

## GEOLOGY.

## INISHOWEN.

INISHOWEN was in all probability insular within the historic period. A paper read by Dr. Sigerson before the Royal Irish Academy (*Proc*, 2 Ser, Vol I, p.212, &c.) brings forward historical evidence from the *Annals of the Four Masters* of the dates 1010 and 1211 A.D. Old maps confirm this statement, and show that the Foyle and Swilly were united by a strip of water to the north of the city of Derry. The "twenty-five feet raised beach" forms the narrow neck of eight miles from shore to shore. At the north of Inishowen another narrow strait must have existed at the same period from Culdaff Bay on the east to Trawbreaga Bay on the west, rendering Malin, the outer northern portion of the peninsula, also insular.

The general strike of the Inishowen rocks is from north-east to south-west. They are metamorphic in character and of Silurian age. They are chiefly quartzite, with granite at several points. Overlying the quartzite in places are beds of schists, and bands of hornblendic trap are of frequent occurrence. Another quartzite series is found superimposed upon these schists, culminating in Slieve Snacht, which is a less solid quartzite than the lower one of Raghtinmore and Malin.

A group of beds, stretching from Inishowen Head to Inch, consisting chiefly of fine conglomerates, has been held to be the highest of the metamorphic series in Donegal, and their geological age has given rise to much controversy.

They are probably altered beds of Lower Silurian formation. Crystalline schists and limestone, apparently containing fossils, occur at Culdaff.

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#### NORTH-WEST AND CENTRAL DONEGAL.

The North-west Donegal Highlands consist, roughly speaking, of a double range of granitic mountains separated by a long narrow depression, that of Gweebarra and Glenbeagh valleys. This depression forms a very conspicuous feature in the landscape from many elevated standpoints. It gives one the impression that the whole outer or North-western Donegal was at one period insular. These ranges are flanked by other parallel ranges to the north-west and south-east, formed chiefly of quartzite, schist, and limestone, rising higher occasionally than the granitic range. Dooish, 2417 feet, and Slieve Snacht West, 2240 feet, are the highest summits of the granite in the county. These lie on the northern side of the depression, while the southern granitic portion culminates at Moylelennanav, 1771 feet. The flanking mountains of quartzite to the north and west are the highest in the county, consisting of Errigal, 2462 feet; Muckish, 2197 feet; and Aghlamore, 1916 feet. The southward quartzite line has for its highest eminences Loughsalt Mountain, 1646 feet, and Aghla, 1916 feet. A secondary line to this is that of Knockalla, on the shores of Lough Swilly, which is a geological prolongation of the Erris Hills of Inishowen.

The granitic mountains are, as is usual, of a more rounded and solid form than the quartzite, which tend to sharper outlines, and the formation of peaks.

The chief river system of Donegal is to be explained by a consideration of the watershed in this part of the county. This watershed commences at Muckish Gap and trends then towards the summit of Dooish. It crosses the Dunlewy road near the northern base of Errigal at 800 feet above sea level. From Dooish, past the head of Glenbeagh, it follows the Glendowan ridge to Croaghacullin, 1430 feet, and thence in a S.W. direction, it keeps the summit of the ridge at the head of Lough Muck. Hence it follows the ridge to Cubbin Hill, along the gap at the head of Lough Finn. From Lough Finn it sweeps to south-east across the road between Martin's Bridge and Stranorlar, and between the partings of the Reelan Water and the Owenea. Thence over Lavaghmore and the summits of Croagh Gorm and Croaghbarnes it strikes the head of Barnesmore Pass. This watershed throws the Ray, Tullaghobegly, Owenwee, Clady, Barra, Owenroe, Owenea and other smaller ones west to the Atlantic; while the Faymore, Carrownamaddy, Dunlatty, Owencarrow, Bullaba, Lackagh, Lennan, Swilly, Finn and Reelan Rivers enter Sheephaven, Lough Foyle and Lough Swilly to the northwards and eastwards.

The schistose and quartzite rocks, together with the crystalline limestones and intrusive bosses and dykes of igneous rocks, so prevalent in this large area, form part of the great metamorphic series extending over a large part of Scotland, whose age is still a disputed question; and the granites are, according to the last testimony of the Geological Survey, probably intrusive and of a later date.

Hence the granites are probably of the same, as yet indeterminate, age, but later than the metamorphism of the original quartzite series. No doubt a further foliation and

metamorphism took place owing to the intrusion of the granite masses, which are themselves foliated in schists in many places.

In one place, at the north-western base of the Knockalla Mountains, in Fanet, occurs a series of beds of red sandstone and conglomerate, which are of the Old Red Sandstone, and similar to the Lower Old Red Sandstone conglomerates of Ross-shire and other parts of West Scotland. They are the only representatives of this formation in Donegal, and a good sample is conspicuous and well-known as the Standing Stone of Fanet in the townland of Drumfad.\*

Peat deposits, sometimes containing stems and roots of trees *in situ*, occur in many places round the coast below high-water mark, and apparently extend (as on Aranmore) for some distance on the floor of the ocean below low-water mark. There is no satisfactory explanation of these deposits, except that of a recent submergence of the land in such localities. In other places, such as along the golf-links at Portsalon, raised beaches, pointing to an elevation of the coast, are conspicuous.

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#### SOUTH-EASTERN DISTRICT.

This part of the county, owing to the unfrequent exposure of rock surfaces, is less interesting and more obscure to geologists. The rocks about Manorcunningham, Strabane, Raphoe, and St. Johnstone, are usually metamorphic limestones, schists, grits and shales. Quartzite masses often

\* These beds were described by me to Dr. Hull many years before the appearance of the Survey.

occurs, and at Raphoe are dykes of fine basalt probably of Tertiary age.

Here, as elsewhere in the county, erratic boulders, glaciated striæ and other evidences of the glacial period are to be met with. Ice-dressed rocks, with the striæ ranging north-eastwards have been observed in many places in the Swilly valley.

Bog iron ore is exported from many parts of this district, also from Inishowen and Fanet. It is used chiefly in the purification of gas, and when its transport can be economically effected, repays well. It forms a singularly barren soil for vegetative purposes, acting indeed like poison to most plants. It is said to be due to the decomposition of iron pyrites, and generally comes to the surface in springs.

Fossilised leaves of alder and hazel are often found in this deposit, near Portsalon.

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#### SOUTH-WEST DONEGAL.

Upon the authority of the Director-General of the Geological Survey we learn, that the chief interest in the geology of this district lies in the variety of crystalline schists and igneous protrusions, and the light thrown by them on problems of metamorphism. Further, a special interest attaches to the band of conglomerate (boulder-bed) at the base of the quartzite.

Another striking geological occurrence in South-west Donegal is the occurrence of two small outliers of Carboniferous sandstone on the summit of Slieve League. The elevated position of these (1900 feet) affords evidence of the vast amount of denudation which North-western

Ireland has undergone. We have here proof that the whole region has been covered with Carboniferous strata, which must have extended some distance to the westward of the present limits of the land.

To the botanist, the most interesting feature in the geological formation of this district is the large area of limestone rocks, which are often deposited in the peculiar fissured slab formation familiar to those who have visited Aran in Galway or Burren in Clare. This limestone is often to outward appearances sterile and forbidding; but, by its absolute freedom from that great monopolist in plant life, heather, it affords a much more varied flora than that of other formations.

We have already described the main watershed of N.W. Donegal. At Lavaghmore in this district, another parting of the waters separates those streams flowing south to Donegal Bay, from those flowing north to Loughross Bay. From Lavaghmore it follows the high central ridge of Banagh, over Silver Hill, Carnaween and Binbane to near Sir Albert's Bridge, and thence northwards by Mulmosog, it crosses the Ardara and Killybegs road at the Nock of the Ballagh. From this by Lough Nalughraman, and the head of Maam Glen, it reaches Glenhead over the summit of Slievetooley.

The Carboniferous formation in S.W. Donegal, to which the limestones belong, has its most important representation to the north of and along the coast of Donegal Bay, over an area of about sixty square miles. The base of the series is formed of conglomerate and sandstone, which rest on those metamorphic rocks that formed the shore of the ancient Carboniferous sea. Next to these beds follow the limestone

group, well represented along the narrow neck of land known as St. John's Point. Over these beds are superimposed others of shale and sandstone, to the eastwards. The limestone beds of St. John's Point (and elsewhere) belong to the Lower Limestone division. Their most westerly occurrence is at Muckross.

The Lower Limestone beds thin out northwards, and are overlain by Lower Carboniferous sandstones and shales, which are well exhibited at Killin Hill, and on the south of Doorin. This Middle Limestone or "Calp" series (which is not nearly so interesting botanically) is especially important, as it produces the famous sandstone beds at Mountcharles, of which the National Museum in Dublin has been constructed. The Middle Limestone is spread over a large area north of Inver Bay and east of Mountcharles. A large portion of the Carboniferous area is covered with boulder clay.

Southwards from the foregoing area, whose crowning glory is Slieve League, we come to the Brownhall, Ballyshannon, Pettigo, and Belleek districts. The most interesting feature in this region, geologically, is an Archæan gneissose tract east of Ballyshannon and north of Pettigo. According to Dr. Geikie (Director-General) these rocks must be assigned to the same series as the ancient gneisses of the Scottish Highlands. Their structure, under the microscope, is parallel with that of the Lewisian gneiss in Sutherland. And they are succeeded by the younger group of slates, schists and quartzites which spread over Donegal, and form the greater part of the Scottish Highlands.

The Lower Limestone is well represented along the west and south of the Archæan tract above mentioned. South of

Ballyshannon, and along the Erne, it forms the surface rock, and again to the north-east of Ballyshannon on the road to Ballintra. The Middle Limestone is conspicuous along the coast at Coolmore and Kildoney Point, north of Ballyshannon, and in many crags inland from these points. The boundary of the Lower Limestone and Middle (or Calp) may be seen at Aughrus Point, north of Bundoran. The Upper Limestone beds, forming the boundary between the Carboniferous and the Old Red Sandstone, occur south of the county at Kesh (Fermanagh), but are not represented in Donegal. Glacial striæ may be seen in many places, and numerous Carboniferous fossils have been gathered and identified.

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#### BLUESTACK AND BARNESMORE.

On the east, and partially between the last two areas briefly spoken of, lies the mountainous tract of the Bluestack and Barnesmore ranges. Bedded in the south-western base of these is Lough Esk, and to its north-east Barnesmore gap is an imposing feature. The granitic mountains above Lough Esk reach a height of over 1700 feet. The higher peaks further from the lake are sometimes, as at Gaugin, of mica schist. Binmore, of the Bluestack range, is the highest point of the granite, 2118 feet. On Lavaghmore the granite ceases at about 1200 feet, and joins the surrounding quartzites and schists. Gneiss enters also largely into the composition of these mountains. Dykes of pitchstone, a rock of rare occurrence, penetrate the granite in the neighbourhood of Lough Esk. Felstone forms intrusive sheets amongst the schists, as at Killygordon, a mile to its north, and a couple of miles south of Stranorlar.

East and south-east of Lough Esk, the gneiss shows much intrusive felstone. The granites of the Bluestack are all regarded as intrusive. Basaltic dykes traverse the Croaghbarnes granite. These and dykes of dolerite generally trend north-west.

The age of the granite is probably pre-carboniferous, but more recent than the metamorphic schists into which it has been intruded. The south-western part of this district is occupied by beds of Lower Carboniferous age. "Calp," sandstone and shale form beds of considerable thickness at Banagher Hill.

A large portion of the area is overspread by boulder drift.

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#### GEOLOGICAL STRUCTURE AS AFFECTING THE DISTRIBUTION OF PLANTS.

The consideration of soils, derived from the rock, or subsoil, or detritus of the locality; and how these soils affect the plants they support, causing some to thrive and increase while others become extinct or never obtain a footing in the same area, is a question of the utmost interest, but altogether too complex to deal with here. Indeed very little can be advanced with certainty upon the subject; so many, so vague, and so delicate are the influences at work. Climate, shelter, hostile neighbours, and original distribution (in itself an utterly unsolved problem) have all to be entertained as factors in the subject. There are, however, some facts that may be mentioned, and some suggestions may arise. The broad and well-known line of demarcation among certain species always appears where limestone rocks meet those devoid of calcareous matter.

Trap rocks do not occur in Donegal, or not of any

sufficiently recent and friable formation to modify the soil in the manner they do at Ben Evenagh, in Derry. I have noticed when dealing with the flora of that mountain\* that plants well known to affect limestone are equally at home on certain derivative trap soils. Probably highly alkaline zeolites afford the same or similar nutriment.

In a paper by Mr. Foot "On the distribution of Plants in Burren," attention was drawn to the lime-loving plants in that district in the County Clare; † and in 1875, in my *Flora of Aran Islands, Galway*, I made a list of the species showing a decided preference for a limestone soil in that part of Ireland. I mentioned there that, amongst others, *Hieracia* and shield-ferns disliked limestone. This requires modification, but it holds true for the limestone of which Aran and Burren are composed, the lower limestone, the rock of St. John's Point, of the district south of Brown Hall, that described in the foregoing remarks. When we get on the Calp above, or to the metamorphic Silurian limestone below, it is not applicable. Speaking only of the Lower Limestone, I find, in Donegal, that as a rule

(a.) *Hieracia* dislike it, with the exception of *H. iricum*, and a form not yet named.

(b.) *Lastræas* dislike it, with the exception of *L. Thelypteris*. Bracken also rarely occurs.

(c.) *Ericaceæ* avoid it, not absolutely, but very nearly so. This applies to the whole order.

(d.) Many marsh plants, peat-lovers, such as several sedges, *Pinguiculas*, *Droseras* and others are absent, even when marshes occur. Others take their place. In the same

\* *Proc. R.I.A.*, 2<sup>nd</sup> Ser, Vol. iv, p.245.

† *Transactions R.I.A.*, Vol. xxiv.

genus a divergence takes place, as in *Carex*; *C. paniculata*, *teretiusecula*, *disticha*, *riparia*, showing, perhaps, a preference for limestone, and *Hypericum elodes* avoids it, while *H. perforatum* becomes prevalent. So also in Saxifrages, *S. stellaris* appears to be absent from limestone. Others thrive.

But a sufficient bed of peat lying above the limestone, a condition of things not commonly met with owing to the drainage afforded by the bedrock, would, no doubt, eliminate largely the above peculiarities.

Thus few plants are more averse to limestone than Rhododendrons, but they thrive at Ardnamona, on the west shore of Lough Esk, where there is sufficient peaty soil. The rock here is, however, the Middle or Calp limestone, whose peculiarities are by no means so strongly marked.

The flora of a limestone district is always interesting on account of the varied way in which species occur. Instead of acres of grass or acres of heather, we have here large areas of rocky ground in which every species, or clump of species, is distinct from its neighbours. But, on examination, it will be found that a large variety of plants are absent. So that the attractiveness is rather fictitious. But there is always the pleasurable feeling that a real rarity may at any time occur. Some of the rarest Irish plants are found in such situations in Clare and Galway.

The following species represent the bulk of the characteristic flora of the dry rocky places in the Lower Limestone. By characteristic I do not mean those only growing thereon, but those which are more prevalent, more luxuriant and evidently in most cases more thoroughly at home there than elsewhere. Those which, so far as I know, do not occur at all, off this formation, in Donegal, I have marked with

italics. I purposely omit aquatics and marsh plants which afford no certain conclusions:—

<i>Thalictrum flexuosum.</i>	Antennaria dioica.
<i>Aquilegia vulgaris.</i>	Eupatorium cannabinum.
Arabis hirsuta.	<i>Carlina vulgaris.</i>
Alliaria officinalis.	Centaurea nigra.
<i>Helianthemum vulgare.</i>	Solidago virgaurea.
Parnassia palustris.	Hieracium iricum.
Polygala vulgaris.	Thrinicia hirta.
Arenaria trinervia.	Ilex aquifolium.
Hypericum perforatum.	Fraxinus excelsior.
Lychnis diurna.	<i>Gentiana amarella.</i>
Sagina apetala.	Lithospermum officinale.
<i>Geranium sanguineum.</i>	Solanum Dulcamara.
<i>G. lucidum.</i>	Rhinanthus crista-galli.
Linum catharticum.	<i>Origanum vulgare.</i>
Medicago lupulina.	Thymus serpyllum.
Trifolium medium.	<i>Calamintha officinalis.</i>
Anthyllis vulneraria.	Anagallis arvensis.
Prunus communis.	Plantago maritima (inland).
<i>Poterium sanguisorba.</i>	<i>Verbena officinalis.</i>
Rubus saxatilis.	Salix repens.
Rosa spinosissima.	Orchis mascula.
Cratægus Oxyacantha.	Gymnadenia conopsea.
Saxifraga aizoides.	Habernaria viridis.
Pimpinella Saxifraga.	Listera ovata.
Epilobium hirsutum.	Epipactis latifolia.
Hedera Helix.	E. palustris.
<i>Cornus sanguinea.</i>	Allium ursinum.
<i>Galium boreale.</i>	<i>Juncus glaucus.</i>
Scabiosa succisa.	<i>J. obtusiflorus.</i>

<i>Arum maculatum.</i>	<i>Equisetum trachyodon.</i>
<i>Carex pulicaris.</i>	<i>Ceterach officinarum.</i>
<i>C. pallescens.</i>	<i>Cystopteris fragilis.</i>
<i>Arrhenatherum avenaceum.</i>	<i>Asplenium trichomanes.</i>
<i>Sesleria cœrulea.</i>	<i>A. Ruta-muraria.</i>
<i>Kœleria cristata.</i>	<i>A. Adiantum-nigrum.</i>
<i>Milium effusum.</i>	<i>Adiantum Capillus-Veneris.</i>

The above list includes various species, rare and common. But if they were removed from the dry rocky limestone places, there would be very little vegetation left; in many places none. Some omissions have, perhaps, occurred, chiefly amongst grasses.

A few species may be mentioned which seem to affect the Calp also, or it in common with the last:—

<i>Ranunculus bulbosus.</i>	<i>Lithospermum officinale.</i>
<i>Arabis hirsuta.</i>	<i>Parnassia palustris.</i>
<i>Draba incana?</i>	<i>Convolvulus arvensis.</i>
<i>Trifolium medium.</i>	<i>Carex strigosa.</i>
<i>Vicia sylvatica.</i>	<i>C. Bœnninghausenia.</i>
<i>Hypericum perforatum.</i>	<i>Briza media</i> (almost confined to the two limestones).
<i>Pimpinella Saxifraga</i> (almost confined to the two limestones).	<i>Sesleria cœrulea</i> (confined to the two limestones).
<i>Sarothamnus scoparius.</i>	<i>Adiantum Capillus-Veneris.</i>
<i>Pulicaria dysenterica.</i>	

Several of the foregoing, particularly the commoner ones, are to be found on other limestones. Thus *Pimpinella Saxifraga* is almost entirely a limestone plant in Donegal, but it occurs on the older crystalline limestones.

A good many marsh plants might be added. The most interesting are:—

Nasturtium amphibium.	C. prolixa.
Rumex Hydrolapathum.	Eleocharis acicularis.
Cephalanthera ensifolia.	E. uniglumis.
Trichomanes radicans?	Utricularia neglecta.
Lastræa Thelypteris.	Potamogeton flabellatus.
Carex acuta.	

These are confined to watery or marshy places on the limestone. *Vaccinium Oxycoccus* is perhaps an exception to the heather family as non-limestone plants. It is only found in one Donegal locality, on a shaky bog, on the margin of the limestone and siliceous rocks.

The characteristic plants of the *non-limestone* formations are readily obtained from the foregoing remarks. The Donegal rocks are almost entirely siliceous, with the exception of the above-mentioned limestones in the south-west. The crystalline limestones are everywhere in bands or areas of limited extent. Friable sandstones are of very unfrequent occurrence. Where these or schistose rocks form masses in the mountains, the botanical interest at once increases owing to the fertility of the derived soil. Of non-limestone plants, a conspicuous one not mentioned above is *Digitalis purpurea*, the foxglove, although I am not sure that it is absent from the Calp.

Large areas of Donegal have been denuded of their natural covering of peat, by the demand for fuel. In many districts this subject has become of vital importance to the people. The scarcity of the peat has driven the natives to cutting for fuel sods of green sward, which are the only

available grazing ground on the mountain slopes. In other places, the last sods have been removed, and the mountains are bare into the rock. Such a headland as that of Dunaff, where turf and peat and sod are almost finally removed, is a painful spectacle. These pages are not about to be made the vehicle of an economic essay, but the subject can hardly be altogether passed by without reference, when speaking of vegetation. I have little doubt that the stony sterility of many a low-lying valley in Donegal arises, more than is generally supposed, to the depredations of generations of turf-diggers, who are often driven to burning the last covering of the rock which would alone provide subsistence for their successors.

Another devastating influence, often resorted to by the country people, is that of burning the heather to provide room for the grass to grow to feed their flocks. If the peat be dry, these fires are liable to take a deep hold, and burn into the rock. Fortunately the Donegal climate is seldom dry enough to render this cause operative.

Where there is a subsoil lying beneath the peat, and drainage also possible, the land can be reclaimed of course for agricultural purposes. Often, however, there is none.

In a district like that around Glenties, it has an odd effect to notice the belts of poor cultivated soil lying along either side of the road, stolen as it were from the peat beyond. When, as in the place mentioned, a village exists, and a considerable population, the result of cultivation is a far less certain source of income than the original and necessary peat.