rocks, 195.
Armagh, drift fossils, 234; mineral localities, 362; rocks, 86, 87, 133, 139, 390.
Aughrim, County Wicklow, 13, 182, 186, 196; River valley, 234, 246.
Auriferous sand, 344.
AUSTEN (Capt.), on Waterford raised beaches, 253, 255.
Avonbeg, 246; Valley, 258.
Avonmore, 13, 196; Valley, 258.


B.


Baginbun, 27.
BAILY (W. H.), on Armagh rocks, 134; Ballaghaderreen rocks, 48; Ballycastle fossils, 92; on Benburb rocks, 87; on fossils, 30, 32, 34, 39, 41, 44, 45, 61, 77, 95, 99, 101, 106, 109, 111, 118, 145, 154, 168; on Lough Neagh beds, 169, 233 *f. n.*; on Permians, 131; on Tullyconnell rocks, 133.
Baked rocks, 184.
Balbriggan, rocks, 34.
Baldoyle, water supply, 13.
BALL (J.), on Lake Como, 331.
Ballagh, erratic, 248.
Ballaghaderreen, Silurians, 48.
Ballinderry, river section, 170.

Ballinhassig, Coal Measures, 60.
Ballinleeny, eruptive rocks, 200.
Ballintoy, Jurassic rocks, 144.
Ballybetagh, fossils, 296.
Ballybig, Salt Measures, 138.
Ballybrood, rocks, 75, 109, 201.
Ballycapple, County Wicklow, iron mines, 354.
Ballycar, fossils and rocks, 32, 38.
Ballycastle Coal-field, 90, 91; Cretaceous, 153, 155; Miocene, 158.
Ballycoog, lodes, 355; slates, 377.
Ballycottin bay, 60.
Ballydowane bay, 27; fossiliferous ophiolite, 188.
Ballygeary, Æolian drift, 240; rocks, 183.
Ballyhean, shore beds, 70.
Ballyheedy, County Cork, Coal Measures, 60, 104.
Ballyknock, trachyte, 162, 208.
Ballyknockan, granite quarries, 389.
Ballymacgibbon promontory, 44.
Ballymena, rocks, 208.
Ballymoney, coals, 29; Series, 24, 31, 32, 33, 35, 36, 183, 195.
Ballymurtagh, 351, 355.
Ballynahinch, County Galway, 205.
Ballynakill and Kylemore Valley, 204.
Ballynakill Bay, County Galway, 256.
Ballynascreen, iron-ore, 159.
Ballypalady, iron-ore, 166; section 168.
Bann river, 322; upper, 395.
Bannow, County Wexford, 16; Section 16, 17, 18, 19, 26, 183, 195.
Banteer, caves, 284; limestones, 68.
Bantry Bay, 55, 59, 202.
Barnavave elvan, 210.
Barrow, 258, 261; estuary, 255, 265; fault, 25; valley, 77, 195, 197, 231, 237, 246, 316; water-basin, 233.
BARTON (Rev. R.), Lough Neagh hones, 171.
Basal Carboniferous rocks (Old Red Sandstone), 71.
Basal series, Miocene, 157.
Basic felstone, 180.
Basic elvans, 180, 209.
BAUERMANN (H.) on iron-ore, 164.
Bays, 2, 3, 328.
Beginish, Valentia, 189, 203, 376.
Belfast, aluminous iron-ore, 164, 353.
Belvoir, County Clare, fossils, 32.
Benburb, rocks, 87.
Ben Evenagh, Jurassic, 147; Triassic, 142; Chalk, 405.
Bennabeola, 244, 308, 309; water supply, 397.
BERMINGHAM (J.) on Slieve Dart felstone, 203.
Billymore, conglomerate, 69.
Bird Hill, County Tipperary, 31; drift, 238, 323.
Birr or Parsonstown, 33; erratics, 249.
Black Head, County Antrim, 153.
Blacksand (gold sand), 235.
Blackball Head, fossils, 61.
Black-Sod bay, rocks, 190.
Blackstairs Mountain, 198.
Blackwater Valley (Cork), 54, 68, 231, 316; Coal Measures, 107.
Blown sand, 238, 394.
Bogs, 267; ash, 270; growth of, 272; human remains in, 273; lake basins, 333; water, 407.
Bohilbreaga, lignite, 159.
Bole, 163.
Boleyneendorrish, plant bed, 267.
Borris, County Carlow, drift, 236.
Boulder-clay drift, 223.
Boyle, rocks, 82.
Boyne river, 35, 322.
BRADLEY (Samuel) on Jarrow colliery fossils, 118.
Bray, Head, 13, 35, 196; valley, 197, 258.
BRENAN (James) on Shandon Cave, 285.
Broadhaven, Æolian drift, 239.
Brosna river, 322.
BROWNRIGG (W. B.) on Jarrow colliery fossils, 118.
BRYCE (Dr.) on fossils, 259, 286, 298.
BUCKLAND (Dean) on flints, 154; on Lias, 146.
BUDD (James) on fossils, 376.

Bull's Head, fossils, 39.
Bunmahon, red conglomerate (Old Red Sandstone ? ), 28.
Burren, 260; cliffs, 300, 301; hills, 300; limestone, 65, 69, 74, 75, 76, 80, 81, 83, 87, 201, 384; water-supply, 401.

C.

Cabra Castle, Trias, 134.
Cahernarry, rocks, 201.
Caherconlish, columns, 201.
Caherconree, fossils, 39.
Cahir, County Tipperary, clays, 168, 233, 317.
Cahirmore, County Cork, rocks, 202.
Cahore, rocks, 16, 17.
Cainozoic, period, 5; rocks, 8, 156 water-supply, 402.
Calcareous rocks, 205; springs, 195.
Callows, 291; of Shannon, 323.
Calp, 65, 74, 76, 77, 80, 81, 83, 87, 88, 201; coal, 86, 90; Draperstown, 89; fossils, 74, 87; resumé on, 90, 91; thinning out of, 75; water-supply, 400.
Cambrian, 5, 6, 11; Belfast Lough, 22, Bray Head, 13, 196; Carnsore, 16, 194; Donegal, 191; eruptive rocks in, 204, 215; fossils, 15, 17; Galway, 20, 21; Galtymore, 20, 30; Granard, 22; junctions with Cambro-Silurians, 26; metamorphic, 182, 189, 215; Nine-mile House, 30; Slieve-na-muck 30; Slieve-na-man, 20; Ulster, 35; water-supply, 397; Wexford, 16; Wicklow and Dublin, 196.
Cambro-Silurian, 5, 6, 15, 22, 23, 191, 198; coal, 29; eruptive rocks, 203, 216; Forth, 195; fossils, 25, 26, 42, 47; fossil zone of, in Silurians, 42; junctions with Cambrians, 26; metamorphic, 182, 186, 189, 216; water-supply, 397.
Cape Clear island, 55, 336.
Carboniferous, 5, 63; cherty zones, 65; conglomerate, 33, 308; eruptive rocks, 195, 196, 198, 199, 203, 206, 218; granite, 195, 198; metamorphic, 188, 219; slabs, 379; water-supply, 398.
Carboniferous rocks, Carlingford, 93; Cavan, 94; Down, 93; Dundalk, 93; Kills, 94; Kilmurry, 59; Macroom, 59; sandstone, 87; shorebeds, 64; Slate, 50, 55, 58, 60; fossils, 61; water-supply, 400.
Carlingford, eruptive rocks, 93; granitoid rock, 209; Lough, rocks near, 34, 209, 212, 328.
Carlow, Cambro-Silurians, 25; dolomite, 188; granite, 197; metamorphic rocks, 187; minerals, 362; shore-beds, 70.
Carnsore, district, 16, 194; granite, 389; metamorphic rocks, 215; rocks, 182.
Carrane-Tual, 2, 305, 307, 308.
Carrick (Rathdrum), granite quarry, 198.
Carrick Mountain, 15, 196.
Carrick-on-Suir, 30, 317.
Carrickfergus, Jurassic rocks, 144; Salt Measures, 137; Trias, 137.
Carrickgollogan, 14, 197.
Carrickmacross, Carboniferous rocks, 93; outlier, 34, 35.
Carrigogunnel, 201.
Carrigaline, Coal Measures, 104.
CARTE (Dr. A.) on fossils, 297.
Cashel Hill, County Galway, 309.
Castle Espie, limestone, 93.
Castle Hill, County Limerick, felstone, 200.
Castlebar, melaphyre, 206.
Castlecomer Coalfield, 112; tableland, 263 *f.n.*
Castleconnell, 200.
Castlehaven, fossils, 61.
Castlemaine harbour, 54.
Castlereagh, rocks, 82.
Catogene rocks, 4, 194.

Cavan, granite, 212; lakes, 335; mineral localities, 362; rocks, 83, 84.
Caves, 284.
Celtic terms, 9. 409.
Central Ireland, 1; lakes of, 335.
Central plain, 1, 2; glaciation of, 242.
*Cervus elaphus*, 294; *megaceros*, 233, 295; *tarandus*, 294.
Chair of Kildare, 33: shore-beds, 70.
*Challenger's* explorations, 56.
Chalk, flints in drift, 261, 262; indurated, 149; upper, 149: water supply, 404.
Charts of lakes, 331.
Chemical changes in rocks, 177.
Chert, Carboniferous, 65, 66, 74.
Cirques, 313.
Clare, caves, 284; Carboniferous, 79; hills, 299; lakes, 334; marbles, 382; mineral localities, 362; raised beaches, 256.
Clare Island, 48.
Classification of the rocks, 5, 49, 179.
Clay-ironstone, 99, 100, 108, 120, 121, 122, 169.
Clay-rock, 374.
Clays, 360.
Clew Bay, 20, 81, 191; islands, 335; rocks, 190.
Clifden, eruptive rocks, 205.
Cliffs, 299, 300.
Clonakilty, quarry, 377.
Clonegal, drift, 233.
Clonwilliam, slate quarry, 377.
CLOSE (Rev. M. H.), glaciation, 241; glaciers, 244; ice, Leinster hills, 261; Irish cooms, 311; shelly drift, 261.
Coagh, eruptive rocks, 208; Trias, 141.
Coal, Calp, 86, 90; Cambro-Silurian, 29; Dundalk, 93; Jurassic, 147; Miocene, 157, 159, 164, 167; Pliocene (?), 169, 170; rods, 80, 99.
Coalfields, 103; Connaught, 120; Dungannon, 122; East Munster, 109; Leinster, 112; West Munster, 104.
Coalhill, Tagoat, 29.
Coalisland Coalfield, 122; limestone, 153
Coal Measures, 5, 7, 50, 53, 54, 61, 75, 95; Ballinhassig and Ballheedy, 60; Ballybrood, 109; Blackwater, 107; Connaught, 119; Fethard, 109; Garbally, 109; Kinsale, 60; Lough Allen, 82; Mitchelstown, 109; West Cork, 103, 104; fish, 129; fossils, 59, 95; hills, 300, 306; water-supply, 402.
Cobalt, 357.
Cod's Head, County Cork, 202.
COLLES (Richard) on marbles, 380.
Collin Glen, Cretaceous, 153; Jurassic, 144; Rhætic, 136.
Colonies of Cambro-Silurian fossils, 47.
Columns, Bengooria, 191; Giants'-Causeway, 164; Limerick, 201, 202; Lough Guitana, 203.
Comeragh Mts., 310; glaciers, 245.
Conglomerate, limestone, 69; peculiar, 32; recent, 230.
Conical hills, 308.
Connaught, Cambro-Silurians, 36; Coal Measures, 119; eruptive rocks, 203; hills, 304; metamorphic rocks, 189.
Connary, lodes, 351.
CONYBEARE (Rev. W. B.), on Permians, 130.
Cookstown, rocks, 87.
Coolbaun, Coal Measures, section 114.
Coole Lough, river system, 325.
Coom-glaciers, 311.
Coomhola grits, 50.
Cooms, 299, 309; sea formed, 312.
Copper mines, 358.
Copperas, 358.
Corbally, slate quarry, 375.
Corcasses, 291.
Corcogemore quartz-rock, 204.
Cork, Carboniferous rocks, 5, 7; caves, 284; cooms, 310, 311; drift, 236; faults, 315; hills, 261, 303; minerals, 363; lakes, 334; mountains, 2, 3, 303; raised beaches, 253, 254, 255; rocks, 50, 58; slate quarries, 376; valleys, 258; water-supply, 399.

Corkers, 269, 277.
Corvockbrack granite, 205, 218.
Courtown, tide at, 251.
Craig-na-shoke, 159.
Crannagh Macknavin, 281.
Crannogs, 278.
Cratloe hills, County Clare, 31, 32, 199, 238.
Creggaunbaun group, 41, 46.
Cretaceous, limestone, 385; rocks, 8, 148; water-supply, 404.
Croagh Patrick, 36, 47, 191, 205, 308; beds, 36.
Croaghan, King's County, 199.
Croaghmarhin beds, 39, 40.
Croaghmoyle group, 48.
Croghan-Kinshella, 342.
Cromac springs, Belfast, 405.
Cronebane Hill, 250; mines, 351.
Crookhaven, beach, 253; slates, 376.
Crossabeg, Cambro-Silurians, 25.
Crossfarnoge, County Wexford, 182.
Cruise (R. J.) on raised beach, 254.
Crumlin river beds, 170.
Cuilcagh, 322.
Culfin group, 41, 43.
Cullion, Limestone, 89.
Cultra, Permians, 132.
Curlew Mountains, rocks, 82.
Curracloe bog, 266.
Curragh of Kildare, 33; recent conglomerate, 230.
Currareavagh, rocks, 44.
Cushendall rocks, 90, 160.

D.

Dalkey, drift, 231: granite, 388.
Damlaght, Cretaceous, 152.
Dana (Prof. J.D.) on sub-ice rivers, 234.
Dargle river and valley, 321, 322.
Dark shale series, 24, 32, 33, 35, 36, 183, 195.
Davidson (T.) on fossils, 42, 61.
Deal-forest age, 268, 272.
Decomposed granite, 394.
Deltas, 3.
Dernasliggaun, faults, 43.
Derreennawinshin, fossils, 46.
Derries (oakwoods), 269.
Desertmartin, limestone, 89.
Devil's Bit mountain, 316.
Devil's Glen, 320; erratic, 250.
Devonian, fossils, 61; rocks, 56.
Diamond Hill, 191.
Dingle and Dungarvan fault, 54, 55, 67, 107; valley, 50.
Dingle bay, 50, 53, 55; glaciation, 245; promontory, 54; Silurians, 38.
Dingle or Glengariff grits, 50, 52, 66, 82.
Dogger Bank, Wexford, 228.
Dolerite, Cainozoic, 163; hills, 306; Miocene, 208; sand, 294; Scrabo Hill, 135.
Dolomite, 76, 188, 205, 221.
Donabate, 34.
Donald's Hill, Cretaceous, 151; Miocene, 158.
Donegal, bays, 328, 330; eruptive rocks, 207; granite, 390; hills, 308; islands, 335; kitchen-middens, 283; lakes, 335; metamorphic rocks, 189, 192, 215; minerals, 207, 364; raised beaches, 256, 259.
Doohylebeg, Rathkeale, fossils, 74.
Doolough beds, 36, 47.
Doonass, Castleconnell, 323.
Doonooney, coal, 29.
Doorus promontory, 44.
Down, Carboniferous rocks, 93; hills, 308; minerals, 364; water-supply, 406.
Down Hill, conglomerate, 158; Jurassic, 147.
Draperstown fault and rocks, 89.
Drift, 223; fossils, 259; lake-basins, 330, 332; pebbles on edge, 236; water-supply, 406.
Dromineen bay, 323.
Drumgoff, Glenmalure, 246, 320.
Drumkelin bog, submerged house, 273.
Drumshambo section, 83.

Du Noyer, (G.V.) 14, 23, 35, 38, 53, 153, 244, 250, 283, 391 ; Ballynock trachyte, 163, 208 ; iron-ore, 160 ; lacustrine accumulations, 8 ; Permians, 132 ; raised beaches, 254, 255, 256, 257 ; Scrabo Hill rocks, 135, 209 ; Tardree trachyte, 162.
Dublin and Wicklow mountains, 3, 245.
Dublin, Bay, 254, 328 ; Cambrians, 11, 182 ; Cambro-Silurians, 25 ; Carboniferous, 76 ; minerals, 365 ; raised beaches, 252, 254, 258 ; shelly drift at high levels, 261.
Duffen (W. le S.) on Miocene rocks, 157, 161, 167, 168.
Duncrue salt mine, 137.
Dundalk coal, 93.
Dungannon Coalfield, 122.
Dungiven, Triassic, 141 ; rocks, 90.
Dunkerron, 51, 52, 54, 310.
Dunleary, Kingstown, 252.
Dunluce, 158.
Dunmanus Bay, 59.
Dunmore cave, Kilkenny, 285.
Dunmurry, Cretaceous, 152.
Durocher (M. J.), on hybrid rocks, 210.
Dursey Island, 202, 336.

E.

East Coast, islands, 336 ; raised beach, 256.
East Munster Coalfield, 109.
Economical products, 339.
Edge (B. B.) on coal-measures, Leinster, 112, 119, 231.
Egan (F. W.), 89, 133, 163, 172, 403.
Egerton (Sir P. de M.G.), coal-measure fossils, 98, 101, 104.
Elvans, 179, 180, 184, 205, 208, 209, 210, 388, 390.
English and Irish Cambro-Silurians, 37.
Enniscorthy, drift, 233.
Enniskeen, Triassic, 134.
Erne river, 327.
Erratics, 241, 244, 247.
Erris, Mayo, 308.
Errisbeg, 308.
Errismore, Æolian drift, 240.
Eruptive rocks, 4, 6, 7, 14, 75, 175, 194 ; Antrim, 166 : Ballymoney series, 199 ; bedded, 182 ; Cambrian, 215 ; Cambro-Silurian, 216 ; Carboniferous, 71, 218 ; Carlingford, 93 ; chronologically classified, 213, 214 ; metamorphic, 192 ; Miocene, 157, 161, 208, 220 ; roots of, 208 ; Triassic, 220 ; water-supply, 396.
Escarpments, 299, 300.
Eskers, Formation of, 226 ; fossils, 230 ; drift, 224, 226 ; sea, 224, 225, 238, 259.
Estuaries, 3 ; drift, 223, 231.
Eurite, 33, 43, 45, 180, 181, 191 sheets, 191 ; Silurian, 45, 46, 204 ;
Eurite series, 42.
Exotic rocks, 194.
Extravasated rocks, 194.

F.

Farran (Dr.) submerged forest, 265.
Fastnet rock, 336.
Fathom mountain, Elvan, 210.
Faults, 25, 31, 43, 83, 89, 109, 113, 128, 129, 141, 197, 314, 321.
Felstone, 180, 181, 391 ; peculiar, Castle Hill, 200.
Fenestella limestone, 71, 72, 81, 201, 309 ; water-supply, 400.
Fergus river, 326.
Fermanagh, Coal-measures, 120 ; lakes, 335 ; minerals, 365 ; rocks, 84.
Fermanagh and Sligo section, 86.
Ferriter's Cove beds, 39, 40.
Ferrycarrig, 27.
Fethard, Coal-measures, 109.
Finlan (P.), Clogh coal-measures, 116 ; fossils, *f.n.* 111, 118.
Fiords, 2, 3, 321.
Fireclay, 99, 100.
Fish fossils, coal-measure, 98 ; list, 87, 92.

Flags, 378.
Flagstone series, 99, 379.
Flesk river, 316; valley, 54.
Flint-gravel, and conglomerate Miocene, 149, 157.
Flints in drift, 262.
Floods, effects of, 235.
Fluviatile drift, 223.
FOOT (F. J.), 22, 35, 75, 100, 105, 106, 244, 255, 284, 360.
FORBES (David), on eruptive rocks, 175, 221.
FORBES (Edward), geological periods, 5; fossils, 34.
FORBES (W.), debacles, 332.
Forlorn Point, County Wexford, 182.
Formnamore Mountains, 45, 46, 244, 308.
Forth mountains, 16, 17, 183.
Fossils, Armagh, 87, Ballycastle, 92; Balleymoney rocks, 31, 32; Ballyheedy, 104; bog, 278; Burren limestone, 76, 80, 82; Calp, 74, 87; Cambrians, 13, 15, 17, 25, 26; Cambro-Silurians, 26, 30; Carboniferous, 61, 84; Caradoc, 46; Castle Espie, 93; Clare, 105; Coal Measures, 59, 95, 101, 104, 105, 111; Creggaunbaun, 47; Cretaceous, 152; Dark shale series, 35; Desertmartin, 89; Devonian, 61; Dingle, 39; Doohylebeg, 74; Drift, 231, 234, 257, 259; East Munster, 111; Eskers, 230; Fenestella limestone, 72; Foynes island, 108; Glengariff grits, 53; Glin, 106; Gowlaun series, 43; Hook, 62, 78; Kiltorcan, 61, 78; Llandeilo, 39; Lough Neagh, 170, 171; Lower Carboniferous, 100; Lower Limestone Shale, 71, 80, 81; Lower Shaly Limestone, 72; Marine drift, 231; Miocene, 168; men, 274, 293; Old Red Sandstone, 80; peat, 267; recent, 230; Rhætic, 136; Rhone Hill, 139; Rosscliff, 105; Salrock, 42; Shore-beds, Carboniferous, 69; Silurians, 45; Sligo, 84; Tallow Bridge and Toe Head, 79; Upper Llandovery, 191; Victoria slate quarry, 376; Whiddy island, 59; Yellow sandstone, 61.
Fossils and fossiliferous rocks, 13, 35, 36, 39, 44.
Foyle river, 322.
Foynes, Coal-measures, 108.

G.

Gabbro, 33, 44, 202; uralitic, 205.
Galtee mountains, erratics, 249; glaciers, 245.
Galtymore, 20, 30, 307, 308.
Galway, Bay 20, 239, 265, 326, 328, 335; Cambrians, 21; Carboniferous, 7, 79; caves, 284; cooms, 310; erratics, 248, 249; granite, 389; gravel, 231; hills, 260, 299; kitchen middens, 283; metamorphic rocks, 189; minerals, 365; raised beaches, 253, 256; valleys, 231, 258, 314.
Garbally Coal Measures, 109.
GARVIN (J.) on fossils, Lough Neagh beds, 171.
GEINITZ (Dr.) on Tyrone Coalfield, 128.
Geological, history, 1: systems, 5; terms, 9, 409.
Giants' Causeway, 155, 164.
Glacial drift, 223; glacialoid drift, 225.
Glaciation, 221.
Glaciers, 9, 241.
Glandore lode, 353.
Glanmire, fossils, 61.
Glanmore, slate quarry, 378.
Glen, Imale, 319; of the Downs, 321; Ow, 246, 320.
Glenarm, whiting, 154; quarries, 161.
Glennawooa, Mayo, 310.
Glenbonniv, relics in peat, 277.
Glenbrian, granite, 195.
Glencar, fossils, 84.
Glencolloo, 307.
Glencree, 318.
Glendalough, 250, 310, 333.

Glenflesk, drift, 245, 260; eruptive rocks, 189.
Glengariff grits, 41, 53, 85, 203; Fintona, 85; fossils, 53.
Gleninagh, 259.
Glenmacanass, 321.
Glenmalure, 246, 320; hills west of, 234.
Glennagappul, 310.
Glin, fossils, 106.
Glynn, Salt Measures, 138.
Gneiss series, 178; Donegal, 192.
Gneissite, 204.
Gokane Point, fossils, 61.
Gold, 339; alluvium, 346; drift, 234; faults, 344, 346; sand, 234, 344; working, 345; ornaments, 341.
Golden, Tipperary, 317.
Golden-vein (Suir Valley), 292.
GOOD (J.) on Dunworley Bay bog, 265.
Goraghwood "granite," 210, 390.
Goresbridge, 77.
Gorey fault, 25.
Gort river system, 325.
Gorumna, County Galway, 204.
Gowlaun, 43; rocks, 47; series, 42; Silurians, 41.
Graiguenamanagh, 255.
GRAINGER (Dr.) on fossils,
Granard, 22, 35.
Granite, 179, 180, 388; Carnsore, 194; decomposed, 394; Dublin and New Ross, 187; grain in, 197, 198; hills, 306; Mourne, 192; Newer, Wicklow, 187; Newry, 210; Silurian, 204: slabs, 378; Slieve Croob, 192; water-supply, 396.
Granitic felstone, 204; gneiss, 178; rocks, 4, 179, 180, 194; sand, 197; soil, 288.
Granitoid rock, Slieve Foye, 209.
Gravels, Lough Corrib, 230; Tyrone, Derry, and Nore, 226.
Great Sugarloaf, 197.
Greenore, County Louth, kitchen-middens, 283: shell gravels, 257.
Greenore, County Wexford, 16; Cambro-Silurians, 26; quartzite, 182; metamorphic rocks, 215.
Greensand, 150.
GRAY (W.) on iron-ore measures, 167.
Greystones, 14.
GRIFFITH (Sir R. W.), 20, 50, 51, 53, 55, 56, 93, 169, 170, 357, 386; Ballycastle rocks, 90; Coal Measures, 112, 121, 122, 123; Cork-rocks, 7 *f. n.*; Fintona rocks, 82, 85; Louisburg, 47; Permians, 133: Tyrone and Fermanagh rocks, 86.
Gritstones, 386.
Growan, 197, 394.
Gulladuff Trias, 141.
Gypsum, 134, 139, 358, 393.

H.

HARDMAN (E. T.), 100 *f. n.*, 124, 169.
HARKNESS (Prof.) on fossils, 44.
HARTE (W.), kitchen-middens, 283.
HAUGHTON (Rev. Dr.), 192, 209, 251.
*Haughtonia pœcila*, 13.
Head of tide, 251.
Hibernian Greensand, 149, 150.
Highlands. Wicklow, 306.
Highly silicious intrusive granitic rocks, 179.
Hills, 2, 3, 299, 303.
Hillsborough, County Down, 162, 208.
*Histioderma Hibernicum*, 13.
Hollywood, County Wicklow, fault, 321.
Hook Promontory, 78, 316, 317.
HOOKER (Dr.) on debacles, 332.
HORE (J.) on red rocks, Bunmahon, 28.
Hornblende rock, 194, 204, 390.
Hornblendic-gabbro, 204; granite, 204.
Hornstone (baked shale), 158, 184.; WEAVER on, 186.
Horses' Glen, Mangerton, 310.
Hospital, Limerick, 200.

Howth, 34; Cambrians, 11, 12; cobalt, 357; quartz-rock and quartzite, 197; water-supply, 397.
HUGHES (Mr.) on fossils, 30, 376.
HULL (Prof.), 87, 133, 135, 162.
Human remains, or relics, 273, 286, 295.
Hungry Hill, County Cork, glaciers, 245.
HUXLEY (Prof.) on Coal Measure fossils, 98, 101, 119.
Hybrid rocks, 180, 181, 210.
Hydraulic limestones, 386.
HYNDMAN (G.) on fossiliferous gravel, 259.
Hypergene and Hypogene rocks, 4 *f.n.*

I.

Ice action, 242, 299; cap, 224; movement, 242; sheet, 9, 235.
Igneous rocks, 194.
Inch conglomerate, 52.
Ingenite rocks, 175.
Innistioge, on Nore, 317.
Intraglacial drift, 225; peat, 234, 267.
Intrusive granite, 179, 180; rocks, 194.
Invers, 3.
Ireland's Eye, 34, 337.
*Irish Elk*, 295.
Iron furnaces, 352; mines, 352, 353.
Iron-ores, 56, 99, 100, 108, 111, 122, 159; and gold, 343; localities, 166, 353; Miocene, 160, 161, 164, 166; measures, 157, 160, 161, 164; Palæozoic, 354.
Island Magee, Jurassic, 144; iron-ore, 166.
Islands, 328, 335.
Isle of Man, 229.
Iveragh, 51, 52, 54, 310.

J.

JACOB (A.), on Leinster Coal Measures, 112.
JAMES (Sir H.), drift Forth mountain, 261 *f.n.*
Jarrow colliery fossils, 118.
JONES (Admiral), Armagh fossils, 87.
JONES (M. H.), on oak beams in drift, 284.
JUKES (J. Beete), 7 *f.n.*, 13, 14, 15, 23, 28, 30, 38, 47, 51, 52, 56, 59, 60, 64, 77, 152, 169, 200, 244, 277, 315, 391; Australian limestone, 73; Ballaghaderreen rocks, 48; Coal Measures, 98, 104, 112, 122; fish Coal Measures, 98; Laurentian rocks, 35, 191, 207; Miocene, 8, 149, 160; White Ball Head agglomerate, 202.
Jurassic, 8, 143; altered 146, 185 *f.n.*; coal, 147; localities, 143, 144.

K.

Kames, 229 *f.n.*
KANE (Sir R.), 132, 287, 342, 359, 380; water supply, 395.
Kaolin, 360, 392.
Keady Mountain, Cretaceous, 151; Miocene, 158.
Keeper Mountain, 31, 306.
KELLY (John, the late), on Quartz-rock, 14; salt measures, 137.
KELLY (J.), on hydraulic limestone, 386.
Kenmare river, 51, 55.
Kerry, bays, 328; Carboniferous, 5, 7, 65; cooms, 309, 311; hills, 260, 304; kitchen middens, 282; lakes, 334; minerals, 367; mountains, 23, 260, 304; raised beaches, 253, 255; rocks, 50; valleys, 258.
KILBRIDE (Rev. W.), submerged land, 264.
Kilbride Bay, 43; promontory, 43.
Kilcoole, County Wicklow, 196.
Kilcorig quarry, 160.

Kildare, Carboniferous, 75, 76; Cambro-Silurians, 25, 27; Chair of, 33; Coal Measures, 119; dolomites, 76, 188; kitchen middens, 283; metamorphic, 187; minerals, 367.
Kilkenny, Carboniferous, 76; Coal Measures, 112; dolomite, 76, 188; Esker gravel, 226; marbles, 381; minerals, 367.
Kilkieran Bay, County Galway, 231.
Killala Bay, 250.
Killaloe, 323; rocks of, 324; slate quarries, 375.
Killarney, drift, 245; eruptive and metamorphic rocks, 189; lakes, 3, 334.
Killary harbour, 36, 43, 190, 199, 204, 206, 256, 259; eurites, 204; silurians, 41.
Killoughter, County Wicklow, 13.
Killowen, County Wexford, "elk-hole," 295.
Killucan, 34.
Kilmacrea, Pass, 320; slate quarries, 378.
Kilmakilloge, lake, 334; section, 58.
Kilmichael, County Wexford, 254.
Kilmurry, rocks, 59.
Kilroot, raised beach, 256.
Kilsella, County Sligo, fossils, 84.
Kiltorcan rock and fossils, 61, 77, 78.
KINAHAN (Dr. J. R.), 12, 13, 15 *f.n.*, 296.
KING (Clarence), glaciers, 224, 249.
KING (Dr.), Galway Cambrians, 20; fossils, 44; joints, 74; Permians, 132, 133.
KING (W., of India), on granitic rocks, 179.
Kings County, Carboniferous, 75; minerals, 368.
Kingscourt, Trias, 134.
King's River valley, County Wicklow, erratics, 250.
Kinsale Head, 60; Coal Measures, 104.
Kinvarra, 326.
Kitchen middens, 257, 282.
Knockadober, County Kerry, 262.
Knockagraffy, County Armagh, fossils, 234.
Knockfeerna, County Limerick, 200, 201.
Knockmahon, mines, 350; red rocks, 28.
Knockmealdown, glaciers, 245.
Knockmore, caves, Fermanagh, 284, 285, 293.
Knocknadona, fossils, 160.
Knocknamohill mines, 355.
Knocksheegowna, 31, 33.
Kylemore valley, 204.

## L.

Lackavrea, quartz rock, 204.
Lacustrine drift, 223, 233.
Lady's Island, Wexford, 228.
Lagan, valley, 292; Permian, 132; Trias, 135.
Lagoons, 3, 259, 328.
Lagore crannog, 281.
Lake dwellings (crannogs), 278.
Lakes, 3, 321, 330; Killarney, 3, 203. (*see* Loughs.)
Lambay, 34, 77, 337.
Larne, 166; Cretaceous, 154; Jurassic, 144; raised beaches, 253, 256; whiting, 154.
Laterite, 163.
Laurentians (?), 35, 191, 207.
LE CONTE (Prof.), California gold, 343; metamorphism, 175.
Lead, 348, 351.
Lee River, 316.
Leenaun, Killary harbour, 256, 259, 311.
Leinster Carboniferous, 75; Coalfield, 112; erratics, 250; granite, 195, 197, 388; hills, 304; range, 195.
Leitrim, Carboniferous, 83; Coal Measures, 120; minerals, 368.
Lemonfield, conglomerate, 69.
LEONARD (Hugh), ash of peat, 270.
LEONARD (W. B.), 134, 135.
Letter Mullen, rocks, 36, 190, 204.

Levaly lake, 81.
Lias, altered, 145, 158; hornstone, 158; typical section, 144; Portrush, 145, 158, 185.
Liffey, river, 321; valley, 258.
Lignite, 157, 159, 164, 167, 170, 171.
Limavady, Cretaceous, 150; Jurassic, Triassic, 142.
Lime, 392; soil, 290.
Limerick, Carboniferous, 65, 70; eruptive rocks, 200; marbles, 382; mines, 350; minerals, 368; plain of, 260; raised beaches, 255, 258.
Limestone, 380; band in Coal Measures, 100, 105, 106; Burren type, 75; Carboniferous, 58; eruptive rocks in, 218; hills, 300, 306; slabs, 379; water supply, 400.
Linfield, columns, 201.
Lisbellaw, Cambro-Silurians, 36.
Lisdoonvarna, springs, 402.
Lisnastrane, limestone, 153.
Lithographic stone, 153.
Lithomarge, 163.
Little Causeway, Rathlin Island, 164.
Little Killary, County Galway, 43.
Little Sugarloaf, County Wicklow, 197.
Llandeilo fossils, 25, 26, 29, 30.
Llandovery fossils, 39, 43, 44, 45.
Local metamorphism, 4, 175.
Local soil, 287.
Londonderry, bays, 328; Cambro-Silurian, 35; Carboniferous, 86; Cretaceous, 150; eruptive rocks, 207; hills, 308; Jurassic, 147; metamorphic rocks, 189; minerals, 368; raised beaches, 256; rocks, 86; Triassic, 140, 141.
Longford, Cambro-Silurians, 34; minerals, 369.
Loughs, 3, 330; Allen, 322, 323; Bray, 310; Cooter, 80, 325; Corrib, 3, 41, 44, 69, 81, 230, 258, 265, 327, 330, 331; Derg, 32, 323, 331; Erne, 88; Forbes, 34, 323; Foyle, 141; Gara, 82, 83; Graney, 33; Guitane, 189, 203; Gur, 201; Hacket, 280; Key, 82; Mask, 41, 43, 44, 45, 69, 81, 205, 331; Moher, 205; Muck, 42, 43; Neagh, 3, 330; Rea, 280; Ree, 323; Shinny, 77.
Lough Muck series, 42.
Lough Mourne, Jurassic rocks, 144.
Lough Neagh, basin, 330: beds, 169, 170, 171; clays and sands, 233; Cretaceous, 153; faults, 90, 128; hones, 169; series, 156, 168.
Loughnahinch crannog, 280.
Loughrea, 80.
Louisburgh, rocks, 41, 47, 191.
Louth, Carboniferous, 76; eruptive rocks, 212; minerals, 369.
Lower Carboniferous, 63, 87; fossils in Coal Measures, 100.
Lower limestone, disappearance of, 75.
Lower limestone shale, 58, 64, 67, 70, 71, 83, 84, 87, 88.
Lowland bogs (red bogs), 271.
Ludlow fossils, 50, 52.
Lugacurren fault, 113.
Lugnanoon granite, 217.
Lugnaquillia, 306, 310; cooms, 311; glaciers, 245.
Lurgan, Cretaceous, 153.
Lusca (cave), 284.
Luscans, or cave-dwellers, 285.
Lyons (Rev. P.), on Galway erratics,

## M.

Macgillicuddy's Reeks, 307.
Macroom, rocks, 59.
Maghera, Triassic, 141.
Magilligan, Jurassic, 147.
Magnesia, 358; springs, 195, 402
Magnesite, Coagh, 208.
Maigue River, 322.
Malahide Bay, 329.
Mallet (R.), on Minerals, 346.
Mallow rocks, 68; eruptive rocks, 200.
Mammalia, 291.
Man, ancient, 282.
Manganese, 56, 355.

Mangerton, Killarney, 310.
Manures, mineral, 374; artificial, 395.
Marbles, 74, 380.
Marine, denudation, 299; drift, 223.
Marl, 393.
Maum Thomoish, 311.
Maum Valley, 43, 45, 48.
Maums, 2, 3, 315, 321, 392.
Maumturk Mountains, 244.
Mayo, bays, 328, 329; Cambro-Silurians, 36; cooms, 310; Carboniferous, 328, 329; erratics, 248; eruptive rocks, 207; islands, 335; metamorphic rocks, 189; lagoons, 323; lakes, 334; minerals, 369; raised beaches, 253, 256, 259; rocks, 20; Silurians, 41, 44; slates, 378; valleys, 231, 258.
McHenry (A.), 36, 190.
McDonnell (Dr.), on fossils, 268.
Meadows (McCarthy), on Coal Measures, 115, 116, 117.
Meath, Carboniferous rocks, 76; kitchen middens, 283; raised beaches, 257; minerals, 369.
Meelick, King's County, 323.
Mesozoic, period, 5; rocks, 130; water supply, 402.
Metallic schist, 178.
Metamorphic granite, 178, 389.
Metamorphic, rocks, 4, 175, 182; Cambrians, 215; Cambro-Silurians, 216; Carboniferous, 218; chronologically arranged, 213; Miocene, 220; Triassic, 220.
Metamorphism, 175.
Metapepsis, 4, 175, 182; Metapeptic action, 175.
Meteoric, abrasion, 299: drift, 223, 235; rocks, 4.
Methylosis, 4, 177.
Methylotic, action, 188; rocks, 192, 204.
Middle (?) gravels, 233, 236.
Milne-Home (D.), on shoals, 228.
Mineral list, 361; manure, 392; soil, 287.
Mines and minerals, 339; ancient, 347, 350.
Miocene, 156; conglomerate, 151, 157; dolerite, 161, 208, 210; eruptive rocks, 161; metamorphic rocks, 220; plants, 160, 167, 168.
Mitchelstown, Coal Measures, 109; Caves, 286.
Mizen Head promontory, 55.
Moira, Cretaceous, 154; eruptive rocks, 209.
Molybdenite, 357.
Monaghan, section, 85; lakes, 335; minerals, 369; rocks, 84.
Moneygall, 31.
Moneymore, Triassic, 141; rocks, 88; water supply, 403.
Moneyneany, Cretaceous, 151; conglomerate, 89.
Moneystown Hill, Cambrian and Cambro-Silurians, 27.
Moraine drift, 223; recent, 245.
Motto stone, Ovoca mines, 250.
Mount Gabriel, County Cork, 245.
Mount Leinster, 187, 198, 261; drift, 236, 261.
Mount Mary, 80.
Mourne granite, 192, 210.
Moy river, 327.
Moyola, rocks, 89.
Mulatto stone, 151, 153.
Mullaghmore, Triassic, 141.
Munster, Carboniferous, 65; Coalfields, 104, 303; hills, 303, 304; metamorphic rocks, 188.
Muntervary promontory, 55.
Murchison (Sir R. I.), on Permians, 131.
Murrisk, County Mayo, 204.
Mweelrea, 46, 244, 308, 311; eurites, 205; group, 44; section, 45; Silurians, 41.
Mweelrea and Toormakeedy group, 44.

N.

Native, copper, 351; gold, 339; silver, 347; sulphur, 356.
Nenagh, erratics, 249; intraglacial peat, 234, 267.

Neozoic period, 5.
New Ross, rocks, 195.
Newport, County Tipperary, erratics, 249.
Newry granite, 209, 210.
Newtown, Queen County, Coal Measures section, 114; drift, 231; intraglacial peat, 267.
Newtownbarry, drift, 233; slate quarry, 377.
Newtownmountkennedy, 15.
Nevadite, 208.
Ninemilehouse, County Tipperary, rocks, 30.
Nobber, rocks, 94.
NOLAN (J.), agglomerate, 210; hydraulic deposit, 386.
Nore, 258, 261; estuary, 255; valley, 226, 231, 246, 316.
Nuggets of gold, 344.

O.

Oak, forest, age, 268, 272; corkers, 265.
Ochreization of schist, 187.
O'KELLY (Joseph), 33, 244.
Old Red Sandstone, 5, 7, 28, 38, 52, 63, 64, 66, 68, 78; Armagh, 87; quartz-rock, 71, 199; slabs, 378; water supply, 399.
Old Red Sandstone (Cork type), 50, 51, 53, 55, 60, 66.
Old Red Sandstone and Shore-beds, 65.
OLDHAM (Dr.), 391.
*Oldhamia*, 12, 13, 14, 15, 17, 197.
Omagh, cave, 285; rocks, 86, 88.
Omey Island, Æolian drift, 240.
One hundred feet beach, 224, 252, 258.
Ormond slate quarries, 375.
Oughterard, 70, 190.
Ovoca, 235, 258, 261; mines, 185, 354.
Ow, 13, 15; Glenow, 320.
Owenduff, paroptetic rocks, 184.
Owenreagh fossils, 53.

P.

Palæozoic period, 5.
Palæozoic rocks, 11; classification of, 49; limestones, 385; marbles, 380.
Pallas Hill, County Limerick, 396.
Paps, the, Co. Cork, 307.
Paramoudra, 154.
Paroptesis, 4, 176, 182, 185.
Paroptetic action, 184.
Parsonstown (Birr), 33.
Partry mountain, 45.
Pass of Salrock, 43.
Peat, bogs, 267; ash of, 270; fossils, 267, 268, 278.
Pebble-iron ore, 164.
Penarth beds, 136.
Permian, 8; at base of Trias, 142; rocks, 130; supposed, 133.
Petro-silex, 180, 204; Bannow, 195.
Philipstown, King's County, 199.
PHILLIPS (Prof.), on Cambro-Silurian, 23.
Physical features, 1, 299.
Pipeclay, 360.
Pisolitic iron-ore, 164.
Placer mines, 339, 342.
Plant beds, Miocene, 160, 167, 168.
Plastic clays, 168, 233.
Pleistocene, 156, 168.
Pliocene (?), 156, 168.
PLUNKETT (Thomas), on Knockmore caves, 284; mammalia, 285, 293.
Plutonic rocks, 179, 194; basic, 181; list of, 180, 181; silicious, 180; Silurian, 204.
Poikilitic formation, 130.
Pollshone harbour, 17.
Pomeroy, Cambro-Silurians, 36.
Porcelaine clay, 360.
PORTLOCK (General), 36, 64, 85, 89, 123, 140, 145, 146, 152, 155 159, 169; Antrim caves, 253, 256; Benburb rocks, 87; fossils, 92, 139; Scrabo Hill, 135, 209; Rhætic beds, 142.
Portraine, 77.

Portrush, 185 *f.n.*, 208; Cretaceous, 155: elvan, 220; Jurassic, 144; Lias, 144, altered Lias, 145.
Portumna, 323; Burren limestone, 80; erratics, 249.
Post-Carboniferous, dolerites, 207; elvan, 209; granite, 198, 210.
Post-glacial, estuarine drift, 232; fluviatile drift, 234; lakes, 234; marine drift, 225.
Pot-holes, 324.
Poulaphuca, 321.
Powerscourt waterfall, 321.
Pre-glacial, drift, 225, 231, 233; peat, 267.
Pre-historic remains, 267, 273.
Prestwich (Prof.), on Coal Measure fossils, 101.
Primary period, 5.

Q.

Quarries, 374.
Quartz with gold, 344.
Quartz rock, 14, 17, 45, 71, 180, 183, 204; altered, 12, 17, 195, 221; Bray Head, 196; Carboniferous, 202; Corcogemore mountains, 221; Forth Mountain, 195; Greisen, 179; Ireland's Eye, 34; Old Red Sandstone, 199; Wicklow, 196.
Quartzite, 177, 178.
Queen's County, Carboniferous, 75; drift, 231; minerals, 370.

R.

Rabbit sand, 238.
Raised beaches, 226, 241, 251.
Raleigh (Sir W.), iron mine, 353.
Ramsay (Dr. A. C.), Cambrians, 21; cooms, 311; Permians, 131; rock-basins, 330.
Rathgormuck quarries, 377.
Rathlin Island, rocks, 155, 158, 164, 166.
Raven banks, 319.
Recent moraines, 245.
Records of ancient man, 282.
Red bole, 164.
Red Carboniferous rocks, 89.
Red bog, 268.
Reenydonagan, 61.
Regional metamorphism, 4, 175.
Rhætic beds, 136, 141, 142, 144.
Rhone Hill, fossils, 139.
Ringaskiddy, 60.
Ripple marks, 53.
Rivers, 3; valleys, 314.
Roaring Water Bay, 59.
Rock basins, 330; with faults, 331; not always lakes, 331.
Rock terraces, 252.
Rockabill, 337.
Roscommon, Carboniferous, 81; eruptive rocks, 207; lakes, 335; minerals, 370.
Rosscarbery slate quarries, 377.
Rosslare bank, 319.
Roundwood reservoir, 15.
Rowan (D. J.), on kitchen middens, 257.
Roxborough, rocks, 201.
Rush Bay, 329.

S.

St. Helen's, County Wexford, Æolian drift, 240.
St. Mullins, County Carlow, 198.
St. Patrick's bridge, County Wexford, 228.
Sallagh Braes, 161, 405.
Salrock, beds, 43; pass, 43; series, 41, 191; slates, 205, 378.
Salt, 358; marshes, 291; Measures, 137.
Saltee Islands, 16, 182.
Salter (J. W.), on fossils, 44, 39.
Salter's Castle, sections, 171.
Sands, 360; calcareous or shelly, 230, 239; silicious, 239, 361; streams, 239.

Sandstones, 386; recent, 230.
Sandy Bay beds, Lough Neagh, 170.
Scalp, Enniskerry, 321.
Schist series, 177, 186, 192, 190.
Scott (Major-General), hydraulic limestone, 386.
Scott (R. H.), Donegal rocks, 192, 207.
Scouler (Dr.), Lough Neagh hones, 172.
Scrabo Hill, eruptive rocks, 209; Triassic, 135.
Scrope (Poulett), on basic igneous rocks 162.
Scullogue gap, 198.
Sea beaches, 251; margins, 251, 262
Secondary period, 5.
Sections :—Annagher colliery, 124; Annaghmore, Coalisland, 171; Ben Evenagh, 142; Ballinderry, 170; Ballypalady, 168; Barrow estuary, 265; Clare and Galway Carboniferous, 79; Coalisland, 123, 125; Collin Glen, 136; Connaught Coalfield, 121; Coolbaun, Castlecomer, 114; Cork rocks, 54, 58; diagrammatic, 54; Dingle, West Cork, and Limerick, 51; Drumshambo, 83; Dungannon Coal Measures, 123; East Munster Coal Measures, 110; Galway Cambrians, &c., 21; Irish Coal Measures, 97; Iron-ore Measures, 167; Kerry Carboniferous, 67; Lagan valley, 135; Leinster Coal Measures, 113, 114; Limerick Carboniferous, 71; Miocene, 160; Munster Carboniferous, 67; Newtown Coal Measures, 114; Rhætic beds, 136, 137; Sandy Bay, 171; Salt Measures, Duncrue, 137; Seefin, Galway, 190; Slaney valley Cambrians, 16; Sligo, 83; Sligo and Fermanagh, 86; Tyrone, 85; Waterloo, Larne, 144; West Munster Coalfield, 105; Wexford harbour, 266.
Sedimentary rocks, 4, 11.
Seefin section, County Galway, 190.
Shanagolden, County Limerick, 201.
Shandon cave, County Waterford, 285
Shanganagh river terraces, 252, 254.
Shankill, 197.
Shannon river, 31, 34, 260, 322; estuary, 253.
Shell sand, 394; shelly drift, 261.
Sherkin Island, slates, 376.
Shore beds and Old Red Sandstone, 65.
Shore beds (at different horizons in the carboniferous), 64, 69, 82; Lough Shinny, County Dublin, 70; Oughterard, Galway, 68; Roscommon, 82; (at the base of Old Red Sandstone), 79, 85.
Sibthorpe (T.), on marbles, &c., 380.
Silicified wood (Lough Neagh hones), 171.
Silicious limestones, 71, 202; sand, 361; springs, 195.
Silurians, 38; Ballycar (?), 32; conglomerate, 47, 48, 52, 53; Cork type, 50, 51; eruptive rocks, 217; granite, 204; limestone, 45; metamorphic, 189, 217; Mayo, 191; plutonic rocks, 204; water supply, 398.
Silver, 347; localities for, 348.
Silvermines, County Tipperary, 31, 347; erratics near, 249.
Skelligs, County Kerry, 335.
Skerries, County Dublin, 77, 337.
Skerries, Portrush, 208.
Skibbereen, glaciation near, 245.
Slabs, 378.
Slaney, fault, 25; valley, 16, 231, 232, 255, 258, 261, 318.
Slate, 32, 374; conglomerate, 26, 27, 183.
Slemish, County Antrim, 208.
Slieve (anglicè, *mountain*), Arra, 31; Aughta, 31, 324; Bawn, County Roscommon, 34, 83; Bernagh, 31, 32; Bloom, 31, 33, 249; Brack, S. W. of Newry, 210; Croob granite, 192, 209; Carna Coal Measures, 119; Dart, County

Galway, 80, 203; Foye, County Louth, 209, 210, 220; Gallion-Carn, 141, 152, 159; Galry, 34; Kimaltha, 31, 307; More, Achill, 308; Nabolea, S. W. of Newry, 210; Namuck, 30, 109; Naman, 20, 29; Partry, 45; Phelim, 31, 199, 249, 316; Roe, County Kilkenny, coal, 29.
Sligo, Carboniferous, 81; Cambro-Silurians, 36; Coal Measures, 120; eruptive rocks, 207; lakes, 335; metamorphic rocks, 189; mineral localities, 370; mountains, 308; raised beaches, 253; section, 83.
Sligo and Fermanagh section, 86.
Sluggas, 324.
Smerwick beds, 39, 40.
SMYTH (Prof. W. W.), on Wicklow gold mines, 343.
Sneem section, 58.
Soft-rock chalk, 151.
Soil, 287; producing animals, 292.
SPENSER (Poet), on the Slaney, 320.
Sphene-rock, 208.
Spike Island, 60.
Srahs, 235.
Stage lode, Knockmahon red rocks, 28.
Steatite, 26, 188, 359; bole, 166—steatitic rocks, 205.
STEWART (S. A.), on drift fossils, 256.
Stewartstown, Triassic, 140.
STOKES (Dr.), Cobalt ore, 357.
Stone crannogs, 279.
Stone turf, 269.
Strabane, rocks, 88.
Stratford on Slaney, 233.
Streedagh, fossils, 84.
Submarine peat, 267.
Submerged, bogs, 265; forests, 241, 264, 265; land, 241, 264; road, 276, 277; wattlefence, 277.
Submergence, ancient traditions respecting, 264.
Submetamorphic rocks, 177, 183, 186, 192.
Subterranean rivers, 324.
Suck river, 322.
Sugarloaves, Bray, 14, 309.
Suir estuary, 255; valley, 231, 258, 261, 316.
Sulphur ore, 356, 395.
Superficial accumulations, 223.
Sutton, 355, 357.
Swallow holes, 324.
Syenite, 181, 204.
SYMES (R. G.), 191, 203, 207.

## T.

Tagoat Cambro-Silurians, 26, 183.
Taghmon, 29.
Tallow Bridge, fossils, 61.
Tamlaght, fossils and rocks, 152, 208.
Tardree, eruptive rocks, 162, 208, 220.
TATE (Ralph), Cretaceous, 148; Jurassic, 144; Lias fossils, 145; Rhætic beds, 136; white limestone, 149.
Templepatrick section, 162.
Terraces (marine), 231, 251, 258.
Tertiary period, 5.
Three hundred feet beach, 252, 259.
Tide, mean height of the, 251.
Tigroney baked shales (hornstone), 184.
Till, 223.
Tin, 357.
Tipperary, Carboniferous, 75; Cambro-Silurians, 32; Coal Measures, 103, 109; mineral localities, 370; mountains, 306.
Tirawley, 81.
Tircrevan Burn, Jurassic, 147.
Toe Head, fossils, 61.
Togher, 15.
Tomines, Ardsolla river, County Clare, 326.
Toomavara, 31.
Toormakeady rocks, 205, 206; Silurian group, 41.
Tory Hill, Limerick, 309.
Trachy-dolerite, 180, 181.
Trachyte, 180—trachytic rocks, 162
TRAILL (W. A.), 161, 163, 164, 167, 192, 207, 209, 212, 254, 256, 391, 404.

Tramore, County Waterford, 27, 188, 371.
Transported soils, 287, 290.
Traps, 180, 181, 391 ; classification of, 221, 222.
Trees in bogs, 268, 271.
Triassic, 5, 34, 134; dolerite, 207. 209 ; eruptive rocks, 220 ; S. E. and E. Antrim, 137 ; Tyrone and Londonderry, 139, 140, 141.
Tubbrid, rocks, 85, 88.
Tullow, 233, 318.
Tullyconnell, Permians, 132.
Turloughs, 324.
Twelve-feet beach, 252.
Twenty-five-feet beach, 254.
Tyrone, Carboniferous, 86 ; Cambro-Silurians, 85 ; Coalfields, 122 ; Cretaceous, 148, 152 ; eruptive rocks, 207 ; Esker drift, 220, 260 ; geology, Portlock, 36 ; hills, 308 ; metamorphic rocks, 189 ; minerals, 371 ; Triassic, 139, 140.
Tyrone and Fermanagh, rocks, 65.
Tyrone and Monaghan section, 85.

U.

Uggool, fossils, 46.
Ulster, Carboniferous, 8, 84 ; Cambro-Silurians, 34: Coal-measures, 122 ; Cretaceous, 8, 148 ; erratics, 251 ; eruptive rocks, 207 ; glaciation, 247 ; hills, 300, 304 ; Jurassic, 8, 143 ; metamorphic rock, 189 ; Permians, 8, 130 ; Triassic, 7, 8, 134, 135.
Upper glacial (?) drift, 233, 236, 238.
Upper Llandovery fossils, 32, 42, 43 ; rocks, 48.
Uralite, White Ball Head, 203.
Uralitic gabbro, 205.

V.

Vale of, Aherlow, 307 ; Clara, 320 ; Ovoca, 258, 261, 320.
Valentia, 52, 53, 189, 335 ; harbour, 203 ; slate quarry, 376.
Valleys, 314 ; Avonbeg (Glenmalure), 246, 258 ; Avonmore (Vale of Clara), 258 ; Aughrim (Glenow), 246 ; Barrow, 246, 258, 261 ; Bray (Dargle), 254, 258 ; King's river (tributary of Liffey), 261 ; Lagan, 292 ; Liffey, 258 ; Nore, 226, 246, 258, 261 ; Shanganagh, 254 ; Slaney, 255, 258, 261 ; Suir (Golden Vein), 258, 261, 292.
Variegated limestone, 45.
Vartry basin, 320 ; waterworks, 15.
Vegetable soil, 287.
Victoria slate quarries, County Tipperary, 30, 376.
Volcanic rocks, 179, 181, 194 ; basic, 181 ; silicious, 180.
Vulcanicity, 6, 7, 176, 205.

W.

Warren (J. L.), Cultra beds, 132 ; Hibernian Greensand, 153 ; Lagan valley, 135 ; Miocene eruptive rocks, 166 ; Petro - silex, 392 ; Scrabo Hill, 209.
Water-supply, 9, 12, 13, 395.
Waterfalls, 321.
Waterford, Carboniferous, 50, 68, 75 ; Cambro-Silurian, 25 ; cooms, 310, 311 ; Cork rocks, 50, 68 ; drift, 236 ; erratics, 250 ; glaciation, 245 ; Hook rocks, 78 ; lagoons, 329 ; minerals, 353, 371 ; mountains, 303 ; raised beaches, 253, 255, 261 ; slate quarries, 377 ; valleys, 261, 317 ; Yellow Sandstone, 68.
Waterloo, Larne, Cretaceous, 154 ; Jurassic, 144.
Weaver (T.), gold, 342 ; hornstone, 186 ; minerals with gold, 345.
Wenlock type fossils, 44, 48, 191.
Westmeath lakes, 335.

Wexford Cambrians, 16; Cambro-Silurians, 23; Carboniferous, 78; drift, 236, 237; dolomite, 188; eruptive rocks, 194; granite, 194, 195; harbour, 16, 319; kitchen-middens, 283; lagoons, 329; metamorphic rocks, 182; minerals, 372; mountains, 304; raised beaches, 253, 254; submerged peat, 266; valleys, 261.
Whiddy Island, Bantry Bay, 53, 59; Coal Measures, 104; fossils, 61.
Whinstone, 180, 181, 221, 222, 391.
White Ball Head, agglomerate, 202.
White Head, Cretaceous, 153; Jurassic, 144.
White limestone (indurated chalk), 149, 208, 385.
White turf, 269.
Whitepark Bay, 155.
Whiting manufactories, 154.
Wicklow, 13; Cambrians, 11, 182, 196; Cambro-Silurians, 23; cooms, 310, 311; erratics, 250; granite, 187, 196; lagoons, 329; minerals, 372; mountains, 3, 306; raised beaches, 253, 254; valleys, 261.
WILDE (Sir W. R.) on crannogs, 281.
WILKINSON (G.), on intraglacial peat, Nenagh, 234.
WILKINSON (Berdoe), 82, 120.
WILLSON (Walter L.), 118, 188, 245, 249, 255.
WILSON (J.) on Duncan's flowbog, County Antrim, 276.
Wilton coal, Cambro-Silurian, 29.
Windy Gap, County Kerry, 53.
WOODWARD (Dr. Henry) on fossils, 171.
WOODWARD (Horace) on Permians, 130.
WRIGHT (Dr. E. P.) on Jarrow colliery fossils, 119.
WYLEY (Andrew), 12, 13, 15, 245, 255, *f. n.*, 261, 262.
WYNNE (A. B.), 31, 33, 72, 83, 163, 169, 255.

Y.

Yellow Sandstone (Griffith), 55, 58, 59, 60, 61, 68; agglomerate beds and dykes, 202; water-supply, 399.

Z.

Zinc, 348.

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