On The Drift in Ireland

Notes on some of the Drift in Ireland.

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Connected with the drift in Ireland, I have observed various phenomena, to which I intend in the first place to call the attention of the Society, and afterwards to offer some suggestions as to the agencies by which they may have been produced.

First. The principal features of the hills and mountains would seem to have been formed in a great measure previous to the drift period ; as in most of the valleys more or less boulder drift occurs, which usually rests upon " ice-dressed" rocks.

These præ-drift-formed features can be well observed in the mountains about Lough Mask, counties of Mayo and Galway. On looking at these eminences from some distance on the south, it will be seen that those on the north of the lake slope gradually down to the plain on the east ; and that on the south of the lake, if a line be stretched from the mountains west of Toormakeedy (Slieve Partry) to the country east of Cong, this line would rest on the slightly-sloping table top of Ben-levy, [1] the isolated mountain between Loughs Mask and Cong ; and also that it would coincide with the previously mentioned slope on the north of Lough Mask. [2]

On an inspection of these hills, it will be found that the floors of the valleys are " ice-dressed," and that many of the valleys contain boulder drift. From this it may be inferred that at one time these mountains stretched in a gradual slope from Slieve Partry to Partry on the N. E., and to beyond Cong on the S. W. ; that, after this, the area now occupied by Lough Mask and its tributary valleys, also the valleys between Slieve Partry and Benlevy, and the undulating ground between Benlevy and Cong, were denuded away, and that subsequently the rocks were " ice-dressed," and the boulder drift deposited in the valleys.

Very similar results can be observed in respect to the hills in Slieve Aughta, the mountain group lying at the junction of the counties of Galway and Clare. Looking at them also from the south, it will be observed that the flats on the table-topped hills, east and west of Lough Graney, if connected, would form a continuous upland ; and, moreover, they are capped with nearly horizontal basal beds of the Old Red Sandstone group ; Now, these hills are separated by valleys in which boulder drift occurs, lying on the " ice-dressed" rocks. [3]

Second. Præglacial drift. Seemingly before the boulder drift period there was a drift that in places contains the remains of trees and plants. This drift has been found in the Bolley-neendorrish River valley, which lies eastward of Gort, county of Galway, [4] and on the Castlecomer table land, the mountainous district that lies at the junction of the Queen's County, Kilkenny, and Carlow. [5] Mr. Wilkinson also seems to have recorded præglacial drift at Nenagh, county of Tipperary, as there a black peaty bed was found, under " forty-three feet of hard calcareous clay, with numerous lumps of limestone intermixed, but unstratified." [6]

Third. Ice-dressed Rocks. With reference to the class of phenomena now entered on, I have observed that there are two distinct sets of striæ, or scratches. The oldest one, which for convenience sake in these notes will be called the *Primary*, as its striæ correspond with the

long axis of the " crag and tail," and of the principal " Tors," [7] or ice-dressed hummocks of rock, has a general bearing of about N. N. E. or N. E., to the S. S.W. or S.W.; and the " crags" and " Tors" are precipitous, or *crag* towards the southward, and dope or *tail* towards the northward. The general bearing of the " crag and tail," *the Primary* " Tors," and the *Primary* striæ is slightly modified while crossing mountains and high ground, having westings or eastings respectively when the slope of the mountain or high ground is eastward or westward.

The Primary set of striæ is crossed at various angles by another set, which may be called *Secondary*, and always coincides with the direction or general fall of the valleys in which it occurs. The Primary striæ are very often quite obliterated by those belonging to the Secondary set ; and often the *Primary* " Tors" are modified by the *Secondary* ice. One side of the " Tors" may have been planed away by the latter, or one corner of the original crag of the " Tors" cut off, giving them a one-sided appearance. The *Secondary* set may run in any direction across the *Primary* " Tors," but it rarely coincides with their axis, except where such axis agrees with the direction or general fall of the valley.

As every valley has striæ belonging to the *Secondary* set, and as most valleys have smaller ones opening into them, it follows, that at the junction of a main valley with its tributary there may be two sets, viz., the striæ of the main valley and the striæ of the tributary ; or there may even be three, as the *Primary* set in this place may not be completely obliterated ; and then in this case, besides the Secondary striæ just mentioned, the Primary striae would also occur.

Fourth. Boulder drift.—This deposit is principally made up of fragments and boulders of the subjacent rocks ; but in many cases foreign erratics have also been detected, such as nearly always belong to rocks in the country lying north-eastward. [8] In some places, however, isolated patches of a foreign drift may be observed with scarcely a fragment of the subjacent rocks in it ; but often in this case the foreign drift will be found to be overlaid by local boulder drift.

It has been observed that in many of the wide valleys, and on parts of the central plain of Ireland, much of the boulder drift occurs in *esker-like mounds*, which have a rude parallelism to one another, and that often associated with them are striæ that have a bearing similar to the parallelism of the mounds.

Fifth. Post-drift gravels, or esker-drift.—In places on the low country the boulder drift is washed into gravels and sands, which are sometimes spread over the ground, but are more often piled up in long ridges (*Eskers*), or continuous systems of mounds and duns.

These eskers, while crossing high ground, or ending on a mountain slope, break into gravel mounds and short ridges that run in various directions, and among them are small mounds of boulder and rocky drift, [9] against which the esker drift is often piled. For these parts of the esker drift, I have in a paper read some time since before the Society, suggested the name of *Shoal Esker*. [10]

Near the foot of some of the mountain slopes there are banks or shelves consisting of boulder drift, rocky drift, and gravels ; and connected with these banks are occasionally to be seen irregular ridges, which run with the outlines of the hills, receding from them if the mountain slopes are gentle, and approaching quite close or disappearing altogether if the slopes are steep, or if cliffs are present.

Sixth. Erratic blocks.—Sometimes on the boulder drift, at other times on the esker drift, are found large and small erratic blocks which may be north, south, east, or west of their parent rocks.

Seventh. More recent deposits.—Overlying the boulder and esker drifts are deposits consisting of peat (*bogs*) alluvium (*corcases* and *callows*) shell marls, brick clays, sands, &c. ; none of these will be again mentioned in these Notes.

The task now before me is to try to account for these different phenomena by natural causes. The first questions I propose to examine into are, whether the country was covered by a large ice field ; or an arctic current with icebergs, flowed over it. As the former is the older theory, it shall be considered first.

Land Field Ice.—Previously to the boulder drift period, as the land was gradually rising, the outlines of the present features of the country were carved out by marine denudation ; and, when the land had risen high enough, that the climate must have been somewhat similar to what we now have in Ireland, would seem to be proved by the vegetable remains which have been found in the præglacial drift. As the land rose, the climate gradually became colder, glaciers began to form, and the ice finished the work that the denuding power of water had begun. This latter would seem evident, as in the valleys and *Cooms* [11] is found boulder drift reposing on " dressed" and striated rocks. The ice should increase more and more as the climate became colder, until eventually the country was covered with a field of ice, which was at least 2200 feet thick. [12]

The field of ice would seem to have had a general movement from N. N. E. or N. E. to the S. S. W. or S. W. by which the " Crag and Tail," the primary " Tors" and the primary striæ were formed. This ice sheet would in time sweep off all the vegetable soil, &c., that had previously covered the country, except such portions as were protected by favourable circumstances.

The latter would have been the case in the localities before mentioned, as on the Castlecomer table land, where the præglacial drift was sheltered by the numerous small hills that occur there, and in the Bolleyneendorrish River valley, where it seems to have been preserved by the bars of rock that cross the valley.

Again, that subsequently the country sank, and, as the climate became warmer, the field of ice gradually broke up into local systems of glaciers which flowed down the different valleys. During this process the Secondary striæ would be produced, and the form of the Primary Tors modified.

One of the best places with which I am acquainted for exemplifying the different actions of the " field ice" and of the local glacier is Slieve Bawn, Co. Roscommon. This mountain rises from the central plain of Ireland, as a large " crag and tail," that *tails* towards the N. N. E. (N. 20° E.), and *crags* towards the S. S. W. On the east slope, the primary and secondary striæ are well marked. The primary striæ have a westing as the ground slopes to the eastward ; near the foot of the hill where the slope is gradual, being N. 22° W.; and higher up, where it is steep, being N. 32° W. The top of the hill is principally covered with heather and bog, and I observed no striæ. The west slope is banked with drift, but at the base the primary striæ nun N. 13° E. On the western slopes no secondary striæ were observed, but those on the eastern slopes run with the fall of the ground (about N. 83° E.).

The ice of the ice field on the low country would first be affected by the change in the climate, and gradually slide off into the area now covered by the sea, leaving our present low country to be occupied by the ice supplied from the higher elevations. Part of the latter in its downward passage was caught in the valleys, and on the hill sides, and remained there until it melted, and left its *debris*, which now form the isolated patches of foreign boulder drift. If while these remained in some of the valleys, and in patches on the hill sides, a glacier flowed over, and melted on them, when the ice finally disappeared from the country, it would leave local boulder drift covering foreign. To the northward of large mountain groups, the Boulder drift is sometimes composed of fragments of the rocks from those mountains. In these cases the Boulder drift is the residue of a large glacier that flowed northward from those mountains ; an example of this is the Boulder clay of the south part of the county of Mayo, which in a great part consists of fragments of the rocks which compose the Partry mountains.

Good examples of the isolated patches of foreign boulder drift were observed on the mountain group called Slieve Aughta. The rocks composing these mountains are of the Silurian and Old Red Sandstone ages, while the country for miles on the north and north-east is Carboniferous Limestone. In the valleys on the north there are various patches of limestone boulder drift on Silurian and Old Red Sandstone ground. [13]

If the movement of the ice field was from the N. N. E., it would have carried with it the *debris* of the limestone country on the N. N. E. ; and when the climate became warmer, and after this movement ceased, this ice charged with limestone debris was on the hills. This mass of ice, going up the hills from the N. N. E. and down the hills towards the S.S. W., had planed all the rocks, leaving a tail towards the N. N. E., and a foil or low cliff towards the S. S. W. But when the field of ice broke up and the ice began to slide down the different slopes, part of it, having no impediment, continued its course down the hill ; but some of it went with the was caught behind the *foils*, and kept there until it melted, and its *debris* formed the before mentioned patches of limestone boulder drift. [14]

Similar results were remarked on the Arra and Keeper Mountains, county of Tipperary which respectively lie N. E. and S. E. of Killaloe. [15] On the Castlecomer table land, where we have Coal Measures with a limestone country on the N. and N. E. ; the hills forming its margin, and some of those in the interior, are free from limestone boulder drift ; while other hills in the interior, when there is no fall from them, are covered with it. [16]

Part of the central plain of Ireland may have been so flat, that, when the movement of the ice field ceased, the ice then on it could not slide away ; it would therefore melt where it was, and deposit its *debris*. If this occurred at the base of a mountain group, it would necessarily bank up the ice on the mountain slope, and prevent the greater part of it from sliding down, and therefore the latter would have to melt and deposit its *debris* on the slope of the hills. In this way the continuous sheet of foreign drift up the sides of some hills might be accounted for.

All this time the land is supposed to be sinking ; and if we next suppose it to be about 300 or 400 feet lower than its present level, and the climatal conditions of the country to be similar to those of Baffin's Bay and thereabouts at the present day, there would be an open sea in the centre of what is now Ireland, bounded on the north-west and south by numerous ice-clad islands, the depressions between many of which would be occupied by large glaciers ; round the land there would be an " Eisfod," or " Icefoot," and numerous icebergs would be floating about in the adjacent waters. But, before we proceed farther, let us consider what would have been the effects of " the Baltic current," [17] instead of a large ice field.

Mr. Campbell, in " Frost and Fire," seems to consider that at the beginning of the glacial period the land was sinking, instead of rising ; and that as it sank, and the current from the North Pole, *viâ* the Baltic, became deeper, the climate gradually became colder ; that the land afterwards rose, while the climate gradually became warmer, as the Baltic current became shallow.

Before the country sank, it must have been as high as it is now, or its climatal condition must have been very similar, as the vegetable remains found in the præglacial drift ; of Ireland and England are like what grow at the present day. [18] During the depression and uplifting of the country, marine action would cut out the principal features ; and when it rose high enough for land ice to form, a new denuding force would have been at work to finish the excavation of the valleys and cooms, and leave them nearly as we now find them. [19]

The results from " the Baltic current" would have been very similar to those from " a field of land ice." Most of the præglacial drift would have been swept away, with the exception of a few small patches which were favourably situated ; the floating icebergs would " dress" the rocks, and produce the Primary striæ ; the latter would run in their regular course (about N. 30° E.) when the icebergs crossed the open sea, or the tops of the submerged hills ; but where an iceberg was too large to float over one of the latter, it would have to coast round it, during which process the primary striæ on the hill's sides would be produced, having a westing if they had to go round the east side of a hill, and an easting if they went round the west side. Afterwards, as the land rose, and the hills became awash, icebergs would strand on them, melt and deposit the boulder drift. This boulder drift would rise with the land, but afterwards the most part of it would be carried off by the glaciers, isolated patches only remaining, that were protected in valleys, or behind *foils* ; and if a glacier flowed over one of those isolated patches, when the ice finally melted, it would leave local boulder drift on foreign. The banks of foreign drift up the slopes of the hills would be formed by a large iceberg grounding and melting at their base, and thereby preventing any boulder drift above from being carried down.

The land during all this time was gradually rising ; and when Ireland was about 800 feet or 400 feet lower than at present, we may suppose, as previously suggested, that its climatal conditions were similar to those of Baffin's Bay at the present day. I have now brought the two theories to the one point, and before we go farther let us review them.

According to the " Land Ice theory," if the features of the country had not previously been sculptured by marine denudation, the land must first have risen about 10,000 feet higher than at present to allow them to have been formed by atmospheric agencies and ice action. [20]

During the latter part of the glacial period the land must have sunk to at least 300 or 400 feet below its present level ; [21] and subsequently it must have risen again till it attained its present altitude.

According to the " Baltic Current" theory the land must first have been at about its present altitude, or a little higher ; [22] it then gradually sank until all or nearly all was covered with water, and afterwards it gradually rose until it reached its present level. In favour of this theory we find marked terraces, which appear to be ancient sea margins, at various levels, which ought not to exist if the country had been covered by a field of ice. Those on Slieve Aughta are well developed in the neighbourhood of Lough Graney ; the highest being at about 1200 feet, and the lowest a little above 300. In the Burren mountains, county of Clare, there are also well-marked terraces ; and in the hills of Yar-Connaught, N. W. of Galway town, lines of cliffs were remarked at heights varying from 300 to 1000 feet. Against this view is the following :—If the boulder drift is the *debris* left by ice carried from the N. E. by

a great current, it ought to be composed of fragments of rocks that formed hills far away to the N.E. ; but all the fragments in the previously mentioned isolated patches of foreign boulder drift seem to be of rocks that are found in the country *immediately* to the N. E., as pointed out when describing the isolated boulder drift patches on Slieve Aughta, &c.

The stumbling-blocks in the way of the ice-field theory are, that incalculable ages of time must have lapsed since the setting-in of the glacial period ; and if all these phenomena were caused by land ice, this monstrous glacier must have been at least 2200 feet thick when passing over Ireland, and it must have started near the North Pole, and flowed south-westward far beyond this country ; there is no existing glacier at all to be compared to what it must have been.

Let us now return to the " Eisfod," or " Icefoot" Doctor Kane, in the " Arctic Exploration," vol. i., pp. 175, *et sqq.*, says of it :—" In this our high northern harbour, an Icefoot is a perennial growth, clinging to the bold faces of the cliffs, following the sweeps of the bays and the indentation of rivers. This broad platform, although changing with the seasons, never disappears." Afterwards he mentions that " It grows wide where the land is low, and narrow where it is high." Doctor Kane also mentions the quantity of the *debris* of the rocks, &c., which it supports. Let us now suppose that a similar " Icefoot" existed in the country which now is Ireland when it was 300 or 400 feet lower than at present. This " Icefoot" should be charged with *debris* of various kinds, that would be dropped when the ice melted, and would form the banks and shelves which exist near the base of some of the mountains. In favour of this idea we find that these banks agree with Doctor Kane's description of the " Icefoot," as they spread out from the hills where they are sloping, and get narrow where they are precipitous. If these shelves are formed by the debris from the melting of the " Icefoot," the irregular ridges of rocky and gravelly drift which are associated with them ought to mark the severity of the different winters ; for Doctor Kane remarks, " that in a severe season the Icefoot extends much farther out from the land than during a mild one ;" therefore, during the thaw after a severe winter, the *debris* carried by the " Icefoot" would be dropped far out, and form one of the outer ridges ; while after a mild winter it would be dropped much nearer in, and form one of the inner ridges. All the different modifications we find in these banks and shelves of drift could be accounted for by circumstances going on at the present day ; for where there is gravel and sand, it shows that there was a strong current which washed and sorted the debris as it fell from the " Icefoot ;" and the rounded bluff hills of drift on the mountain slopes show that a " slide," or a stream, during the thaw, had emptied itself over the " Icefoot." [23]

Looking at the contour map of Ireland, it will be seen that there is a low tract extending south from Killala Bay by Castlebar, Galway, and Ennis, to the Shannon ; this tract seems to be nearly free from esker and boulder drift, and from this and other reasons mentioned in the paper of mine previously referred to, [24] I suggested that a continuous current flowed here from north to south. If this current existed, we should have the area now occupied by Ireland under the following conditions :—The central plain of Ireland would be a sea that had an open space on the east, and was bounded on the north and south by islands, between which the tide could ebb and flow, while on the west there would also be islands, but between them and this sea there would be a continuous current, that would prevent the tide having ingress or egress through them ; these circumstances ought to make the tidal conditions somewhat similar to those of the present day. If the tidal map of the Irish Sea in Johnson's Physical Atlas be examined, the north and south tidal waves will be seen to meet between Dundalk and the Isle of Man ; moreover, if the eskers on the published Sheets of the Geological Map of Ireland be looked at, it will be found that they form a compound bar, occupying a strip of country which stretches nearly east and west from Dublin to Galway ; this compound bar

consists in parts of well-defined ridges or *bar eskers* [25] and in other places of *shoal eskers* ; the bar eskers from Galway to Tullamore, or thereabouts, are usually on ground under the 250 feet contour line ; and from Tullamore to Dublin on ground under the 300 feet contour line, while the shoal eskers towards the west are on ground between the 260 feet and the 300 feet contour line ; and towards the east, between the 300 feet and 400 feet contour line. From these facts I would suggest that the land was then between 300 and 400 feet lower than at present, having since risen more toward the east than it did at the west ; that the climate was somewhat like that of the region of Baffin's Bay and thereabouts at the present day ; that this compound bar of eskers was formed by the meeting of the northern and southern tidal waves, which washed and sorted the boulder drift ; and that the complicated structure of this bar is due to the nature of the ground, having to fringe round some islands and submerged hills, to form bars between others, and shoals in the shoal water. [26]

If this compound bar was formed by the meeting of the northern and southern tidal waves, there ought to be bar eskers in some at least of the straits between the islands which bounded the Esker Sea on the north and south ; as in these narrows, the tide could not come in or go out as fast as in the open space on the east ; about the northern straits I can give no information, but in all the southern straits with which I am acquainted there are bars. In the valley of the Barrow there is a bar near Bagnalstown ; in the Maryborough valley, at that town ; in the Shannon valley, south of O'Brien's Bridge ; in the Nenagh valley, at Kilmastulla ; and in the valley of the Suir, at Tipperary. [27]

It will naturally be asked if the eskers were formed by marine currents, why do they not contain fossil shells ? The condition of the eskers is against fossil shells now being found in them, as it is of such a porous nature, that they would have decayed away years ago. I remember about fifteen years ago, at a place called the Breaches, seeing a river cut made through the bank of gravel that forms the sea margin between Bray Head and Wicklow. This is quite a recent formation compared with the esker gravel, and yet in it all the sheils that were found were so rotten, that they crumbled to pieces on being handled. Furthermore, I believe that the places where shells once were can be observed in the eskers, as in most sections that I have examined, little pockets of " Earth foam" were remarked, which may be the calcareous residue of the shells. In the sandpits N. E. of Carrigogunnel, county of Limerick, there are a great number of them, and in some I imagined that I could even recognise shell forms. [28]

Furthermore, in favour of the marine origin of the eskers, are the erratic blocks perched on them. These latter will again be mentioned farther on in these Notes. [29]

The next question to be considered is : Has the east portion of Ireland, since the glacial period, risen more than the west ? If my suggestions are correct, the eskers were formed near the close of the glacial period ; and the *shoal eshers* are those parts of the eskers which were awash, or had not more than fifty or sixty feet of water on them, while the bar eskers were formed in deeper water. Near Galway, the eskers shoal bolow the 250 feet contour line ; in the neighbourhood of Athenry, they shoal above the 250 feet contour line, and are barrier eakers up to about that level. This is well shown about four miles north of Loughrea, where an esker ridge runs S. W. from Ballafa Bridge towards Raford, the highest point in which is 232 feet ; a little S. E. of this, about Benmore, the country is over 250 feet, and we find it covered with irregular hills ; and if we trace the esker ridge towards the N. E., east of Woodlawn demesne, we find it breaking into a large shoal esker on the high ground there situated ; while farther east, between Kilconnell and Ballinasloe, where the ground is not so high, it again becomes a bar esker.

The farther we go east, the higher does the level for the shoal eskers become : east of Tullamore the bar eskers are found above the 250 feet contour ; and at the Green Hills, county of Dublin, the 200 feet contour line runs close to the base of the eskers, while there is a rather distinct mound forming part of the esker, the summit of which is 254 feet above the sea, but what seems to be the highest part of the esker is 290 feet. Moreover, crossing into Scotland, we shall find in the neighbourhood of Greenlaw that the Ben Shiel eskers are 700 feet above the sea level. [30] Besides, if the theory that the eskers were formed by tidal currents before the end of the glacial period is correct, there is evidence in the county of Cork that the ground north of Bantry Bay has not risen more than 140 feet since the ice disappeared from the country. This can be proved in one of the valleys immediately east of Hungry Hill, the valley of the north branch of the Reen Eiver, where striæ may be found winding down an *aille*, and ending at a well-marked terminal moraine, on ground only 140 feet above the present level of the sea. This moraine could never have been under water, or it would have been washed out of shape. [31]

These facts would give the following levels : —

	Feet.
Maximum height of the sea at Bantry Bay, . .	140
Top of shoal eskers near Galway, ...	about 240
Top of shoal eskers east of Athenry (Clooncar),	269
Top of bar eskers S. S. W. of Woodlawn (8. W. Ballafa Bridge),	232
Top of bar esker east of Tullamore, . . .	about 270
Top of bar esker, Co. Dublin, Green Hills, .	. . 290

Icebergs floating about in the Esker Sea, wafted hither and thither by the currents and the wind, would in their transit drop the erratic blocks that are found perched on the esker drift, [32] and also some of those which occur on the boulder drift, but seemingly not all, as many of the blocks on the boulder drift appear to be its residue, left after the associated clay, &c., were carried away. There are to be found on the crags in the county of Galway numerous large blocks, most of which are evidently the residue of the boulder drift, as under some of them are found patches of it ; and if the residue of the boulder drift was left on the crags, why might not similar blocks be left on the boulder drift, if only part of the mass had been swept away ? We also find in favour of this idea that some of the blocks which seem to be lying on the boulder drift are in reality half buried in it. That some of the blocks even on the bare crags were dropped from icebergs would appear evident, because in places they can be traced in lines from their parent rocks, and in others they occur in groups, small and large blocks being mixed together, evidently the freight of a stranded iceberg. If these icebergs and glaciers existed during the esker period, their existence would account for the erratics being found miles east, and even north, of the course they would have taken if carried either by the " field ice," or on icebergs in the " Baltic current."

A peculiar porphyritic granite, with large pink, or rather flesh-coloured crystals of felspar, is the rock in the hills N.W. and W. of Galway town. Large blocks of this granite are found north, east, and south-east of their present site. They are found north of it in the valley that extends west from Oughterard, a small town about fourteen miles N.W. of Galway town. In the neighbourhood of Headford, which lies east of Oughterard, they are rare ; but opposite Galway Bay they become plentiful, and stretch for miles towards the east, occurring in great numbers between Woodlawn and Loughrea ; and some I have remarked as far east as Ballinasloe, Eyrecourt, and Portumna ; and Mr. O'Kelly has found them even farther east, on Slieve Bloom, the mountains that lie at the junction of the King's and Queen's Counties. [33]

On the west parts of Slieve Aughta, and on Slieve Bernagh (the mountain group north of Limerick), they occur ; but I do not remember having remarked any of very large size. Opposite the mouth of the Shannon they are found a long way to the east, Professor Haughton and Mr. A. B. Wynne having noted large ones in the neighbourhood of the Silvermines, county of Tipperary : and I myself have remarked that drift in some of the valleys on the west of the Keeper Mountains is nearly entirely made up of granite fragments.

I shall offer the following suggestions to account for these blocks being more numerous in certain places than in others :—The Oughterard valley was filled with a glacier similar to one of the large glaciers mentioned by Dr. Kane, as occupying straits between islands in the Arctic Seas. This Oughterard glacier would have southern branches which started from the porphyritic granite hills ; and on these branches porphyritic granite blocks would be carried to the main glacier, and by the latter to Oughterard, where they would be floated off on icebergs into the previously mentioned current that ran from Killala to the Shannon. The icebergs that were launched into this stream ought to have been carried south by its current, and undoubtedly many were ; but if the west wind was as prevalent then as now, which is not unlikely, many of the icebergs would have been driven out of the stream. The icebergs floating down with this stream were sheltered from the west wind, except while crossing the openings at Galway Bay, the Ennistymon valley, and the mouth of the Shannon, therefore the icebergs that were launched at Oughterard ought to float to Galway Bay ; but when there, some were driven east by the west wind, many of which were stranded on the high ground about Loughrea, Woodlawn, &c., while others of them were driven as far east as Slieve Bloom. Similarly the blocks in the neighbourhood of Silvermines could be accounted for ; as the icebergs that carried them might have been driven eastward by the wind that came either through the Ennistymon valley, or up the mouth of the Shannon. In the former case they would have been floated through the Scariff valley, which lies between Slieve Aughta and Slieve Bernagh, in the latter case up the valley of the Shannon.

Some of the icebergs that were driven out of their course by the wind that blew up the valley of the Shannon would drop their freight in the country south of Limerick, and on the Galtee mountains, where they were found by Mr. Wynne ; [34] and a few might even be carried south by the tide into the county of Cork, which would account for the granite boulders found by Mr. W. L. Willson and other observers.

Before leaving the erratic blocks, I should mention that S. W. of Woodlawn, a little S. W. of Ballafa Bridge, large blocks of the porphyritic granite are found perched on the eskers there situated ; and that farther S. W., south of Raford, they were also observed on esker drift, and Mr. Foot has found them similarly circumstanced in the neighbourhood of Ballinasloe.

These facts about the erratic blocks would seem to me to be additional evidence in favour of a north and south current from Killala Bay to the Shannon. Moreover, there is the evidence that I put forward in the previously quoted paper of mine, that the drift on the hills bounding the Shannon on the south, from Foynes to Tarbert, is in a great measure made up of fragments of the rocks that form the hills in the west parts of Galway and Mayo, in some places being altogether composed of them. Besides, if this current existed, it would always be inclined to go west, and therefore it would hug the Yar-Connaught and west of Clare hills. At the mouth of most of the mountain valleys in Ireland there is an accumulation of drift, the *debris* brought down by the glaciers ; as, for instance, opposite the valleys coming out of Slieve Aughta, Slieve Bemagh, &c.; but, comparatively speaking, there is none opposite the valleys that open towards the east out of the Yar-Connaught and west of Clare hills, it having been carried away by this current.

In conclusion, allow me to allude to the different cliffs, terraces, &c., which seem to be ancient sea margins. In a previous part of these Notes I have referred to those in Yar-Connaught, Slieve Aughta, and the Burren, and mentioned that they were at various heights between 300 and 1200 feet. If these were ancient sea margins, during the elevation of the land, each must mark a period of rest, one of which periods may have been during the formation of the eskers. That there was a period of rest while the eskers were being formed is likely, if the idea " that the west of Ireland was about 300 feet lower than at present" be correct ; for, as before mentioned, there are terraces at that height in Yar-Connaught, Slieve Aughta, and the Burren hills. To the west of Ballingarry, county of Limerick, and about four miles south of Rathkeale, I traced a well-marked gravelly beach for miles. The Ordnance height on this beach, or a little above it, is 287 feet ; and to the north of the Shannon, on the south slopes of the Cratloe hills, there is a bank of fine sand at about the same level : these would give the following height for the margin of the Esker Sea in the West of Ireland :[35] —

	Feet.
Limerick,	287
Clare, south of (north slopes of Cratloe hiUs), about	290
„ north of (Burren hills),	300
„ „ (SlieveAughta), ...	800
Galway, south of (Slieve Aughta),	300
„ west of (Yar-Connaught)	300

I have now laid before the Society suggestions to account for the different phenomena that I have remarked connected with the drift in Ireland ; and I think it will be found in favour of these suggestions, that all the phenomena have been produced by *existing agencies, gradual in their process, and such as have been noted by different Arctic observers*. The north and south current, from Killala Bay to the Shannon, may be objected to, as it may be said, " If it prevented the tide from going east between Killala and the mouth of the Shannon, it would also prevent it farther north, and so altogether change the tidal system." But farther north, where the ocean was deep, might not the tide have flowed over this current, as it is supposed to flow over an Arctic current at the present day off the west of Ireland ?

In these Notes no suggestions have been offered to account for " the rudely parallel esker-like ridges of boulder drift" that are found in wide valleys and on sloping ground. All I can say about them is, that they seem to be connected with the secondary striæ ; for I have found them running in the same direction in the valley between Slieve Aughta and the Burren Hills, also in valleys in Yar-Connaught, and in the plains of Mayo. In the Scariff valley they coincide with the fall of the valley, and lie in the direction that the secondary striæ ought to run, and the same thing can be said of the part of the valley of the Shannon south of Killaloe. Mr. Close has recorded them in the county of Dublin as running in the same direction as striæ ; but the latter he seems to consider as primary.

Some of the foregoing theories coincide with those of previous writers, but many I believe are new, and are based on personal observation. Possibly I may have been anticipated by observers whose works have not come under my notice.

[1] *Gable Hill* ; so called from its likeness to the gable of a house.

[2] From Derradda, the hill S. W. of Oughterard, county of Galway, there is a good panoramic view of all the Yar-Connaught and Connemara hills, from which it would appear that they once formed one great slightly undulating table land.

[3] See " Mems. Geological Survey, Ireland," Ex. Sheets 116 and 116, p. 28.

[4] See " Mems. Geol. Survey, Ireland," Ex. Sheets, 115 and 116, p. 28.

[5] See " Mems. Geol. Survey, Ireland," Ex. Sheet 137; and paper by Author, " Geological Magazine," Oct, 1865.

In a Paper read before the Society, May 13th, 1846, " Note on the Tertiary Deposits of the County of Wexford," the author, Captain James, R. E. (now Sir H. James), mentions seventy-four species of fossil shells, some of which are Arctic, that were found in what he seems to consider præglacial drift. (See " Journal of the Geological Society, Dublin," vol. iii., p. 195.)

[6] See paper by T. Oldham, M. R. I. A., " Journal of the Geological Society of Dublin," vol. iii., p. 64.

[7] This English name for the dressed hummocks of rocks has been copied from " Frost and Fire," by J. W. Campbell, as it is more concise than the Continental term, Roches Moutonnèes.

[8] In a few localities—as, for instance, the south part of the county of Mayo—the Boulder drift has evidently come from the southward. The explanation of this will be given hereafter.

[9] Rocky drift is a term used for a peculiar drift, which consists of large and small angular, subangular, and round blocks of rock, mixed with a little clay or gravelly day ; in some places it seems to be half-washed boulder drift, but when found at high levels in the hills it has the appearance of being the *debris* left after the melting of the glaciers.

[10] See " Dublin Quarterly Journal of Science," vol. iv., p. 109.

[11] Local name for a valley that runs into a mountain or hill, and is bounded on three sides by precipitous or nearly precipitous sides, answering to the French term *Cul-de-sac*, or the Scotch *Corrie*.

[12] Bengower (2184 feet), about eight miles east of Clifden, Co. Galway, is polished and dressed to its summit, and Mr. Campbell has recorded on Shanaunnafeola, Co. Galway, horizontal grooves at 2000 feet (See " Frost and Fire," vol. ii., p. 165).

[13] See " Mems. Geological Survey, Ireland," Ex. Sheets 115, 116.

[14] The author of " Through Norway with a Knapsack" directs attention to the boulder drift under the glaciers in that country.

[15] See " Mems. Geological Survey, Ireland," Ex. Sheet 134.

[16] See " Mems. Geological Survey, Ireland," Ex. Sheet 137, p. 60.

I should mention that all round the Castlecomer table land there is a Carboniferous Limestone country, and as patches of limestone boulder drift are found all down the valley of the River Dinin which leaves it on the south, this case does not prove the drift to have come from the north-east, which would have been proved had granite fragments from the country about Ballintore been found. On looking at my notes I do not find any recorded, but I never carefully looked for them, because while examining that district my attention was principally directed to the coals.

[17] See " Frost and Fire."

[18] See " Mems. Geological Survey, Ireland," Ex. Sheets 115 and 116, p. 28 ; also Lyell's " Antiquity of Man," 2nd Ed., p. 215.

[19] Atmospheric agencies could have done very little work in carving out the features of

Ireland *since* the glacial period, as the rocks forming the bottom of all the large valleys and cooms are polished and grooved by ice action. A few of the small valleys and *ailles* or ravines, especially if the subjacent rock is of a soft nature, may have been cut by atmospheric agencies, but in many of them ice action is visible.

[20] The reason I mention this particular height is, that " it has been shown by the soundings of Vidal and Hoskyns that on the west of Ireland the sea bed is in the form of a submarine plateau, extending from 50 to nearly 200 miles into the Atlantic, with a depth rarely exceeding 200 fathoms. Beyond the line circumscribed by this depth the plateau suddenly ceases ; its edge merges into a slope, which descends at a considerable angle, never stopping until the bottom of the great abyss of the Atlantic is reached at a depth of from 1700 to 2000 fathoms." This slope may have been the margin of the land during the Glacial Period as previously suggested by Professor W. King, of Galway. See " Frazer's Magazine," October, 1863.

[21] I do not mean to say " that the land did not sink lower than 300 or 400 feet ;" but what I want to express is, that " a short time previous to the close of the glacial period the land was at about that level." If the country sank lower than this, it would quite change its conditions, as nearly all the land ice would disappear, and as the land again rose a new system of glacier would have to form ; in fact, it would bring the country to conditions similar tothose Mr. Campbell suggests.

[22] It might have been 1200 feet higher than at present, and have included the whole of the 200-fathom plateau.

[23] (See " Arctic Explorations," vol. ii., p. 226.) Since the above was written, I find, Mr. Campbell, in " Frost and Fire," has anticipated me in considering that these shelves of drift on the mountain sides were formed by an " Icefoot." It is very satisfactory to me to find that a man who has watched the " ice engine at work" had come to the same conclusion as one who only had seen " the work done."

[24] (See " Dublin Quarterly Journal of Science," vol. iv,, p. 109.) In that paper, besides the current just mentioned, I suggested that there was also another current that [entered toward the N. E., " on the north of Lough Neagh, and from thence flowed by that lough, Cavan, Loughs Ree and Derg, to the mouth of the Shannon." This current could not have been a *continuous* current ; for if it were, the various bar eskers which cross that valley would have been swept away ; but that some current besides the tidal current existed hereabouts, would seem to be suggested by the breaks in the bar eskers to the north-east of Portumna, and also by the shoal eskers on low ground that exist north from Portumna to Kiltormer. These latter would have been formed by the meeting of this current and the south tidal wave, hereafter to be mentioned.

If Mr. Campbell's Baltic current once existed, the north and south current from Killala to the month of the Shannon would be the last trace of the once great current that flowed over this island from the North Pole.

[26] While examining the gravels in the eskers, I have never found striated or polished blocks high up in them : near the base I remarked a few ; but these latter never had the fresh look of those that are newly extracted from the boulder drift, but rather the appearance of the polished blocks that are found in the bed of a stream after a large flood. Many geologists class the *esker-like* ridges of boulder drift with the true eskers or kaims. This appears to me not to be correct, as in many places the esker gravel is banked against these ridges ; and if a section across them is exposed, a well-marked boundary will be found between these two kinds of drift.

[27] Doctor Kane, in " Arctic Exploration," mentions glaciers that fill up straits between some of the Arctic islands. If a similar phenomenon occurred in one or more of the straits out of the Esker Sea, these strait glaciers, if I may so call them, would be more likely to occur among the northern islands than the southern. Of course, if a glacier had filled up a strait, no *bar esker* could now be found in it.

[28] Mr. Oldham seems to have found fragments of shells in the esker close to the town of Roscrea, county of Tipperary. (See his paper, " Journ. Geol. Soc. Dublin," vol iii., p. 66.)

[29] If the eskers in Ireland were formed by the meeting of the tidal waves, the *kaims* in Scotland ought also to have a similar origin. This appears not to be unlikely ; for Mr. Stevenson, of Dunse, was kind enough to mark for me, on a map of Scotland, most of the principal kaims, the mass of which occupied a tract of country between the Frith of Clyde and Berwick-on-Tweed. On looking at the tidal map, it will be seen that a faint south tidal wave extends as far north as Berwick. This wave could not have formed the kaims ; but, if England and Scotland were lowered from 600 to 800 feet, the tidal conditions would be quite altered ; and, in place of a faint wave, the full force of the south tidal wave would sweep up at least as far north as this place.

If the eskers were formed by the meeting of the north and south tidal waves, and if there was during the esker period a continuous current flowing from Killala to the mouth of the Shannon, esker drift ought to have been deposited at the meeting of the tidal waves and that current. High ground (Slieve Aughta and Slieve Bernagh) occurs where the south tidal wave and this current ought to join ; but there is low ground to the north, where it and the north tidal wave should meet. The maps of the last-mentioned place have not yet been published by the Geological Survey of Ireland ; but Mr. Birmingham, in his papers read before the Society (see its " Journal," vol. viii, pp. 28 and 111), mentions the eskers which occur in that country. These, if formed as I suggest, ought to have a general north and south bearing, unless when going over or round high ground, when, of course, the general bearing would be more or less deflected.

[30] See paper by Mr. Stevenson, of Dunse, " Proceedings Berwickshire Nat. Club," vol. v., p. 124.

[31] As the highest ground in Ireland lies in the counties of Cork and Kerry, the glaciers may have existed thereabouts after they had disappeared from the rest of Ireland, and therefore after the age in which the eskers were formed. If that was the case, this terminal moraine may have been formed at a much later date than I have mentioned above.

[32] For some *locale* of remarkable erratics on eskers see " Mems. Geol. Survey of Ireland," Ex. Sheets 115 and 116, p. 84, and the forthcoming Mems. of Sheets 106 and 107. All these are granite erratics; but a large limestone erratic, about 8 ft. x 6 ft. x 8 ft. can be seen by any one who drives from Gort to Loughrea, perched on a sanddan, about 2·5 miles south-west of the latter place ; and in the county of Limerick, south of Shanagolden, I observed another, about 9 ft. x 5 ft. x 3 ft., also perched on a sand dun. In both these places the duns have been opened to carry away the sand and gravel, so that a section of the materials that support the erratics can be observed.

[33] See " Mems. Geol. Survey, Ireland," Ex. Sheet 127.

[34] See " Mems. Geological Survey, Ireland," Ex. Sheet 166.

[35] The heights of the margin of the supposed Esker Sea in the east of Ireland are not given, as I have not carefully examined that part of the country.

In the following papers reference is made to marine fossils found in gravelly drift, principally in the east part of Ireland : —

" Account of certain elevated Hills of Gravel containing Marine Shells which occur in the County of Dublin," by Dr. Scouler, &c., &c. ("Journal of the Geological Society of Dublin," vol. i., p. 266). The author mentioned having found these shells at Howth up to an elevation of about ninety feet, and on the south of Bray Head at about 150 feet. Of them he says, " All the shells whose species could be ascertained belong to races at present existing in the Bay of Dublin."

" On the more recent Geological Deposits in Ireland," by T. Oldham, M. R. I. A., &c. ("Journal of the Geological Society of Dublin," vol. iil, p. 61). In this Paper, Dr. Oldham, besides adding to Dr. Scou1er's list, refers to Captain Portlock having found marine shells

at 200 ft. above the sea in the county of Sligo, and in the county of Londonderry up to 300 feet ; to Messrs. Bryce and Hyndman, at Belfast, up to 150 feet ; to Mr. Smyth, at Portrash, at about ten feet ; and to Mr. (now Sir R.) Griffith, at Tarmon Hill, county of Mayo, at 250 feet. He also mentions the following localities of his own, with their height above the sea :—Telegraph Hill, Killiney, 400 feet ; N. W. side of Sugarloaf, county of Wicklow, 600 feet ; south of Wicklow Head ; between Enniscorthy and Wexford, 260 feet ; Finglas, county of Dublin, 200 feet ; Clane, county of Kildare ; Naas, 380 feet ; between Athy and Castlecomer, on the flanks of the elevated coal-field ; and at Roscrea, 400 feet."

In a second paper by the same author (see " Journal of the Geological Society of Dublin, vol. iii., p. 130), the previous list of marine shells in the county of Dublin is added to—" making in all twenty-six species."

Captain James, R. E. (now Sir H. James) gave a paper—" Notes on the Tertiary Deposits of the County Wexford" (" Journal of the Geological Society of Dublin," vol. iii., p. i96)—and mentions seventy-four species of marine shells, the highest of which " were found at an altitude of 400 feet on the side of Forth Mountain ;" but these, as previously mentioned, he seems to consider, as occurring in Præglacial Drift.

Mr. Du Noyer (see " Journal of the Geological Society of Dublin," vol. iii., p. 225) found marine shells at different places in the cuttings for the Dublin and Drogheda Railway. At Skerries he mentions that " the railway cuts through an esker," and " the calcareous clay overlying this sand and gravel contains many sea shells of the same species as those now living." He also says that at the twenty-six mile post, and near the Nanny Water, there are deposits " containing quantities of recent sea shells, bones of fish, teeth and bones of animal." (*Quere* might not these be ancient kitchen middens ?)

Dr. Kinahan (see " Journal of the Geological Society of Dublin," vol. viii., p. 87) is mentioned as having found marine shells in the drift at Bohemabreena, county of Dublin. Of these my colleague, Mr. W. H. Baily, says—" None of them are strictly Arctic, and most, if not all, are found in the seas round Ireland at the present day." It is not mentioned at what height these shells occur, but the gravels at Bohemabreena are between 400 and 450 feet above the sea level.

Some of these gravels may have been deposited towards the end or after the Esker Drift period, when the sea was losing its Arctic character.

In the counties of Limerick and Galway, at low levels, there are what seem to be ancient sea beaches ; but as they are on lower ground than that occupied by the eskers, they seem to me to be more recent, and therefore will not be further mentioned in these Notes ; but I hope to describe those found in the county of Galway in a forthcoming Memoir of the Geological Survey.

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