The strata belonging to these Formations are the oldest known definitely recognizable by means of their fossils. They consist chiefly of greenish gray, and blue grit, with green, gray, and purple slate, irregularly alternating in stratigraphical arrangement—the grits in certain places having been converted into quartzites, and the slate into mica-schist. They occupy a large area of the country, in all about 4,736 square miles, extending along the eastern coast, from Dublin southward almost to Dungarvan Bay, and from Balbriggan northward by Dundalk to Belfast Lough, except at a few points where newer strata intervene. From the coast they spread inland to Baltinglass in Wicklow, except when interrupted by the great outcrop of the Leinster granite ; and almost to the Shannon westward from Down and Louth, forming a triangular area, which comprises the counties named, as well as parts of Monaghan, Cavan, Longford, Leitrim, and Meath. Within that area, however, occur some small tracts of more recent sedimentary rocks, and of igneous rocks—granite, gabbro, etc.—in the regions of Mourne and Carlingford.

Isolated Silurian Areas.

A tract of Silurian rocks lies around Pomeroy in Tyrone ; and, in the centre of Ireland, several isolated areas of Silurian grits and slates occur, cropping out from beneath the newer strata which surround them ; they form groups of low hills which overlook a wide extent of the adjoining country, the latter being flat and low-lying. In these hills, therefore, is exhibited the phenomenon of rocks, stratigraphically lower and older, forming the higher ground.

Such tracts—*inliers*—denuded of their former covering, are to be seen at Rooskey, Longford, and Chair of Kildare, as well as in Slieve Bloom hills in Queen’s County ; Slieve Aughty, Slieve Bernagh, and Cratloe hills in Clare ; Slieve Arra, Keeper Hills, Galtees and Slievenaman in Tipperary, Limerick, and Kilkenny, and a large area lying to the west of Waterford. An area of Silurian rocks also occurs to the south of Clew Bay ; and islands off the coast of South Mayo and North Galway consist of similar rocks. Between Charlestown and Ballaghaderreen, in South Mayo, occurs an interesting tract ; and two other small areas of Silurian strata are known to exist in the Dingle promontory.

Of all the areas mentioned, that lying to the south of Clew Bay is the most interesting from a lithological point of view. Nowhere else, perhaps, is so great a variety of strata presented within so small an area, and limited to one Formation. All the members of the Silurian system, except perhaps Arenig, are to be met with, viz., Llandeilo black shale, Bala lime-stone, Caradoc sandstone and conglomerates, Lower and Upper Llandovery, Wenlock and Ludlow. Conglomerates are to be seen near Lough Mask containing pebbles up to two feet in diameter ; and every gradation of such rock and of grit, is to be found, down to the finest arenaceous variety. Shale, slate, and mica schist, with intermediate varieties—phyllites and sericite schist—occur in the region ; in some of those argillaceous beds, the most delicate fossil forms are preserved, while in others, all such relics of ancient life are obliterated by

metamorphism. The grits, too, have suffered such alteration in certain places, that amongst the newest members, gray grit (of the Wenlock stage) [1] has been converted into quartzite, as in Croagh Patrick.

Important beds of limestone of Bala age, associated with igneous rocks, occur near Lough Mask and Lough Nafooey ; and interesting bands of earthy limestone, and calcareous slate and grit, form a large part of the Wenlock member of the Silurian Formation south of Clew Bay. The same character of limestone is to be found in the area of Silurian rocks between Charlestown and Ballaghaderreen.

Scenery of the District.

From the rocks described above, the agencies of denudation have sculptured an array of scenic features which are sublimely imposing and picturesque. Rising from the shores of Clew Bay is the Croagh Patrick range, culminating in the celebrated conical peak, 2,510 feet above the sea. In the same region occur the precipitous ranges of Sheeffry, Bengorm, Formnamore, Leenane, and Maam, with their massive flat-topped and terraced hills, the chief of which is Mweelrea, 2,688 feet high, overlooking the entrance to Killary Harbour. The harbour is a strikingly picturesque arm of the sea running some nine miles inland, and is the principal one of several deep valleys which sever the mountain groups ; others of these sublime valleys are the gorges of Delphi, Doo Lough, and Lough Nafooey.

Throughout the other Cambrian and Silurian areas of Ireland, alternations of fine grit and slate prevail, further varied by the intercalation of conglomerate bands and rarely those of limestone. The limestone bands are of Bala age, and occur in parts of Dublin, Kildare, Wexford, and Waterford. Slate predominates in certain places, grits in others : in Dublin, Wicklow, Wexford, and Mayo the grits have in certain places been converted into quartzite.

Physical Features

With the exception of the rocks of the western area those of the Cambrian and Silurian Formations do not form hills of great height. In the north-eastern region, they occupy for the most part an undulating tract of low average elevation, the chief eminences being Loughanleagh (1,116), near Bailieboro', and Slieve Glah (1,057), south-east of Cavan. In Wicklow and Wexford, several hills of moderate elevation dot the Silurian area, mostly formed of arenaceous strata transformed into quartzite. The principal hills are Croaghan-Kinshela, 1,987 feet above the sea, on the confines of Wicklow and Wexford ; Sugar-loaf mountain (1,659), Kirikee mountain (1,559), and Trooperstown Hill (1,408), in Wicklow ; and Slieve Boy in Wexford. The diversity and arrangement of the rocks of this district, and the difference of degree and manner in which they yield to denudation, have resulted in a character of scenery which presents an attractive combination of beauty and grandeur : hills of massive proportions and varied outline, striking conical peaks, solitary and weird cooms with their mountain-embosomed tarns, deeply cleft glens and wooded vales ; rivulets, cascades, rushing streams, and meandering rivers—all combine to render the region of Wicklow and its borders justly celebrated.

The Silurian districts in Central Ireland for the most part present irregular groups of gently swelling hills, rendered striking in some instances by more or less horizontally imposed and truncated cappings of Old Red Sandstone. The Keeper Hill to the south of Nenagh, and Devil's Bit east of that town, may be mentioned as examples.

While the Silurian rocks weather more slowly than the neighbouring limestone strata, the intervening Old Red Sandstone, when present in force, yields more slowly than either. The result of this is well seen in the Galtee, Slieve-na-man, and Comeragh regions, where the Old Red Sandstone towers above the Silurian tracts ; the latter thus form hill-enclosed plateaux some 400 feet higher than the Carboniferous area.

The hill-tops and flanks of the Silurian ground are thinly covered with a coating of directly derived soils. In the lower parts and the valleys, however, thick accumulations of detritus are usually to be found. This detritus is probably Drift, though the distance of its transplacement may be insignificant. That the accumulations in certain places present evidence of having been transported from distant localities will be shown in a future chapter.

Facilities for Irrigation.

The undulating character of much of the Silurian ground, with regular and, to a great extent, unbroken curving profiles—as indeed shown in the two previous sketches—suggests its suitability for improvement by irrigation. Even when a deficiency of lime is noticeable in the soils derived from the Silurian strata, the spring water flowing from these strata, and trickling through the rubble which frequently forms the subsoil, is impregnated with a proportion of carbonate of lime, and is often quite " hard." It is unfortunate that circumstances, apparently trifling, but calculated in the aggregate to be of great advantage to agriculturists, and for this reason scrupulously recorded at numerous foreign agricultural stations, have hitherto been overlooked in this country. The contents of the waters flowing over the different rock Formations might be reckoned amongst such circumstances ; but systematic analyses of water, any more than of a typical series of the country's soils, do not seem to have been attempted. Such analyses of waters in the case of the Silurian Formation would probably reveal a good proportion of lime, and a not inconsiderable percentage of potash, as well as some phosphoric acid. These are carried away in the drainage, and irretrievably lost to husbandry. Were they conserved, and applied to the land by suitable irrigating systems, how profitably they would supplement the resources existing in the soil.

M. Risler, Director of the Agricultural College at Paris, will scarcely be regarded as an Utopian theorist ; and he sets so high an estimate upon such means of enhancing the productiveness of land, that he writes :—" The distribution of waters, as that of mineral matters, depends upon the geological constitution of a country. By regulating their flow according to the needs of nourishment of agricultural produce, the wealth of France could be doubled." Necessary demands upon a soil's resources are sufficiently great, and the expense of artificial fertilizers forms so considerable an item upon the debtor side of the farmer's accounts, that the prevention of continuous waste, when at all consistent with economy, is an object which well merits his attention.

Old Red Sandstone.

This Formation stretches over the greater part—more than half—of the County of Cork, where it forms the Magillicuddy Reeks and the mountainous tracts of the Iveragh promontory. It also forms the hilly ground lying between Kenmare River and Bantry Bay, and the minor promontories, which in Cork extend southwestward into the Atlantic. Rocks which are supposed to correspond in age, known as the Dingle Beds, form the promontory north of Dingle Bay. From Cork, the Formation extends into Waterford and Tipperary, where it forms the Knockmealdown and Comeragh mountains, and thence into Kilkenny. It forms the cores of hills in Limerick, or fringes the Silurian cores described in last chapter, in that county,

Tipperary, Clare, King's and Queen's counties, and elsewhere in central Ireland. Still further north, strata of this Formation are to be seen throughout the large area around Fintona in Tyrone, which stretches northeastward from Enniskillen to Pomeroy.

It may be judged, from the manner in which the strata pass beneath those of the Carboniferous Formation and repose in isolated patches (outliers), here and there upon Silurian rocks, that the Old Red Sandstone had once a very wide extension throughout Ireland. The conclusion is strengthened by the occurrence of other outlying patches which have escaped denudation, at Draperstown in Londonderry, as far north even as Cushendun in Antrim, and Fanad in Donegal, as well as at Donabate near Dublin, and near Westport in Mayo.

Lower and Upper Divisions.

The Formation is usually described in two divisions, namely. Lower and Upper Old Red Sandstone. The reason for the distinction is not obvious in the County of Cork ; for throughout that county the rocks form a continuous series which passes up by regular sequence into the strata of the Carboniferous system. In the North of Ireland, however, Carboniferous strata, including some at the base of the system, which resemble Upper Old Red Sandstone of Scotland, are separated by a great stratigraphical break—an unconformability—from the Lower Old Red Sandstone of the Fintona tract. In Kerry a similar discordance of a very striking character occurs, to which reference will be made. In the Iveragh promontory, West Cork, an immense Old Red series, known as the Glengarriff Grits, is to be seen, consisting of red, green, and purple highly micaceous grits, with occasional conglomerate beds and green and purple slate. A characteristic feature of the series is that it contains thin bands of compact limestone, and of highly calcareous grit, all of which are commonly known as " cornstones." It is overlain in regular succession by Upper Old Red Sandstone, and, taken together, the series attains a thickness of 13,000 feet. The Glengarriff grits pass laterally into the Old Red Sandstone of East Cork and Waterford, which consists of red sandstone, often argillaceous, with " cornstones." This likewise passes up into Upper Old Red Sandstone without a break or any striking lithological change. The thickness of the Formation here drops to 9,000 feet in East Cork and even to 5,000 in Waterford. The lowest beds of the Formation in Kilkenny and at Galtymore, consist of massive red conglomerates resting upon the upturned and denuded edges of Silurian strata.The same arrangement of strata is noticeable in South Galway, where Upper Old Red conglomerates sandstone and shale crop out, rising from beneath the limestone of the plain, and partially concealing the Silurian strata of the Slieve Aughty hills, on the west side of Lough Derg.

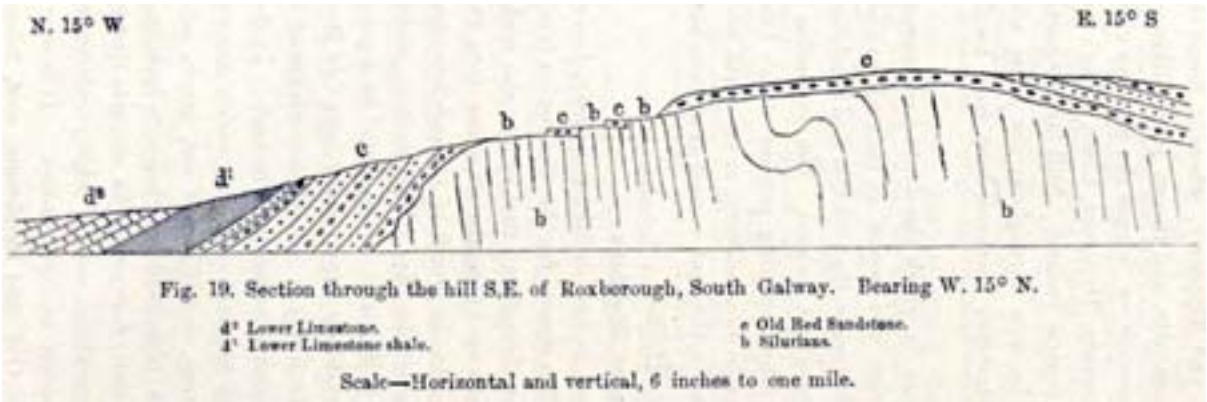

Fig. 19. Section through the hill S.E. of Roxborough, South Galway. Bearing W. 15° N.

d² Lower Limestone.
d¹ Lower Limestone shale.
e Old Red Sandstone.
b Silurians.

Scale—Horizontal and vertical, 6 inches to one mile.

The unconformability thus illustrated may be observed in several stream courses on the slopes of the neighbouring groups of Sl. Bernagh and Sl. Arra, as well as on Slieve Bloom in Queen's Co., Slievenaman in Tipperary and Slieve Baun in Roscommon. The thickness of the Upper Old Red series in these areas is inconsiderable for the width of outcrop presented, since the beds dip with the slope of the ground. The same may be said of the Old Red Sandstone which skirts the metamorphic ground north of Clew Bay. The Old Red beds to the north-east of the bay, and at Old Head and Clare Island, at the entrance to the bay, are probably Lower Old Red, as are those of the Curlew Hills, near Boyle and the Fintona tract : while those which form Slieve Dart and Mount Mary, in North Galway are Upper Old Red.

Oldest Land Plants.

The conglomerates above-mentioned pass upward into liver-coloured sandstone and shale. At a celebrated fossil locality, at Kiltorcan in Kilkenny, the Old Red Sandstone contains yellowish-green compact grit beds, which have yielded some remarkably beautiful fossil ferns, *Palæopteris* (*Andiantites*) *Hibernica*, and an estuarine mussel shell, *Anodonta Jukesii*, which may be seen in the Geological Survey Collection in the National Miiseum.

The fern is especially interesting as forming the chief member of the earliest group of land plants, of which remains have been met with in Ireland ; as well as being the precursor of an important class which attained remarkable development during the Coal Period. *Palæopteris* has also been found near Ballyhale, at Jerpoint near Thomastown, at Tivoli near Cork, and at some other points.

Munster and Ulster,

The Lower Old Red Sandstone lessens considerably in thickness in the regions last mentioned, and does not appear in the Tipperary hills, Clare, nor in the central Irish counties.

Both divisions of the Formation appear in the promontory which terminates in Kerry Head, and to the south-west of Tralee. The Lower Old Red beds there rest unconformably upon the Dingle beds.

This discordance is a perplexing geological fact upon which it would be out of place here to dwell. It must suffice to say that eminent geologists have classed the Dingle beds as Lower Old Red Sandstone, because of their striking resemblance to the Glengarriff grits. If this judgment be correct it involves the unusual circumstance of a great stratigraphical break *in* the Lower Division of the Old Red Sandstone.

The Fintona series consists of red, purple, and brown sandstone, with conglomerates in many places, made up chiefly of felsite pebbles, and felspathic particles. [2] No " cornstones" have been met with in the Tyrone Old Red Sandstone ; their absence is an important point of contrast between these rocks and their congeners in the South of Ireland.

Physical Features.

The Tyrone tract presents no very notable natural features ; the chief hills are Slievemore (1,033 feet above the sea), near Ballygawley ; and Brocker Mountain (1,046), and Topped Mountain (909), near Enniskillen. Two escarpments run north-eastward, one along the southern boundary of the tract by Killyfaddy towards Ballygawley, and another by Fintona and Seskinore. These escarpments, and several of the valleys and glens which traverse the area, are considerably picturesque.

The Old Red Sandstone in the south forms some of the highest mountains in Ireland, with striking escarpments, cooms, and picturesque hill cappings. Those upon the Keeper and Devil's Bit hills have been already mentioned. The massive cappings upon the Silurian rocks in Galtee Mountains overlook the area of the latter rocks, which form the western portion of the range, and rise to the height of 3,015 feet in Galtymore. The sublime background to the celebrated scenery of the Killarney Lakes—the Magillicuddy Reeks, with their valleys and glens—is carved out of this Formation. The massive features of Carrantuohill (3,414), and Mangerton (2,756), of the Reeks, form the nucleus of a group which extends into the Iveragh and Glengarriff promontories.

The Dingle promontory also, culminating in Brandon Hill (3,127) and Benoskee (2,713), consists, as has been stated, almost entirely of rocks supposed to be of Old Red Sandstone age.

Soils of the Formation.

The strata, consisting of slate or shale with red and green sandstone—sandstone predominating—in general give free-working soils, with the probability of a goodly supply of potash in those places where highly felspathic grits and conglomerates are met with, as in the Tyrone Old Red area. Comparing this area with the Old Red regions of Cork and Waterford, an observer will perceive some difference in the fertility of the soils, in favour of the latter region. This is probably to be accounted for by the Old Red strata in Cork, &c., being on the whole more calcareous than those in Tyrone—a judgment suggested by the occurrence of " cornstones" amongst the Old Red rocks in the southern half of the country, and their absence from the corresponding rocks in the north. The southern strata were laid down in lime-charged waters, in waters at all events supercharged with lime from time to time ; [3] while no evidence for such conditions obtains in the northern area.

Irrigation.

The waters flowing from the Old Red Sandstone in Tyrone would doubtless be poor in lime for the purpose of irrigation. They, however, probably contain such a proportion of potash as would justify some expense in distributing them over meadow-land, or pasturage while not being grazed. The amount present in water flowing off granite may, in the absence of more definite information, generally indicate the proportion available in the strongly felspathic grits of Tyrone; and its application to plants on the favourable rooting soil, there afforded by the Old Red Sandstone, should be attended with better results than attend irrigation in the granite regions mentioned by Risler. The waters flowing from rocks in this (Old Red Sandstone) Formation in the south, would probably be found somewhat strongly calcareous, and, consequently, useful for irrigation. In many places throughout the southern counties. Old Red Sandstone, and Silurian rocks, are covered with accumulations of gravel and clay containing limestone boulders and pebbles. The waters flowing therefrom are almost always calcareous, so much so that in some places they deposit carbonate of lime (" marl"), upon the stream banks where they exude, after making their way through soils and subsoils on sloping ground.

Salts in Solution.

The property of waters, known as " hardness," is attributable to their containing salts of lime and magnesia, and occasionally of some other bases, which, with those of potash and soda, are of frequent occurrence, especially in waters issuing from springs. It causes the curd-

ling of soap in the process of washing, by which the formation of lather is prevented, or rather delayed ; and upon this delay Dr. Clark based a method of estimating the degree of water-hardness, the principle of which is the ascertainment of the quantity of soap solution, of certain known standard strength, requisite to form lather with a certain quantity of the water to be examined.

Water containing only carbonates loses the power of retaining them in solution, through the escape of an extra quantity of carbonic acid, either when the water is boiled, or when long exposed to the air. For this reason the hardness due to carbonate in solution is spoken of as *temporary*. Frequently, however, water contains sulphates as well as carbonates, and in this case the hardness is known as *permanent*, because boiling does not remove it.

[1] The quartzite and accompanying rocks of Croagh Patrick were formerly believed to be metamorphosed Lower Silurian strata. See report of Director-General for 1896 and 1897.
[2] A full description of the formation, with lucid notes, comparing the rooks in various regions, is to be found in a Paper by the late J. Nolan, M.R.I.A.
[3] No fossils have been met with in these " cornstones." They have probably been deposited by chemical precipitation from waters highly charged with carbonate of lime ; which is present in many of the grit beds, though such may not be sufficiently calcareous to be considered " cornstones."

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