Chapter 9 The Glacial Deposits

Introduction

From its geographical position the Isle of Man offers an unrivalled field for the study of the conditions which have ruled in the northern part of the basin of the Irish Sea during the Glacial Period. The Island has, in fact, constituted a natural glaciometer, which has retained the marks of the successive stages of growth and decay of that great invasion of ice which has been the most remarkable episode in the later geological history of our planet. It is pre-eminently an area wherein the several theories by which the drift-phenomena of the Irish Sea basin have been explained may be put to the test.

In the present chapter it is proposed to give a general review of the Glacial geology of the Island, with descriptions of typical examples only of the phenomena, leaving the less important local details for record in a separate chapter.

The great development of diluvium containing compound rocks not in *situ*<ref>Geol. Trans., 1st ser., vol. ii., pp. 46–50. </ref>in the northern part of the Island was fully recognised by the earlier investigators at the beginning of the present century. Macculloch ascribed it to diluvial action passing from south to north and leaving this material under the shelter of the hills.<ref>Account of the Western Isles, etc., vol. ii., p. 526. </ref> Henslow noticed that the hardened sand contained "fragments of shells and some perfect specimens of recent cerithea"; and also that the blocks from the Dhoon Granite did not occur north of the outcrop, and that the transport of the Foxdale Granite blocks indicated a current from northeast to south-west on the east side of the Island.<ref>Geol. Trans., 1st ser., vol. v., pp. 495 & 503. </ref> In 1843 H. S. Strickland<ref>Proc. Geol. Soc, vol. iv., p. 8.</ref> described the occurrence of shells in the drifts. Rev. J. G. Cumming was, however, the first to give an adequate account of the whole subject, which he did in his paper, published in 1847, on "The Geology of the Isle of Man. Part II. The Tertiary Formations".<ref>Quart. Journ. Geol. Soc., vol. ii., p. 335.</ref> In this and his later works Cumming discussed the facts with his usual accuracy and acumen, showing that ice must have been the chief agent in the production of the drift deposits and the striation of the solid rocks beneath them. He drew especial attention to the dispersal of boulders of Foxdale Granite on the hill-range of South Barrule [SC 25766 75939] high above their parent mass, a subject afterwards discussed by Charles Darwin.<ref>Quart. Journ. Geol. Soc., vol. iv., pp. 315–323.</ref>

Cumming's classification of the superficial strata was as follows: "1, Boulder-clay and erratic blocks; 2, Diluvium; 3, Drift-gravel; 4, Alluvium". As we shall see, his divisions correspond, in the main, to those adopted in the present work.

Among the later literature, Mr. Jno. Horne,<ref>Trans. Edinb. Geol. Soc., vol. ii., pt. iii., p. 323.</ref> in 1874, contributed a short sketch of the subject in which he, for the first time, ascribed the deposits to *land-ice;* and Rev. J. Clifton Ward,<ref>Geol. Mag., dec. ii., vol. vii., p. 1.</ref> in 1880, published some useful notes. Mr. J. A. Birds,<ref>Geol. Mag. dec. ii., vol. ii., pp. 80–85.</ref> in 1875, and Mr. (Sir) H. H. Howorth,<ref>Geol. Mag., dec. ii., vol. iv., pp. 410 & 456.</ref> in 1877, added papers to the bibliography of the subject.

The latest paper to which I need here refer is that of Mr. P. F. Kendall,<ref>Yn Lioar Manninagh (Proc. Isle of Man,Nat. Hist. and Antiq. Soc.), vol. i., No. 12, p. 397.</ref> prmted in 1894, which is the most valuable contribution to this literature since the time of Cumming. As this paper will receive frequent mention in the context, it is only necessary here to state that its leading conclusions have been confirmed by the fresh evidence now placed on record.

The drifts of the Island, as of all glaciated tracts, are profoundly influenced by the physical characters of the ground. The reader is therefore recommended at this stage to revert to the first chapter of this memoir, in which the physiography of the area is described, if he do not already possess a knowledge of the main facts therein stated. Except for the addition of the drift-plain of the north, the outline of the Island at the present day is not much different from its outline just before the Glacial Period. Its main valleys were then in existence and its sea-coast nearly corresponded with its present shores, except where these are now formed by drift-deposits.

We will now proceed to consider the facts under the following headings: The Glacial Deposits and their fossils; Glaciated Rock-surfaces; Dry Rock-channels and allied phenomena; Transported Boulders; and Late-glacial Flood-gravels.

Composition of the Glacial Deposits

Cumming and all the later observers have noticed that the drifts of the Island are separable into a high-level and a low-level series, the former consisting entirely of local material deposited among the hills either in the form of a hard bluish-grey till or as a looser slaty rubble; and the latter, largely composed of material foreign to the Island, usually either red stony clay or loam, or stratified gravel and sand, occupying the northern plain and the lower flanks of the hills.

In tracing out these divisions, however, it has been found that in certain localities the low-level series creeps up the gentler hill-slopes to considerable elevations; and, on the other hand, that the high-level series descends in places to the plain; while along the flanks of the hills the two are inextricably interlocked. Hence it is by their lithological constitution rather than by their altitude that they are best distinguished, and we shall therefore designate them respectively, the Insular Drift, and the Extra-insular Drift; or they may be more briefly referred to as the Grey Drift and the Red Drift, from their prevalent tints.

The Insular Drift

This material needs little description. It possesses the characters usual to the glacial accumulations of hilly districts. In the deeper valleys and on the upland plateaux it occurs chiefly in the form of tough till full of scratched stones of local origin; but on the hill-slopes, more often as loose clayey subangular rubble in which striated fragments are not plentiful. Both types are banked locally in thick masses in the lower and deeper portions of the valleys, but attain their widest horizontal extent in the shallow depressions around the heads of the drainage-systems, where they frequently sweep in smooth sheets up to and over cols at elevations of 1,000 to 1,400 feet. On parts of the central ridge of the Island, where the ground is not too steep for it to rest the rubbly drift rises still higher, occurring in little patches up to the highest summits. In some places where it ends off upwards against steep rock-slopes, as on the south-eastern flanks of North Barrule [SC 44322 90920] and Snaefell [SC 39737 88117], and on South Barrule [SC 25766 75939], this drift occasionally assumes a moundy form, probably due to the sliding down of the loose material in wet weather while the hill-side was yet bare of vegetation.<ref>I owe this suggestion to my colleague, Mr. G. Barrow, who has noticed the same feature in the Scottish Highlands.</ref> Where both types of the insular drift occur in the same section, as is often the case, the rubble almost invariably overlies the till.

There is no record of organic remains having been found in any portion of the Insular Drift.

That the local till is the product of land-ice would probably be granted by every field-worker in glacial geology, while many would hesitate to acknowledge the same origin for the Shelly Extra-Insular Drift. Yet the inter-relations of the two series are such that whatever origin be assigned to the one can scarcely be denied to the other.

The rubbly drift is probably the *remanié* deposit of the ice-sheet largely modified by sub-aerial agencies. If there had been any submergence since glacial times this material could not have remained in the positions in which we now find it.

The absence of local moraines among the hills has been noticed by several observers. The explanation will, I think, be furnished in the context.

The Extra-Insular Drift

It is in regard to the Extra-Insular Drift that the peculiar interest and chief problems of Manx glacial geology arise. Its typical development is in the northern plain, where, fortunately, it has been carved out by the sea in admirable sections on both sides of the Island. The wasting cliffs thus formed are continuous on the western side for 8 miles, and on the eastern side for 6 miles, rising in several localities to elevations exceeding 100 feet, and in one place, at Point Cranstal, reaching over 200 feet. In the interior the chief exposures are to be found in the numerous old 'marl-pits', whence clay has been dug for enriching the sandy tracts, and in a few small brickyards and sand pits; while the deep borings on the northern coast, described in Chapter 7, have incidentally revealed the deposit to an unexpected depth below sea-level.

This drift is of very variable composition, comprising both stratified and unstratified material, the former predominating. The cliff-sections generally show, at the base, red or purple boulder clay or loam, in which stones are not particularly abundant and are usually more or less rounded, but often beautifully striated; and above this, a considerable mass of stratified material varying in texture from fine laminated warp-clay to coarse bouldery gravel; while in the upper part of the cliff there is frequently another band of red clay with scattered stones. Of these divisions the last is perhaps the most constant, but the whole are so intermingled and so interchangeable that, so far as the beds above sea-level are concerned, we can scarcely escape from Mr. Kendall's conclusion, "that the Manx drift forms one great irregular series" (op. cit., p. 408). Though in some places the middle stratified beds repose upon an eroded surface of the lower boulder clay, in others there is a gradual passage, either with more or less stratification throughout the whole section, or with the boulders and stones of the lowest division set in a matrix of compressed unstratified sand which fades away into bedded deposits in all directions.

It is, indeed, by their mode of arrangement rather than by their lithological characteristics, that these Extra-Insular Drifts may be differentiated. They are in places spread out in almost level sheets, and in other places heaped up into mounds and ridges, as will be subsequently described.

Fossils of the Extra-Insular Drift

The occurrence of marine shells in tolerable abundance in this drift is one of its chief characteristics. These are found both sporadically and in streaks and patches<ref>Kendall, op. cit. p. 410; see also pp. 342 and 428 of present work. </ref> in the lower boulder clay, but are more common in fine gravel among the middle stratified beds. So far as I have observed, they are invariably absent from the laminated warps and clays; and in the fine sands are as a rule represented only by minute flakes and crumbs They are usually fragmentary, and much worn by attrition. They present an admixture of forms from different depths of the sea, and also of northern and southern species. While most of the species are still living, eight forms occur which are considered to be extinct (see list, p. 473).

These shells have been collected and worked out with great care by Mr. P. F. Kendall, and the list given at the end of Chapter 11 is reproduced from his above-quoted paper, with slight alteration and additions as duly noted.

In Mr. Kendall's opinion the beds in which these shells occur are not truly marine but represent the material of a sea-bottom redistributed by an ice-sheet<ref>Op. cit pp. 423–433.</ref> and the general trend of the evidence supports this conclusion.

It is probable that a portion of the original marine deposit was passed through in No. 6 Boring [NX 46712 04835] (see p. 342) at a depth of over 200 feet below sea-level, consisting of 20 to 30 feet of muddy gravel and sand full of shells and foraminifera, differing in many respects from any bed seen in the sections above sea-level. This bed was not recognised in the borings farther westward, in none of which, however, was the drift found to extend to this depth (see p. 338; also details at pp. 418–21).

Boulders of the Extra-Insular Drift

Large boulders of distant origin are of frequent occurrence in the Extra-Insular Drift, both among the stratified deposits and in the boulder-clay, and are not found except in the area occupied by this drift. They include, in the order of frequency, Galloway Granite; Silurian rocks from the Southern Uplands, especially Queensberry Grit; Carboniferous Limestone; Carboniferous Sandstone; Permian and Triassic Sandstones; with occasional examples of Lake District rocks, Arran Granite, Pitch-stone, and a few others. At a rough estimate, it may be said that about nine-tenths of these have had their parentage in the hilly south-western corner of Scotland, and that the remaining tenth has been contributed by the Lake District, the Clyde Basin, and perhaps the maritime part of north-eastern Ireland. These boulders range in size from a foot or less up to several feet in diameter.

Among the smaller stones are rather abundant pebbles of the riebeckite-rock (Paisanite) of Ailsa Craig, first discovered by Mr. Kendall; chalk-flints; several varieties of porphyrite; and an occasional fragment of gneiss like that of Western Scotland (see pp. 420, 425 *et seq.* for details).

Mr. Kendall<ref>Op. cit., p. 406.</ref> has noted that the majority of the Scotch granites seem to have come from Creetown and the Cairnsmores, though other varieties are present. The same observer is inclined to refer a few of the west-coast boulders to the granite of the Mourne Mountains; and for the flint pebbles he infers a derivation from flinty gravels "which have lain in the path of the ice by which the Isle of Man was glaciated".

Among the rarer blocks brought to light by the researches of the Rev. S. N. Harrison of Ramsey,<ref>See Yn Lioar Manninagh (Journ. Isle of Man Nat. Hist. and Antiq. Soc.), vol. i., p. 375, and vol. iii., p. 21.</ref> are several boulders of gneiss; "the highly characteristic Porphyritic Pitchstone of Arran" a granite and "the Felspar-porphyry of Bennan Head" from Arran; and the granite of Shap in Westmoreland. During the progress of the Survey aboulder of Shap Granite, 3 feet in diameter, was observed between tide marks in Perwick Bay near Port St. Mary, and another of the same rock at Wills Strand on the west coast north of Peel; also three or four large blocks probably from the Borrowdale Series of the Lake District, one on Maughold Head, a second near Ballameanagh on Clay Head, and a third on the northern plain at Lagagh Mooar. It is probable that these rarer erratics have in the first place been distributed over the sea bottom by floating ice, and afterwards dragged forward from their marine bed by the advancing ice-sheet (see p. 345); while the Galloway Granites and other Southern Upland rocks are more likely to have been directly transported by a stream of land-ice leaving the Scottish coast around Luce Bay as indicated by the glacial striations of that district and of Manxland.

Typical sections of the Extra-Insular Drift

To illustrate the general character of the drifts of the northern plain, three sections have been selected, from-the cliffs of the eastern and of the western coast, and from the No. 6 Boring [NX 46712 04835]. The first, (Figure 88), which lies 2½ miles northward from the nearest part of the Manx Slate massif, shows a predominance of stratified material; while the second, (Figure 89), on the west coast, half-mile north of the nearest slate outcrop, exhibits the lower boulder-clay as its more prominent constituent; but in both instances these relative proportions of stratified to un-stratified material are only local and are reversed in other sections not far distant.

The section in Boring No. 6 [NX 46712 04835], given on pages 340–41, shows a downward succession of the drifts below tide-mark from about the level of the base of the above cliff-sections. Of the three borings, Nos. 4, 5, and 6, in which the opportunity occurred for closely investigating the drift by washing and sifting the material from different depths, the records of Nos. 4 and 5 will be found on pp. 418 and. 419, and contain some points of interest not observed in No. 6, but show a much less thickness of drift. A depth of only 173 feet of driftwas found in No. 4 [NX 40164 03040], and of 212 feet m No. 5, against an approximate depth of 476 feet in No. 6, the deeper beds of the last boring apparently not being represented in the other sections. Except in regard to these deeper beds, viz., those below 215 feet, the general character of the drifts of the above-mentioned borings resembled that of the cliff-sections; the erratic stones were of the same kind; the shell-fragments occurred in the same manner and were of the same species, though somewhat differently grouped (p. 421); the clays and sands were similar in composition; and there was the same absence of peaty material and of any indication of a break or change in the climatic conditions.

The beds below 215 feet in No. 6 Boring [NX 46712 04835] are, however, exceptional and deserve careful consideration. Between the depths of 220 and 240 feet the material, as previously stated, represents a marine deposit of glacial age, either an accumulation in place or a large displaced mass embedded in the drifts like the well-known instances in East Yorkshire. As the lower part of the section includes much local drift, apparently non-marine and probably due to the agency of land-ice, and as the drifts above sea-level are almost certainly of similar origin, it follows that if the marine bed be actually in place we must allow two distinct invasions of land-ice separated by an interval of open sea; and for this there is no other evidence in the Island.

Between 240 and 363 feet the boring passed through sands and gravels below the marine horizon, which, judging from the only sample that was preserved, appear to have represented stratified glacial material like that above sea-level; but our information respecting this part of the section is unfortunately inadequate. Below 363 feet the material was apparently a local boulder-clay made up from the subjacent Triassic Marl mingled with a few extraneous pebbles. From the specimens examined, the thickness of this bed appears to have been not less than 65 feet, and may have been much more, the marls being crushed and in places mixed with extraneous pebbles for at least 50 feet deeper (if the material supplied to us was correctly labelled) and partly reconstructed for a further 50 feet. As the boring was tubed down there seems no probability of the pebbles having been introduced accidentally from above; and the crushed condition of the marl in the specimens bore out the other evidence.

Section of Glacial Drift in No. 6 Boring, Point of Ayre

[NX 46712 04835] From the Engineer's Journal; with additional descriptions in square brackets

	Feet	inches
Shingle [Raised Beach.]	16	0
Gravel	32	0
Sand and gravel	8	0
Sand	12	0
[No samples of the above beds were obtained.]		
Sand and gravel	37	0
[Sample of the gravel at depth of 100 feet contained shell-fragments, including *Mytilus* with *Serpula;* also a pebble of dark blue grit, 2 inches in diameter, encrusted with nullipores and *Serpula,* and with indurated sand, full of shell-fragments, adherent to it; another pebble, of vein quartz, 1 inch in diameter, similarly encrusted, with polyzoa; also some small pebble-like fragments of indurated sand with bits of shell.]		
Hard sand	8	0
Clay	27	0
[Sample at 130 feet consisted of dark purplish brown clay with small foreign stones; like that seen at foot of cliff at Point Cranstal (see Boring No. 4, p. 420, for further description of similar material).]		
Sandy clay	8	0
Sand	6	0
Sandy clay and stones	10	0
[Sample at 160 feet; a pebbly clay, similar to that at 130 feet, but mixed with more sand and grit; effervesced freely with acid]		
Reddish clay	3	0
[Sample at 166 feet; smooth dark brown clay without stones or grit; probably like laminated warp-clays of cliff-sections: effervesced freely with acid.]		
Sandy clay	5	0

Sandy clay with stones	10	0
Sandy clay	20	0
[Sample at 190 feet; fine brown sandy clay or silt, without stones or shells; probably 'laminated warp': effervesced freely with acid.]		
Sandy clay with stones	13	0
[Sample at 206 feet; purple clay, with pebbles of dark blue grit and vein-quartz 1 to 11 inches diameter; also a shell-fragment; effervesced freely with acid. Another sample marked "between 202 to 215 feet"; dark greenish-purple sandy clay with stones; on washing, yielded pebbles like last, with one of pink felsite, ½ inch diameter, the finer siftings consisted of dark gravel with small much worn shell-fragments including *Mytilus* and *Mactra.* Another sample marked "215 to 220 feet"; similar material to last; pebbles included piece of slate, 1½ inches diameter, which might be Manx; finer siftings contained many angular shell-fragments, including *Astarte compressa, Rhynchonella, Nucula* or *Leda, Mactra, Balanus,* etc. This material seems to mark the top of the marine bed.]		
Silt	5	0
[Sample at 218 feet; greenish sandy mud or clay with small pebbles, full of crushed shells with the fragments angular and in proximity to each other; material resembles the shelly streaks in the drift at Bridlington and Dimlington in Holderness.]		
Gravel with shells	1	0
[*Mytilus edulis* largely predominant; *Tellina balthica; Astarte sulcata* var. *elliptica; Natica* sp.; *Buccinum umdatum.*		

Pebbles; dark green trap encrusted with nullipores and containing *Saxicava rugosa* in a hollow; two pebbles, each of 1 inch diameter, completely encrusted with nullipores and *Serpula;* 'basalt, grey micaceous grit, and dark grit, from 1 to 1½ inches diameter with patches of nullipores; hard cherty chalk, 1½ inches (from Antrim ?); flint; slate, possibly Manx, 3 inches; pale pinkish felsite, l½ inches diameter.]		
Sand	7	0
[Sample at 221 to 228 feet; fine yellowish grey sand with many foraminifera, and small fragments of shell; on sifting, the only residue a few grains of dark grit and fragments of *Rhynchonella, Balanus,* etc.]		
Muddy sand with shells	12	0
[Sample marked '228 to 240 feet'; "reamy"<ref>"When there is a considerable admixture of mud with coarse sand, it forms what is known to the trawlers as a "reamy bottom". See "Marine Biology of the Isle of Man", by Prof. W. A. Herdman, in "Handbook to Liverpool: British Association, 1896", p. 187.</ref> sand full of shells, fragments of *Mytilus* and *Balanus* predominating; on sifting, yielded:		
Mytilus edulis		
Astarte sulcata		
Astarte compressa		
Astarte borealis (young)		
Mya truncata		
Natica clausa		
Tellina balthica		
Rhynchonella psittacea		
Trophon clathratus		
Trophon Bamffius		
Turritella terebra		
Buccinum undulatum		
Lacuna divaricata		
Balanus Hameri		
Balanus crenatus		

Sample from 238 feet; sandy mud full of shell-fragments of a different facies from the above, *Rhynchonella psittacea* being the commonest shell and *Mytilus* rare or absent; the shell-fragments frequently coated with polyzoa; no gravel except a few worn grains not larger than ■ inch diameter; residue on washing, nearly all bits of *Rhynchonella* and polyzoa; the only shells recognised besides *Rhynchonella psittacea* were *Astarte striata* and *Cardita* ?]		
Reddish sand	36	0
[Sample marked 240 to 276 feet; reddish yellow or brown sand, becoming paler and greyish on washing; on sifting, very little residue, consisting of a few dark rolled grit grains the size of small shot, some highly polished grains of quartz-sand like those of the Permian Sandstone of No. 4 Boring [NX 40164 03040] (see p. 285), and some indeterminable crumbs of shell; also a few foraminifera. Probably not a marine sand.]		
Sand and gravel [No samples preserved]	2	0
Sand and gravel with pieces of coal [No samples preserved]	2	0
Gravel [No samples preserved]	35	0
Coarse gravel with clay [No samples preserved]	9	0
Reddish sand [No samples preserved]	24	0
Gravel [No samples preserved]	6	0
Stone [Apparently a large boulder; no specimen seen.] [No samples preserved]	0	8
Gravel and sand with clay [No samples preserved]	8	4
Disturbed Marls 181 feet:		
Red marl with stones and gypsum	65	0

[Sample at 380 feet; dull red clay with pebbles; effervesced with acid; on washing, yielded pebbles—dark (Carboniferous?) limestone, 2 inches diameter; well-rounded quartzite, same size; and smaller bits of limestone, dark grit, etc.: no shell-fragments: fine residue contained small gravel of quartzite, vein quartz, and various dark and reddish rocks, with some bits of gypsum: seems like a boulder-clay largely composed of red marl, different from any seen at surface.		
Sample at 426 feet; like last, but contained a piece of gypsum of 2 inches diameter; gravelly residue on washing, coarser than last, contained dark limestone, brown and red sandstones (New Red rocks ?), gypsum (rather abundant), manly slate, black and dark purple grits, fragment like Ailsa Craig rock (4 inch diameter), polished grains of vein-quartz, etc.; no shells.		
Sample at 427 feet; like last; gravelly residue contained dark limestone, quartzite, quartz, gypsum, flint, greenish sandstone, dark grit, etc.		
Sample at 428 feet; clay, red dappled with pale grey did not effervesce with acid; residue, small gravel like above, of well-rounded quartzite and quartz, gypsum, red felsite, etc., etc.]		
Brown marl with gypsum	72	0
[Sample at 453 feet, and another, similar, at 462 feet red and grey marl with crystals of gypsum, disturbed but not crushed down like that below; on washing, sunk into a red mud with rounded bits of gypsum but no extraneous material; may be a displaced mass of the Triassic marl.		

Sample labelled 476 feet; marl crushed down into clay, with some subangular foreign stones; the following pebbles obtained on washing: dark sandy slightly calcareous shale, 2 inches by 1½ inches; pale grit with faint markings like glacial striae, 1½ inches; and smaller pebbles of vein-quartz, pale chert or flint, gypsum, dark limestone, dark sandy shale with cast of a fossil, etc.; fine residue, a small quantity of speckled sand made up of materials similar to the pebbles. This seems to be a local boulder-clay like the specimens at 427 and 428 feet. If the specimen be correctly labelled it indicates the presence of extraneous drift material among the disturbed Triassic marl at this depth. Samples at 485 feet and 498 feet; crushed red and grey marl, with a pebbly structure as if reconstructed; residue on washing, bits of marl and gypsum only.]		
Gypsum mixed with sandy marl	2	0
Brown and grey marl mixed with gypsum	42	0
[Samples examined at 523, 535, and 541 feet showed disturbed red and grey marl (with crystals of salt in the deepest example) m which bedding was scarcely recognisable; yielded no extraneous admixture when washed and sifted.]		
Stratified saliferous marls, etc. (see p. 290 and Appendix, p. 585)	376	4
Total depth of boring	920	4

The site of the above boring is on the outer edge of the Post-glacial Raised Beach (see Chapter 7., p. 283). On the inner or southward edge, this Raised Beach is bounded by an old marine cliff, which has been carved out of a high platform of glacial drift (see (Figure 96), p. 355). This drift-platform has evidently once extended much farther northward, so that its height above sea-level should be added to the depth proved below sea-level in estimating the original thickness of the drift in this locality. In the present cliff at Point Cranstal [NX 46203 00159], two miles south of the boring, the drifts attain a thickness of about 250 feet, but their average is much lower, and we probably ought not to allow more than an additional 80 to 100 feet for their original development above sea-level at the borings. This would give an approximate initial thickness of between 525 and 575 feet for the drifts near the Point of Ayre [NX 46641 05107] before their erosion; and they probably still attain not loss than this depth in the hills around Kirk Bride (see diagram, (Figure 96)), a thickness, I believe, nowhere, surpassed in the British Islands.

The discovery, from the borings, that the drifts rest upon a disturbed floor of soft Triassic marl and sandstone in the north of the Island, with the inference that similar conditions obtain over a large area in the adjacent part of the Irish Sea basin (p. 289), is sufficient indication of the source whence most of the material of the red drift has been directly or indirectly derived. The marine bed found in No. 6 Boring [NX 46712 04835], with its far-transported pebbles encrusted with polyzoa and serpula, when taken along with other evidence, goes far towards proving that a sea in which arctic conditions prevailed has existed in this basin during an early stage of the Glacial period; and the subsequent ice-sheet seems to have incorporated the marine detritus of this sea with the debris of the Red Rocks and with material transported directly from the Galloway uplands, to form the drifts above sea-level.

Indications of the redistribution of material from a glacial marine bed are frequently afforded by the boulders of the drift. For example, a block of Carboniferous Limestone, measuring 2½ feet by 2 feet by 1½ feet, lying in 1894 on the north side of Orrisdale Head [SC 31838 92786], at the foot of the cliff of drift from which it had recently fallen, was encrusted in places with hardened shelly sand, with glacial striations traversing this incrustation as well as the limestone, as shown in (Figure 90) After its first glacial transportation this boulder must have lain in a matrix of shelly sand, presumably on the sea-floor, and must subsequently have been caught up and reglaciated, to be finally incorporated in the upper part of the drift. The same story was told by a subangular fragment of the Ailsa Craig riebeckite-rock 1½ inches in diameter, which was found encrusted with nullipores at a depth of 165 feet in Boring No. 4 [NX 40164 03040] (see p. 420).

Relations of the Extra-Insular to the Insular Drift

The relation of the shell-bearing drift of the northern plain to the slaty hill-drift is fortunately exhibited in cliff-sections on the flanks of the hills on both sides of the Island.

On the eastern coast the plain ends off against the massif immediately to the southward of the town of Ramsey, and a fine cliff-section shows very clearly the interdigitation of the foreign with the local drift. Although this section has been previously figured by Mr. Horne and again by Mr. Kendall, it is of sufficient importance to be worth refiguring, especially as it is now less obscured by talus than formerly. (Figure 91)

The solid slate-rock descends below sea-level at the foot of the old cliff on the S.E. side of this section, and there appears to be a pre-glacial tidal rock-shelf below that of the present day. This shelf is covered with red boulder-clay containing shell-fragments, resembling upper beds 6 and 10 of the section, and this material, when not hid.cren by modern beach-stuff, may be traced down to low water, and along the shore eastward for half mile to Port Lewaigue. Between this strip of clay and the present cliff of slate there intervenes a narrow rock-bench which marks the extent of coast-erosion which the slate has undergone since Glacial times (see p. 123). At Port Lewaigue [SC 46678 93075] the red boulder-clay passes inland across the promontory through the depression between Maughold Head [SC 49698 91435] and the hills to the westward, and reappears in the cliffs at Port Mooar. On the rocky ridge of Maughold Head itself foreign boulders are rather abundant, but do not attain the same elevation on the slope west of the depression. Farther south we find patches of the red drift here and there along the bold coast wherever the ground is not too steep, either in the form of stony clay or of gravel with many foreign stones; and where, as at Garwick [SC 43377 81557] and at Onchan [SC 40029 78198], a depression strikes inland approximately parallel to the hilly axis of the Island, the foreign material passes up along it for a short distance, gradually merging into the local drift. That this train of extra-insular drift marks the direction taken by moving ice on the south-eastern side of the hills is confirmed by the orientation of the glacial striae on the solid rocks (see p. 476). A patch of the red clay has lodged on the northern slope of Clay Head [SC 44324 80435], the promontory jutting out on the southern side of Laxey Bay; and again in the recess of Douglas Bay; and in various places around Santon (St. Ann's) Head [SC 33286 70259]. But to the southward of a line traversing the Island from Santon on the east coast to Cronk ny Arrey Lhaa on the west—that is to say, around the south-western or leeward end of the main hill-ranges —no clear distinction can be drawn between the local and the foreign drift; and instead, there is, in nearly every section, a small proportion of extra-insular material incorporated with the local detritus which forms the bulk of drift.

On the western side of the Island the phenomena are similar, excepting that separable red drift extends for several miles farther southward, and also rises to higher elevations before merging with the local material. This we should expect, since the glacial striae on the highest ground of the Island show that the ice-movement, where free from local deviation, was from north-north-westward, the western slope being thus the stoss side of the hills. On the west coast there is a steadily-increasing quantity of local slaty material among the shelly gravels of the red drift southward from Orrisdale Head [SC 31702 92610]; but it is not until we reach the first outcrop of the slate rocks at Gob ny Creggan Glassey [SC 29585 88519], nearly 2 miles south of Kirk Michael, that any local till is developed in the coast-section. Between this place and Glen Mooar the interdigitation of the insular and extra-insular drift is as well marked as at Ramsey, though the sections are somewhat overgrown and difficult of access. The main facts are as shown in the foregoing diagrams, the one representing the section parallel to the cliff-line, and the other that at right angles to it. (Figure 92) and (Figure 93).

The structure shown in the above sections is prevalent, with local modifications, in most of the drift of the hill-slope bordering the coast for the next two miles southward, but south of Wills Strand, where there is a lower tract occupied by the Peel Sandstones, the red drift occurs alone, chiefly m the condition of boulder-clay. This low tract is margined on the east by steep inland bluffs of slate, which terminate rather abruptly at the valley of the Neb near St. John's; it is also bordered by steep hills of slate along its westerly edge south-west of Peel, and by similar hills to the southward between Kirk Patrick and the south bank of the Neb at St. John's, where rises the mountainous ground of Slieau Whuallian (1,094 feet) [SC 26554 80550]. The low sandstone tract is thus encircled with high ground on all sides except the sea ward, in which the only gaps are the valley at St. John's and a low dry col south of Kirk Patrick which has probably once carried the drainage of Glen Rushen (see page 10). The distribution of the red drift around this cul-de-sac seems necessarily to imply the presence of a great south-moving ice-sheet in the basin of the Irish Sea.

To the south and west of Peel the red drift, somewhat gravelly and intermingled with local material, sweeps up through the gap at Kirk Patrick into Glen Meay [SC 23547 79792], where it Joins with the similar drift which covers the lower flanks of the hills bordering the coast southward to Dalby [SC 21921 78321]. Eastward it spreads up the depression as far as St. John's, patches of red boulder-clay containing many fragmentary marine shells being visible in the bed of the Neb at the mouth of Glen Mooar. At St. John's [SC 27747 81737] three valleys unite, that of the Neb coming in from the north, that of Foxdale from the south, and the central valley of the Island from the east (p. 458). Into the first the red drift does not penetrate beyond the mouth; into the second it enters for only a short distance, and then dovetails out among the local drift in a manner well shown in the river-bank one mile south of St. John's, as illustrated over-leaf in (Figure 94).

In the bottom of the central valley the drift is buried deeply under alluvium and terrace-gravels, and is not seen; but on the lower part of the hill-slopes yellow sandy reconstructed drift containing foreign boulders and pebbles mixed with local material can be traced eastward as far as the narrow pass at Greeba [SC 31298 80400], while among the hills to the northward the drift is all of insular origin. The central watershed of the Island lies a little to the westward of the Greeba pass, at an elevation of only 160 feet above sea-level; but though the foreign drift crosses the summit, it appears not to have descended the valley eastward beyond Greeba, and all the glacial material visible between Crosby and Union Mills is of local origin, except a few far-transported pebbles occurring in old flood-gravels lining the valley (p. 459).

Thus, so far as the valleys are concerned, the foreign drift fairly well maintains its character as a low-level deposit, the only remarkable point being its failure to find passage farther along them. But this character is quite lost on the hill-slopes to the south-eastward of St. John's, where we unexpectedly find that the red drift rises out of the valley and sweeps in a broad belt south-south-eastward up the gentle incline which forms the shoulder between Foxdale and the central valley, and spreads out on the summit at a higher elevation than it attains in any other part of the Island.

The drift occurs on the slopes and summit of the incline in the form of yellow clayey sand or loam, containing many rock-fragments foreign to the Island along with others of local derivation. This material lies thickly in a shallow depression on the summit of the ridge at an elevation of 600 feet above sea-level, underlying the northern part of the tract newly planted with trees; and spreads southward more thinly nearly to the highest portion of Archallagan, the rounded summit beyond, reaching an altitude of about 700 feet. Glacial striae are of rare occurrence in this district owing to the unfavourable character of the country-rock for their incision, but it happens fortunately that one finely-scratched surface of slate- is revealed underlying the drift with foreign stones, in a little water-channel in Archallagan plantation [SC 29840 79189] 200 yards south-east of the old Cornelly or Townsend Mine (p. 459). These striae are directed from N. 35 W. to S. 35 E.; and on facing this direction we look straight through the gap in the hills at St. John's and across low ground to the open sea. Large boulders of Galloway granite, one of which is 8 feet in diameter, are dotted over the path of the drift on the high ground, and there are also many smaller erratics, including Silurian grit from the Southern Uplands, red porphyry, diabase, and others — in fact, the usual assemblage found in the extra-insular drift. These are numerous in the vicinity of the above-mentioned old mine, and many have been carried down into Glion Darragh [SC 29695 80229], the steep rocky gully below the mine. (See further details on p. 459.)

It seems impossible to explain the position of the red drift in this tract except by granting that, like the local drift, it has been the product of an ice-sheet which has overwhelmed the hills. Its distribution is then seen to depend directly upon the configuration of the surrounding district. The abrupt slopes of Slieau Whuallian [SC 27312 81209] immediately south of St. John's have been too steep for the drift-laden basal layers of the advancing ice-sheet to surmount, and rock-slopes nearly as steep have similarly hemmed it in on the north-eastward, leaving a narrowing gap, like the base of a funnel, for the passage of the lower part of the ice, with a gentle incline leading upward from the orifice. With land-ice pressing in across the open ground to the north-northwest in the direction indicated by the striae, and the valleys already partly occupied by local glaciers (see p. 391), we realise easily the conditions of glaciation at this place; whereas under the supposition of the marine origin of the red drift, the facts would be inexplicable.<ref>It would be waste of space to consider, as a possible alternative, the recently revived "waves of translation" hypothesis of drift-formation; it is negatived by the whole tendency of the evidence in every part of the Island.</ref>

After crossing the main watershed of the Island at Archallagan [SC 29924 78653] the extra-insular drift becomes less distinct, owing to the greater admixture of local detritus; but it may be traced, hugging the ridge for about a mile farther, to the high ground above Garth, by the presence of its far-transported boulders in the walls and fences.

Its individuality as a stream is then lost, probably through its having been caught in the south-westerly drag of the ice under the lee-side of the hills (p. 347); but its gradual dissipation in this direction may. be held accountable for the presence of a few foreign pebbles in the local drift of the east bank in the upper valley of the Santon River.

Other examples of a similar though less extensive dragging up of the foreign drift to high levels will be described in the subsequent chapter.

Though differently attained, the same conclusions are implied in the relations of the drifts at the mouths of the valleys which break the bold scarp-like northern termination of the mountains between Ballaugh and Ramsey in the north of the Island. These valleys—Glen Dhoo [SC 33058 78492], Sulby Glen [SC 38131 91450], and Glen Auldyn [SC 435 935] — are pre-glacial, and trench into the solid rocks deeper than the level of the present drift-plain; and the red drift is banked continuously along the front of the hills at higher levels than the valley-floors. They all contain much glacial detritus, and in Glen Auldyn and Sulby Glen this apparently consists entirely of local material, the foreign drift barely entering their mouths. In Glen Dhoo, however, there is yellow sand and gravel with foreign stones and streaks of red clay as far up as Riversdale, about a mile from the entrance, and the local drift is confined to the upper reaches of the valley. This difference may be explained by the fact that the two former glens possess open drainage basins among the hills, while the last is only a deep trench cut back into the end of a ridge and terminates in a coomb, as can be gathered at a glance from the hill-shading on the one-inch map. The glens with extensive upland catchment-areas were probably blocked with local glaciers at an early stage in the Glacial period, so that no room was left for the extraneous ice when the Island was afterwards enveloped in the south-moving sheet; but Glen Dhoo and one or two similar valleys in other parts of the Island were partly unoccupied from lack of sufficient gathering ground, and were therefore filled up by a tongue of the main ice sheet.

Again, on the western coast south of Dalby [SC 21922 78260] the hills are for the most part too high and abrupt for any drift to have lodged; but where the range is gapped by depressions, as at Fleshwick [SC 20185 71542] and at Port Erin [SC 19456 69296], the red shelly drift has entered in upon the land in a stream which mingles gradually with local detritus. (See pp. 461 and 471 for local details.)

The above facts are throughout consistent with the view that the accumulation of the extra-insular drift on the low ground and flanks of the Island has been practically contemporaneous with that of the local drift in the interior; and that both are the product of land-ice. Their relative distribution is everywhere in keeping with Mr. Kendall's supposition that only the lowerlayers of the ice-sheet were drift-laden,<ref>Op. cit., p. 426.</ref> and that these were diverted by the steeper hill-slopes and swept round the flanks of the massif as an undercurrent. As will presently appear, this view is borne out by other evidence, especially by that of the glacial striations and the transport of local rocks in the Island. It is, likewise entirely consonant with the result of recent investigations of existing glaciers in Greenland<ref>Prof. T. C. Chamberlin, Bull. Geol. Soc. America, vol. vi. (1895), 199220; and Journ. Geol. of Chicago, vols. ii., iii., and iv. Also G. H. Barton, Technology Quarterly, vol. a. (1897), pp. 213–244.</ref> and Spitzbergen.<ref>E. J. Garwood and J. W. Gregory, Quart.

Journ. Geol. Soc., vol. liv., pp. 197–227; and E. J. Garwood, *ibid.,* vol. lv., pp. 681–691.</ref>

Topographic features of the Extra-Insular Drift

In all questions relating to the origin of the drifts, the topographic forms which the deposits assume are of at least as great importance as their lithological composition. This is strikingly exemplified in the Isle of Man, where the study of the surface-features yields much more information as to the conditions of accumulation of the drifts than can be obtained from the most careful examination of the cliff-sections.

Near the northern margin of the drift-plain the extra-insular drift is heaped into a chain of mounds or ridges, rising suddenly from a level plateau to a height of from 200 to 300 feet above sea-level. This chain, rarely more than ½ mile in width, sweeps round for twelve miles in a rude crescent, from the east coast at Bride [NX 46721 01168] to the west coast at Jurby [SC 34247 98149] and Orrisdale [SC 31683 92760]. The feature was known to the geologists of the early part of the century as the Ballachyrrim Hills, but this name has been displaced by the term Bride Hills, applied by Cumming and the later writers from the village which shelters under the eastern summit. As seen from the low ground to the southward (see (Figure 95)) the chain seems at first sight to be continuous; but on closer investigation it is found to be composed of three or more segments set *en échelon.* The encroachment of the sea has carried away most of the ground on the northern or convex side, and has destroyed the eastern horn of the crescent and also broken through the western margin at Ballakinnag [NX 41275 02288]; but there is still a strip of lower drift land lying to the north of it between Kirk Bride and Ballamacskelly. On its southern or concave side the drift deposits are arranged in a series of plateaux, mainly composed of gravel, which either slope gently inward of descend by two or three distinct steps to the boggy alluvial hollow, known as The Curragh, under the bold slopes of the old massif. These plateaux are furrowed by numerous drainage hollows, now for the most part dry or occupied only by artificial drainage trenches; and these channels, with one notable exception, descend inward towards the Curragh [SC 36407 95059] even when, as at Dog Mills [SC 45234 97826], 2 miles north of Ramsey, the head of the channel is quite close to the existing coast.

Stratified material predominates in the composition of the ridges, especially on the concave side of the crescent; but they also contain much stony red clay or boulder-loam, only in part stratified, especially on thenorthern slope where this is occasionally the chief constituent. On the published drift-map the sand and gravel of the mounds has been indicated by a deeper tint than the similar material of the plateaux, and the outline of the hills is partly defined thereby. Where, however, the boulder-clay forms part of the hills, as around Kirk Bride, this is shown by its proper colour, and a dotted line has been drawn to mark off the northern limit of the ridges.

The structure of the interior of the mounds is excellently revealed in the cliff-sections at Point Cranstal [SC 46020 99917] on the east and at Orrisdale Head [SC 31872 92851] on the west. These show that the hills are chiefly due to the local thickening of the middle or stratified part of the drift-series. The lower boulder-clay is usually found at the base of the cliff; passing under the mounds without much change of level; while above it the rest of the section is made up of a confused pile of coarse current-bedded boulder-gravel, fine shelly gravel, sand, warp, and stony loam, frequently contorted, though generally well stratified. At Point Cranstal the cliff-section is nearly at right angles to the ridge, and is continued southward through the gravel plateaux towards Ramsey, and northward across the strip of lower drift-ground between the Bride Hills and the raised beach of The Ayre, as represented in the opposite diagram. (Figure 96).

As indicated in the diagram, when traced northward beyond the mounds, the pile of stratified material is seen in part to thin out and in part to pass into red boulder-loam or clay containing many large well-glaciated erratics.

This structure is remarkably similar to that which I found in the drifts of East Yorkshire, where the Purple Boulder Clays, forming comparatively flat and low ground, pass laterally into a chain of mounds composed principally of shelly gravel and sand.<ref>"The Drifts of Flambro' Head", Quart. Journ. Geol. Soc., vol. xlvii., P1. Ma, fig. 15. </ref> There is indeed in all respects a close analogy between the structure of the drift-plain of the north of the Isle of Man and that of Holderness. In both cases the pre-glacial floor of the solid rocks lies far below present sea-level, so that the existing land is due to the local heaping up of the glacial deposits; in both, again, irregular ridges of stratified material form prominent surface-features at some distance from the solid hills, with an intervening lower tract which drains inland from the coast and in which wide sheets of gravel and alluvium have collected; in both, marine detritus is abundant in some of the boulder-clays andgravels; and in both the bulk of the drift-material has been introduced from extraneous sources. In fact, the only noteworthy difference is that as the materials have been collected from tracts of widely different geological composition, the stones of the Manx drift differ widely from those of Holderness.

Another strikingly similar area is the strip of low drift-covered land which forms the southern part of the Cumberland coast, between the massif of Black Combe and the Irish Sea; and in this case the resemblance to the Manx drift-plain extends to the actual composition of the drift-material.

We cannot doubt that in these tracts, and in others of similar character, there has been a sameness of conditions during glacial times so that whatever explanation is adequate for the Isle of Man will be capable of wide application.

Returning to the study of the Bride Hills, we find clear evidence in their topography that neither during nor since their formation can they have been under the influence of marine action. Among the hills deep dry hollows are everywhere present, which, from their winding courses, especially in the vicinity of Kirk Bride, have often the appearance of enclosed basins and have been mistaken for "kettleholes". But when systematically traced, they are found to constitute definite valley systems, running back to the crest of the chain, and in some cases cutting deeply across its entire breadth, always with the principal drainage-slope descending inwards towards the gravel plateaux. The larger of these dry valleys are 80 to 120 feet in depth, and from 10 to 90 or more yards wide at the floor. In one or two instances an older valley has been broached by a later hollow, but in all cases the original gradient and course of the stream is clearly indicated. To illustrate these features, a portion of the six-inch field-map on which these valleys were traced is reproduced in (Figure 97).

These dry valleys and the gravel platforms are in direct relationship. Where the larger of the old channels leave the hills we find a broad low fan of stratified material spread out upon the plain, at first of considerable thickness, but afterwards thinning off until insufficient to cover the underlying boulder-loam; and with the decrease in thickness there is a corresponding decrease in the size of the constituent pebbles. The largest of these 'over-wash plains' or gravel-deltas lies to the eastward of Jurby, at an elevation of 80 feet above O.D., and covers about 3 square miles. Though in this locality the sea has removed the greater part of the marginal hills, the direction of transport of the gravel may be traced, by its increasing roughness, to the neighbourhood of Sartfield [SC 35600 99426], near Jurby, where the plain ends off among low billowy ridges of coarse gravel of extra-insular origin, containing stones up to 12 inches in diameter. Other smaller spreads of similar character lie between Kirk Andreas [SC 42738 99111] and the Bride Hills [NX 44559 00439], as partly shown on the map (Figure 97), and these can be followed up to the valleys whence they came.

It is clear that the same agency which scooped out the dales has spread the gravel-deltas on the plain; and it is manifestly impossible to ascribe such features to submarine action. In every particular we are confronted by the characteristics of stream-erosion.

Thus far the explanation is simple: but the question arises, whence came running waters of sufficient magnitude ? Granting even the most favourable conditions of frozen subsoil and melting snow, it is impossible that the water necessary to carve out such trenches as those around Bride [NX 44962 01167], and to spread such gravels as at Jurby [SC 34305 98184], could have collected on the narrow ridge. One can judge from the diminutive valleys on the northern slope of the mounds, where owing to the clayey subsoil there is still some superficial drainage, how comparatively insignificant the work of the surface-water has been since glacial times. Besides, we have to explain instances where the trenches are cut completely across the ridge, as at Lamb Hill [NX 45303 00781], Thurots Cottage [NX 43591 01539], and Smeale [NX 41954 02061] (see pp. 432–3).

This difficulty is overcome by applying Mr. Kendall's suggestion that the "great fans of gravel and sand may have been laid down by water washing freely out from the edge of the ice".<ref>Op. cit., p. 428.</ref> The crescentic ridge itself has probably formed a moraine of retrocession at the margin of the waning ice-sheet, where its front had receded as will presently be shown, as the result of the solvent effect of the north-flowing rivers of the Island (p. 397). Streams draining from the ice-sheet into the lake-filled hollow which lay at this time between the solid hills and the ice-front trenched deeply into this moraine; and the detritus which they carried was spread out into gravelly 'overwash plains' or 'kame deltas', partly by fluviatile action and partly by the lake-waters. This seems to be the only explanation consonant with the whole of the facts; and it is at the same time borne out by the conditions actually observed at the margins of existing low-ground or 'piedmont' ice-sheets.<ref>Consult J. C. Russell's description of the Malaspina Glacier of Alaska, in 13th Annual Rep. of U.S. Geol. Survey (1891–2), part ii. Also papers on Greenland and Spitzbergen glaciers quoted on p. 352.</ref>

Some of these phenomena are repeated on a small scale in the south of the Island, but are there less clearly developed (see details, pp. 470–2). They are all the outcome of the waning phases of the glaciation. The facts next to be described relate to the solid hill-mass of the Island, and are chiefly records of conditions during the maximum stage of the glaciation; they afford irrefutable evidence that an ice-sheet has moved across the highest summits, regardless of their contours.

Glaciated rock-surfaces

The presence of glacial striations on the Carboniferous Limestone, near Castletown and Port St. Mary and on the slate-rocks at Cregneish was first noted by Cumming;<ref>Quart. Journ. Geol. Soc., vol. ii., p, 339, and vol. x, p. 214.</ref> and similar markings on the slates of Banks Howe north of Douglas attracted the attention of Rev. J. C. Ward,<ref>Geol. Mag., dec, ii., vol. vii., p. 6.</ref> while others on Maughold Head and South Barrule have been recorded by Mr. Kendall.<ref>Op. cit., p. 405 and map. Certain of these, near Ramsey, not examined by Mr. Kendall himself, have proved to be the marks made by the sliding of screes on steep slopes, and are therefore not included in our list.</ref> These are the only examples hitherto recorded; and as it happens that all are on the south-eastern or lee-side of the central hill-range, where the direction of ice-flow was influenced by local conditions, they have given rise to some misconception as to the general direction of the ice-movement across the Island. During the prosecution of the Survey about 150 new instances of these markings were observed, occurring at all elevations up to the highest summit, and in nearly all parts of the solid massif, thus affording a singularly complete body of evidence as to the character of the glaciation and the movement of the ice. The more important of these striae have been shown on the published map, and a detailed list is given in the next chapter (p. 476), so that we need here consider only a few selected cases of especial interest.

The markings are most plentiful on the flanks of the Island and on its higher ridges, and are of rarest occurrence in the glens. In exposed places, where the general rock surface retains only its flowing outline in evidence of glaciation, fine striae may still be sometimes found on the quartz veins, with which the slate-rocks are often seamed.<ref>These glaciated surfaces of quartz possess a peculiar smoothness which one soon learns to distinguish by the touch. The scratches on them are very fine, but become easily visible when rubbed with the scrapings of a lead-pencil.</ref> In places where the ice-flow was least likely to be influenced by the local topography, as on the higher ridges and summits, the bearing of the strife is usually from points between N. and N.W. to points between S. and S.E. On the flanks of the hills and on the lower ground generally, the deflection from this direction is always such as, from the form of the ground, might be expected to take place in a semi-plastic mass moving across the Island from N.N.W. to S.S.E. Thus, south of Ramsey the striations swing round the north-eastern shoulder of the hills, and gradually take up a southwesterly or even a west-south-westerly course under the lee of the central chain, but swerve back to their former direction as they leave its shelter in the south-western peninsula west of Port St. Mary and on the Calf Islet. On this sheltered side of the Island, especially towards both extremities, intercrossing strife are of frequent occurrence; in which cases the markings can usually be resolved into two sets, the one having the dominant N.N.W. to S.S.E. direction and the other showing the E.N.E. to W.S.W. deflection. These, no doubt, indicate the changing effect of local conditions upon the movement of portions of the ice-sheet at different stages of its growth. On the western side of the Island, also, there is evidence of local deflection when the ground rises steeply from the sea, as at Contrary Head where the striae run nearly parallel to the coast. These deflected streams may have taken the form of drift-laden undercurrents, over which the upper, and perhaps driftless, part of the ice-sheet held its normal south-south-easterly. course. We have already seen that the extra-insular drift material seems usually to have been confined to these lower streams, its dispersal corresponding exactly with the currents indicated by the deflected striae.

Of individual striated surfaces one of the most interesting is that in a shallow cutting at the side of the electric tramline within 30 or 40 feet of the summit of Snaefell [SC 39712 88092], the highest mountain of the Island, at an elevation of about 2,000 feet above sea-level. The striations occur on a surface of slate 40 yards distant from the summit-terminus of the line. Their direction is S. 15 E., which is transverse to the longer axis of the mountain. Other striations, having approximately the same direction, are exposed in the cuttings at slightly lower levels. In the northward prolongation of the same hill-chain, between Snaefell and North Barrule [SC 44292 90932], there are further instances of high-level striae, at altitudes ranging between 1,400 and 1,600 feet, in the shallow cols leading into the Cornah Valley [SC 42245 88564]; and again south of Snaefell, at 1,560 feet on Mullagh Ouyr [SC 39814 86152], and at 1,340 feet on Carn Gerjoil [SC 39301 84096], the direction of the strife being always across the axis of the ridge. South of the central valley, striations similar to the above-mentioned were observed on the Slieau Whuallian range at 1,090 feet; on South Barrule [SC 25771 75949] at about 1,300 feet; and on the Carnanes north of Fleswick [SC 21154 71722] at about 800 feet.

The clearest proof that the markings were made by the flow of a mass piled up in the basin of the Irish Sea to the northward of the Island, and not by local ice, is afforded by an instance which occurs two miles N.N.W. of Snaefell at over 1,200 feet above sea-level on the rounded upland of Slieau Menagh (Monagh of the ordnance map) overlooking Sulby Glen [SC 39625 90997]. A crag of vein-quartz known as Creg Bedn [SC 39466 91335], jutting out on the northern side of the moorland, has been rounded off and striated by the uphill flow of ice from the north-north-westward (Figure 99), in which direction there is no high land. The upland is bounded on the west by the deep preglacial valley of the Sulby River; on the east and north, by a depression drained by a tributary of that stream; and is cut off from Snaefell on the south by the glen of another tributary of the Sulby. The profile of the land in the line of the stride is shown in the accompanying diagram (Figure 100), which, without further discussion, will render apparent the impossibility of local ice having moved in the indicated direction.

It is also noteworthy that striations sometimes occur on vertical or overhanging rock-faces. Besides examples of this character on a small scale on the Carboniferous Limestone in the south, noticed by Mr. Hewitt<ref>Proc. Liverpool Geol. Soc., vol. v. (1887–8), p. 352. </ref> and by Mr. Kendall, two fine instances on a larger scale were observed on the slate-rocks. One of these is on a vertical rock-face at an elevation of about 1,300 feet on the craggy side of North Bennie overlooking the Cornah Valley, 280 yards to the westward of the fence which crosses the ridge from Park Lewellyn; the other is on the lower crags of the eastern slope of. Bradda Hill, 280 yards W. 10 S. of the farmstead of Ballalonney, in the latter instance a vertical rock-face has been undercut and fluted, the grooves being inclined at 10° towards the north, probably denoting the upward movement of ice under pressure through the low pass at Fleshwick between Bradda Hill [SC 19485 71216] and the Carnanes [SC 20849 71529].

The only deduction which seems possible from the evidence of the striations as a whole is that the Island has been surrounded and its highest summits overwhelmed by an ice-sheet.

Dry rock-channels and allied phenomena

Evidence of the former existence of an ice-sheet, as strong in its way as that of the striae, is furnished by the presence of rock channels here and there among the hills, excavated by running water in positions where the land could have supplied no stream. These channels have not been observed on the main or Snaefell hill-range, but are rather numerous on the spurs which run out from it on both flanks. They usually take the form either of a shallow notch cutting the spur in a direction more or less parallel to the main range, or of a dry gulch with low craggy walls starting from the crest of the ridge. Examples of the former type may be studied on the ridge between the parishes of Onchan and Lonan [SC 40765 82544] ?, south of Laxey, at heights of 600 to 900 feet above sea level; and of the latter on the south-western slope of Slieau Curn near Ballaugh, starting at an elevation of 1,058 feet. There are other instances on the westerly slope of Slieau Curn, one of which, at Ballacooley, goes parallel to the hillside and not down the slope, beginning and ending without any relation to the general form of the surface. It is noteworthy that in the vicinity of channels of this character the ground is in most cases unusually free from drift. Lower down on the same hillside, on the Bishopscourt Demesne [SC 33996 92313] 500 yards north of Bishop's Glen, at an elevation of 200 feet above the drift-plain or 300 feet above sea-level, another singular notch is carved out in the slope, parallel to the contours, ending off indefinitely at both ends in the manner which we have attempted, not very successfully, to illustrate in the following diagram (Figure 101).

Two miles farther south, on the western side of Glen Wyllin near Kirk Michael, there is a good example of another type of dry valley. In this case the narrow steep-sided rock-ridge forming the western margin of Glen Wyllin is transversely trenched by a gully starting on the very crest, at an altitude of between 300 and 400 feet above the bottom of the Glen,<ref>The absence of contour-lines from the Ordnance map prevents a more precise statement of the elevations, as no opportunity was found for special levelling.</ref> with the ground sinking abruptly to within 60 or 70 feet of sea-level at the head of the gully, as shown in the sketch map (Figure 102).

The gully has been cut out of solid slate and greywacke to a depth of 50 or 60 feet, and has bold craggy walls, now somewhat shattered by weathering. To excavate this channel through such rocks must have required a strong stream of water; yet there is no catchment area whatever at the head of the gully. Nor can it be part of an old valley which has been beheaded by Glen Wyllin, for the adjacent part of Glen Wyllin is clearly a preglacial valley (p. 447), while the gully has been excavated since the deposition of the drift which is piled up in mounds on both sides of it. Besides, a broad pre-glacial depression lower than the crest of the ridge extends back from Glen Wyllin [SC 31549 90075] to the western slopes of Slieau Freoaghane [SC 34051 88417]. The drift lies thick in this depression, but can never have filled it to the level of the ridge; nor is the configuration of the depression such that any glacially-dammed lake which it may have contained could have found an outlet through the gully. Nevertheless, except by postulating some temporary obliteration of the Glen Wyllin depression it seems impossible to account for the water-flow adequate for the excavation of the channel. The necessary conditions may have existed when the waning 'piedmont' ice, lingering for a time in the hollow, filled Glen Wyllin to the brim, so that a stream running partly on ice and partly on land could flow westward across it and down the channel at Ballalheigh [SC 31274 89059] to the outer margin of the hills at Glen Mooar. Such a stream may have had its sources in the two deep mountain-coombs between Slieau Freoaghane and Slieau Curn [SC 34180 89745], which still send a strong tributary westward into Glen Wyllin almost directly in line with the dry gully on the opposite side of the valley.

A similar explanation will apply to all these dry channels. In some cases the streams by which they have been cut may have been the outflow from temporary lakelets hemmed in between the land and the ice; while other streams have been the flood-waters of the ice-sheet itself, with courses lying for the most part on the surface of the ice, but in places crossing the solid ground as it gradually emerged from the thawing sheet. These channels are not peculiar to the Isle of Man. They may be observed in almost every hilly district which the ice-sheet has overwhelmed. Many instances have recently been found by Mr. P. F. Kendall and other observers<ref>P. F. Kendall, Rep. British Assoc. for 1899, p: 743; J. E. Wilson, *ibid.* for 1900, p. 755; A. Jowett and H. B. Muff, *ibid.* for 1900, p. 758.</ref> in different parts of Yorkshire, and I have myself noticed good examples under the Carboniferous escarpment in the Eden Valley east of Appleby, and on the western slopes of Black Combe above Whitbeck. The abnormal dry valleys in Eastern Berwickshire described many years ago by Sir Archibald Geikie<ref>Memoir of Geol. Survey of Scotland. Sheet 34 (1863), pp. 51–52.</ref> are probably of the same character. They are common in many parts of the glaciated area of North America, where they frequently attain very large dimensions.<ref>For references to American literature on this subject see H. Le Roy Fairchild, "Glacial History of Western New York", Geol. Mag. dec. iv., vol. iv. (1897), pp. 531–537.</ref>

That these valleys should occur in the Isle of Man at all elevations nearly down to sea-level proves the continuity of sub-aerial conditions in the area throughout the waning phases of the glaciation.

The transport of local boulders

The larger plutonic masses of the Island are admirably adapted in their lithological characteristics and in their position for yielding evidence regarding the general direction of ice-movement as shown by the transport of their boulders. In this respect the Dhoon Granite, the Foxdale Granite, and the Oatland or Santon Granitite deserve our special attention. The dispersal of these boulders is roughly indicated on the sketch-map, (Figure 98), p. 360, which will serve to illustrate the following descriptions.

Dhoon Granite — This granite has an exposure of about ½ sq. mile on hilly ground close to the north-eastern coast-line, but it does not actually reach the coast (see pp. 142–4). Although there is lower ground to the northward of its outcrop, no boulders from it have been found in that direction, as Henslow long ago noticed (p. 332); but a broad train may be traced going southward over the upland, thus taking the course indicated by the local ice-scratches. The major part of train is intercepted by the waters of Laxey Bay, only the western fringe remaining on land.<ref>Mr. Kendall mentions (op. cit., p. 401) an altered rock in the drift near Snaefell which he thought might have come from the neighbourhood of the Dhoon Granite, but which proves to have been derived from a more immediately local source. There are no Dhoon boulders in the bract referred to</ref> Two miles farther south, however, the projection of Clay Head catches the stream again, though here they are mixed with others of extra-insular origin. Thence they may be traced, in rapidly diminishing numbers, into Douglas Bay, where they are relatively scarce. South of Douglas, though a few stones of Dhoon Granite occur in the gravels, the train is no longer recognizable. The course taken by these boulders is only explicable on the supposition that the bed of the sea to the eastward was occupied by an ice-sheet which barred the passage of the boulders in that direction and forced them coastwise southward under the lee of the hills. This conclusion is in perfect accordance with the bearing of the numerous local striae (see map (Figure 98)).

Foxdale Granite — The boulders from this granite hold a notable place in glacial literature, since they furnished a classical and oft-discussed example of transport from lower to higher levels (for references, see ante p. 332; and Bibliography, p. 589). Cumming described the main facts with his usual accuracy, and Mr. R. H. Tiddeman supplied the true interpretation in 1872 in his well-known paper on "The evidence for the Ice-sheet in North Lancashire".<ref>Quart. Journ. Geol. Soc., vol. xxviii., p. 488.</ref> Though much has since been written on the subject, scarcely any additions have been made to the facts observed by Cumming until the present examination, which has thrown fresh light upon the dispersal of these boulders, while fully confirming the theoretical conclusions of Messrs. Tiddeman, Kendall, and others.

The granite is exposed on a col of the main watershed south of the central valley, at an elevation of 600 to 700 feet<ref>Mr. Kendall states, on the authority of the Director of the Ordnance Survey, that "Granite Mountain" is 657 feet above O.D.: op. cit. p. 401.</ref> above sea-level (see p. 165). The deep trench-like valley of Foxdale drains northward from shallow depressions at the margin of the granite; and from the same boggy ground spring the Santon River and the Silverburn, which flow southward in broad open valleys with a much more gradual descent. To the eastward the ground rises gently towards Archallagan, and to the westward mounts steeply for 500 feet into the truncated end of the ridge of South Barrule, and then more gently to the summit of that mountain, 1,585 feet above sea-level.

Boulders of the granite are scattered sparsely on this mountain up to its very summit, attaining a maximum elevation of about 900 feet above their source within 1¾ miles of the granite outcrop. It seems hitherto to have been taken for granted that they have travelled from the outcrop directly up the nearest slope, but this does not appear to have been the case. They have probably travelled by a more circuitous route, under less simple conditions than are at first sight suggested, though not essentially different.

Participating in the dominant ice-movement, the main stream of boulders has passed southward down the parallel valleys of the Silverburn and Santon, spreading out slightly towards the east, so that stragglers have gone over a low water-parting into a more easterly depression which drains to the sea at Port Soderick. On the shore at the last-mentioned place may be found an occasional block of the granite, and westward they become more plentiful, so that between Santon Head and Port St. Mary they are often rather abundant between tide marks in sheltered places. The greater part of this southerly boulder-train has, however, been deflected westward as it left the hills, by the south-westerly lee-side current of ice, and has not reached the coast. Consequently the boulders are strewn in greatest profusion over the parish of Malew between the outcrop of the granite and the village of Ballasalla [SC 27988 70308], and over all the ground in Arbory [SC 24944 70443], the next parish to the westward, between the mountains and the west-going main-road through Colby. To the westward of Colby [SC 23035 70398], boulders of the granite, along with other local and a few foreign erratics, are scattered here and there over the southwestern peninsula of the Island, and also on the Calf of Man [SC 15769 65632], but no definite train is distinguishable. As the rock-striae indicate that a tongue of the main ice, from the westward of the Island, has pressed in south-south-eastward through the gap at Fleshwick [SC 20194 71436], and has also overwhelmed Bradda Head [SC 18426 69882], the obliteration of the local current in this quarter is perfectly explained.

Considering the small extent of the granite outcrop, the number of boulders which it has sent off is remarkable. Within the main train, over an area of 6 square miles the fences and farm buildings contain little other material, and the moorland south of the granite is strewn thick with blocks. The boulders lie for the most part at or near the surface; and as apparently only a small number have been carried beyond the present coast-line we probably still see a large proportion of the blocks originally transported. Their removal must, of course, to some extent, have lowered the level of the outcrop; but, judging from the shape of the ground, the lowering does not appear, after all, to have been great. An estimate might possibly be made of the total number of the boulders, which would afford the basis for an approximate calculation of the thickness of rock removed.

The high-level boulders on South Barrule [SC 25759 75920] and Cronk ny Arrey Lhaa [SC 22453 74675], lying to the westward and west-south-westward of the granite, cannot have been transported in the stream just described. As Cumming pointed out in 1846<ref>Quart. Journ. Geol. Soc., vol. u., p. 341.</ref>,they lie on the northwestern as well as on the south-eastern side of South Barrule; and he remarked on the difficulty of accounting for this distribution on the opposite sides of the mountain by the then prevalent theory of floating ice and marine current action. Ward and Kendall, likewise, have drawn attention to the anomalous position of these blocks on the north-western slopes of the hill-range. But the difficulty disappears when the ground to the north and north-westward of the granite outcrop is closely examined, as it is then found that a small train has been given off in this direction also.

This minor train seems to have gone northward down Foxdale for about a mile, hugging the western slope of the valley, and has then turned westward out of the Foxdale depression into the high-lying hollow between South Barrule and Slieau Whuallian [SC 25746 78790] in which lies the watershed between Foxdale and Glen Rushen (see p. 10). On the moorland forming the south-eastern side of this hollow from Doarlish Head [SC 27010 78337] ?to Ballavell the boulders are abundant, rising steadily to higher levels; the majority of these lie below the old highroad, which is from 900 to 1,000 feet above O.D., but there are numerous examples above the road, scattered over the western slope of South Barrule up to the summit [SC 25769 75926]. They are also scattered, in diminished numbers, around the head of Glen Rushen at about 1,200 feet above O.D. on Cronk Fedjag [SC 25769 75926], and at over 1,400 feet on Cronk ny Arrey Lhaa; and stragglers have apparently been carried southward over the ridge and thus into the territory of the previously described main stream on the south-eastern side of the mountains. The striated surfaces of the area fully confirm the evidence of the boulder-trains. On the granite outcrop and on the north-eastern crest of the ridge of South Barrule, the striations are in the direction of the principal ice-flow, viz., N.N.W. to S.S.E.; and the same is the case on the southern spur of Cronk Fedjag; while on a well-glaciated surface on the north-west slope of South Barrule, at the small slate trials south of the highroad, the strive bear nearly N.E. to S.W.

The curious westerly uphill divergence of the north-moving train from its apparently inevitable course down Foxdale was doubtless caused by the lobe of foreign ice which crossed the mouth of the valley on its way up the Archallagan slope as previously described. (p. 350). With this intruding mass to the north and east, the local ice which had previously accumulated at the head of the valley could find no passage along the ordinary drainage channel, and was pent back into the lateral depression and forced up westward along its slope. At a later stage, the ice-sheet in the sea-basin to the north-westward was piled high enough to flow across the summit-ridges of Slieau Whuallian [SC 26472 80455] (p 458) and South Barrule [SC 25754 75935], and across the local ice which lay between them; and then the local stream was gradually frayed out and dragged, with its contents, southward across the hill-chain. By this route have the boulders reached their present position on the mountain; and consequently they are absent or at any rate extremely rare (the ground is partly obscured by young trees and gorse) on its eastern slope immediately overlooking the outcrop of the granite (see map, (Figure 98)). From what has been elsewhere noted (p. 352) it is clear that the bluff character of this slope would in itself have deterred the passage of the boulders even had the general movement of the ice been in its direction.

As to the question whether the changes of direction may not represent separate and distinct stages of the Glacial Period, it may be pointed out that the facts are all consonant with the other evidence, in leading to the conclusion that from the beginning of the accumulation of local ice on the uplands to the overwhelming of the Island by an extraneous ice-sheet, and to its reappearance on the shrinkage of the ice from its slopes, there has been a progressive development of conditions, without marked interruption. Changes of direction of flow must in many localities necessarily have accompanied the growth and wane of the ice, and these seem sufficient to explain all the observed phenomena.

The Oatland Granitite — The small boss of granitite with its interesting marginal rim of basic rock which is exposed at Oatland [SC 32457 72496], in the parish of Santon (p. 320), has sent a fan-shaped stream of blocks southward and south-westward, as shown in (Figure 98), in a direction corresponding with the local striae. The south-eastern fringe of the principal Foxdale boulder-train overlaps upon this stream in such a manner as to suggest that the two may have lain at different horizons in the ice; and this is the more likely since the parent-rock at Oatland is 400 feet lower than at Foxdale. In other respects the evidence of the Oatland boulders is a repetition of that of the Dhoon boulders. (For further details, see p. 469.)

Other Local Boulders — A dyke-rock of peculiar character outcropping at Ballapaddag Farm [SC 34517 75882], near Ballabunt 3 miles west of Douglas, at an elevation of 300 feet above sea-level, has sent boulders south-westward up the slope of Richmond Hill [SC 33924 74769], and southward around its shoulder. These boulders rise in half a mile 200 feet above the parent-mass, and avoid lower ground to the eastward.

In the sister valleys of the Baldwin and the Glass in the interior, south of Snaefell and Beinn y Phott, the local drift contains boulders of peculiar actinolitic greenstone and of quartz-veined grit, which are abundant southward up to the union of the valleys. But while the drainage depression turns sharply south-eastward from this point, the boulders, reinforced by others from a pale micro-granite dyke, rise south. ward up the slopes out of the valley, indifferent to the local contours; and crossing the dividing ridge, pass down into the main central valley between Crosby and Union Mills.

In every case there seems no escape from the assumption that the dispersal of the boulders has been effected by an ice-sheet which occupied the surrounding sea basin and covered the Island. In no instance is the agency of floating ice adequate to explain their distribution.

Late-Glacial Flood-Gravels

The later stages of the Glacial Period in the Isle of Man are marked by a set of phenomena which carry on the history of the episode to its close, passing without a break, insensibly into the Post-glacial or Sub-recent stages.

The state of affairs which accompanied the disappearance of the ice-sheet from the flanks of the hills is, as previously explained, partly illustrated by the dry rock-valleys and by the crescentic drift-ridge of the Bride Hills. It is further indicated by the presence of patches of re-arranged drift, sometimes stratified and sometimes not, overlying the till in places on the hill-slopes where stream-action under existing conditions would be impossible. At the lower levels this re-arranged material sometimes forms terraces, which probably mark the sites of small fresh-water lakes temporarily held in between the ice and the land. One such lake seems to have lain in the central valley between Peel and Greeba; and another in the same valley between Crosby and Douglas. In the south of the Island the low ground between Port Erin and Castletown was probably occupied by a similar lake, which seems to have received a river from the westward ice-sheet through the gap in the hills at Fleshwick, as indicated by the gravel delta spreading out between Bradda and Kentraugh.

In such basins the alluvial fans of local material at the mouths of the little hill streams are remarkably large and out of proportion to the drainage areas; and most of these seem to have been deposited while the lakes still existed. (See details, pp. 437–40, *et seq.*)

These re-arranged drifts constitute the chief part of the deposits classed by Cumming as "Diluvium", to distinguish them on the one hand from his "Boulder Clay", and on the other from his "Drift-Gravel" divisions.<ref>Quart. Journ. Geol. Soc., vol. ii., p. 341.</ref>

It is in the north of the Island, however, that these phenomena are best displayed. There, in the great hollow formed, as subsequently explained (p. 397), between the ice-front and the Slate hills, we have on the northern side the broad gravel platforms or overwash-plains already described, representing the extra-insular drainage from the ice-sheet, and on the southern side great flats and spits of slaty gravel running out from the mouths of the larger valleys into the Curragh [SC 36559 95023], which show how powerful were the floods from the land at this period. At the mouths of Glen Auldyn [SC 43643 94108] and Sulby Glen [SC 38409 93985] these land-stream deltas are separated from the northerly drift-gravel platforms by lower tracts of alluvium and peat-bog; but the fan from Glen Dhoo, at the western edge of the hollow, has coalesced along its northern margin with a low-level drift-gravel platform, and the two can only be distinguished by their composition (a dotted line on the published map marking approximately the limits of the slaty gravel). To this period of rapid erosion we may likewise assign the excavation of the craggy ravines seen here and there in the upper reaches of the valleys, where the swollen streams in clearing out the glacial debris from their pre-glacial channels have temporarily lost their way and bitten into the solid rock (p. 449).

In its earlier stage the waters of the lake which filled the northern depression seem to have stood at from 80 to 100 feet above present sea-level, though probably subject to occasional or seasonal fluctuations of wide extent. To this time must be assigned the construction of the great terrace at Jurby [SC 35571 98744] and those fringing the Bride Hills east of Andreas, by material derived in part directly from the waning ice-sheet, and in part from the erosion of the valley system of the Bride Hills [NX 44873 01021]. The discharge of the lake at this stage may have been round the north-eastern shoulder of the mountains at Ramsey, and thence southward through the depression of Port e Myllin [SC 47467 92735] and Port Mooar [SC 48793 90969] and along the south-eastern flank of the Island, which may explain the general though slight fall of the gravel flats towards the east. With the further retreat of the ice-sheet a pass would be opened northward through the drift-ridge at Lagagh Mooar [NX 40952 01544] between Knock-e-Dooney and Knock-e-nean, where the morainic chain is broken for a space; but whether there was ever any discharge in this direction can scarcely now be established, as the post glacial encroachment of the sea has carried away the tract which might have yielded the requisite evidence.

The lake was subsequently drained down to between 40 and 50 feet above present sea-level. At this level it remained for some time, carving out a well-defined margin in the incoherent drift-material south and east of Jurby and producing a lower terrace from the wash brought down into it by small streams whose trenches, now mainly dry, furrow the higher platform (p. 434). By this time the ice-front seems to have withdrawn beyond the limits of the Island, and the waters from the lake found a passage northward through the channel known as The Lhen, which forms the most striking feature in the topography of the northern plain (see map, Pl. I.).

The later history of this curious valley properly belongs to Post-glacial times, and should be left over for consideration in the next chapter; but the dividing line between Late-glacial and Post-glacial is so ill-defined that no excuse is needed for carrying on its record here. From its commencement at the northern margin of the Curragh to its mouth the valley is over four miles long, cutting in graceful curves through the high gravel-plateau and the morainic ridge till it reaches the sea at the north-western angle of the Island, three-quarters of a mile S.W. of Blue Point [NX 38329 01894]. It is clearly of fluviatile origin, with banks 30 to 50 feet high and a singularly wide and level floor, now mostly occupied by boggy alluvium, from 100 to 300 yards across. There is some reason to believe that it affords an example of reversed drainage, having probably been originally one of the valleys by which the waters from the ice-front were carried inwards to the lake-hollow, as the principal channels tributary to it on both banks trend southward, and at their confluence with it make an acute angle on the present down-stream side; and moreover its floor is three times wider in the southern or present up-stream than in the northern or present down-stream part of its course, although the character of the material in which it is excavated is the same throughout. Its south-flowing stream ceased, however, with the disappearance of the ice; and the abandoned bed served afterwards as the main channel of the northward-pouring waters of the lake-filled basin which on the opposite side was fed by the copious mountain-streams from Sulby Glen and Glen Dhoo. Lastly, as the climate became drier, these sustaining mountain-streams shrank until they were no longer able to surmount the barrier of their own old flood-gravels and were thereby dammed out of the hollow and diverted, the Sulby River into an independent eastern and the Glen Dhoo stream into an independent western course to the sea. Thus once more did the Lhen lose its river; and its broad channel became a peat-bog until about 150 years ago, when an artificial trench was dug along it to carry off some of the lowland drainage.

Thus the whole history of the Curragh basin shows a continuity of land and fresh-water conditions from the Glacial Period to the present time.

In a little basin lying between the north-western flank of the mountains at Bishops Court [SC 32813 92459] and the drift-mounds of Orrisdale [SC 32501 93048], some of the phenomena of the Curragh are repeated on a smaller scale. At Kirk Michael [SC 31675 90729], about a mile farther south, there is a larger delta-platform of slaty gravel, lying around the mouth of Glen Wyllin, between 100 and 150 feet above sea-level, which has probably been likewise bounded by drift-mounds to the westward until broken into by the encroachment of the sea.

That these delta-gravels were deposited on land and not in the sea was clearly proved at this place. A well sunk in 1894 at a new house 50 yards south-east of Kirk Michael Railway-Station [SC 31577 90693], at an elevation of about 120 feet above O.D., passed through a seam of peaty material at a depth of 15 feet from the surface, overlain and underlain by the slaty gravel. Some of this peaty bed, sent to Mr. Jas. Bennie (of the Scottish Survey) for treatment, yielded, under his skilled manipulation, the remains of the little Arctic fresh-water crustacean *Lepidurus* (*Apus*) *glacialis,* which lives now in icy pools around the glaciers of Norway and Spitzbergen. This organism had previously been detected by Mr. Bennie in fresh-water deposits of Late-glacial age in three localities in Scotland, viz.: Hailes, Corstorphine, and Dronachy,<ref>See Annual Report of the Director-General of Geol. Survey for 1894, p.287; and J. Bennie, Annals of Scottish Nat. Science for Jan. 1895, p. 55.</ref> but had not hitherto been found so far south in the British Isles. Among other remains associated with this crustacean were the leaves and seeds of plants, including an Arctic willow (*Salix herbacea*) and an Arctic sedge.<ref>Ann. Rep. of the Geol. Survey for 1895, p. 13.</ref> I am indebted to my colleague, Mr. Clement Reid, for the following list, based on the material prepared by Mr. J. Bennie*:*

Fossils from neat and silt in nlatform-aravel near Kirk Michael Station.

Flowering Plants

Ranunculus aquatilis, *L.*

Viola (palustris?), *L.*

Potentilla Comarum, *Nestl.*

Hippuris vulgaris, *L.*

Menyanthes trifofiata, *L.*

Salix herbacea, *L*.

Potamogeton sp.

Eleocharis palustris, *R. Br.*

Carex alpina, *Sw*.<ref>Determined by Mr. C. B. Clarke.</ref>

Carex (glauca?)

Mosses.<ref>Determined by Mr. W. Mitten, who remarks, "nothing to denote difference of climate".</ref>

Philonotis fontana, *L.*

Hypnum cuspidatum, *L.*

Pogonatum alpinum? *L.*

Polytrichum juniperinum, *Willd.*

Grimonia sp.

Lepidurus (Apus) glacialis, *Kroeyer.*

Daphne.

Insect remains (undetermined).

Regarding, the conditions under which this bed was accumulated Mr. Reid notes "the peat is not lacustrine, but was evidently formed in a slack. Three of the plants (*Ranunculus aquatilis, Hippuris vulgaris,* and *Potamogeton*) though perhaps most often aquatic, have all bog varieties. The others point definitely to a spongy bog".

The same arctic freshwater fauna has since been found in a small hollow on the plateau of slaty gravel at the mouth of Glen Dhoo, bordering the western Curragh one mile east of Ballaugh [SC 34784 93490], at an altitude of 70 feet above sea level. At this place the generally plane surface of the gravel is broken by a group of nine or ten curious shallow depressions, the larger occupied by water-pools, the smaller dry, ranging from 20 yards or less to 150 yards in diameter. These pits have no outlet and are not connected with the surface-drainage. They apparently date back to the time of the deposition of the gravel, and may perhaps represent the melting out of buried masses of ice, in which case they might be considered small 'kettle-holes'; or they may only mark eddies where the stream-waters poured into the lake. Though not altogether confined to this one locality, they are nowhere else so clearly developed (see p. 438). Most of them contain more or less alluvium, and those which still hold water-pools must have been continuously in this condition since their formation. Their freshwater deposits may therefore range from Late-glacial times to the present day. Early in the nineteenth century large numbers of bones of Irish elk were obtained from marl-pits in these hollows 0.382); and with the object of investigating the conditions under which these remains occurred, a British Association Research Committee was appointed in 1896 to co-operate with a local committee which had previously been formed; and under their joint auspices excavations were made in the hollow known as Loughan Ruy, on the farm of Ballaterson, 950 yards E.N.E. of Ballaugh Church. The following extracts from the reports of this Committee give the results of the investigation:<ref>See Reports by the secretary, Mr. P. M. C. Kermode, in Reps. British Assoc. for 1897, p. 346, and for 1899, p. 376. The plants were determined and reported upon by Mr. C. Reid from material prepared by Mr. J. Bennie.</ref>

Section at Loughan-ruy, Ballaterson, Ballaugh.

	Thickness	
	Feet	**Inches**
A. Peat	1	6
B. Sand, yellow	1	0
C. Sandy silt, grey (with *Salix herbacea* and *Lepidurus* (*Apes*) *glacialis*)	2	6
D. Loamy peat	0	8
E. Gravel	1	0
F. Marl ('Chara Marl')	0	4
G Sharp sand and gravel	0	6 and more.
Depth excavated	7	6

The following species of plants and animals were obtained on washing samples of the deposits:

Bed A.

Ranunculus Flammula, *L.*

Potentilla Tormentilla, *L.*

Hydrocotyle vulgaria, *L.*

Potamogeton, sp.

Also caddis cases and eggs of insects.

The plants are all common Isle of Man species.

Bed C.

Ranunculus aquatilis, *L.*

Poterium officinale, *Hook.*

Salix herbacea, *L.*

Care; sp.

Schoenus?

Moss

Lepidurus (Apus) glacialis, *Kroey.*

Daphne (winter eggs).

Numerous leaves of the dwarf Arctic willow *Salix herbacea* and fragments of the Arctic crustacean *Lepidurus glacialis,* neither of them now living in the Isle of M an, point to climatic conditions considerably more severe than those now holding in the district.

Bed D.

Ranunculus aquatilis, *L.*

Ranunculus Flammula, *L.*

Ranunculus repens, *L.*

Littorella lacustris, *L.*

Potamogeton crispus, *L.*

Carex.

Chara.

Beetle (elytron).

The plants are widely distributed species still living in the Isle of Man. *Littorella* is usually northern.

Bed F.

Ranunculus aquatilis, *L.*

Ranunculus Flammula, *L.*

Ranunculus repens, *L.*

Littorella lacustris, *L.*

Empetrum nigrum, *L.*

Potamogeton natans, *L.*

Potamogeton *sp.*

Carex.

Chara, 2 sp.

Lepidurus glacialis, *Kroey.* (A single specimen.)

Insect remains.

This marl thus far has yielded nothing to indicate the climatic conditions except the single specimen of *Lepidurus glacialis* which, as Mr. Reid points out, may possibly have been introduced from the higher bed, where it is abundant. The absence of arboreal vegetation seems, however, to indicate a severe climate.

In a later exploration of the same site (described by Mr. Kermode in Rep. British Assoc. for 1900, p.349) a trench was cut in a deeper part of the basin, a few yards north-west of the section above described, and showed a considerable thickening of all the beds, besides yielding traces of the elk both in the silt and in the marl. The following is quoted from Mr. Kermode's report:

'In the peat [A], which extended from the surface to a depth of 3 feet, were several pieces of timber, the largest being about 15 inches diameter at the root': this bed rested upon silt [C], which extended to a further depth of 7 feet. It varied slightly in different parts, here more sandy, there more loamy, but was really all one bed, the bottom of which consisted chiefly of small flat water-worn stones. At a depth in this bed of 6 feet, that is to say, about 9 feet from the surface, was a layer of leaves about half an inch thick.

In this layer, on the south-east side of the trench, about 3 yards from its south-west end, was found a fragment of antler, thickly covered with the blue phosphate which appears to be confined to this leaf-deposit. All around it were minute decayed fragments of bone or antler.

Three or four yards away, at a depth of 10 feet from the surface, being about 3 inches from the white marl bed, but distinctly in the silt, was another fragment of antler: this was in the north west side of the trench, and about a yard from its south-west end.

The marl [F] was struck at a depth of 10 feet to 10 feet 3 inches; and at A point from 9 to 12 inches within it, that is to say about 11 feet below the present surface, there was still another antler fragment, some 3 yards further south-east than the last, in the south-west end of the trench. Immediately below this the marl was bluish black, exactly as it was round the head of the skeleton found near St. John's (Close-y-Garey). This darkened marl was from 9 to 10 inches thick, and extended over an arca from the southwest end of the trench of about 3 feet square. All through it were crumbs of decayed bones, doubtless Irish Elk.'

'The following paragraph was added to our last [1899] report after it was in type, and the bone in question exhibited at our Dover meeting, but by some accident it was omitted from the report as published, so we insert it here. 'At a depth of about nine feet below the surface at the bottom of the silt (Bed C of our first report), and just above the white Chara-marl, were found two fragments of bone, which were forwarded to our Chairman [Prof. W. Boyd Dawkins], who has identified one as the scapula of *Bos longifrons,* and in a letter to the Secretary adds: "This establishes the presence in the island of an animal which was domesticated and introduced into the British Isles in the Neolithic age. It proves that this deposit in which it occurs is not earlier than the Neolithic age".' [See foot-note.<ref>With regard to the last quoted paragraph, however, we may be permitted to state that it is doubtful whether the bone in question should be assigned to *Bos longifrons.* Mr. E. T. Newton, of the Palaeontological Department of the Survey, has examined the specimen since the report was written, and is of opinion that it more probably belongs to an immature individual of *Cervus giganteus;* and the presence of fragments of antlers in the same bed lends support to this opinion. At any rate the evidence is at present insufficient to justify the conclusion drawn by Prof. Dawkins as to the age of the deposit.</ref>]

In the above excavations only fragmentary relics of the Irish Elk were discovered; but the study of the old records leaves no doubt that the fine specimens previously obtained from this place were found in the Chara-marl, F, which was much thicker towards the middle of the hollow where the old pit was worked. In later researches carried on by the same Committee at another locality, as presently to be described, a good skeleton of the elk was unearthed. There has been much discussion respecting the age of the elk-bearing deposits in Ireland and their exact relation to the Glacial Period; and as the Irish sections appear to be closely analogous to those of the Isle of Man, the discovery of arctic remains in the above section, in a bed overlying that which yielded the elk, is of wide interest.

We may therefore profitably devote a few pages to the discussion of the previous records of the occurrence of *Cervus giganteus* in the Isle of Man, and to their comparison with the results of the recent investigations.

Cervus giganteus in the Isle of Man

Since the discovery of the first nearly complete skeleton of the Irish Elk in a marl-pit near Ballaugh early in the present century, the Isle of Man has been recognised in geological literature as one of the typical localities for the occurrence of this animal. Curiously enough this is the only Pleistocene vertebrate yet definitely proved to have existed in the Island, though a drifted fragment of elephant's tusk has been found at Jurby (p. 423) and another fragment supposed to be a cetacean rib is mentioned by Cumming<ref>Isle of Man, p. 360.</ref> as having been obtained from, the drift at Douglas, and there are doubtful records of the red deer and horse (p. 384) and of *Bos longifrons* (p. 377). The elk-remains have been found in four or five localities only, apparently always in the smaller boggy basins, and never in the broad Curragh although much draining and peat-cutting has been done there.

The earliest reference to these remains which has come under our notice is by J. Feltham in his "Tour through the Isle of Man", published in 1798, where he mentions (p. 205) that bones of " elks, or seghs", found near St. John's, were shown to him by Rev. Mr. Corlett. "The horns measure 9 feet from tip to tip, and from other bones, conjecture is warranted to suppose the animal must have been 17 feet high". Woods (1811) also records this specimen (p. 13). It must have been an earlier find than the first one mentioned by Mr. P. M. C. Kermode in his recent account of the local history of the subject, which is of a head and antlers "found in a marl pit in the parish of Ballaugh in June, 1815". The latter discovery may be the one mentioned by Train in his "History of the Isle of Man" (1845), who stated, probably incorrectly, however, that the specimen was from " the extensive morass called the Curragh". "Another discovery—the date not recorded—was that of a skeleton found in a marl pit on Ballaterson Mooar, Ballaugh"<ref>P. M. C. Kermode. Yn Lioar Manninagh, vol. iii., pt. viii., p. 395.</ref>, the head and antlers of which are now in King William's College at Castletown.

The first scientific reference to these elk-remains appeared in a letter on Phosphate of Iron, by J. Murray, dated May 19th, 1818, which was published in "Annals of Philosophy " for that year (vol. xii., p. 147). Mr. Murray described the occurrence of bones of elk in a bed of shell-marl overlain by peat on the farm of 'Ballatesin', Ballaugh, and of a blue earthy mineral, supposed to be phosphate of iron, on the horns and in the peat-earth. He also stated that chips of flint were found in the marl, a circumstance not mentioned by any later observer.

The more celebrated discovery was made in the adjacent hollow of Loughan Ruy [SC 34690 94536]? in 1819, of which Henslow gives the following account<ref>Trans. Geol. Soc., vol. v. (1821), p. 502, footnote. Short notices of this discovery were also given anonymously in the Edinburgh Philosophical Journal for 1821, vol. v., p. 227, and. for 1823, vol. viii., p. 198.</ref>: "Whilst I was in the island, in August, 1819, two heads with the branches and a vast number of bones were dug up in the finest preservation. An ingenious blacksmith in the neighbourhood, taking the skeleton of a horse for his model, has contrived to put together these bones with great accuracy, and form a skeleton in which the only parts wanting are the 'half of one hoof and the end bones of the tail. It has a most magnificent appearance, stands 6 feet 6 inches to the top of the back, and 13 feet to the top of the horns". The ingenious blacksmith' seems however to have used his equine model rather freely, making up from it the parts which were wanting in the elk skeleton.<ref>Kermode, op. cit., p. 397.</ref>

When completed, this specimen was exhibited for payment by Kewish on behalf of himself and James Taubman, the tenant of the field, but was then claimed by the Duke of Athol as Lord of the Manor; and, after a law suit, an agreement was made by which the elk came into the Duke's possession, and was by him presented to the Museum of the University of Edinburgh.<ref>Kermode, op. cit., p. 398, and Yn Lioar, vol. i., No. 1, pp. 23–4. 2 </ref> This skeleton was figured by Cuvier in his "Ossemens Fossiles", (tom. iv., p1. 8, and p. 82), from an engraving transmitted to him by Prof. Jamieson.<ref>Cumming, Isle of Man, p. 214.</ref> Regarding this figure Dr. Traquair notes (in a letter to Mr. Kermode quoted in a footnote in Yn Lioar Manninagh, vol. iii., pl. viii., p. 397), "I found when I took office in the Museum that the pelvis in the skeleton was that of a common horse, which I accordingly had replaced by the pelvis of a real Irish elk from Ireland… . (Cuvier's) figure represents the skeleton exactly as it was before I had it altered by replacing the horse pelvis with one of the Irish elk, and giving a proper curve to the vertebral column, which was absolutely straight in the dorsal and lumbar regions".

Henslow gave a description of the section in which the bones were found, which may be tabulated as follows:

At the top; 'turf and vegetating matter'	1 or 2 feet.
'A kind of peat, composed of rotten leaves and 1 small branches closely matted together, mixed with sprinkles of sand, and containing a vast number of the exuviae of beetles, bees and their nests, crushed together with seed-vessels, rotten, but having their external coating well preserved…. In general the hard wings are the only parts of the beetles which are preserved, and these are in appearance as fresh as on a living insect. Dr. Leach was enabled to identify a few with species at present existing in England.'	About 1½ feet.
'A bed of sand of a light colour'	6 feet.
The marl… white or greyish, and the fracture resembles that of a highly decomposed peat, converted to a loose earthy calcareous substance, and through it are dispersed in every direction the traces of small branches and roots which partake of the character of the mass. When dry it does not become indurated, but is easily reduced to a powder between the fingers. Native phosphate of iron, in an earthy and pulverulent state, is sometimes found in contact with the bones.'	No thickness stated.

The section was again described a few years later by H. R. Oswald, in a letter dated May 29th, 1824, addressed to the Bishop of the Island, which was printed as an appendix to a paper on the discovery of the elk by Dr. S. Hibbert in the "Edinburgh Journal of Science", vol. iii. (1825), p. 28. Oswald gives a rough diagrammatic section across the basin to show the thinning away of the deposits on both sides, of which the following is a copy. The differences between this section and that of Henslow on the one hand, and that exposed in the recent excavation by the British Association Committee on the other, are readily explained by this diagram.

Oswald seems to have been the only observer who had the opportunity to examine the thicker portion of the deposits. He states: "The superficial stratum is peat of excellent quality, light and fibrous, and containing a few trees of bog-timber. It is 6 feet thick in the middle part of the morass, but passes out thin, into a black peaty turf towards the margin". [Compare Bed A. of section on p. 375] "Between it and the marl, a layer of fine bluish-white earthy sand is interposed, from 2 to 3 feet in thickness". [Compare Beds B, C, D of section on page 375] "The marl lies at a depth of from 7 to 10 feet at the middle parts of the pit, but, like the peat, becomes thin at the margin, and passes out when within a foot and a half of the black till which forms the surface crust. Nearly one-half of this deposit has been worked during dry seasons, but I have-never seen the pit completely drained of its water. According to the calculation of the workmen, the bed of marl in the middle parts of it is from 11 to 14 feet thick, independent of the layers of turf and sand which I have noticed. When the workmen penetrate at any time through the marl the pit is suddenly inundated by water springing up from below, from the sand and gravel which form the subsoil. This marl is highly fibrous, and somewhat laminar in its structure, and when dry is as light and nearly as white as chalk. The shells are delineated white upon a darker ground, and are seen by separating the fibrous layers, but are seldom, if ever, found in their original state. I question much whether shells exist in all parts of the basin, certainly not at its margin". [From this it appears that the conspicuous absence of shells in the marl of the recently-opened section, and from that described by Henslow, is characteristic only of the margin of the hollow.] "In this basin vast quantities of bones of the large species of elk are found. The workmen have constantly met with them since the first opening of the pit, and therefore conclude that an incalculable number still remains. These bones occur at all depths of the marl. At and towards the surface of it the bones, like the shells, are merely delineations of what they once were, with little or no difference in consistence from the mass in which they are contained, and therefore will not bear handling; in the bed of sand above the marl all vestiges of them disappear. The deeper these elks are in the marl the more fresh and perfect they seem, and near the bottom of the bed complete heads are found. They sometimes, though very seldom, are observed imbedded partially in the gravel below. Those in the marl are generally charged with calcareous matter, yet I have frequently seen the thick part of the stem of the horns so unchanged as to admit of being worked. *The bog-timber is in this instance solely confined to the peat on the surface".* [Italics not the author's.]

Oswald next describes the conditions under which the Edinburgh specimen was obtained and put together. He then notices other " basins of white marl in which no shells now appear. These lie lower down the plain, nearer the deposits of common clay-marl " [glacial clays]. "In one of these basins, distant upwards of a quarter of a mile from that described " [probably that at Ballaterson Mooar, or Dollagh Mooar [SC 34704 94569] of Ordnance map, alluded to by Mr. Kermode], " the marl lies at a depth of from 4 to 6 feet only, being covered by a hard, sandy, blackish earth. The field in which it is situated is crusted over with wet soil. Before the surface of this basin was broken up, it had a thin layer of turf upon the middle or deepest part of it, but there is none now to be seen. Between the alluvial covering and the marl there is a bed of dark turfy, fibrous earth, from 2 to 4 inches thick, each horizontal layer showing different degrees of shade. The marl is darkest near the top, continuing thus to a depth of 18 inches. In this upper part of the marl slight veins or rents occur. This marl is also fibrous, and somewhat slaty, and exhibits between its layers white delineations like grass. It likewise contains bones, but they are few in number, and much decayed; of these are pieces of ribs, condyles of- bones, and stems of large horns, etc. This deposit of marl, though near the surface, and in a field almost level, is basin shaped, like that last described, varying in depth from 7 to 10 feet in the middle, and passing out to the thinness of a few inches at the margin".

The basin last mentioned is probably that at the margin of which Dr. Hibbert saw a section which he describes<ref>Edinburgh Journal of Science, vol. iii. (1825), p. 27.</ref> as showing, at the base, 3 feet of marl mixed with sand and small pebbles of clay-slate and quartz; covered by 1 foot of the same substance mixed with more sand and containing some little vegetable matter; above which was 1 foot of sand mixed with white quartz pebbles; then 6 inches of drift peat, 6 inches of black mould, and over the whole a thinner coat of drift peat.

Dr. Hibbert illustrated his paper by a figure and measurements of a skull and antlers at that time in the possession of Dr. Burman of Douglas (op. cit., pl. II., fig. 1); this specimen, Mr. Kermode thinks, may be the specimen afterwards acquired by J. F. Campbell of Islay; but the measurement of the Islay antlers seems to indicate a smaller example than that figured by Hibbert.<ref>Yn Lioar Manninagh op. cit., p. 398.</ref>

In another communication on the subject in the same volume (p. 129) Dr. Hibbert suggests, on the authority of Dr. Burman, that a second species, " apparently of the present race of elks which inhabit the north of Europe", occurred in the marl of Ballaugh; but the evidence is altogether insufficient, since the antler figured (Pl. II., fig. 3) in support of his view was not the actual horn found at Ballaugh " but that of a recent animal of the same kind from Norway", in Dr. Burman's possession, which was thought exactly to resemble it, the discoverer of the fossil not being willing to part with it.

Cumming, who found the original sections no longer accessible, was at first of opinion that the elk belonged to the later portion of Post-glacial times,<ref>Quart. Journ. Geol. oc., vol. ii. (1846), p. 344.</ref> but afterwards changed his views, stating that " on closer examination I find good reason for concluding that the white marl [of Ballaugh] is… perhaps more ancient than the Jurby marl, though this is apparently an alluvium older than the forests of which the remains are found in the Curragh".<ref>"Isle of Man" (1848), p. 216, foot-note.</ref>

Edward Forbes (who was a Manxman by birth, and spent part of his youth at Ballaugh), in discussing the elk in his classical memoir "On the Geological Relations of the Existing Fauna and Flora of the British Isles", expressly states that the basins of fresh-water marl in which the bones were found were " distinctly, both in the Isle of Man and Ireland, overlaid by the peat, with its ancient included forests", and he illustrated this arrangement by a diagram representing the Ballaugh section.<ref>Memoirs of the Geological Survey, vol. i. (1846), p. 394.</ref>

Thus these old records show clearly that none of the Ballaugh elk-remains were found in the forest-peat, but all in the lower marl, which was separated from the peat by a bed of sand. Equally clear is it that this sand represents the horizon of the recently discovered Arctic remains of the Loughan Ruy section given on p. 375, as will be recognised on comparing this section with those described by Henslow (p. 379) and Oswald (p. 380).

These Ballaugh hollows are in a porous substratum of gravel, but are close to the margin of the Curragh, and would all be filled with percolating water when that area was a fresh-water lake. Further investigation is required to decide whether the accumulation of marl was stopped in Loughan Ruy by the gradual silting up of the pool, or whether, as has been suggested, it may have ceased upon a change of climatic conditions.<ref>See Report of Irish Elk Committee, British Assoc. Rep. for 1897, p. 347.</ref> The sand and gravel overlying the marl were evidently washed in from the margins; and probably in part represent the shore deposits of the pool synchronous with the marl and peat of the middle of basin.

We will now turn to another well-known locality where the elk has been found in the Island. Hibbert (op. cit., p. 17) mentioned that "about a mile to the north-west of the Tynwald Hill [SC 27628 81900], at a short distance from the Peel [Neb] River, there is a low marshy piece of ground from which large quantities of shell marl have been procured,… and in this marl numerous bones of the elk have been observed in an imbedded state… . The shell marl… is of a milk-white colour, also, when dried, very light and porous. All the shelly portions are in such a comminuted state, and so mixed up with clay and sand, that I could not find a specimen in which the organic structure of the animals to which the marl owes its origin was preserved". [Later researches have shown this to be a charamarl.] "The bones of the elk are said to be found about 6 to 10 feet deep in this marl, and mixed along with them, particularly in the more superficial strata, are the remains of numerous aquatic plants, as of willows, ferns, reeds, etc., indicative of the ancient marshes which succeeded to the levelling of the land, and to which the elks appear to have resorted. In the upper beds the calcareous matter gradually lessens

A stratum of sand, the pure and nearly unmixed debris of the neighbouring hills, is superjacent to the shell-marl, while a comparatively modern bed of peat covers the whole".

Cumming also refers to this locality;<ref>"Isle of Man", p. 182.</ref> and Mr. Kermode had collected information as to specimens found here.<ref>Yn Lioar", op. cit. p. 399.</ref> It was therefore selected as a site for further exploration by the British Association Committee, with the result that a large and nearly perfect skeleton was exhumed in 1897. Through the energy of Mr. Kermode this fine specimen has been carefully restored and mounted, and is now preserved in Castle Rushen at Castletown.

The conditions under which it occurred resemble in most respects those at Ballaugh. An uneven platform of sandy and gravelly glacial deposits, extending inland from Peel to the foot of the mountains (pp. 457–8), is broken towards its southern margin by several little basins. From these basins small valleys lead southward to the broad hollow drained by the Neb between St. John's and Glenfaba, which has wide gravel terraces on both sides, and appears to have been occupied by a lake in late-glacial times (p. 410). The site of the excavation was at the southwestern side of the Close-y-Garey basin [SC 26890 82585], on the eastern side of the railway line 400 yards south-west of the farmstead of Breck-y-Broom (6-inch Sh. 9). As reference to the geological one-inch map will show, this little irregular basin, about 200 yards long by 40 to 100 yards wide, is only separated from another somewhat larger depression to the eastward by an esker-like ridge of sand and gravel from 50 to 100 yards wide; and the two are connected at the southern end by an old drainage channel, which is prolonged into a little valley opening southward to the upper gravel platform of the Neb valley near Ballaleece, at an elevation of about 105 feet above O.D. (p. 458). The following passages describing the results of the excavation are quoted (not in their original order) from Mr. Kermode's Report<ref>British Assoc. Rep. for 1898 (Bristol), pp. 548–551. The report contains full measurements of all the bones of the skeleton by Professor W. Boyd Dawkins.</ref>:

"About sixty years ago the bog had been worked for marl, and the present well-defined banks mark out a rectangular hollow some 50 yards square and about 3 feet below the surrounding surface. Across one corner of this a trench was dug to carry off the water, and the operations of the Committee i.vere confined to a triangular area on the west side of the trench, measuring about 15 yards east and west, by about 30 yards north and south… .

The result of all the excavations, allowing for the disturbed state of the ground, showed the following beds:

	Feet	**inches**
A. Disturbed soil and peat, an average of about	3	0

B. In one place a blue clay or silt was observed resting on the white marl.		
C. White marl containing the Elk remains	6	6
D. Blue marl<ref>"This was noticed below the skeleton, and may have been discoloured by the decay of the body".</ref>	1	0
E. Red sand with gravel	0	3
F. Brown clay} ?Glacial drift	0	3
G. Sand and gravel } ?Glacial drift	0	3
H. Clay } ?Glacial drift	4	0

As stated above, the whole surface had been lowered about 3 feet in digging for marl; the peat had for the most part been removed, and a great deal of the marl also; indeed, we were fortunate in finding this one spot in which the marl itself had not been disturbed… .

The finding of detached bones shows that other individuals had perished here In association with these were remains of horse, represented by a radius and lower jaws of two individuals. Though the ground had been disturbed the horse bones probably belonged to the same age as the elk. A fragment of a metatarsal, met with in digging the trench, had an artificial perforation.

The skeleton lay in white marl at a depth of about 9 feet from the present surface, on its right side, the legs drawn up to the body, the head towards the margin of the ancient pool, now a morass, which lies in a hollow in the glacial drifts.

From the position of the bones the animal appeared to have died where it was found, not to have been washed down by floods… .

The bones were nearly all in juxtaposition and, excepting the ribs and pelvic bones and one shoulder-blade in a very fair state of preservation. The antlers were nearly complete; the beams, however, are represented by fragments, the skull also is fragmentary.

The left antler is the larger; it measures across the palm 15 inches, allowing for a piece of the front edge which has decayed away; the right measures 13 inches. With the tines, most of which dropped off on lifting from the marl,, they are respectively 56½ inches and 53 inches long, and the beam would have been about 10 inches more. They show six points, besides the brow-tines which had fallen off, the portion of the beam to which they were attached having decayed away.

The palm of the left antler lay over the lumbar vertebrae, and the right over the forequarters. The upper jaw teeth were preserved on both sides, and those of the left lower jaw were embedded in the *ramus.* A fragment of the right symphysis was also present, and there were various fragments of a skull which had been broken up before the discovery. Death had occurred in its full prime, as shown by the perfection of the teeth and the dimensions of the antlers.

Among the bones, but not of this individual, was one which had been perforated, probably by the point of an antler of another elk in one of their usual fights. It was fractured as well as perforated, and had been healed…

Samples of the marl and other beds were forwarded to Mr. James Bennie, of Edinburgh, who again most kindly undertook the laborious task of washing and sifting the material. The organic remains thus obtained were examined by Mr. Clement Reid, who has determined the following plants:

From Peat B [A?]

Ranunculus Flammula, *L.*

Viola palustris, *L.*

Rubus fruticosus, *L.* (very small)

Potentilla Tormentilla, *Neck.*

Potentilla Comarum, *Nesl.*

Carduus crispus, *L.*

Menyanthes trifoliata

Empetrum nigrum, *L*

Potamogeton, sp.

Carex, 4 sp.

Also beetles, 3 sp., and caddis cases.

From Marl C.

Ranunculus repens, *L.*

Viola palustris, *L.*

Potentilla Comarum, *Nestl.*

Myriophyllum spicatum, *L.*

Rumex obtusifolius, *L.*

Empetrum nigrum, *L.*

Potamogeton.

Carex, 4 sp.

Chara.

Umbelliferous plant (unripe).

From Red Sand E.

Plant remains, not determined.

From Bed F.

Betula alba, *L.*

Potamogeton.

Carex.

Bracts of sedge. Leaves. (7)

Mr. R. Okell examined the White Marl for Diatoms, but found no trace. There are no freshwater shells in it".

Mr. Reid, in reproducing the above lists in his recent work on "The Origin of the British Flora"<ref>Dulau and Co., London (8vo.): 1899.</ref>, remarks: "B. is Recent or Neolithic, C. and F. [E in Mr. Reid's book] correspond with the marl at Ballaugh, and are classed provisionally as Late Glacial".

It will be noticed that the 'stratum of sand' mentioned by Dr. Hibbert as occurring between the marl and the peat was not found in the recent excavation, unless represented by the patch of the blue clay or silt, B., of which, unfortunately, no specimen was preserved. If its absence be not accounted for by the disturbed condition of the upper portion of the section, the bed may possibly have been originally limited to one part of the basin. It was at a corresponding horizon in the Ballaugh section that the Arctic remains were found; so that if the bed could have been examined, it is possible that similar remains might have been found at Close-y-Garey [SC 26890 82585], since the general similarity between the sections is so close.

Of the other localities in which elk-remains have been found in the Island we have little definite information. Cumming, writing in 1861 ("Guide Book", p. 112), stated that "in the alluvial gravel in the Valley of Glen Mooar [near St. Johns] [SC 27792 82315]? were discovered, 30 years ago, some fine specimens of the *Cervus niegaceros*", but gives no further details, and may possibly refer to the Close-y-Garey finds. He also mentioned ("Isle of Man", p. 56) that some remains of the animal had been turned up in the south, near Castletown, from a whitish marl underneath a patch of turfy ground in a field in the Silverburn valley opposite Creggans; and again (Quart. Journ. Geol. Soc., vol. ii., p. 345) that he obtained the right pelvis of a *Megaceros* from blue alluvial marl on the Balladoole Estate, at a depth of six feet, the marl being covered by 2 feet of "marine sand". In the same neighbourhood, it is recorded by Mr. J. M. Jeffcott<ref>Lioar Manninagh, vol. i, pt. 2, p. 56.</ref> that fragments of an antler of the elk were found in the peat on the beach at Strandhall [SC 23600 68752], probably the specimen now in the possession of Mr. J. M. Gawne (see p. 414); and Dr. Clague, of Castletown, possesses an antler from Kentraugh [SC 22644 69054].<ref>Kermode do. vol. iii., p. 400.</ref> In the north of the Island, at Ballalheaney [SC 42715 98438] near Andreas, an antler was dug up from a bed of peat covered with sandy wash, at a depth of 4 feet (p. 436).

In reviewing the above evidence, we find that wherever the details of the sections are known, the elk-remains have keen obtained from the lowermost portion of the alluvial deposits, and from beds which contain the first indications of organic life after the emergence of the land froth under the ice-sheet In this respect the Manx evidence is in full accord with what is known of the principal occurrences of the elk in Ireland. Indeed the similarity of the Loughan-ruy and Close-y-Garey [SC 26890 82585] basins to the best-known Irish sites is remarkably close, both in topographical situation and in the general sequence of the deposits; as will be seen on comparing the sections given above with that of the Balleybetagh Bog, 9 miles south-east of Dublin, described by Mr. W. Williams <ref>"On the occurrence of *Megaceros Hibernicus* in the ancient lacustrine deposits in Ireland", Geol. Mag. (new ser.), dec. ii., vol. viii. (1881), pp. 354–363. </ref> as a typical Irish locality; or with the generalised Irish section reproduced in a recent number of the *Geological Magazine*<ref>Geol. Mag., n s, dec iv., vol v. (1898), p. 133 (review of "British Deer and their Horns" by J. G. Millais).</ref> from Mr. J. G. Millais' book on "British Deer". In Ireland as in the Isle of Man, the elk-remains are embedded in marl at the bottom of hollows in the drift; the marl is covered by clayey, silty, or gravelly wash; and this again by peat, sometimes containing trees. Moreover, in both districts the marl is a *Chara*-marl; and in regard to this, Mr. C. Reid has made the following apposite suggestion: "Those familiar with the pools containing *Chara* will be well aware of the appearance of shallowness and of a solid floor, which is so deceptive. The *Chara* and *Potamogeton* may grow from a depth of several feet, but they often appear to form a carpet of bright green turf a few inches under the surface of the clear water. Any animal treading on this turf would immediately plunge headforemost into the water, and the wide-branching antlers of *Cervus megaceros* would become entangled amid the *Chara* stems, and still tougher Pondweeds, so that the animal would have scarcely a chance of escape".<ref>"The origin of Megaceros-marl", "Irish Naturalist", May, 1895.</ref>

The plant-remains found in the Irish marl are most, if not all, species which occur also in the Manx deposits; Mr. Reid remarks that they are "all of wide range, and throw no light on the climatic conditions that held during the *Megaceros* period". Arctic remains corresponding to those of the Isle of Man have not yet been found in Ireland, probably, as Mr. Bennie suggests,<ref>"Irish Naturalist", April, 1894.</ref> because proper search has still to be made. Mr. Williams is of opinion that the elk-marls were accumulated in Ireland during a mild and genial interlude which followed the cold wet climate of the great thaw, and was succeeded by a return of glacial conditions, " the cold of this period having probably exterminated the Megaceros in Ireland."<ref>Op. cit., p. 362.</ref> In the last (third) edition of his "Great Ice Age", Prof.

James Geikie to some extent endorses this view, and after discussing the evidence concludes,—"it seems to me probable that the Megaceros-beds may be of interglacial age—that, in short, they may occupy the horizon of the interglacial deposits of the Baltic coast-lands". <ref>"Great The Age", 3rd ed., p. 417.</ref> Mr. Reid in his report on the plant-remains from Ballaugh has the following pertinent remark: "It is important to ascertain whether there is any evidence in the Isle of Man of a mild period after the melting of the ice, and before the deposition of the bed with Arctic willows. If the shell-marl (F) containing the *Megaceros* remains was formed during a mild interval, the complete disappearance of the Irish elk, so difficult to understand, may be due to cold or to scarcity of food during a less genial period. This point has never been cleared up in Ireland, notwithstanding the numerous remains of the Irish elk that have there been obtained".<ref>British Assoc. Rep. for 1897 (Toronto), p. 348.</ref>

In view of such evidence as that recently obtained at Hoxne and other places<ref>See C. Reid. "Rep. British Assoc. for 1896, pp. 400–415; also "Origin of the British Flora". Lond. 1899.</ref> for wide-reaching alternations of climate since the departure of the last great ice-sheet, it would be rash to deny the possibility of the *Megaceros*-marl being the product of a genial interval between two cold periods; but so far as the Manx evidence alone is concerned, there appears to be no necessity for the theory of alternating climates, as all the known facts seem consistent with a regular amelioration of temperature, such as might accompany the gradual disappearance of an ice-sheet.

For reasons which are discussed on a subsequent page (p. 396) it is probable that a great amelioration of climate had come about before the Island was uncovered by the waning glacier, and that the conditions were favourable to the growth even of comparatively temperate-climate plants as soon as ever these could find footing on the emerging land-surface.

Hence by the time that the ice had sunk to the foot of the hills the land was probably clad with verdure, and offered tempting pasturage for the great elk, just as the Barren Lands of Northern Canada and the tundras of Northern Siberia, under somewhat similar conditions, at present constitute the favourite feeding-ground of its living analogues. The flora, as Mr. Reid notes, consisting almost entirely of a few common species of wide range, is exactly the vegetation which we should look for to be first established in such an area; and its dispersal could scarcely fail to be assisted by hairy migratory animals like the elk. If there had been forest growth at the time we should not have failed to find trace of it in the marl, where its absence is conspicuous. Indeed, one can scarcely imagine the elk to have originally developed such wide-spreading antlers in a forested country, though the species, elsewhere originated, might manage to survive for a time among forests. The little Arctic crustacean and the Arctic plants were probably contemporaneous with the elk, and are indications of the proximity of the ice-margin when the animal first reached the area. It is true that only a single example of the crustacean and none of the Arctic plants have yet been found in the marl with the elk; but this is probably an accident of preservation, as seeds only have endured in this material, and the Arctic willow is represented by leaves alone in the overlying bed. The relationship of the sandy beds to the marl in taese little basins seems to be that of shore deposits to deeper water sediments, their accumulation going on contemporaneously, but the former gradually overspreading the latter as the pond contracted and grew shallow.

It seems reasonable to believe, as elsewhere suggested (pp. 397–8), that the elk, possessing the instincts of its living representatives, may have reached the Island, and Ireland also, across ice-fields when a remnant of the great glacier still occupied the sea-basin; and it may never have been a permanent resident, but only a migratory visitor. The animal may have lingered on into the age of forests, when the principal peat bogs of the Island were accumulated; but for this there is at present no positive evidence.

Our enquiry, therefore, leads us to the conclusion that *Cervus giganteus* in the Isle of Man must be regarded either as a Late-glacial or early Post-glacial inhabitant according to the limits, in any case arbitrary, which we may assign to the Glacial Period.

Theoretical conclusions and review

It remains now to combine the inferences drawn from the facts into a short history of the probable course of events in thispart of the Irish Sea basin from the beginning of the Glacial Period to its close.

The fundamental deduction, that an ice-sheet must have filled the depression surrounding the Island, is merely a re-statement of the conclusion forced upon many previous workers, including R. H. Tiddeman,<ref>Quart. Journ. Geol. Soc., vol. xxviii., p. 488.</ref> J. G. Goodchild,<ref>Quart. Journ. Geol. Soc, vol. xxxi., p. 56; also "Ice work in Edenside", Trans. Cumberland Assoc., No. 12 (1886–7), p. 111; and other papers.</ref> and J. Geikie,<ref>"Great Ice Age", map, pl. 1, p. 69 *et passim.*</ref> by their studies on the mainland; and upon J. Horne,<ref>Trans. Edinburgh Geol. Soc., vol. ii., pt. iii.</ref> the late H. Carvill-Lewis,<ref>"Glacial Geology of Great Britain and Ireland" (1894. Longinsas London and New York), p. 359.</ref> and P. F. Kendall,<ref>Yn Lioar Manninagh, vol. i., p. 397.</ref> by their personal examination of the Island. It is on subsidiary points as to the conditions during development and disappearance, and as to the direction of flow of this ice-sheet that the present investigation has thrown fresh light.

Of Pre-glacial conditions in the Island we gather faint glimpses only, from topographical evidence and from the shells in the drift. No deposits of this age have anywhere been found below the glacial beds, not even in the deep borings of the north, where the base of the drifts was far below sea-level. The presence of so much marine detritus in the drifts and the absence of any land-remains seem to indicate that the Island was surrounded by the sea right up to the advent of glacial conditions. The broad platform of erosion at the foot of the Pre-glacial cliff-line shows that this sea must for a long time have stood at approximately the present level; and afterwards have sunk somewhat lower, since this platform has in places been trenched by streams. From the character of the shells derived from this sea-bottom and incorporated in the drift, the marine conditions may date back to Late Pliocene times, but not earlier; their mixed facies and the presence of northern species betoken a changing climate; and the far-travelled pebbles coated with marine organisms indicate the presence of floating ice before the marine conditions terminated. Whether after being supplanted by the ice-sheet, the sea ever recovered its basin until the close of the Glacial episode, is doubtful. The only evidence in favour of its having done so is the presence of the belt of marine material among drift of the usual character in the deeper part of No. 6 Boring [NX 46712 04835], at over 200 feet below sea-level; and as we have already seen, this material may possibly represent strips of the old sea-bottom not redistributed piecemeal like the rest, but displaced *en masse* by the ice-sheet. The juxtaposition of a band in which the comparatively deep-water *Rhynehonella psittacea* is the most abundant shell with another in which the shallow-water *Mytilus edulis* plays that part, is scarcely compatible with original deposition; and the indefinite character of the evidence in the other borings is likewise unfavourable to the occurrence of a true marine horizon in this part of the drift.

Even if the shell-bed be in place it need not denote more than a minor variation of climate during the growth of the ice-sheet, which changed its general advance over the sea-bed to a temporary retreat. Under such circumstances, strips of sea bottom with northern shells might become locally interspersed with the basal moraine. But one thing seems clear, that nowhere in the Manx drifts do we find evidence for an Interglacial Period in the sense in which that term is usually understood, *i.e.,* of a warm period during which a previously existing ice-sheet entirely disappeared, afterwards followed by the growth of a new ice-sheet. All the known facts support Mr. Kendall's conclusion that in this area " the glacial period was one and indivisible, and that any withdrawal of the ice and re-advance over a spot, was merely such an oscillation as is observable in the case of the glaciers of the Alps, and of other places".<ref>Op. cit, p. 424.</ref>

The state of the climate in this region at the beginning of the Glacial Period was undoubtedly such that the snowfall accumulated from year to year, at the comparatively low altitude of the hills of the Island and of the uplands of the mainlands surrounding the Irish Sea, so that the valleys became filled with glaciers. Along the shores an ice-foot probably formed in the winter and broke away in the summer into floes, which distributed their burden of rock-fragments broadcast over the sea-floor. This seems to be the explanation of the curiously wide dispersal of the fragments from Ailsa Craig, which have been recognised in the drift almost all round the northern part of the Irish sea-basin, in Ireland and Wales, as well as in the Isle of Man.<ref>Kendall, op. cit, p. 407; J. Lomas, British Assoc. Rep., 1892, p. 707; G. A. J. Cole, "Nature", vol. xlvii., p. 464. </ref> The sea-girt precipices of splintery rock in Ailsa could not fail to cast off a load upon an ice-foot below; and thus these fragments became strewn over the sea-floor almost as widely as the shells, and were subsequently carried by the ice-sheet into nearly every district to the southward where the shells were carried.

Gradually the permanent snow-line crept downward on the bills, and the glaciers crept outward into the shallow sea, perhaps in the deeper channel partly afloat like the great glaciers of some of the Greenland fiords; until at length the open water-surface was obliterated, and an icy bridge stretched from Britain to Ireland, with the Isle of Man as its central pier.

Then ensued a set of conditions to which I would especially call attention, as I think they have hitherto been almost overlooked by students of the subject. Up to this time the hill-ranges surrounding the basin had played the chief part in the production of the land-ice; and had formed independent centres of ice-drainage, as proved by the dispersal of their boulders, corresponding in the main to their previous systems of water-drainage. But when once the glaciers had overspread the enclosed sea-basin, they would constitute an ice-sheet which with the then-existing climate could grow independently, even at a comparatively low elevation, from the accumulation of permanent snow upon its own surface. And as the flow from the hills would also continue, without any, compensating discharge from the low ground, the ice would rapidly increase in depth in the basin, like water under similar circumstances, without proportionate increase on the high ground.

In any irregular land-area undergoing glaciation there must be this general tendency towards the obliteration of surface-relief. In the present case the ice-plateau in the basin rose higher and higher, from the above causes, until the relative importance of the hills as centres of glacial flow was lost, and the direction of movement of the mass was determined by independent factors and i particularly by the position of the area of maximum thickness n the ice-sheet. In the earlier stages the snowfall, like the present rainfall, was no doubt heaviest on the hills; but as the ice-sheet increased in elevation, its surface must soon have lain high enough to rob such moderate heights as those of the Lake District or the Southern Uplands of their advantage, and to arrest a precipitation at least as great as their own, and over a much wider area.

Moreover, as the principal moisture-laden winds, then as now, must have come in from the Atlantic, every increase in the elevation of this western ice-plateau would tend more and more to intercept and lessen the downfall upon the hills to the eastward, and correspondingly to increase its own rate of growth. And the greater its altitude the less would be the thawing of its surface during summer. Hence, given the initial circumstances, the growth of an ice-sheet in such an area must proceed at an increasingly rapid rate, until its dimensions bring retarding factors into play, or until the secular conditions become unfavourable.

The growth of the West-British ice-sheet went on until, in the vicinity of the Isle of Man, as shown by the high-level strife, its surface was, at least, more than 2,000 feet above present sea-level, while its base was from 400 to 800 feet below that datum-line in the deeper part of the basin to the north-west-wadr of the Island. With a total thickness, as thus indicated of not less than 3,000 feet, this sheet had, as we know, attained great lateral extent, reaching at this time south-westward to the Irish margin of the basin, and southward and south-eastward to North Wales and Lancashire. Hence, as already pointed out, the drift-phenomena of the Island are of especial importance to the glacial geologist in showing conditions in the heart of the sheet, which explain many difficulties met with in the marginal districts.

Let us consider, for example, the direction of ice-flow over the Island in relation with its direction on the mainlands, as shown on the sketch-map, (Figure 103)<ref>The striae on this map are taken chiefly from the published maps of the Geological Survey, with a few from other published sources, supplemented in regard to Anglesea by information kindly given by my friend, Mr. E. Greenly.</ref> We obtain, I think, clear proof that, at the maximum stage of the West-British ice-sheet, its principal centre of dispersal lay, not among the hills, but over an area in the basin somewhere in the region of the North Channel, where presumably the ice had accumulated to its greatest altitude. The divergence of the Clyde ice westward over Cantyre; of the Galloway ice eastward up the Solway Firth; of the Lake District ice south-eastward up and over the watershed of the Eden Valley and southward across Morecambe Bay; and of the East Irish ice southward along the coast, all indicate that the uplands had lost control of the flow and could barely defend themselves from actual invasion. As for the local accumulation on the Manx hills, like the hills themselves it had ceased to be distinguishable beneath the surface of the plateau, and had become pail of the general current moving south-south-eastward. The influence of the Island upon this current was exactly that of a sunken boulder in a river, and no more.

The upper portion of the ice-sheet at this stage, having been derived from snow-fall on its own surface, must have been free from detritus, like existing ice-sheets of similar origin; but its lower part was no doubt laden with morainic material brought in by the original glaciers, and with marine debris from the sea-bottom over which the ice was passing. As the basal layers must have been under the enormous pressure, they would likewise frequently tear up the underlying rock-floor in moving forward.

The much-discussed problem as to the physics of ice-motion is not of immediate consequence to the field-worker in glacial geology, who sees all round him the evidence that the moving mass behaved to all intents and purposes as a plastic body, be the cause what it may. On a plane surface or in an irregular basin the base of the ice-sheet would doubtless tend to obtain relief from superincumbent pressure by flow towards the point where the pressure was less severe. In this way, the basal drift-laden layers would move gradually outward, and to some extent upward, from the centre of the mass towards its circumference, the altitude they eventually attained above their starting point depending partly upon the shape of the ground, and partly upon the relative height of the column of ice at different points.

The inequalities of the old rock-surface undoubtedly played an important part in directing the flow of the lower layers of the ice-sheet. I fully agree with Mr. Kendall that "although glacier-ice can ascend slopes of considerable steepness, there is a certain critical angle which cannot be surmounted, and when that is reached, instead of overriding the obstruction, the ice cleaves and glides past on either side, while, if the obstruction be not very high, the upper strata of ice will move on over the top".<ref>Op. cit., p. 426.</ref>

These considerations account perfectly for the distribution of the foreign drift with marine debris on the flanks of the Island: for the absence of such material from most of the high ground: for the direction taken by the local boulders: and for the bearings of the striae on the rock-surfaces. The lower layers impinging upon the steep northern slopes swerved to right and left as an undertow; and the clean upper portion passed over them and also over the local ice filling the deeper valleys of the interior, and swept across the uplands transverse to the ridges, which were glaciated with their own debris only.

It has often been urged that the increase of an ice-sheet beyond a certain thickness would be rendered impossible by the liquefaction of its base by simple pressure. In view of the great thickness of the existing ice-sheets of the interior of Greenland and of the Antarctic, this supposition has not much weight; but if valid, it might perhaps explain the production of thick sheets of ground-moraine in regions of great pressure, through the constant liquefaction and elimination of ice from the drift-laden lower layers and the compression of the accumulated solid residue.

We have no positive evidence as to the maximum altitude which the West-British ice-sheet attained, That its thickness above the crest of Snaefell (2,034 feet) must have been considerable is proved by the striae that cross the summit transversely to the contours; and similarly in the case of South Barrule (1,585 feet), by the rapid uplift of the Foxdale granite boulders to its top. Its altitude, independently of its thickness below ordnance datum, was therefore certainly not less, and probably kg-eater here than on the northern borders of the Lake District, where according to J. G. Goodchild (whose results in this respect agree with those obtained by J. Clifton Ward and R. H. Tiddeman farther southward), "The upper limit stood somewhere between 2,200 and 2,400 feet above the present sea-level at the points where the ice-sheet attained its greatest thickness".<ref>Quart. Journ. Geol. Soc., vol. xxxi., p. 98.</ref> Farther south, over the Lancashire and Cheshire plain, its height seems to have been well below 1,000 feet.

Without pursuing the argument in its wider aspects, it may be stated that the same conditions appear to have obtained also in the East-British ice-sheet, which occupied the bed of the North Sea. The Laurentide ice-sheet of North America, which gathered on the low Archaean plain and spread thence towards the Appalachian Highlands of the Eastern States, may be cited as a parallel example on a larger scale. In fact, all the great ice-sheets of the Glacial Period seem, after their earlier stages were passed, to have grown and spread from the snowfall which they received on their surfaces rather than from the inflow of upland glaciers.

As the British ice-sheets must always have received their increment principally from the moist Atlantic winds, it seems probable, as I have elsewhere suggested,<ref>"Glacialists' Mag"., vol. 1, No 11 (1894), p. 231.</ref> that without any change of climate, the centre of greatest accumulation and consequently of maximum glaciation would tend to shift steadily westward and south-westward as the icy plateau rose higher in the path of the moisture-laden winds and compelled their earlier precipitation. This effect would, moreover, be accentuated by the obliteration of the open water in the sea basins to the eastward. The West-British sheet might from this cause go on increasing, while its East-British and Pennine equivalents were already diminishing from lack of sufficient snowfall.

It is worth noting in this connection that in studying the drifts of East Yorkshire some years ago, I arrived at the conclusion that the ice-sheet of the North Sea had begun to diminish before the overflow from the westward across the Pennine Chain commenced, though the reason was not at that time clear to me.<ref>"Drifts of Flamborough Head", Quart. Journ. Geol. Soc., vol. idyll. (1892), p. 428.</ref>

May not the cold dry "steppe-period" which has been recognised in Central Europe be a further result from the same cause ?

For the above reason, the shrinkage of the ice-sheet covering the Isle of Man is likely to have commenced while the Welsh and Ivernian sheets were still increasing.<ref>On a vastly larger scale, there appears to have been a similar shifting of the centres of glaciation in the ice-sheets of North America. see J. B. Tyrrell. "The Glaciation of North-Central Canada". Rep. British Assoc. for 1897, p. 662, and Journ. Geol. Chicago, vol vi. (1898), pp. 147–160.</ref>

But it was not until there had been a great amelioration of climate that the Island began to emerge from the waning mass. The duration of its burial we have no means of estimating; time passes unchronicled in the middle of an ice-sheet; and it is only at its margin that there is any record kept. We begin to get glimpses of events, however, as soon as the higher of the mountain-ridges were bare; and from that time onward the records lack nothing.

Just as there had been an automatic acceleration of the rate of growth of the ice-plateau with its increasing elevation, so by a reversal of the process, was there a corresponding acceleration in the rate of shrinkage while its melting was in progress.

As above hinted, the shrinkage may have begun from a diminution in the amount snowfall alone; but before it could proceed far there must have been a wide-spread change of climate, and an essential difference between the conditions of this stage and of the initial stage of the period.<ref>The writer called attention to this point in "Nature", vol. lvii. (1898), p. 245.</ref>

At the beginning of the period the climate was such as to permit the permanent snow-line to descend nearly to sea-level; while when the ice-sheet had reached its maximum it was requisite that the climate should be warm enough to prevent snow lying permanently at over 2,000 feet above sea-level before a positive lowering of the surface by melting could take place. Thus, an ice-sheet already in existence may be able for a long time to withstand a climate in which it could never originally have accumulated; and ameliorating changes may attain an advanced state before their effect on such an ice-sheet becomes marked. But when the permanent thawing of the surface once commences, it must go on with accelerated rapidity as lower levels are reached.

It may be objected that the ice-sheet was perhaps melted back from its margin, or that it may have sunk to lower levels by gradual out-flow without equivalent replenishment. But the evidence is convincing that the ice around the Island, like that of Eden-side, so well described by Mr. Goodchild, "melted as it stood, and the waning ice-sheet did not pass in reverse order through the series of changes that accompanied its increment".<ref>"Ice-work in Edenside", Trans. Cumberland Assoc., No. 12 (1886–7), p. 134.</ref> Its flow, always sluggish, seems to have been arrested by the changed conditions; and the ice disappeared from the hills before a new direction of movement of sufficient strength to leave a record could be established. In this way only can we explain the remarkable conformity of the phenomena in regard to the ice-flow in the Island, and the absence of any trace of subsidiary local glaciers at the close of the period.

It is clear that by the time the hill-tops had reappeared the Arctic conditions of climate had passed away, and permanent snow was no longer possible on rock-surfaces, even at the higher levels. The ridges then stood out as rocky nunataks above the sinking ice-fields, and hastened the withdrawal of the ice immediately surrounding them, in the same manner as the nunataks of existing 'piedmont' glaciers.

Further differential melting was almost inevitable under the conditions.<ref>See "Outline of the Geology of the Isle of Man "; Handbook for British Assoc., Liverpool (1896), p. 179.</ref> On the surface of the ice-sheet the rate of liquefaction, whether due to warm air, direct sunshine, or rain, must have been approximately equal over wide areas, leading to a general lowering of the plateau, and the resultant water, whether flowing or stationary, could scarcely rise above the temperature of its icy bed. But the contemporaneous drainage from the bare ground might be endowed with considerable melting power, the initial temperature of the rainfall being increased by whatever degree of warmth the land-surface might possess. Hence, where land-streams impinged upon the ice, there would be an accelerated melting back of the mass and the development of depressions, in which the waters often accumulated in small lakes. The streams from these lakes, discharging principally across the ice, but touching the land in places, are no doubt mainly responsible for the excavation of the curious notches on projecting hill-spurs and the production of patches of stratified local drift on open slopes.

With the increase of the land-surface and the uncovering of lower ground this differential melting seems to have become still more pronounced; so that the whole Island was freed from ice while there was still an icy plain surrounding it. It was at this stage that the main features of the northern plain were produced. Nowhere in the Island along an equal extent of border is the discharge of drainage from the uplands approximately as great as in the north, where three great valleys (Glen Dhoo, Sulby Glen, and Glen Auldyn) have their mouths at the edge of the hills within a space of six. miles. The combined effect of their waters was to beat back the ice-front into a great crescentic embayment, with its western horn approaching the mountains between Ballaugh and Kirk Michael, and its eastern horn, now in great part carried away by the sea, curving round towards Ramsey, while directly opposite the above-mentioned glens it lay four or five miles distant. The history of Lake Andreas, which filled this hollow, has already been followed and need not be repeated (pp. 372–3).

Similar circumstances accompanied the wane of the East-British ice-sheet in East Yorkshire;<ref>"Drifts of Flamborough Head", op. cit., p. 425.</ref> and have doubtless prevailed wherever the 'piedmont' as distinguished from the 'alpine' type of glaciation has ruled.<ref>See I. Russell, "Glaciers of North America", Boston, 1897, p. 3. </ref>

The peaty layer in the late-glacial gravel. platform at Kirk Michael, with its limited flora of wide climatic range associated with one or two Arctic types and with the little Arctic freshwater crustacean, affords us a further glimpse into the conditions of this stage. The ice-sheet in covering the whole Island must have blotted out all the previous life; so that in spite of the relatively rapid emergence of the land and its insular position, this flora and fauna must have been re-introduced; and, though scanty, they indicate that the thawing back of the ice had, at any rate, occupied sufficient time for the re-establishment of plant life. Toward the close of this period, therefore, the Island probably formed a green inviting lake-bordered nunatak rising out of desolate icy plains; and it is quite possible that the Irish Elk, and perhaps other animals, may have reached it by crossing the ice-fields,<ref>In making this suggestion in a letter to "Nature " (Jan. 13th, 1898, vol. lvii., p. 245), I supposed it to be original, but find that it had been made long previously in regard to Ireland by Dr. J. R Kinahan, who however believed that the frozen sea, and not the ice sheet, afforded passage to the great elk. (See G. H. Kinahan's "Geology of Ireland", p. 296.)</ref> the as the mountain-goat, fox, wolf, and bear are known, at present day, to traverse the Malaspina ice-sheet of Alaska for many miles on their way to the Chaix and Samovar Hills, which m like mafiner rise out of surrounding deserts of ice;<ref>See I. C. Russell, Thirteenth Ann. Report U.S. Geol. Survey, 1891–2, p. 26. </ref> and as the reindeer crosses the frozen sea from island to island off the Siberian coast.

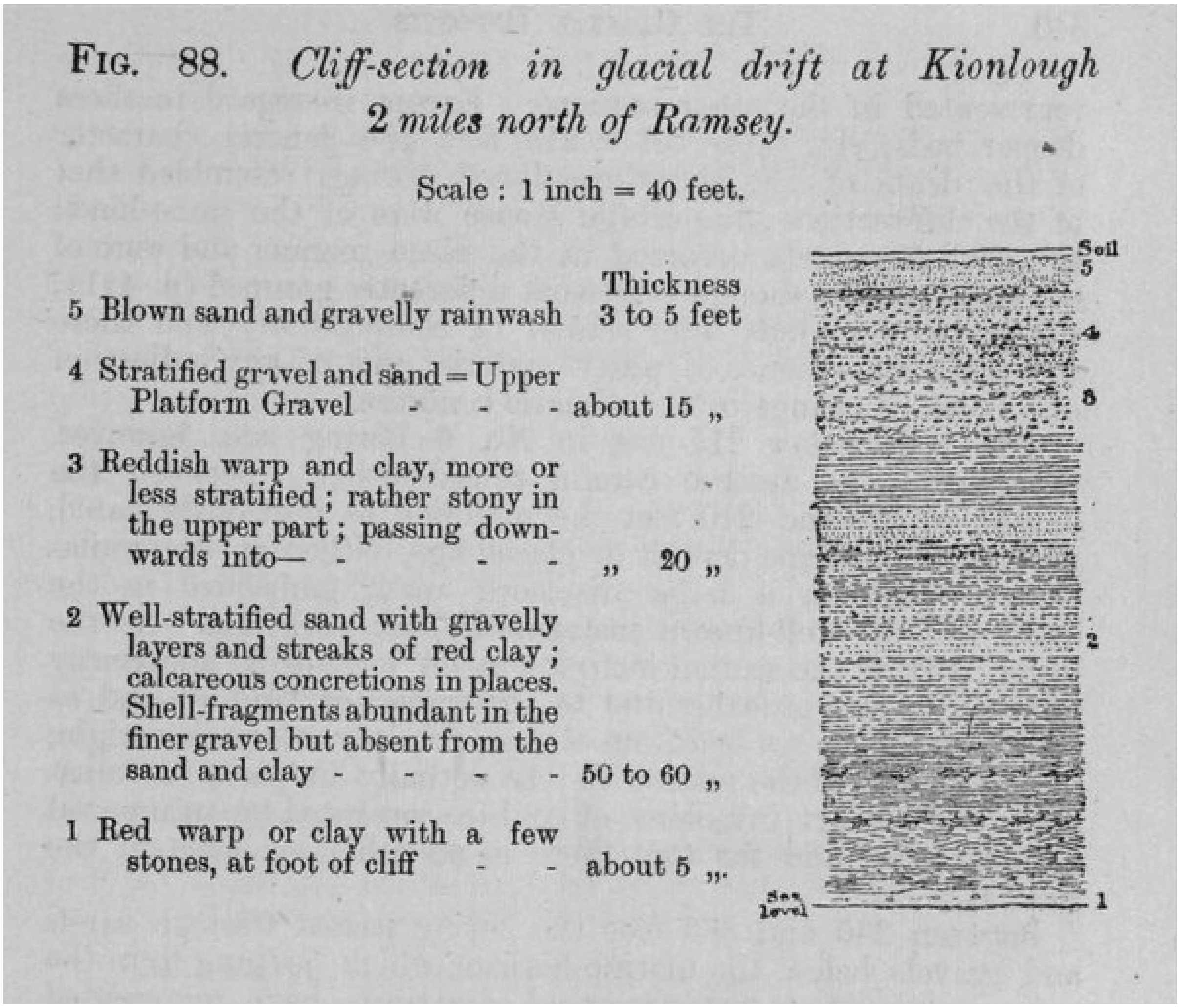
The final disappearance of the ice-sheet from the vicinity of the Island may be considered as marking the termination of the glacial episode in the stricter sense, so far as this region is concerned, though the climate may have remained for some time longer less clement than at present. There was no return of the glacial conditions, nor was there any submergence of the area beneath the sea. The record of the interval between that time and the present is contained in the fresh-water alluvial deposits, which will be dealt with in the next chapter.

Summary

The main conclusions of the preceding pages may be summed up as follows:

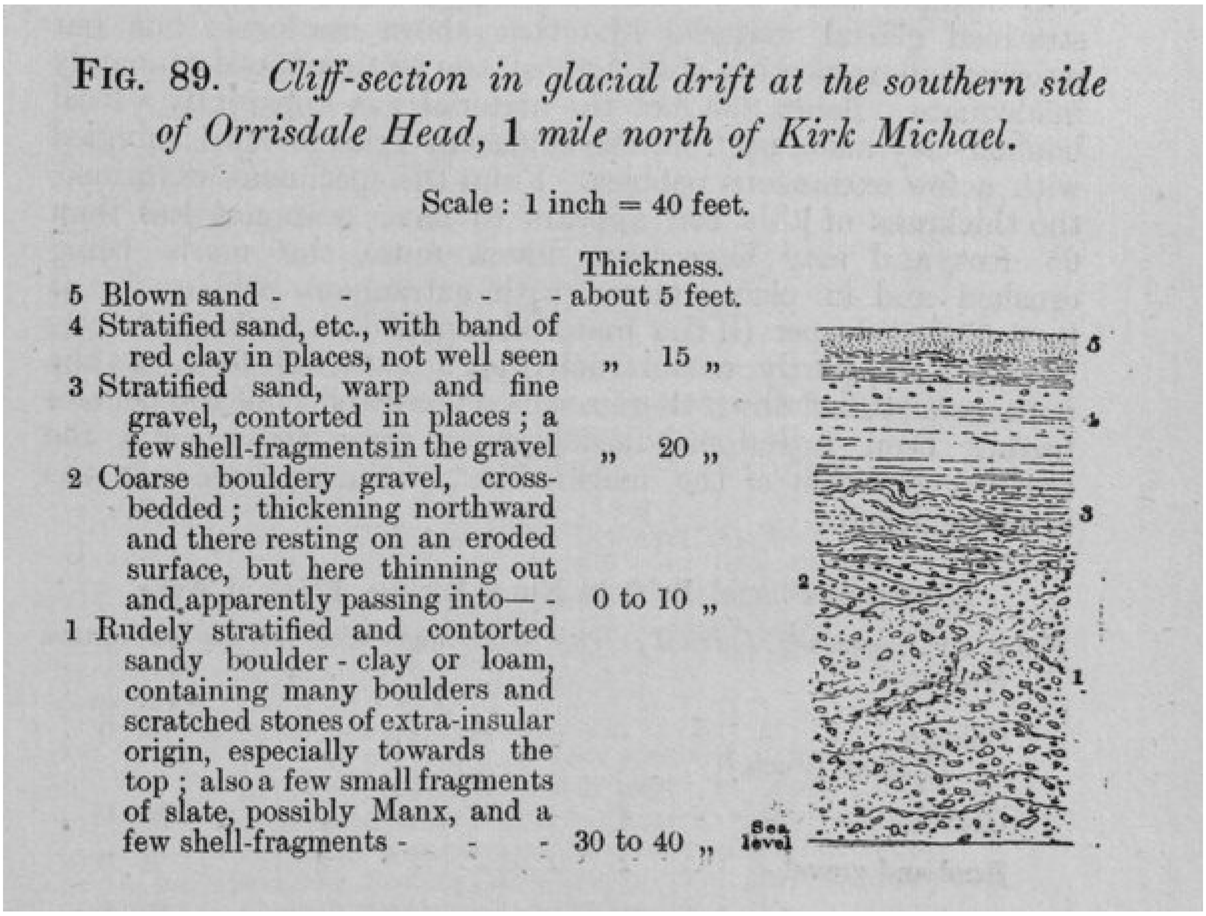
1. The sea-basin surrounding the Island has been filled by an ice-sheet which, when at its maximum, attained an elevation of not less than 2,000 to 3,000 feet above present sea-level and completely overwhelmed the Island. This is proved by the character of the Glacial deposits; by their arrangement and, relations to the solid features; by the glacial strife and other forms of rock-sculpturing; and by the transport of the Insular and Extra-Insular erratic boulders.

2. The general direction of ice-movement was approximately, from north-north-west to south-south-east, being transverse to the main hill-ranges of the Island; but there was local deviation, probably in the form of an undercurrent, on the flanks and especially on the lee-side of the principal hill-chain.
3. The material of the pre-existing sea-bottom was incorporated into the lower layers of the ice-sheet and was redistributed by it in the form of shelly drift. This distinguishes the Extra-Insular deposits from the Insular drift of entirely local derivation, but the two are- due to a common and contemporaneous agency.
4. The glacial and post-glacial surface-features are shown to be wholly due to glacial, fluvio-glacial, and subaerial agencies. The sea has had no part in the arrangement of the drift deposits either during or since their deposition.
5. The facts indicate an uninterrupted progression of events from the commencement of the glacial conditions to the period of maximum glaciation, and thenceforward to the amelioration of the climate and the disappearance of the ice-sheet. The sections offer no evidence for an interglacial period in this area.
6. The West-British Ice-sheet which surrounded the Isle of Man and extended across the Irish sea-basin to the borders of England, Wales, and Ireland, probably attained its ultimate dimensions mainly from the accretion of snowfall upon its surface, and in only a minor degree from the inflow of tributary glaciers. The mass attained its greatest thickness in the area lying to the north-westward of the Isle of Man.
7. During the closing stages of the period the melting of the ice-sheet in the vicinity of the Island was relatively accelerated at points of contact with the land-drainage, which was greatly in excess of that of the present day. The hollows thus formed between the retreating ice and the land were temporarily filled by freshwater lakes. A flood-terrace of this stage has yielded sub-arctic remains.
8. The Irish elk probably made its first appearance in the Island while a remnant of the waning ice-sheet still lingered in the surrounding basin.

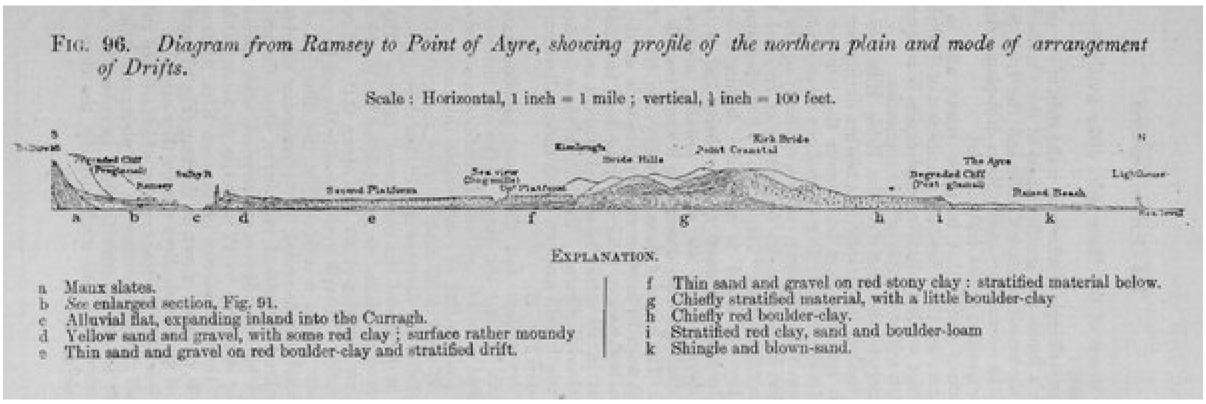


(Figure 88) Cliff section in glacial drift at Kionlough 2 miles north of Ramsey. Scale:1 inch = 40 feet. 5. Blown sand and gravelly rainwash — Thickness 3 to 5 feet 4. Stratified gravel and sand = Upper Platform Gravel — about 15 feet 3. Reddish warp and clay, more or less stratified rather stony in the upper part; passing downwards into —Thickness 20

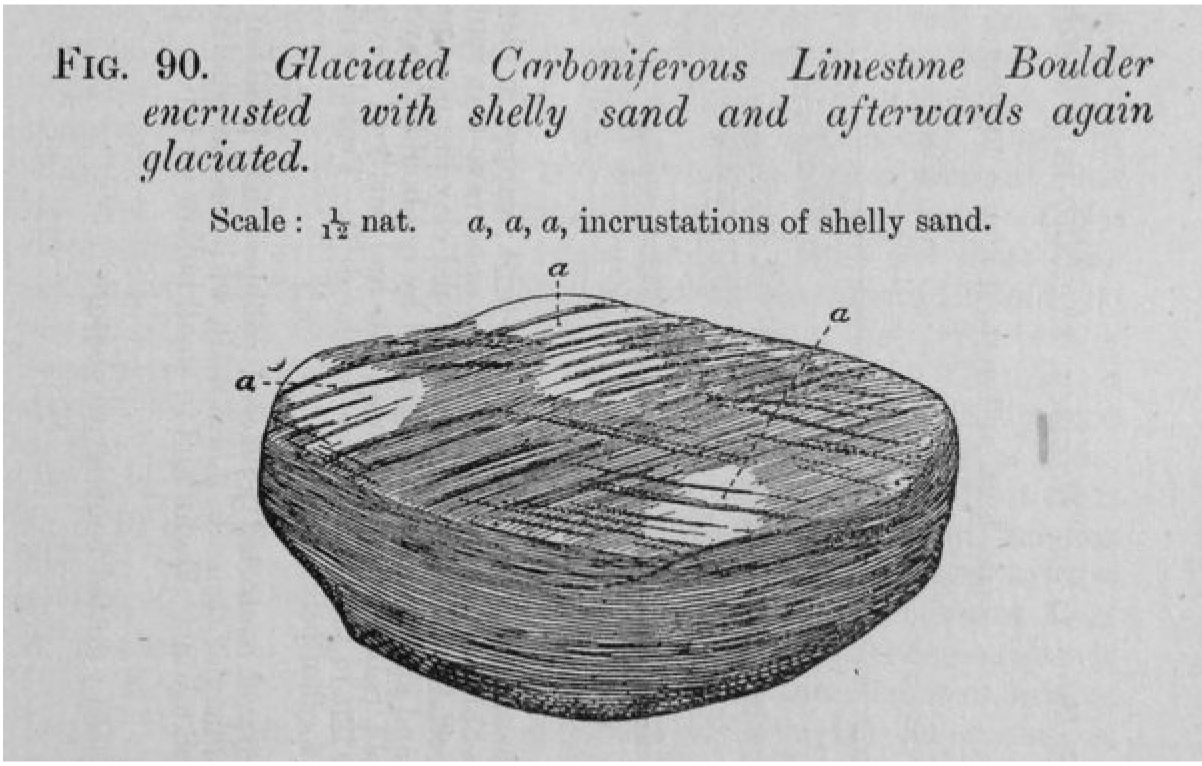
feet 2. Well-stratified sand with gravelly layers and streaks of red clay; calcareous concretions in places. Shell-fragments abundant in the finer gravel but absent from the sand and clay Thickness 50 to 60 feet 1. Red warp or clay with a few stones, at foot of cliff Thickness about 5 feet.



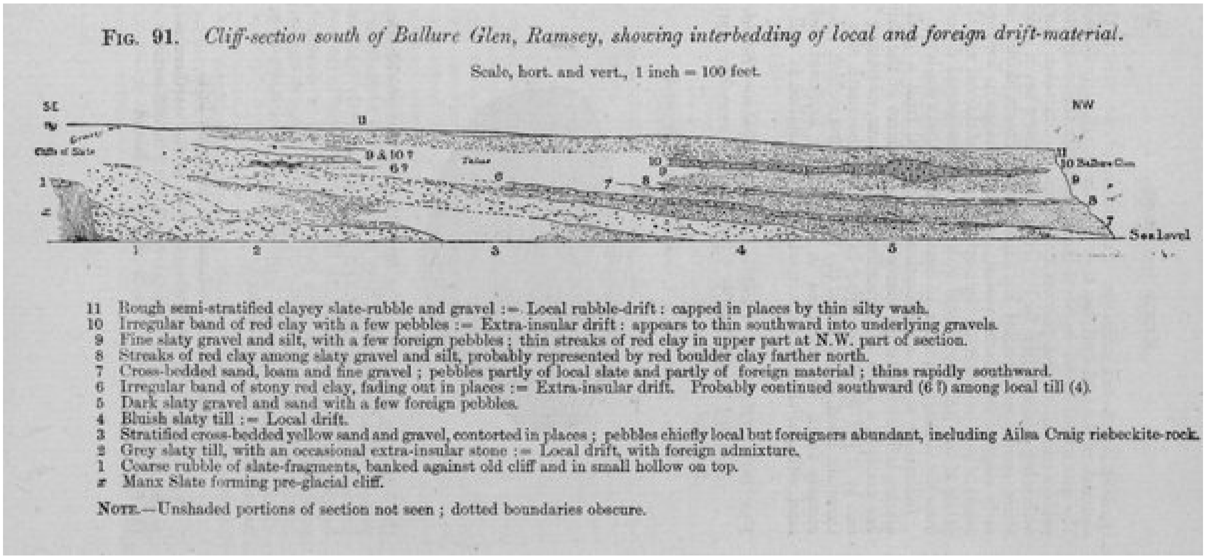
(Figure 89) Cliff section in glacial drift at the southern side of Orrisdale Head, 1 mile north of Kirk Michael. Scale: 1 inch = 40 feet. 5. Blown sand about 5 feet. 4. Stratified sand, etc., with band of red clay in places, not well seen 15 feet thickness 3. Stratified sand, warp and fine gravel, contorted in places; a few shell-fragments in the gravel 20 feet thickness 2. Coarse bouldery gravel, cross bedded; thickening northward and there resting on an eroded surface, but here thinning out and apparently passing into — 0 to 10 feet thickness 1. Rudely stratified and contorted sandy boulder clay or loam, containing many boulders and scratched stones of extra-insular origin, especially towards the top; also a few small fragments of slate, possibly Manx, and a few shell-fragments 30 to 40 feet thickness.



(Figure 96) Diagram from Ramsey to Point of Ayre, showing profile of the northern plain and mode of arrangement of Drifts. Scale: Horizontal, 1 inch = 1 mile; vertical, ■ inch = 100 feet. Explanation. a. Manx slates. b. See enlarged section, (Figure 91) c. Alluvial flat, expanding inland into the Curragh. d. Yellow sand and gravel, with some red clay; surface rather moundy e. Thin sand and gravel on red boulder-clay and stratified drift. f. Thin sand and gravel on red stony clay: stratified material below. g. Chiefly stratified material, with a little boulder-clay h. Chiefly red boulder-clay. i. Stratified red clay, sand and boulder-loam k. Shingle and blown-sand.



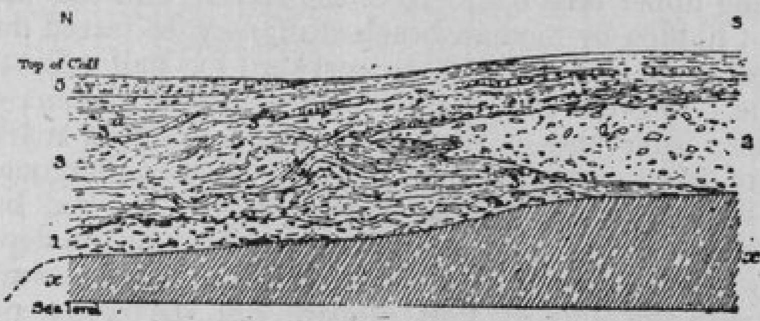
(Figure 90) Glaciated Carboniferous Limestone Boulder encrusted with daily sand and afterwards again glaciated. Scale: 1/12. nat. a, a, a, incrustations of shelly sand.



(Figure 91) Cliff-section south of Ballure Glen, Ramsey, showing interbedding of local and foreign drift-material. Scale, horiz. and vert., 1 inch = 100 feet. 11. Rough semi-stratified clayey slate-rubble and gravel: =, Local rubble-drift: capped in places by thin silty wash. 10. Irregular band of red clay with a few pebbles:= Extra-insular drift: appears to thin southward into underlying gravels. 9. Fine slaty gravel and silt, with a few foreign pebbles; thin streaks of red clay in upper part at N.W. part of section. 8. Streaks of red clay among slaty gravel and silt, probably represented by red boulder clay farther north. 7. Cross-bedded sand, loam and fine gravel; pebbles partly of local slate and partly of foreign material thins rapidly southward. 6. Irregular band of stony red clay, fading out in places:= Extra-insular drift. Probably continued southward (6 ?) among local till (4). 5. Dark slaty gravel and sand with a few foreign pebbles. 4. Bluish slaty till:= Local drift. 3. Stratified cross-bedded yellow sand and gravel, contorted in places; pebbles chiefly local but foreigners abundant, including Ailsa Craig riebeckite-rock. 2. Grey slaty till, with an occasional extra-insular stone:= Local drift, with foreign admixture., 1. Coarse rubble of slate-fragments, banked against old cliff and in small hollow on top. x. Manx Slate forming pm-glacial cliff. NOTE. — Unshaded portions of section not seen; dotted boundaries obscure.

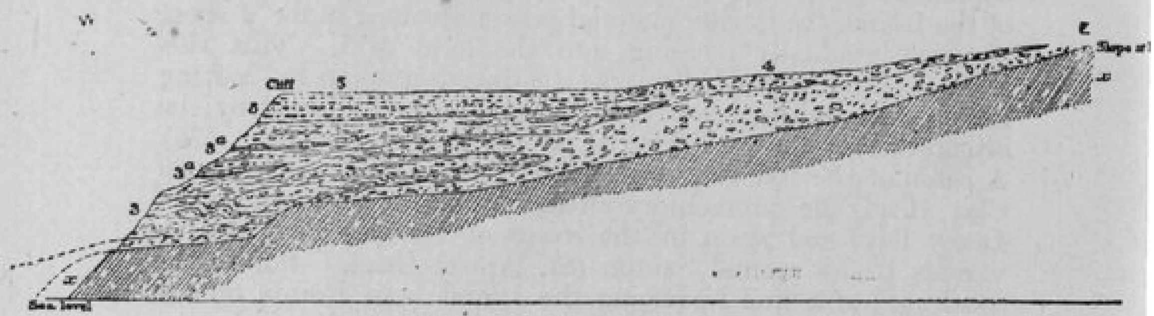
FIG. 92. *Diagram showing replacement of stratified shelly drift by local boulder-clay in the cliff-section near Gob ny Creggan Glassey, Kirk Michael.*

Scale, for both Figs. : 1 inch = 100 feet, hor. and vert.



(Figure 92) Diagram showing replacement of stratified shelly drift by local boulder-clay in the cliff-section near Gob ny Creggan Glassey, Kirk Michael. Scale, for both Figs.: 1 inch = 100 feet, hor. and vert. Explanation (for both sections). 5. Stratified slaty platform-gravel, probably passing into (4) at foot of slope. 4. Upper local rubble-drift. 3. Stratified extra-insular drift; cross-bedded and confused in places; composed of sand, silt, gravel, with a few shell fragments, and thin patches of red clay, 3a, towards the top; the gravel, a mixture of local and foreign material. 2. Dark grey or blue local till, with a few foreign stones. 1. Slaty rubble passing in places into dark slaty till (2). x Manx Slates.

FIG. 93. *Diagram at right angles to the above, showing general arrangement of the drift deposits on the lower slopes of the hills; based on sections in Glion Thoar and Glion Shellan.*



EXPLANATION (for both sections).

5 Stratified slaty platform-gravel, probably passing into (4) at foot of slope.

4 Upper local rubble-drift.

3 Stratified extra-insular drift; cross-bedded and confused in places; composed of sand, silt, gravel, with a few shell fragments, and thin patches of red clay, 3a, towards the top; the gravel, a mixture of local and foreign material.

2 Dark grey or blue local till, with a few foreign stones.

1 Slaty rubble passing in places into dark slaty till (2).

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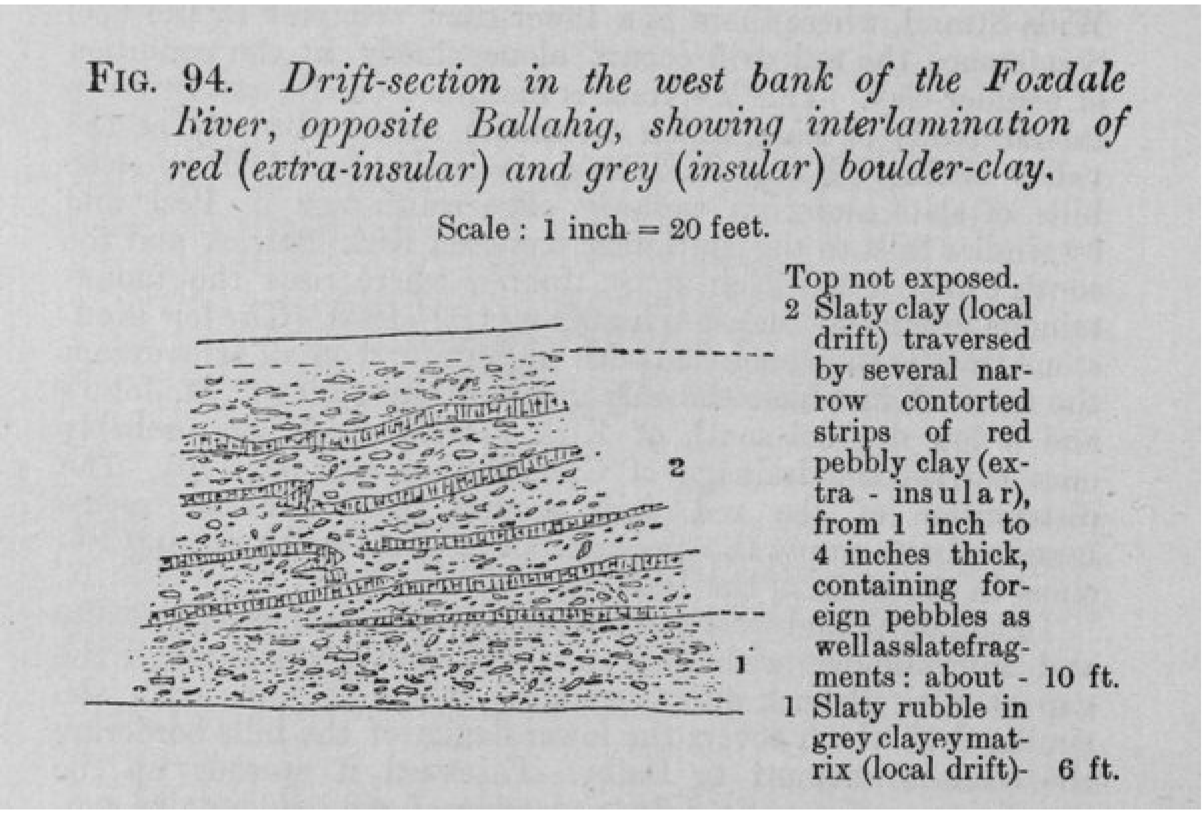
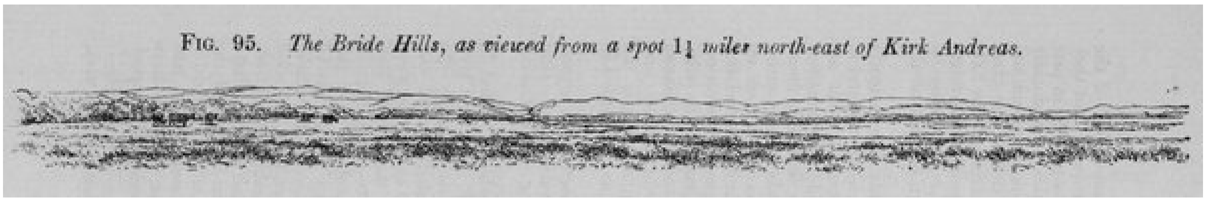


(Figure 94) Drift-section in the west bank of the Foxdale River, opposite Ballahig, showing interlamination of red (extra-insular) and grey (insular) boulder-clay. Scale: 1 inch = 20 feet. Top not exposed. 2. Slaty clay (local drift) traversed by several narrow contorted strips of red pebbly clay (extra insular), from 1 inch to 4 inches thick, containing foreign pebbles as well as slate fragments: about 10 ft. 1. Slaty rubble in grey clayey matrix (local drift) — 6 ft.



(Figure 95) The Bride Hills, as viewed from a spot 1¼ miles north-east of Kirk Andreas.

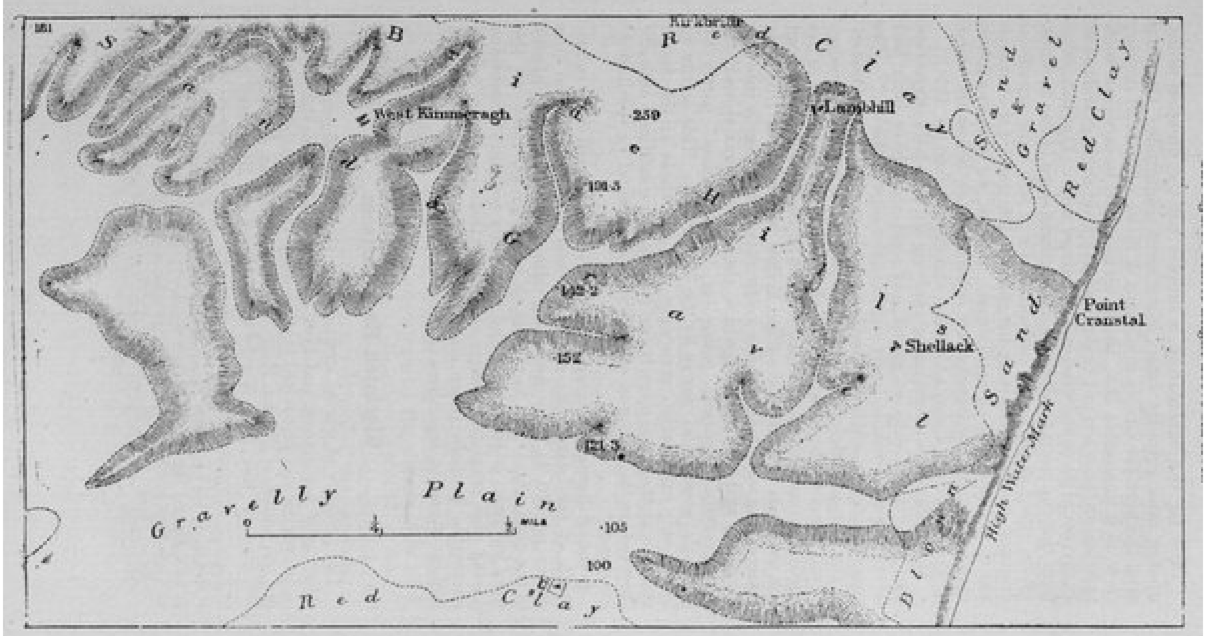


FIG. 97. *Plan of dry valleys near Kirk Bride.*
The figures denote height above sea-level.

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FIG. 99. *Sketch-view of Creg Bedn, on the northern side of Slieau Monagh (Meanagh), near Sulby; looking west: a glaciated crag of vein-quartz, with striæ pointing S. 15—25 E.; height of crag about 15 feet; width (N—S) 20 feet; length (E—W) 60 feet.*

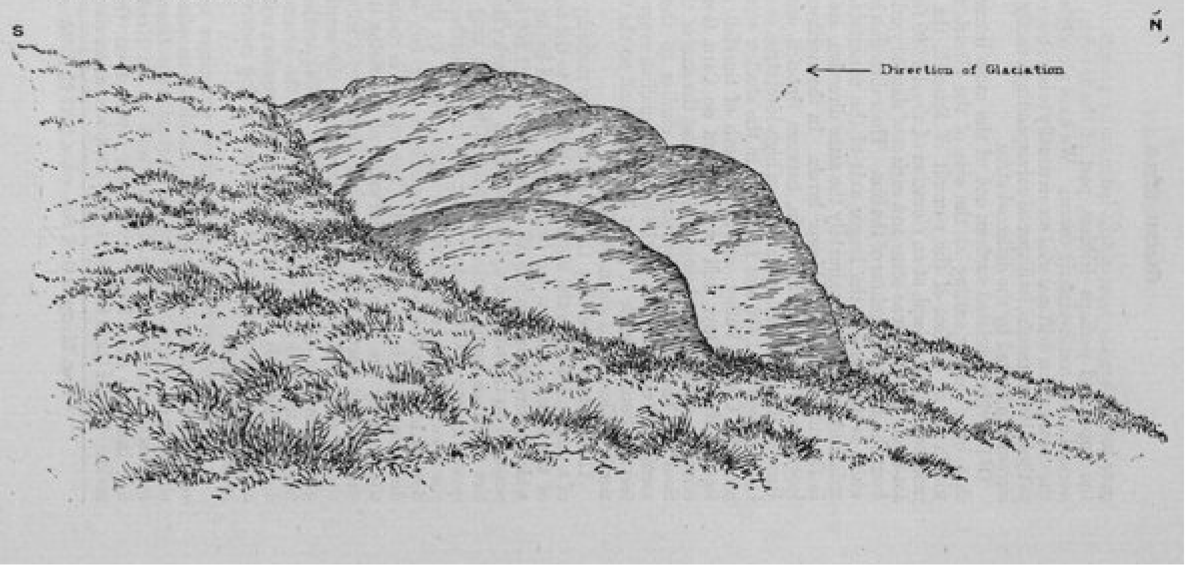

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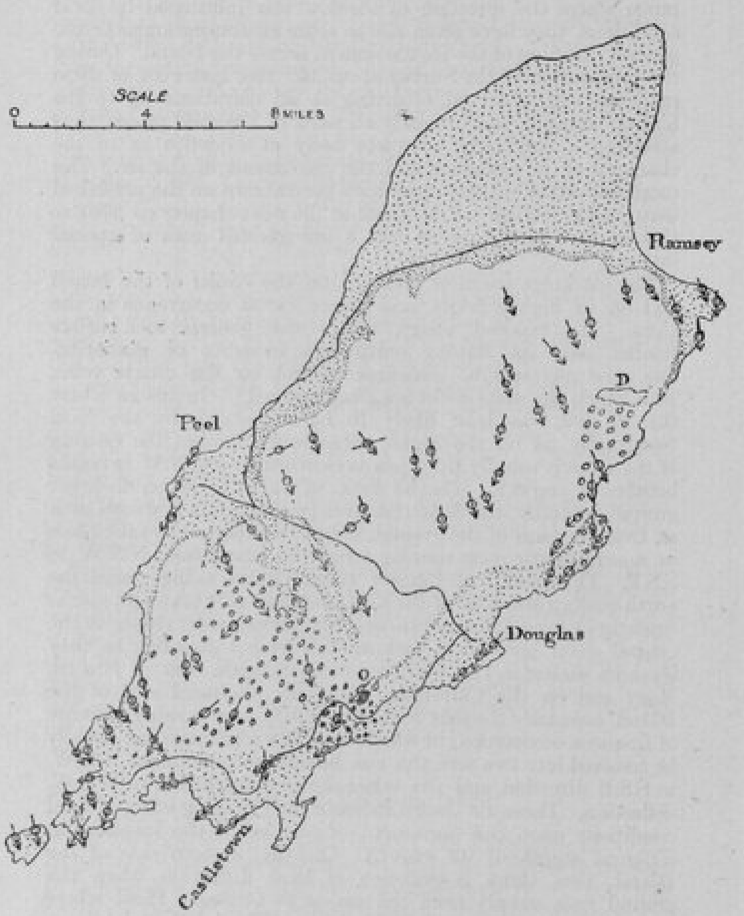
FIG. 98. *Sketch-map of the Glacial phenomena of the Isle of Man.*



The arrows with ovals indicate glacial striæ and the direction of ice movement.
The dotted area marks the distribution of extra-insular drift-material: the area left plain contains local drift only.
D = Dhoon Granite; F = Foxdale Granite; O = Oatland Granitite; with their respective boulder-streams indicated by circlets.
The black lines indicate railways.

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