Chapter 34 The development of the land-surface

The Platforms

The Menaian Platform

Anglesey is a fragment of a platform or plateau (such as is often called by the hybrid name of 'peneplain'), an old base-level of erosion, standing now at a height of some 200 to. 300 feet above the sea. This platform is not confined to Anglesey: it extends across the Strait, the mountains rising very suddenly some four miles inland. Looking thence to the north-west, no one would, as Ramsay remarks, 'suspect the existence of the Strait' in the great even tract that seems to extend unbrokenly into the blue distance 20 miles away. The total area of the plateau, which may be called The 'Menaian Platform', cannot be much less than 400 square miles. The platform is varied (apart from features due to its subsequent erosion) by numberless undulations and irregularities; which often, close by, seem to be of considerable importance, but which melt imperceptibly into the general level when seen from further off. Viewed — from anywhere in the neighbourhood of Bangor, the Island sky-line is so straight (Plate 51) that a ruler held up to the eye will coincide with it for miles. Similar outlines can be seen from any positions along either shore of the Marsh of Malldraeth. Views at right angles to the direction of these, such as that from Newborough, looking to the north-east, show profiles of the same plain. Seen from places in the heart of the Island, one of the best being near Mynydd-mwyn-mawr, where the road rises to the 317-foot level, a mile and a half from Llanerchymedd (Plate 50), the same even sky-line sweeps round the whole circle of the horizon. The bossy features of the Mona Complex, the smoothly curving outlines of the Ordovician, and the strong escarpments of the Carboniferous Limestone, all stop as soon as they meet the horizon of the platform, whose uniformity betrays no sign whatever of the extraordinary complexity of the tectonics. The rugged granite moor of Gwalchmai, when seen from Caer-glaw, only half a mile away, assumes the aspect of a plateau, just below the 300-foot contour. Very striking are the views from the top of the Column (Plate 52), for the mountains contrast vividly with the smooth and low Menaian Platform; which, traversed by the trench-like Strait, sweeps inland towards their feet.

This even surface, however, is not horizontal, but has a steady, gentle inclination to the west. Its highest parts are near the eastern coasts, where, about the main watershed, many square miles lie within the 300-foot contour.<ref>The sky-line of the platform in (Plate 50), (Plate 51), and the mainland portion seen about midway between the bridges in (Plate 52), are just at the 300-foot contour. In (Plate 53) and (Plate 54) the westerly decline is perceptible.</ref> Along the western sea-board, we have levels as follows: Newborough, 131 feet; Bodorgan, 200; Aberffraw, 130; Rhoscolyn, 208; Llanfaethlu, 280; and Penrhos-feilw (Holyhead), 250 feet. Seven lines taken across the Island in a generally westerly direction give measurements of the fall:

Beaumaris to Newborough, 10 miles	13 feet per mile
Tyn-y-gongl Cromlech to Bodorgan, 12 miles	8 feet per mile
Tyn-y-gongl Cromlech to Aberffraw, 13 miles	13 feet per mile
Parciau to Rhoscolyn, 15 miles	6.6 feet per mile
Parciau to Llanfaethlu, 10 miles	1.3 feet per mile
Parciau to Holyhead, 15 miles	3.3 feet per mile
Parciau to Pen-bryn-yr-eglwys, 14 miles	3.0 feet per mile

The average inclination of the surface of the platform is therefore about 6.9 feet per mile, while the average height on a line drawn from Parciau to Holyhead is about 275 feet.

Over large tracts in the west and north the rocky surface is at quite low levels (particularly in the basin of the Alaw), 40 or 50 square miles being below the 100-foot, and perhaps 12 or 13 of these below the 50-foot contour.<ref>An aspect of continuity is fictitiously maintained in these regions by the presence of the great drumlins, which erect themselves into a sort of substitute, so that, but for knowing their real nature, one might hardly suppose that there was any interruption of the platform.</ref> It must not be supposed, however, that the Menaian Platform has declined to the sea-level. The fragments of it that survive at Rhoscolyn, Llanfaethlu, and Holyhead show that these wide lowlands are due to

subsequent erosion, and that it extended much further to the west, while the rugged hills along the northern coast, which reach 297 feet at the Graig Wen quartzite, testify to its extent in that direction.

The truth is that there is reason to think (see Chapter 33) that the present limits of the Island are determined towards the north and west by the boundaries of large inliers of the Mona Complex and the older Palaeozoic rocks, surrounded by Carboniferous and later formations; and towards the east by the emergence of the Carboniferous Limestone from beneath Coal Measures and Trias. The Menaian Platform, as an old base-level, must have extended many miles beyond the limits of the present Island; but its outer portions, composed of much softer rocks, have, since the elevation of the whole, been cut away by denudation.

The Monadnocks

Rising abruptly from the Menaian Platform are nine conspicuous hills<ref>The heights not given on the maps were kindly estimated by the Ordnance Survey from hill-shading, and afterwards checked by the barometer. The discrepancies were trifling.</ref>:

Bwrdd Arthur	530 feet
Llanddona Common	510 feet
Mynydd Llwydiarth	520 feet
Mynydd Bodafon	583 feet
The Hill of Nebo	550 feet
Parys Mountain	480 feet
Mynydd Eilian	585 feet
Mynydd y Garn	555 feet
Holyhead Mountain	720 feet

No two of them have the same composition or structure. Bwrdd Arthur is a tabular outlier of massive Carboniferous Limestone (whence its name, 'Arthur's Table'); Llanddona Common a tract of quartzose Gwna Green-schist; Mynydd Llwydiarth is composed of a siliceous portion of the Penmynydd mica-schists, with tough hornblendic bands; Holyhead and Bodafon of quartzites. Gneiss rises into the upper parts of Nebo; cleaved shale, toughened by the picrite sills, forms the top of Mynydd Eilian; the felsite and shale of Parys are silicified; while the crest of the Garn is a massive conglomerate. The only character, indeed, in which they all share is the possession of a summit-rock endowed with unusual power of resistance to erosion, accentuated by one or more lines of rupture that bring this mass into contact with less resistant beds. Though now remodelled by glaciation, they are for the most part extremely rugged, and as varied in features as they are in structure.

The basal plans, on which they are, as it were, projected upon the Mennian plane, are approximately oval, with major axes ranging north-east and south-west, and areas that average roughly about three-quarters of a square mile. Nebo, Parp, and Eilian, Llanddona, Llwydiarth, and Bwrdd Arthur, form a pair of triplets; and all save Holyhead, which is completely isolated, stand upon some portion of the watershed. Seven of them rise within three miles of the eastern, while two are close to the western coast, not one occurring in the broad central parts of the Island, so that their distribution is marginal.

In fact, they are manifestly true relict-hills, of the kind that have been called by the American geologists 'monadnocks', isolated eminences rising from a plain (Plate 50).

It will be noticed that, with the exception of Holyhead, none of them are far from 500 feet in height. Holyhead, moreover, is not the complete exception that it seems. A small part only, some 300 yards in each direction, overtops the other hills, and from this to the South Stack is a mile of moorland that, at the larger quartzite outlier, rises to 520 feet (Figure 339), while the tip of the rugged northern shoulder (Plate 16) attains 582 feet. The body of the mountain thus belongs to the same class as all the others. Excluding its exceptional crest, their average height is 544 feet. This uniformity, totally independent as it is of structure and composition, can hardly be an accident, and it points to the former existence of a higher platform, standing at about 550 feet, now almost entirely destroyed, of which these hills are the surviving

fragments.<ref>Of what feature the crest of Holyhead may be a survival it is impossible to say, but it must have been a monadnock on that platform.</ref> From their nature, it may be provisionally termed The Platform of the Monadnocks.<ref>Local terms are adopted for these platforms, in order to avoid the semblance of a premature attempt at correlation with similar features known elsewhere; though such correlation will doubtless be achieved ere long, when certain difficulties have been overcome.</ref>

They are not, however, the sole survivors. Just above the town of Bethesda, and traceable for some two miles past Llanllechid, a tolerably well-marked terrace, cut in rock, skirts the steep fronts of the mountains, running along a little within the 500-foot contour. Its width at Coetmor is about half a mile, and its height about 570 feet above ordnance datum. Looking out from it to the distant monadnocks of Anglesey, one can realise the denudation.

The Tregarth Shelf

Since this chapter was written my friend Mr. Henry Dewey has very kindly lent me the manuscript of his paper (subsequently published in *Geol. Mag.,* 1918, pp. 145–57), 'On the Origin of some Land-forms in Carnarvonshire', wherein he shows that a 430-foot plain or shelf can be traced along the feet of the mountains from the Ogwen to beyond the Seiont<ref>The present paragraph has been added, and several other expressions modified, in order to incorporate Mr. Dewey's results.</ref>; which, for the reason just given in a footnote, may be referred to as the 'Tregarth Shelf'. It is rarely more than a mile in width; and two preliminary traverses across that country showed that it overlooks the Menaian Platform in an abrupt feature, which is well developed about Tregarth and on one of its outliers -behind Port Dinorwic. Accordingly, it became evident that such a shelf might be looked for on the shoulders of the monadnocks of Anglesey. On Mynydd Ll`wydiarth, Nebo, Eilian, the Garn, and Holyhead, nothing that can be called a 430-foot shelf can be discerned, for though it is certainly suggested by the profile of the South Stack Moor, the average level there is about 450 feet. About Llanddona, Llansadwrn, and Bwrdd Arthur, where some three or four square miles are within the 400-foot contour, the Marian-dyrys and a ridge at Bryn-cogail just touch 430 feet, but there is a more terrace-like feature on Llaniestyn Common at 460 feet. On Mynvdd Bodafon and Parys Mountain, however, the northern and western shoulders (respectively) are decidedly terrace-like, and touch or approach the 430-foot level too often for mere coincidence. A limestone ridge near Parcian, moreover, just reaches it, and Foel Hill at Llanerchymedd, although barely exceeding 400 feet, may be a degraded survivor of the same feature, as may Parciau Camp and some other eminences about the eastern watershed. The evidence is meagre, but when considered in connexion with that of Carnarvonshire, it points to the presence in Anglesey of some degraded representatives of the Tregarth Shelf. Whether that was originally a platform extending over the whole region, or a terrace incised upon the flanks of the monadnocks during a temporary submergence, has not yet been ascertained.

Age and origin of the platforms

We have thus obtained evidence of the successive development of three platforms, which may be tabulated as follows:

The Monadnocks' Platform	550 feet
Tregarth Platform	430 feet
Menaian Platform	275 feet

The Menaian is, at present, by far the most extensive and conspicuous, the two others including, together, only one-thirtieth of the surface of the Island.

Is it possible to arrive at any idea of their ages? To begin with, all are certainly Post-Carboniferous. All are also later than the faults that cut the Red Measures. We have seen that the outer portions of the lower one must have been composed of softer rocks, and there is good season to believe (Chapter 33) that, on the east at any rate, these were of Mesozoic age. Dykes that must be ascribed to Tertiary (presumably Oligocene) time emerge upon the Menaian Platform. One of them, the Henborth dyke, rises up to within 30 feet of the base of the Holyhead monadnock, with a width of 90 feet and without the least sign of incipient chilling, which implies the presence at that time of a considerable cover, probably composed of uneroded Mesozoic rocks.

We may therefore ascribe the base-levelling of the Menaian Platform to a late stage of Tertiary time, and that of the Monadnocks to a somewhat older, but not much older, stage of the same period. On the plateaux of Western Cornwall, at about the same general level as our lower one, there are small outliers of older Pliocene deposits.<ref>'Geology of the Lizard and Meneage' (*Mem. Geol. Soc.*), pp. 1–3, 229–31; 'Geology of the Land's End District' (*Mem. Geol. Surv.*), p. 71. Mr. Dewey also cites the Cornish evidence.</ref> It is therefore probable that the Menaian Platform is, like them, the work of Pliocene denudation.

Its surface is so even that the last stages of levelling would seem to have been accomplished by the sea. Not a single fragment of the deposits of such a sea has yet, however, been discovered on it. Few survive, indeed, even on the Cornish platforms, which have been subject only to ordinary waste; so that the chance of their surviving the heavy scour of the ice that traversed Anglesey would be extremely small. If any such (or, on the contrary, any traces of a Pliocene terrestrial fauna) do remain, they should be sought for beneath the glacial drifts at the south-western ends of the monadnocks, where there was tolerable shelter from the pressure of the ice. Mr. Dewey urges that the characters of the Tregarth Shelf can be explained only by marine erosion. There is another consideration. The three platforms do not appear to be truly parallel. For though the two older ones are but scantily preserved, they show no sign of inclination; whereas the Menaian Platform declines westward at 6.9 feet per mile. This decline, accordingly, cannot be due to earth-movement (which would affect all three equally), but must be original. Thus, as the sea works horizontally, whereas pure sub-aerial agencies need some, if a very trifling slope, we may perhaps regard the two older platforms as true plains of marine denudation, and the Menaian as a base-level of sub-aerial waste.

What are the relations of these platforms to the mountains, which rise from them with such singular abruptness? Ramsay, the great pioneer of physiographical research in Wales, showed long ago that the Welsh Highland is itself an ancient plain of denudation. He was inclined to ascribe it to the Permian period. It is probable, however, as has been pointed out by Geikie and Goodchild,<ref>A. Geikie: 'Scenery of Scotland', Chapter VII. J. G. Goodchild: 'Phys. Hist. Greystoke Park' (*Trans. Cumb. West. Assoc.,* 1888); 'Geol. Hist. Edenside' (*Proc. Geol. Assoc.,* 1889).</ref> that these elevated platforms have been base-levelled more than once. The great table-land of the Scottish Highlands is partly built up of Tertiary plutonic rocks, and its dissection is manifestly a work of Tertiary time. The last base-levelling of the Highland of Wales may be of late Cretaceous age. The erosion of its valleys, at any rate, cannot be regarded as Pre-Tertiary, beginning, probably, in Oligocene times. They are on the same scale as the Scottish valleys, and indeed, with the example of the Alps before us, their depth is no objection to that date. Those valleys now open out upon existing sea-level. In what would seem to have been Pliocene time, they opened out at the Menaian level. Somewhat earlier, they opened out upon the Tregarth Shelf and the level of the Monadnocks. The three platforms may therefore be regarded as successive planes of denudation to which a wide region surrounding the Welsh Highland was reduced, at three stages of the prolonged erosion during which old Miocene and Pliocene High Wales was transformed into the deeply-cut and rugged mountain region of to-day.

Tertiary decay

Mention has already been made (pp. 702, 740–41) of certain sheltered places where depths of 50 to 80 feet of decomposed rock have survived the glaciation. Most of the material is Gwna mélange in a low state of anamorphism, whose matrix (E11070) [SH 300 896] is now quite soft and oxidized to a bright-straw-yellow colour, the decay being so severe as to disintegrate even the quartzites, picking out every grain of unstable mineral and filling their joints with veins of limonite. The process is Post-Ordovician, for Glenkiln conglomerates are involved. It is also later than the Palozoic Metasomatism, for though the decayed material is readily permeable, it has not been re-cemented by the silicification that has affected Ordovician grits about 150 yards from Porth-wen. The Old Red and Carboniferous rocks furnish no evidence; but fortunately that is needless, for we have seen (pp. 776–8) that the site of Anglesey must have been covered by Mesozoic beds, ranging from the Trias to the Chalk. Had the Trias lain at the base, permeable decayed matter already developed would have been stained<ref>As have been the much older products of decay that (pp. 581–2, 599) underlie the Old Red Sandstone.</ref>; had either the Jurassic rocks or the Chalk lain at the base, it would have been calcified. It is neither, so the process must be assigned to Tertiary time. Now at the time of the intrusion of the dykes, the cover they imply (p. 783) would have been a. protective shield; and even as late as while the Monadnocks' Platform remained intact, there would still have been a depth of 300 feet. The decay may have begun in the course of the

destruction of that platform, but as the rock-surface at Porth-swtan is at least 180 feet lower than the sunlmit of Llanfaethlu hill, it is more likely to have been initiated upon the surface of the Menaian Platform. In Pleistocene time, long before the on-coming of the ice-sheet, the process would have been checked by freezing of the surface; and the cover of boulder-clay has probably prevented . its penetrating appreciably deeper since the departure of the ice.

We may infer, therefore, that, at the places now referred to, we obtain glimpses of the condition to which the less chemically stable rocks of the Menaian Platform were brought in the course of the long-continued genial climate of the Pliocene period.

The erosion of the platforms

So little remains of the 'Monadnocks' and Tregarth platforms that nothing can now be made out (at any rate in Anglesey) of' the history of their destruction. Even the Menaian Platform, comparatively intact though it appears from a distance, has already been both deeply and extensively eroded, a study of the contours revealing that considerably less than a half, probably not more than a third of the Island is really undissected plateau. As for minor detail, its diversity is quite remarkable. Few residents know the country as does Mr. Thomas Prichard, and he once remarked to me that if a level field happened to be required for any purpose, it was (except in the marshy alluvia) by no means an easy thing to find. This erosion is at the present time in an anomalous and interesting stage.

Watershed and valley systems

The Watershed keeps near the eastern coast. Beginning at Mynydd Eilian, it passes along Parys Mountain, at the end of which it sends off a long branch westward that will be considered later on. Curving inland by Coedana church, it attains its greatest distance from the coast, but swings at once back to the road near Craig-fryn, and passes thence over the Carboniferous plateaux to the west end of Cors Bodeilio. Crossing the line of the Berw faults at Hendre, it once more bends eastward along Mynydd Llwydiarth to Llanddona. There it forks, one branch passing southwards to Beaumaris, the other to Penmon along the Carboniferous escarpments. The bends at Bodeilio and Coedana are diversions due to special causes, the real main line pursuing a tolerably steady course from Parys Mountain to Beaumaris. Its original position seems to have been determined by the conditions which determined the survivals of the monadnocks. Its present proximity to the eastern coast may be ascribed to the presence of Mesozoic rocks (pp. 776–8). These have succumbed rapidly to marine erosion, so that the coast has gradually retreated towards the watershed.

The Valley system

This watershed, however, is not conspicuous to the eye. By far the most striking feature of the surface is the strong system of valleys that traverses it in It north-east and south-west direction, ridge and trough succeeding each other in a remarkably regular and parallel way over the greater part of the Island. The same valley system traverses also the mainland portion of the platform. The largest of these hollows is that which, 'following the line of the Berw faults, is continuous across the whole width of the Island, and includes both the Malldraeth Marsh and Red Wharf Bay. Next in magnitude are those of the Braint, the Ffraw, the Crigyll and the Alaw. The Braint Water has been diverted southwards by the sand, the real direction of the features being across the lower part of Newborough Warren to the sea in Llanddwyn Bay; while the Vale of the Alaw is continued across the marine alluvium of Holy Isle to Tre-Arddur Bay. From these there are gradations, through lesser and lesser hollows, down to mere trenches along the sides and summits of the ridges, and even to the gaps between the bosses. The floors of the Malldraeth, Red Wharf, and Ffraw are below sea-level for considerable distances, the Malldraeth no less than 100 feet (p. 769), so that its total depth is as much as 360 feet.

Several of these valleys notch the main watershed, the two principal deflections of which (noticed above) are due to this cause. In two other cases they breach (at, and a little south of Bod-Grynda) the Carboniferous escarpment. The most remarkable case is that between the Malldraeth Marsh and Red Wharf Bay. Between the heads of the two long inlets of marine alluvium, that is, from Pentraeth to Ceint, is a deep trench-like hollow rather more than three miles long, along which the new railway has been taken. Its waters part in a boggy tract whose highest point is due east of Hendre (just at the 'r' upon the map), and here the level (kindly given by the engineer) is 86.86 feet above ordnance datum. But there is evidently some depth of peat upon the bog, and drift again below that, for 15 feet of boulder-clay was cut into on the

south side of the valley at the time of making the railway, without reaching rock. The slopes of the valley sides, when protracted, with reasonable allowance for curvature, indicate a depth of about 25 feet for the superficial deposits. The level of the true watershed on the floor of rock is therefore not likely to be more than 60 feet above ordnance datum, so that this valley fails but little of being another open sea-channel.

The valleys of this system are remarkably straight, they are also long, and with a very gentle fall, almost all are smooth upon the sides, which are seldom steep, and even when they are, have hardly any vertical and no ragged crags. In short, they have none of the characters manifested by valleys of ordinary fluvial erosion, but all of those that may be observed in glacial furrows. Their trend, moreover, is that which we have seen to be the direction of the movement of the ice. By whatever agency they were initiated, it is safe to conclude that they have at least been re-modelled by glacial erosion.

Another valley-system, however, exists, which, though much less conspicuous in the landscape as a whole, supplies a clue without which the process of erosion of the platform could not be made out. The trend of its valleys is in a generally north-west and south-east direction (their drainage may be either way), and thus at right angles to the dominant system. Most of them are small, but those of the Cefni (above Llangefni), the Cadnalit (on the Strait), Rhyd-yr-arian (near Holland Arms), and Nantanog (on the side of Cors y Bol) are of considerable size. They contrast with those of the dominant system in every particular, having short courses, full of sharp curves, a rapid fall, and very steep and craggy sides; possessing, in fact, all the characters of water-cut valleys as conspicuously as the others lack them. Now these valleys, lying directly across the path of the ice, must be either Pre- or Post-Glacial. In the Cadnant, just above the Factory, and in the Cefni, at the south point of the great bend south of Pandy, as also at the Dingle, a little boulder-clay has been found. That in the Cadnant may have slipped, that in the Cefni seems to be *in situ.* In the Rhyd-yr-arian ravine tough blue boulder-clay can be seen above and below the bridge. They must therefore be regarded as Pre-Glacial.

They are now, however, tributary to valleys of the dominant system, and, as it is evident that no other outlet for them to the sea can ever have been open, it follows that some at any rate of the dominant valleys must have been excavated, and that to a considerable depth, in Pre-Glacial times. The trend of the latter was manifestly determined at the outset at once by the original inclination of the plane, and by the dominant strike; and they are most pronounced where, as in the case of the Malldraeth and its Red Measures, the surface of the Platform was composed of unusually friable rocks, let down against a powerful strike-fault.

The strong parallel valley system of to-day thus results from local coincidence between the direction of the strike and that of the glaciation. But its valleys have been so much deepened, widened, smoothed and straightened by the ice that their present aspect is essentially that of great glacial furrows; while the innumerable parallel minor hollows can hardly have been even initiated by ordinary drainage.

There is evidence (pp. 706, 725) that some of the narrow notches in the watershed have been deepened by flood-waters during the waning of the Glacial Period, when it is likely that the retreating ice-front stretched across Red Wharf Bay from Marian-glas to Careg-onen, impounding a lake, for a while, between it and the land. Such a lake would find its exit at the lowest places on the watershed, and cut them, one after another, lower still. There is a curve near Hendre that is suggestive of the furrow having been modified by water in this manner.

The presentation to the Post-Glacial streams of so many new valley-levels, however, has introduced countless anomalies into the behaviour of the waters both of the longitudinal and the transverse channels, leading especially to the excavation of short new transverse cuts; and in general to a complexity of drainage-development that is by no means easy to unravel. When we consider also (pp. 732–3, 742) the great modifications that are due to the drifts, especially to the drumlins, it will be seen that the valley-system as it is presented to us to-day has been profoundly modified by glacial action.

The Northern Country and its Barrier — The two valley-systems just described can be traced as far out as the basins of the Dulas and the Alaw; but north of these the configuration is different. That branch of the watershed which goes wet from Parys Mountain curves through Rhosgoch along the rugged Mynydd Mechell, and thence north-westward past Llanrhyddlad upper village and over Mynydd-y-Garn to Carmel Head. There is, in fact, a continuous ridge of high, rocky, bare land, extending in a great elliptical curve all the way from Carmel Head to Freshwater Bay. This may be called the

Northern Barrier, for it dominates all the physiographical phenomena of the northern district, which it shuts off completely from the rest of the Island. It may readily be traced upon the one-inch maps by its comparative bareness of glacial drift. Except at Pant-yr-eglwys, it is everywhere above the 200-foot contour; and thereareonly four gaps of any impor-tance—Pant-yr-eglwys Gap, 110 feet; Llanifiewyn Gap, 203 feet; the Gap of Rhosgoch, 226 feet; and the Gap of Pensarn, 262 feet. That it has been determined by the outcrop of the Cannel Head thrust-plane will be noticed at once. But the coincidence is not exact; its centre is to the north, its east and west wings to the south of that line, the oscillations being determined by the relative durability of the rocks on either side. That this great feature is Pre-Glacial is quite evident; its trend is independent of the direction of ice-movement, which crosses it at different angles in different parts, though doubtless its gaps were accentuated by the glaciation. There is reason to think that it is of considerable antiquity, for no less than four out of the nine monadnocks of the Island stand upon it. The northern district is in reality a wide valley, lying between it and the sea-board remnants of the Menaian Platform, but so crowded with drumlins (pp. 742–3) that it no longer presents the appearance of a valley.

Studies of special features

At various stages of the erosion of the Menaian Platform, certain features were produced which are of especial interest, and some attempts will now be made to trace out their causes and the processes of their development. The most striking and remarkable of them is, of course, the Menai Strait:

The Cefni and the Braint

A short study of two rivers, the Cefni and the Braint, will illustrate Some of the curious modifications that were imposed upon the old drainage during the glaciation, many more of which will appear upon an inspection of the maps.

The Cefni

is a name given to a complicated system of streams which drain some 60 square miles of the interior of Anglesey. At Llangefni the river emerges, rather suddenly, from the deep ravine already alluded to, which is about a mile and quarter long, and is the most striking of its class in the Island. It is 140 feet deep at the wood's end by the old mill<ref>This measurement was kindly made some years ago by Mr. Tobias Clegg, of Llangefni, by means of an ingenious extemporised theodolite, and since found correct by aneroid.</ref>and, in places, less than 400 feet wide at the top, with precipitous and rocky sides. At its upper end, instead of proceeding from an upland valley in the same direction, we find that it issues, almost at right angles, from the side of a north-east and south-west valley of the longitudinal system, which extends for several miles to right and left. This, which may be called the Trefollwyn Valley, is a closed oval basin, all its waters converging to the exit at the Cefni Ravine. Now the Trefollwyn Valley could not have existed when the Ravine was initiated. For its south-west barrier, close to Mona House on the Holyhead Road, is less than 150 feet above sea-level, whereas the lowest part of the platform trenched by the Ravine is 200 feet in height, so that waters lying in the Trefollwyn Valley would have chosen the south-west exit and deepened that channel<ref>No sign of an ice-dam has been observed at this place.</ref>', and the Ravine could not have been cut. On the further side of the Trefollwyn nearly opposite the exit at the head of the Ravine, a small stream enters from the north-west, after a course (cut in rock) of about a mile. This channel is in the natural position for the missing upper portion of the Cefni, and has a slight but sufficient fall. How, then, did it become severed from its lower portion by the broad valley of Trefollwyn? That valley is a typical smooth, straight, ice-modelled hollow. If we suppose it to have been initiated by two small tributaries of the Pre-Glacial Cefni, one from north-east, the other from south-west, and suppose that their combined channels were deepened and greatly widened by glacial erosion<ref>The behaviour of the complex waters which. coming from the Coedana country, past Llangwyllog, enter it at Bodfordd, is also anomalous, and evidently modified by glacial furrowing at various levels, and the resulting transverse cuts.</ref> we shall be able to understand its existing features and proportions. By such an hypothesis, the severance of the two portions of the Cefni, the closed oval hollow, and the anomalous drainage and configuration, find an explanation.

An interesting consideration in connexion with the ancient river Cefni is that, at an early stage of its history, far back in Pre-Glacial time, there must have been a fine waterfall close to where Llangefni Station is. For, at that point, the river has

cut through a lenticular quartzite of the Mona Complex (p. 350), about 100 feet thick, and very hard, whose white crags are to be seen among the fir-trees. It gives rise, even now, to a rapid. In the early stages of erosion, while freely allowing the river to cut back to it from below, it must have retarded cutting-down in its rear for a very long time; and, consequently, for ages a fine cataract must have poured over a crag 80 or 100 feet in height.

The Braint

The behaviour of this river is also anomalous, but in the converse manner. Almost the whole of its course is along a valley of the longitudinal system; but on its way it is intercepted by a valley of the other system, running from Carnedd-fawr Covert to Pwll-fanogle in an east-south-east direction, and along which the railway has been carried for some way between Llanfair and Gaerwen, evidently a shallow Pre-Glacial transverse valley whose features have been degraded by glacial erosion. The Braint enters this valley from the north-east, *crosses* it, and passing out on the other side, goes on its way to the sea in a steady south-west course. The transverse valley, however, robs it of some of its waters. At Rhosbothan is to be seen the unusual phenomenon of a forking of streams downwards, and part of the Braint goes to enrich that whicji plunges into the ravine at Pwll-fanogle. The features suggest that in Pre-Glacial time a tributary came into the Gaerwen Llanfair valley from Bryn-celli-ddu, but that the ice ploughed out the low watershed of this little stream, and reversed its flow, thus enabling the Post-Glacial and augmented Braint to take immediate possession of the Bryn-celli valley.

The Menai Strait

Few valleys in Britain have been more discussed than has the Menai Strait. The 15 miles of river-like channel, overhung by quiet inland woods, yet fringed all along their shores with sea-weed; the clear waters; twice a day placid like a lake, yet twice a day moving in a tide-race that can be heard a mile away; these things are a sort of paradox of Nature, that cannot but rouse the scientific imagination to inquiry.

Yet, as was pointed out by Ramsay long ago, the Strait, as a valley, is by no means unique; it is but one of the many valleys that traverse the genaian Platform; its uniqueness lies in its being low enough to be filled with the waters of the sea. Had the watershed at Hendre been cut but some 60 feet lower than it has, another strait would, as we have seen, have united Red Wharf with Malldraeth Bay. Whatever, then, be the origin of that, and of the many other less remarkable valleys of its kind, such must have been the origin, to some extent, at any rate, of the Menai Strait. We have seen reason to regard them as old longitudinal valleys that have been deepened, smoothed, and straightened by glacial excavation. So far, then, we follow Ramsay.

Nature of the Channel — The problem of the Strait, however, is not so simple as that of most of the hollows of the Platform. For it is not one valley. It is really three. It falls into three natural divisions — an eastern, a western, and a middle reach ((Figure 340), and (Plate 51), (Plate 52), (Plate 53), (Plate 54).<ref>(Plate 51) is taken from the Suspension Bridge, the level of whose roadway is 115 feet above ordnance datum. (Plate 52), (Plate 53) are taken from the gallery near the top of the Column at Llanfair-pwll-gwyngyll (just at the foot of the statue), and the three dim pointed objects in (Plate 52) are the spikes on the gallery-railings (out of focus). This gallery is 95 feet above the base of the Column, on which is a 238.70-foot bench-mark, so the view-point is 333.70 feet above the sea. The level of the roadway in the foreground of (Plate 52) is 151 feet. The highest mountain seen 101 miles away is Carnedd Llewelyn, 3,482 feet.</ref> The eastern and the western reaches are typical north-east and south-west valleys belonging to the great longitudinal system that has been discussed above; but the middle reach, between Llanfair Church and Port Dinorwic ((Figure 340), stage 3), sonic two miles long, runs very nearly north and south. For the two first-named the theory of glacial enlargement may be with confidence adopted; to this portion between them it cannot be applied. The problem of the Middle Reach is the problem of the Menai Strait.

In considering that problem it is necessary to realise that the Eastern and the Western Reachesareparallel valleys, essentially independent of each other. For not only are they on different axial lines, but the Western Reach is really part of another valley altogether, being a direct prolongation of the straight and trench-like hollow that runs through the old city of Bangor and out into the Strait at Port Dinorwic. The Eastern Reach dies out near Plâs Llanfair, its place in Anglesey being taken by the vale of Braint, with which it is not in line but en echelon'. This reach is really straighter than it seems

upon a map. The curve at the Suspension Bridge (not shown in (Figure 340)) may be neglected, for the tongue that comes out from Anglesey is of the nature of an 'island', being only 86 feet high, and isolated by a deep hollow running through the village, that is nowhere as much as 30 feet above the sea, and is, moreover, filled with drift to an unknown depth.

An elaborate series of soundings has been taken (with revisions from time to time) throughout the whole length of the Strait, the depths given upon the Admiralty charts being those of dead low water at spring-tides. Towards Carnarvon and Beaumaris they are, for the present purpose, vitiated by the existence of large and ever-shifting sand-banks, but are unaffected by such banks between Port Dinorwic and Garth Ferry. The first thing brought out by a study of these soundings is that there is a well-marked submarine 'watershed' between the bridges. Quarter of a mile east-northeast of the central pier of the Tubular Bridge is a reef known locally as the Cribiniau<ref>It is not shown on most of the maps, but the Director-General of the Ordnance Survey has very kindly had it engraved (though there was no room to engrave the name) on the new one-inch geological map of which this book is an explanation. In (Plate 52) the tide is too high for it to be visible, but its position may be found by measuring off two to two-and-a-quarter inches leftwards from the middle of the foot of the central pier of the Tubular Bridge.</ref>, where the main channel is only 83 yards wide (Plate 52). Here there is less than 10 feet of water, and other shallow soundings have been obtained close by. Moreover, this 'watershed' is evidently a true rock watershed. The most experienced fishermen on the Strait report that there is no clay or sand in the Cribiniau channel. The scour of the tide, they say, is far too strong to allow any fine material to remain in it. They find nothing at the bottom there but great blocks and rock. Eastwards the channel begins to deepen, till it is sonic 30 feet near the Suspension Bridge, and so on till a depth of 49 feet is attained at Garth Ferry. Westwards also it deepens in like manner, exceeding 20 fet after the Railway Bridge is passed. Then, southwards along the Middle Reach we have the following soundings:-24, 29, 45, 38, 38, 43, 42, 57 feet.

It is evident from these soundings that the Strait cannot be regarded as part of the course of a vanished river, nor even as a glacial overflow channel, considered as a whole from sea to sea.

But the soundings bring out also a completely unexpected feature (which is no less an obstacle to the theory of simple glacial excavation). On the Anglesey side of the channel, at Pwll-fanogle, only three-quarters of a mile from the Cribiniau 'watershed', the gentle westward slope is suddenly interrupted by a hole no less than 77 feet deep!<ref>With a spring tide and westerly gale there must be nearly 100 feet of water. The position is indicated by the little ring in (Figure 340), and is also visible in (Plate 53), just beyond the group of buildings whose roofs are outlined against the water.</ref> That is about 50 feet below the average level of the Strait-floor in that part, and is a depth that is not found anywhere until well out into the open sea at either end. To the consideration of this cavity we shall return later on.

Development of the Menai Strait — The direction of the Middle Reach was first determined in Pre-Glacial times ((Figure 340), stage 1). Let us consider the Vale of Cadnant. This ravine is one of the transverse valleys that have been shown (p. 787) to be Pre-Glacial. Where, then, was its exit? That could only have been in the direction in which it is now, out into the sea beyond Beaumaris. There must, therefore, have been a longitudinal valley (determined by Pre-Glacial erosion along the margin of the Mona Complex) info which it fell, on the site of the present Eastern Reach. But it may have been quite shallow. The deep lower part of the ravine is determined by a decomposing dyke, and could have been cut down to its present level after the longitudinal valley had been deepened by the ice. The source of that old valley must be placed in the neighbourhood of the Railway Bridge, for we must regard the present submarine 'watershed' as a degraded representative of the real watershed of that time. But water still runs off Anglesey at the head of the Middle Reach, coming out of the Gaerwen–Llanfair valley, which is a modified Pre-Glacial valley of the transverse series. Passing to the west of the old watershed, its natural course would be to the south, to find its way into another old longitudinal valley (determined by Pre-Glacial erosion of the Red Measures let in by the Dinorwic fault) that has since been deepened into the Western Reach. So passing southwards, it sketched out the first shallow indications ((Figure 340), stage 1) of the Middle Reach.

Let us consider a time when, rather early in the waning of the Glacial Period, the ice of the Mountain-Land and of the Sea-Basin had ceased to be confluent in the region of the Strait. We have seen that the zone of confluence had long been a. zone of oscillation (pp. 723–4). It would still be so; but the Mountain-Land, with its heavy snow-fall, would no longer be hindered from pushing tongues of its glaciers out across the lowland. This would not happen all along the

mountain-front, but only at the mouths of the great valleys, like Llanberis and the Ogwen. The moraines of Penrhyn Castle were long ago recognised by Ramsay as a monument of one such episode. A little earlier the great Ogwen glacier must have pushed out still further, reaching easily across to the opposite shore, very likely maintaining (by its great *vis a tergo* a local confluence with the retreating ice of the Sea-Basin after the general confluence had ended.

At this time, the Eastern and Western Reaches (but not the Middle Reach) would be in existence much as they are now ((Figure 340), stage 2), and they would be emptied of their ice. But the melting-waters of that which was still quite near would at once find its way down into them. The water in the Western Reach would have an unobstructed exit into the sea beyond Carnarvon. Not so that in the Eastern Reach. At one end would be the land between Llanfair and Vaynol, not less than 100 feet in height; at the other a great ice-dam, which might easily be 200 or 300 feet in height, pushed out from the Ogwen glacier against the lofty wall of rock near Pen-y-parc. So that reach would quickly become a long and narrow glacial lake. Its overflow level would be attained at the western end, where the land was lower; and erosion of an overflow-channel would begin, which would be comparatively rapid upon the relatively soft rocks of the local Carboniferous. But why should the channel not have been cut straight out south-westward in prolongation of the Reach itself? The answer is that, as soon as it had passed across a very little width of barrier, the water would find itself in the old channel of the Gaerwen river, and be immediately diverted to the southward. Once established in that channel the powerful flood-waters went on widening and deepening, until they had drained the Eastern Reach to the level Of the submerged watershed', where, even if the ice-dam were still present, they would receive a check at the hard surface of the mica-schist. Thus was cut the Middle Reach ((Figure 340), stage 3).

At Port Dinorwic the waters would join those of the Western Reach, and so pass out to sea. It will be seen that the soundings, 'showing a gentle slope all down the Middle Reach, are quite in accord with this. view that it has been cut by water. The features, also, of the channel, with limestone cliffs, often undercut, especially on its western side, towards which the stress-of the flood-waters would be directed, are quite unlike those of the normal ice-cut hollows.

The process must not be thought of as taking place at the present levels, which would, indeed, make its later stages quite impossible, for the last outflow from the lake would be at least 10 feet beneath the sea (though, as the tide-race must have considerable erosive power, it may not then have been quite so low). There is a large body of evidence that during a great part of the Glacial Period the land stood much higher than it does at present, and this would provide an ample fall for the escaping waters.

Finally, the deep hole in the floor at Pwll-fanogle remains to be considered. The cliffs of the northern shore are here cut suddenly back into a deep wooded gorge that extends as far as the road at Aber-braint, down which the old river Braint still leaps in a succession of cascades fiom ledge to ledge of the beds of horizontal Carboniferous conglomerate. The body of water is even now considerable, and at the close of the Glacial Period must have been greater still. When the vale of Gaerwen became free from' ice, that river began to flow again, but it found itself in new surroundings. Part of its waters had been stolen from it for the new Braint river (p. 790), but this was made up to it by the drainage of the deepened longitudinal valleys on its northern side. When it arrived, however, at Pwll-fanogle, it found, in place of the old shallow channel along which it once ran to Port Dinorwic, a huge chasm, the newly excavated Middle Reach ((Figure 340), stage 3), some 60 or 70 feet lower than its bed. Into this it would plunge in a great cascade at the cliff's brow, for that would then have been unbroken by the gorge into which the river has ever since been cutting its way back. The Strait;' it is strange to think, must have been for a long time almost a dry valley, for the eastern ice-dam once removed, and its floor standing well above the sea, such drainage-waters as it received, especially so near the watershed, would have been insignificant in such a hollow. Into this open hollow, then, the river plunged. The cliff over which it fell was of conglomerate. But it happens that the floor of the Strait at Pwll-fanogle is composed of the purple marls described on pp. 648–9, which are the softest rocks in the whole district. In them it would be an easy task for such a waterfall to excavate even a gigantic pothole, and the conglomerate would have sufficient powers of resistance to give it a good long time in which to work.

Then came the Post-Glacial oscillations of the land. Without attempting to follow their effects in detail, let us confine ourselves to the last of them, that indicated by the 'Submerged Forest'. The Forest-beds of Anglesey (pp. 766–8) afford no measure of this movement; but a measure was obtained at Barry, Glamorganshire, from which it appeared that the land then stood at least 55 feet above its present level. And a peat-bed has been pierced by a boring at Rhyl at a level

seven feet lower (measured from ordnance datum) than the peat-bed of Barry.<ref>A. Strahan: 'Submerged Land-surfaces at Barry, Glamorganshire' (*Quart. Journ. Geol. See.,* 1895, p. 483). A. Strahan: 'The Geology of Rhyl, Abergele, and Colwyn' (*Mem, Geol. Surv.,* 1885, pp. 40–42).</ref> No doubt the Menai had been invaded by the sea during the period of the Raised Beach; but at that of the Forest-bed it must have been dry almost from end to end. Then the land sank, the sea crept along the Eastern and the Western Reaches, until at last the Middle Reach was filled, and the tides of the two fiords met at the Cribiniau. So that it is by virtue of the 'Forest-bed ' submergence that the Menai hollow is for us to-day the open tide-way of the Menai Strait.

The Strait of Holy Isle

This romantic channel, with its labyrinth of rocky creeks, all filled with clear sea-water at high tide, owes its existence to a combination of agencies. Its general trend was first sketched out by Pre-Glacial decay along the line of the Namarch faults (p. 211), two small streams running, apparently, to north-west and south-east from a now degraded watershed situated somewhere about Four Mile Bridge. Then came the Glaciation, with its great development of north-east and south-west hollows, to which class nearly all the tributary creeks belong. Where they intersect the Namarch lines, broad pools were excavated, such as that at the railway, which is at the intersection of the Vale of Alaw, there making for the Tre-Arddur gap; and the expansion at Rhyd-bont, at the intersection of the marine alluvium of Valley facing Rhyd-bont creek. Smaller expansions occur at Fadog and Cymyran. The anvil-shaped eastern creek at the first of these is a combination of a glacial hollow with one along a Namarch line; and the present opening at Cymyran has been determined by decay along the Bodior dyke. None of these features, however, are products of marine erosion, but of sub-aerial waste (which could not have operated at the present levels) modified by glaciation, such as may be met with anywhere on the rocky surface of the Mona Complex. The last touch was, as at the Menai Strait, the Forest-bed submergence, which admitted the sea, isolated Rhoscolyn and Holyhead, and converted all this labyrinth of intersecting hollows into the Strait of Holy Isle.

Fydlyn

The profound hollow at Fydlyn (Folding-Plate 13), cut down to sea-level amid rugged heights of mountain-like aspect, is incapable of explanation in accordance with normal drainage. Unlike all the other adjacent features, it is oblique to the strike, which it crosses at an angle of 40°. There is no catchment area to speak of, since the Gader promontory is hardly more than a mile in width, so that its waters are, and under normal conditions must always have been, insignificant, and out of all proportion to the magnitude of the hollow. Only half a mile in length, it nevertheless has a fall of 200 feet per mile, which is double that of the torrential Ogwen of Carnarvonshire. It is unlikely to be a Pre-Glacial feature, for the submarine 50-foot contour, instead of curving in landwards in the usual way, positively curves out seawards opposite. its mouth. Coincident with nothing else, its course is parallel to that of the glacial striae as they run across the watershed of the promontory and down to Fydlyn, suggesting that it was initiated by glacial erosion, acting on the decayed felsitic schists. Yet its upper parts only can have originated in that way; for its lower parts display different characters. Above the 100-foot contour its sides are ice-worn; below it they bristle with angular and jutting crags<ref>One only, on the south side of the alluvium, is rounded off, and that might be the work of water. A possibility to be borne in mind, moreover, with regard to hollows excavated by glacial flood-waters is that they may not all date from the final retreat of the ice. Why should not some of them have been produced in the course of its partial retreat (p. 724) 7 Such hollows, however, would have been glaciated in the course of the second advance of the ice, though less so than Pre-Glacial valleys. And if similar fiuvio-glacial conditions recurred in the course of the final retreat, their ice-worn features would be wholly or nearly obliterated.</ref>, especially along its middle reach, which is a deep craggy ravine only a few yards in width. Another anomalous circumstance is that, below the, same contour, not a trace has been found of boulder-clay or any other glacial drift; for the accumulation at Fydlyn crag's foot is composed entirely of semi-consolidated ancient scree. In short, above the 100-foot contour the features bear every mark of the work of ice; below it every mark of that of water.

Now, the hollow begins precisely at the Pant-yr-eglwys gap (p. 788), which cuts across the Barrier at the 110-foot level; and with which gap its origin is plainly in some way connected. Behind that lies the broad hollow of Mynachdy marsh (p. 772), in which, even in Post-Glacial times, there was a lake at the level of 60 feet above the sea.<ref>It may have risen to 75 feet, for the waters have cut themselves a narrow exit (deepened artificially, to drain the marsh) in the direction of

Hen-Borth.</ref> Given a northern ice-darn only 60 feet higher, and the waters of that basin would find their way across the gap and into the direction of the glaciation. It is true that, were ice lying equally against both coasts, there would be no such exit. But, with sun-heat reflected from the lofty western cliffs, the retreating ice would leave the Fydlyn coast while it still rested heavily upon the northern hills about Mynachdy and Caerau. Under such circumstances, a temporary lake would gather in the Mynachdy basin. Its flood-waters, escaping over the gap, would find their way into the Fydlyn glacial furrow, and meeting with but little resistance in the decomposing felsitic rocks, would rapidly deepen it, cutting back easily to the limit of those beds. In the floor of the valley there lies an alluvial plain, just below storm-beach level, called Llyn-y-Fydlyn, on which a shallow lake still occasionally forms in rainy seasons. Its landward end coincides almost precisely with the limit of the felsitic rocks, where erosion would meet with a check, and where, accordingly, the steep ravine begins. Thus, in the action of glacial, succeeded by fluvio-glacial erosion, it seems possible to find an explanation for the anomalous features of the deep and craggy valley that exists to-day.

The Lakes

There are still (p. 772) 30 lakes in Anglesey<ref>Or were until a few years ago.</ref>, and such particulars as have been ascertained about them are shown in the following table. Some of the heights are given on the six-inch maps, the rest have been obtained from the contours and by other means:

Name	Depth	Height above sea	Probable Nature	Remarks
Bodafon tarns		440	Rock-Basin	Rocky exit.
Cadarn		260	Rock-Basin	Rocky exit.
Llwydiarth	20	275	Rock-Basin	
Bod-gylched	5	331	Rock-Basin	
Pen-y-parc	15	290	Rock-Basin	Raised by a dam.
Hendref		195	Rock-Basin	Rocky exit.
Caer-glaw		140	Rock-Basin	Lately drained.
Penrhyn		23	Rock-Basin	Very doubtful.
Dinam		23	Rock-Basin	Very doubtful.
Bwch tarns		190	Rock-Basin	Lately drained. Rocky exit.
Llanfftewyn, Creigiau		250	Rock-Basin	Small, among rocks.
Llygeirian		149	Held up by boulder clay}	Lowered by a drain.
Hafodol		225	Held up by boulder clay}	
Wyth-eidion	33	149	Held up by boulder clay	Sounding rather doubtful.
Padrig		70	Held up by boulder clay	Lowered by a drain.
Traffwll	19	23	Held up by boulder clay	
Llywenan	8	109	Held up by boulder clay	Raised by a dam.
Gareg-lwyd		160	Held up by boulder clay	Raised by a dam.
Frogwy		160	Held up by boulder clay	Raised by a dam.
Newborough		25	Held up by sand on drift}	Two exits.
Maelog		10	Held up by sand on drift}	
Coron	15	30	Held up by sand on drift	Depth a mean of estimates.
Parciau		295	Solution of limestone.	
Cemlyn		0	Lagoon	Rises with tide.
Malldraeth Yard		0	Lagoon	Percolation through dam.

Berw	0	Subsidence	Over old coal mines.
Morfa-mawr	0	Subsidence	Over old coal mines.

Llywenan is three-quarters of a mile in length, but the largest that are wholly natural are Traffwll and Maelog, about five-eighths of a mile each.

Their distribution is interesting. Only two (besides Cemlyn) lie either east or north of the watershed, though several of the little tarns are almost on its crest. Their surface-levels have a vertical range of 440 feet; whether the floors of any of them are below sea-level is not yet known, though that could be ascertained by accurate soundings of Maelog, Penrhyn, and Dinam. Several of them, lying in alluvium, are mere remnants of much larger ones. This is especially the case with Llyn-yr-wyth-eidion (the Lake of the Eight Oxen) in the midst of Cors Erddreiniog (p. 771), and it has a curious legend. Their present forms rarely show the northeast and south-west elongation that might have been expected, but when their old extensions (pp. 770–72) are considered (particularly if we add those which are wholly silted-up), it appears at once that most of them belong, after all, to valleys of the longitudinal' system. As many as 21 rest upon the Mona Complex, only two upon Ordovician and three upon Carboniferous rocks (the remaining four having no relation to any rock-formation), from which it is evident that the features of the Complex (pp. 803–5), like those of the Lewisian Gneiss of Scotland, are peculiarly favourable to the development of lake-basins.

Still more significant is their nature. No less than 25 owe their existence (wholly or partly) to glacial operations; one seems to be a solution-basin; one is marine; three are indirectly due to the operations of man.<ref>The numerous pools about Parys Mountain, being wholly artificial, are not included.</ref> Of those due to glacial agencies, none have actually been demonstrated to be rock-basins, but the configuration of the land, in relation to their rocky exits (p. 771), renders this highly probable in 14 cases.

Most of their alluvial fringes are manifestly of the same nature and the same general age as the lacustrine alluvia described in Chapter 32, but very little is yet known of their older flora and fauna. Sir Richard Williams-Bulkeley, however, writes me that antlers of the Red Deer, a species long extinct in Anglesey and indeed in North Wales, were found in about five feet of peaty silt on the floor of Llyn Pen-y-parc when clearing it for Beaumaris waterworks. Six have been considerably modified by draining or damming, while three have been drained altogether during the last quarter of a century. Others are known from old records to have been drained or silted-up in remoter times, and as we have seen in Chapter 32, the number of lakes at the close of the Glacial Period must have been very great, and the size of some of them considerable.

It is clear, indeed, that nearly all the fresh-water lakes of the Island belong, as do such vast numbers in northern Europe and America, to the class whose origin is due, in one way or another, to the work of Land-Ice.

Cemlyn — This lagoon (already alluded to on p. 770) is really part of a marine strait which once made an island of Trwyn Cemlyn, but which has been abolished at one end by the silting-up of the cove south of Craig yr Iwrch, and at the other by the rise (on a shallow inner part of the old bay, which then ran in to the feet of the hills) of the great Cemlyn storm-beach, half a mile in length, behind which lies the lagoon. This ridge has an interesting history. In the first half of the nineteenth century it was much lower than it is now, and had a surface so firm that a cart-road ran along the top. It was built up to its present height, some 20 feet above ordnance datum, by a single storm, the great northerly gale of October 26, 1859, that wrecked the Royal Charter' on the rocks at Moelfre, and is still known in Anglesey as The Royal Charter gale'.

The forms of the coast-line

Deeply indented as this is to-day (in curious contrast to the 60 miles of gentle curvature that, interrupted only at the Ormes, extend along the mainland from Nevin to the Dec), a map of the rocky skeleton of the Island, stripped of the glacial deposits, would show far deeper indentations. There are four coasts, the Menai (which we have just considered), the eastern and western, which are dip-sections, and the northern, which is a strike-section.

The many bays of the east and west, such as Dulas, Lligwv, Red Wharf, Llanddwyn, Malldraeth, Aberffraw, Crigyll, and Tre-Arddur, are the seaward ends of valleys of the longitudinal system. They once penetrated much farther into the land, for great parts of themarechoked by boulder-clay and other superficial deposits, their true rock-floors, let down by the Forest-Bed submergence, being below sea-level for considerable distances. The Malldraeth once ran in as far as Hirdrefaig, Aberffraw as. far as Coron Lake, Llanddwyn, which hardly seems a bay at all, as far as Dwyran, while Gwichiaid was a deep inlet under Mynydd Eilian, other short coves being due to marine erosion of boulder-clay choking old hollows that were once much longer. These inlets tend to be acutely cuneiform, with cuneiform headlands pointing seawards between them. Several of them are compound. The curiously rectangular Traeth Bychan, is determined on the north by a small valley of the dominant system, at its back by the side of an escarpment, and seawards by a transverse valley that is due to waste along the Dinas Valley fault. Red Wharf Bay receives the openings of two parallel valleys of the longitudinal system. Cymyran is compounded of the longitudinal Crigyll and the transverse Strait of Holy Isle; while Tre-Arddur is the old opening of the longitudinal Alaw. Holyhead Bav seems to be the mouth of the transverse valley now degraded into a strait (p. 796), but the old longitudinal bays tributary to its eastern shores from Bodlasan to Crug-mor are overwhelmed with drift and almost obliterated. No bays now exist along the Menai coast, but a large one once ran along a pair of transverse hollows into the vale of Llangoed.

The northern bays are never cuneiform, their major axes being apt to lie parallel to the land, and their sides to curve into deep recesses; while their corresponding headlandsareusually anvil-shaped; features due to the tendency of the sea to attack rocks in the direction of the strike. Yet these bays also are the openings of land-valleys, transverse instead of longitudinal, and rarely containing the rivers of to-day, being usually (pp. 741, 746) Pre-Glacial channels blocked with boulder-clay, as may be seen in the westerly nook of Bull Bay. Cemlyn Bay, as we have seen, is part of an old group of inlets which once included Hen Borth, and into which two Pre-Glacial valleys opened, Llanrhwydrys being at that time an islet. The circular aspect of Porth-wen is deceptive. It was initiated as the opening of a narrow Pre-Glacial valley determined by a small north-and-south fault coming from near Ty-du. At the mouth of this creek the north-westerly gales worked in along the Trwyn-bychan thrust-plane, and enlarging the gap, swept out first the Ordovician shales and afterwards the tracts of old Pre-Glacial decay (p. 702), some of which still survive along its western side. The unusual complexities of Cemaes Bay are due to a combination of causes. First, the tendency of the sea to excavate lateral recesses along the strike has been accentuated by the tract of Pre-Glacial decay at the Lifeboat Station, as well as by the presence of the Ordovician shales on the opposite shore. In the second place, it contains the mouths of two Pre-Glacial streams (both choked with drift), one coming from the south-west at Wylfa cove, the other from the south-east at the beach below the Coastguard Station. While the fact that no less than 11 different formations emerge in the bay, together with the shattered condition of the Gwna Beds, have diversified its five main curves with innumerable nooks and chasms.

The submarine contours, as elsewhere<ref>See 'The Geology of Caithness' (*Mem. Geol. Surv.*), p. 161.</ref>, close in upon the land where it is lofty, and recede from it where it is low. The 100-foot contour approaches to within 275 yards of the South Stack, and 220 yards of Dinas Cynfor; while the 200-foot contour, in the tract known as Holyhead Deep, is only two and, three-quarter miles from the summit of Holyhead Mountain, so that the deepest marine hollow is nearer to the highest terrestrial elevation than to any other part of the Island. All but two of the outlying islets are within the 75-foot submarine contour; the Sherries being just within, the Middle Mouse just without, the 100-foot contour. That the Skerries channel, though two miles wide, is not so deep as the half-mile channel of the north, indicates a submarine ridge, which, being manifestly in line with the Northern Barrier (p. 788), shows that the Skerries rise upon a continuation of that feature. Just off Carmel Head, however, there is a deep nook in the 75-foot contour, opening to north-north-east, as do some of the inlets of the northern coast which are determined by small transverse faults. The curves of the 25-foot contour usually correspond to the Pre-Glacial inlets, and so (though not so closely) do those of the 50-foot contour, while the 75-foot contour seems almost independent of them, merely conforming in a general way to the major curves of the land. The 50-foot contour shows its greatest tendency to correspondence round the lofty coasts of Holy Isle and the north.

Types of scenery

Each of the principal formations of the Island has developed a special type of scenery. The Mona Complex is everywhere sculptured into knobs or bosses (Plate 55), that call vividly to mind the scenery of the Lewisian gneiss of Scotland. 'If', writes Sir Archibald Geikie (with special allusion to the Gneisses), 'the geologist could be suddenly transported. from the

rounded rocky knolls of Sutherland, Ross-shire or the Hebrides to those in the middle of Anglesey… he would hardly be aware of the change, save in the greater verdure of the hollows'. They will be considered more fully further on. Where the North Stack fault crosses Holyhead Mountain, the Quartzite rises in a long line of crag nearly 200 feet in height, which is at right angles to the strike both of the bedding and of the foliation. The Ordovician grits outcrop in short escarpments, while the country of the shales has a smoothly undulating surface, even where driftless, as about Nantanog. The loftiest escarpmental crag in the Island is that of the Old Red cornstones at Coed-y-gell, 200 feet in height, but it dies out in about a mile. The Carboniferous Limestone, especially in the Principal and Penmon areas, develops bold escarpments, often with long grey lines of crag, which are quite strong features below Parcian and on the western face of Prysain moor. In the interior of these districts there are many- tabular hills of bare limestone, whose tops are so seamed with ' gaping joints, widened by the carbonic acid in the rains, that', as Ramsay remarks, ' the pedestrian must give good heed to his feet in traversing the terraces and bare table-land'. In these crevasses we often find a ferruginous loam, evidently the insoluble residue from higher beds of limestone that have disappeared. On the bare platform quarter of a mile south-east of Gamdda-fawr there stands an interesting rock-table of limestone, anvil-shaped, and about 10 feet high, a remnant of a vanished bed (Plate 56); and another such table, seven feet high, will be found among some bushes about 100 yards north of Parciau Camp.<ref>Photographs of these have been kindly presented to the Survey Collection by Mr. E. Neil Baynes.</ref> The special features of the Glacial Drifts, such as their broad and gentle undulations, their drumlins, and their eskers, have been described in Chapters 30 and 31. All over the Island, however, the scenery may be said to be a kind of resultant, varying according to the degree to which the features of the older formations have been buried under these accumulations. There can hardly be an escarpment or a boss that is not robbed of some of its relative height by boulder-clay that, filling the bottoms of the intervening hollows, gives rise to winding narrow tracts of pasture-land. Emergence of rock is usually to be looked for upon the surface of the Menaian Platform or upon the monadnocks, the valleys being choked with drifts. In certain tracts, however, as about Mona House and Felin-engan, groups of knobs rise along the valley-floors, as if boulder-clay had been ploughed or washed out at a late stage of the glaciation. In the drumlin countries, though, of course, for a different reason, rock is also to be sought, not on the hill-tops, but on the valley-floors.

Along the coast, which is about 150 miles in length, many different types of scenery have been developed, as, even in one formation, they are continually changing, according to the direction in which the structures are presented to the sea. Trwyn-Dinmor in the Carboniferous Limestone is an overhanging cliff about 100 feet in height (Plate 41) and (Figure 341), produced (as in Caithness) by erosion at the back of a gentle dip-slope; while in the mica-schists to the south of Tre-Arddur Bay, cliffs equally undercut, and about 50 feet in height, have been produced where the folding pitches landwards. The headland overlooking Fydlyn island is tunnelled completely through, from cove to cove, by a group of branching caverns 50 yards in length, accessible only at dead low water. The great cliffs that, from a height of some 400 feet, look down upon the South Stack (Plate 55), Frontispiece) are among the finest on the British coasts; and equally grand, though less accessible, are those of the Holyhead Quartzite along the line of the North Stack fault (Plate 1). These, which are about 500 feet high, are the loftiest in the Island, and their impressiveness is added to by the great caverns close to the North Stack. Clear, beachless water never leaves Holyhead Mountain, splendid with its heathery crest, and foot planted in the deep sea', as Ruskin wrote of it; and the same is the case with most of the bolder headlands of the coast—another effect of the Forest-bed submergence.

Features due to human agency — Most of these are (fortunately, perhaps) on a small scale. The old Breakwater quarries in the Holyhead Quartzite, however, are more than 100 feet in depth, and have considerably altered the profile of the land. The two open pits at Parys Mountain (pp. 561–2, 565, and Chapter 36), though only visible close at hand, are on a similar scale, while the great brown spoil-banks of the old mines are now conspicuous features in the outline of that bill, and can be seen from eight or nine miles away. By the reclamations in the Malldraeth and at Valley (pp. 768–9), by draining some lakes and enlarging others, man has not, indeed, altered any features of the surface, but has greatly changed its aspect. Less obvious, but perhaps geologically more important, are changes in the distribution of the sand- and mud-banks that have resulted from the roads and railway that cross the Strait of Holy Isle, which constrict the channel and concentrate the tides into fierce torrents at the archways.

The nature, origin, and age of the boss-lands

No study of Anglesey would be complete without some attempt to trace out the development of those rugged bosses which are the most characteristic of all its types of scenery. Pre-eminently a feature of the Mona Complex, they are developed upon all its members, and may be admirably seen about Allor, Gwalchmai, and Henblâs (Plate 15), on the moor at Amlwch Port (Plate 55), in the Mynydd Mechell, over most of Holy Isle, in Gwna Vale, about the Bodorgan headlands, among the dunes of Newborough (Plate 49), (Plate 6), and many other places, as well as upon such monadnocks as Llwydiarth and Bodafon. But though a student of the Complex, after many years passed among their quiet haunts, naturally associates them with that formation, they are not confined to it, for the same features appear upon Ordovician grits and Palaeozoic Intrusions.

At first sight, there seems to be a bewildering variety of shape, yet certain leading forms can be recognised. Approximately isodiametral ground-plans are in a minority, the most frequent plan being rudely elliptical, with axial proportions about 1: 2.5 or 1: 3, while there is a common variety in which the ellipse is abruptly truncated. The sides are usually (though seldom equally) steep, truncated ends very steep. Such truncation is apt to affect several at once, and to take place along an approximately straight line that crosses the whole group. In size they range from insignificant little knobs to great bosses like those of Mynydd Bodafon, quarter of a mile in length and with a net height of 100 feet Or more; but elliptical domes with a length of 300 to 500 feet, and a net height above the intervening hollows of 30 to 50 feet, make up most of the typical boss-land scenery.

Their age — In the aspect which they wear to-day, they have (p. 700) been remodelled by the ice; but it is certain that they are but modifications of ridges which existed in Pre-Glacial times. If we consider the mutual relations of the strike, the major axis of the elliptical dome, and the direction of glaciation, we find that (with certain exceptions, to be considered below) major axis always coincides with strike, that over large parts of the Island all three coincide, but that there are extensive tracts where, strike and major axis coinciding, the glaciation is oblique to both. In (Plate 55) we see a typical tract where major axis keeps persistently to strike, but is crossed at some 43° by the direction of the glaciation; while between Bull Bay and Porth Wen the major axes, holding still to the strike, are crossed at no less than 90° by the glaciation, relations of the same kind continuing to obtain over the whole of the northern country, as well as in some other tracts.

Having thus obtained a *terminus ad quod,* let us consider the relations of these Pre-Glacial ridges to the greater Pre-Glacial features. Nowhere are they so grandly developed as (Plate 16) upon the great monadnocks, whence it follows that they must be later than the base-levelling of the 'Monadnocks' and Tregarth Platforms. But they appear also in countless numbers on the open surface of the undissected plateaux of the Menaian Platform, in general views of which, such as (Plate 51), and the left-hand part of (Plate 52) they can be made out here and there, as little irregularities of its profile. As they cannot have been produced by marine, or by the last sluggish stages of terrestrial erosion, they must be later than the Menaian base-levelling, while some of them also appear upon the floors of hollows 100 or more feet below the plateau-surface. They are therefore asperities of the platform due to sub-aerial waste after its elevation had begun, and thus probably in the course of Later Pliocene time, before (p. 785) any serious chilling of the climate had set in.

Development of the ridges — We have seen (pp. 192–4, 538–9) that the Mona Complex and (to a less degree) the Lower Palaeozoic rocks are traversed by a great number of minor thrusts. Their extraordinary profusion in the Complex is dwelt upon on p. 194, while in Chapter 41, it is shown that they are crossed by numerous transverse faults. Foliation has (in varying intensity) developed upon the older thrusts, but the later ones (p. 201) and the faults are wholly cataclastic. All three, but especially the two latter, are planes of chemical and physical instability. Anastomosis of the thrusts tends to isolate the more stable portions of the rock as rudely lenticular cores whose major axes lie along the strike (Figure 69), (Figure 166), (Figure 169), &c., (Plate 22), (Plate 7), groups of such cores being abruptly truncated where the transverse faults cross them.

Now, after the base-levelling, and during and after the elevation of the Menaian Platform, there ensued, in the course of Later Pliocene and Early Pleistocene time, a long process of sub-aerial weathering, which induced very widespread, and locally (pp. 702, 782) very deep decay. Such a process would search out all the aforesaid planes of instability, decay setting in along and spreading out laterally from them, the decomposed material washing gradually away. Thus a labyrinth of anastomosing channels, isolating elliptical ridges, would be etched out upon the surface of the Menaian

Platform. The ridges would conform to the strike<ref>To this there would be an exception. Where a well-cemented structure, such as an old crystalline foliation, locally oblique to a prevalent strike, is crossed by mylonising thrusts that conform to that strike, the latter, being the planes of greater instability, will be the ones picked out for decay, so that the ridges will have the usual trend but will be crossed obliquely by the old foliation.</ref>, dying down where their bounding thrust-planes come together; while the results of minor pitching isoclines, bringing up rapid alternations of stable and unstable beds, would not be very different. Waste along any transverse fault will truncate whole groups of them at once along a line to which they will tend to present steep or even vertical ends. All their prevalent forms can thus be accounted for by the reaction of these peculiar structures to decay. At their full development these ridges must have displayed all the asperities natural to sub-aerial waste.<ref>See Sir A. Geikie: 'Scenery of Scotland', ed. 2, p. 201.</ref> Those composed of undefortned igneous rocks probably bore some resemblance to the tors of Dartmoor, but flaggy beds with tolerably steady dip must have risen in short, sharp escarpments, while in tracts where foliation is vertical we should have found narrow ridges with acute and jagged axes. The various types of minor folding (symmetrical, isoclinal, a-elinal, and polyclinal) would give rise to bristling edges in directions determined by the type, in addition to which they would end off acutely at the crest of the pitch-escarpment.

Then came the Glaciation, sweeping out from the hollows what may have remained of the old products of decay, grinding off every angularity<ref>The pitch-escarpments, from coinciding frequently with lee-side of glaciation, have been less obliterated than any of these ancient features, and have been able to re-develop, especially in parts of Holy Isle, where they are sometimes considerably undercut. Some of the plane-escarpments have also re-developed where similarly situated.</ref>, and remodelling this curious ridge-landscape of the close of Tertiary time into the boss-lands of to-day.

Post-Glacial erosion

Inland

The rate of sub-aerial denudation has been reduced by the notching of the watershed, by the late submergence, and some other causes; but even as it is, the fall on the principal streams is more than might have been expected, as will be seen from. this table—

Alaw: 200 feet in 12 miles, or 16 feet per mile.

Cefni: 182 feet in 7 miles, or 26 feet per mile.

Ceint: 80 feet in 2 miles, or 40 feet per mile.

and those on the eastern slope are steeper still. The fall of the Carnarvonshire Ogwen, it may be remarked, is 100 feet, and that of the Thames two feet per mile.

Erosive force in Post-Glacial times has been, and still is being expended in great measure upon the removal of the drifts; but many of the streams have cut through them, and are once more attacking the Menaian Platform. Between the Menai Strait and the Dulas–Alaw line, where that platform is not extensively eroded, and where the thickness of the Glacial deposits is moderate, so that ridge after ridge of rock rose 100 feet or more above them, the rivers have not often failed to discover their old channels, though they have (p. 788) found the levels of the longitudinal ones curiously modified, compelling them to pass from one to another through new short cross-gorges often cut in rock, such as that at Llyn Frogwy, Bodfordd.

Diversion of rivers by the drifts — On the high land of the north-east, however, near Mynydd Eilian, drift has choked the old valleys that emerged at Porth-y-G-wichiaid and Porth Helygen, whose brooks, failing to re-discover them, have been curiously diverted. The waters which once ran out at Porth Helygen enter the sea now 340 yards to the south of that cove, and have been compelled on their way to cut a little ravine in the Gneisses. Much more disturbance of drainage has been effected in those parts of the west and north where (pp. 732–3, 742–3) the Menaian Platform has been destroyed over wide areas. For the low grounds have been overwhelmed with boulder-clay, upon which the streams, wandering among the great drumlins, have utterly lost their way. In the country about Llanfwrog and Llanfaethlu, indeed,

the old courses have been so completely obliterated that no attempt has yet been made to trace them.

In the northern country, whose drainage, transverse to the local strike, ran from the Barrier (p. 788) to the gaps in the rugged hills along the seaboard, while obliteration is complete in the tracts about Rhydgroes and Ysgellog (p. 742), it is possible to trace out some of the diversions. The old channels that entered the sea in the west nooks of Bull Bay and Porth-wen have been filled up and never rediscovered by the local waters. The only long stream that seems to have picked up most of its original course is that which runs out in Porth-y-pistyll. But its head-water front Llanfilewyn, impounded by a drumlin to form Llyn Llvgeirian, and prevented from proceeding northward, has found its way west for quarter of a mile into the course of a former tributary, wherein, turning sharply round, it regains its old channel at Cefn-coch. Streams once entered Cemaes Bay at Wylfa cove and at the nook beyond the Coastguard Station, but both exits are choked with 50 feet of drift, over which the merest driblets pass to-day. The Coastguard nook, as may he seen from the features, was the mouth of an important water coining from the south-east, and draining spacious tracts as far back as Bodewryd, which has never found its ancient channel, now obliterated by great drumlins 100 feet or more in height. Diverted first by Rhydgroes drums, it turned west as the 'Afon Wygyr' of to-day, and cut a little trench in mica-schist at Rhosbeirio. Confronted then by the great Carog drums, it found a north-westward passage between two of them, and lowering this first in boulder-clay and then in mica-schist, cut out a deep narrow ravine. Emerging thence, it was confronted by a drumlin lying right across its conrse, turning round which, it once more cut its way down into the rocks in a passage it found between that and the next drumlin, entering the sea at last at Cemaes Bridge.

Limestone escarpments — Probably, however, the most conspicuous effect of Post-Glacial waste has been the re-development of escarpments upon the Carboniferous Limestone. In the Principal and Peninon Areas (p. 802) these are now craggy and sharp, even on the north-eastern faces of the high plateaux, which were the faces exposed to the glacial onset. To suppose that this limestone was capable of resisting an erosive power that could model even the quartzite monadnocks of Holyhead and Bodafon were manifestly absurd. When released from the ice it must have presented the rounded profiles that it still retains (Figure 334) beneath the boulder-clay. The recession and sharpening of its escarpments, as well as the constriction of outliers into rock-tables (Plate 56), must therefore have been accomplished in Post-Glacial time. in the labyrinthine crevassing of the rock (p. 802) down vertical joint-fissures we can study the process of disintegration.

The Coast

That enormous quantities of boulder-clay have been removed from the periphery of Anglesey, especially on the west, since the Glacial Period, we have (p. 703–4) already seen. On a cautious computation, some 15 to 20 square miles of land appear to have been lost; while a more liberal but not unreasonable estimate might place the loss at more than 30 square miles. The process will have been alternately checked and accelerated by Post-Glacial changes of level, and also<ref>See 'The Geology of Caithness', p. 152, and (Figure 30).</ref> by the local relations of drift and rock.

Some places on the coast have yielded interesting measures of the erosion by the sea. The ancient house of Trefadog on the western coast is now protected by a sea-wall 20 feet in height, built 19 years ago against a cliff of boulder-clay. Land, at that time, was being lost rapidly, the road had been carried away, and the stack-yards flooded. On the northern coast, Mr. Jones of Ty'n-llan farm, Llanrhwydrys, finds that in the course of his residence there of 37 years, the boulder-clay cliffs have retreated one yard in sheltered, and six yards in exposed places; giving a maximum rate of about six inches a year. At that rate the excavation of Hen-borth bay would have taken some 25 centuries. It may, however, have taken rather longer, for the loss of land on this part of the coast is said to have been accelerated after the building of the breakwater at Holyhead.

The lonely little old church of Llangwyfan (Plate 57), (Plate 58), near Aberffraw, stands on an islet of boulder-clay 220 feet long, 84 broad, and 15 high, which rests upon a smooth flat reef of mica-schist that forms the floor of the bay. It is completely isolated at high-water. During spring-tides and westerly gales the boulder-clay used to be attacked by the sea, so that the graves became exposed in the cliff and fell away; the islet was being rapidly reduced; and in the year 1904 the cliff was faced with heavy masonry to prevent the destruction of the church.<ref>Unfortunately, it was not examined geologically before the building of the seawall. But there can be no doubt of its being composed of boulder-clay. Had it been composed of mica-schist, its destruction would not have been imminent. And there is an old photograph, taken

before it was walled up, in which the boulder-clay is unmistakable. A copy of this is now in the Survey Collection.</ref> The cliffs at the back of Porth Cwyfan are composed of boulder-clay of about the same thickness as at the church, resting on the same low reefs, and it is evident that the islet is a surviving outlier of a sheet that once filled the bay from side to side. Now in Speed's Map of Anglesey-, published in 1610 (to which my attention was first drawn by Profs. Ainsworth Davis and J. E. Lloyd), Llangwyfan Church appears upon the mainland! The church, Therefore, became isolated rather less than three centuries ago. It is now 183 yards away. Taking a mean of this and the distance to the present position of the further end of the islet, we find that the cliff has retreated at least 216 yards in 300 years, which is at the rate of a little less than three-quarters of a yard a year.

The structure of the cliffs between Porth-wen and Bull Bay lends itself to land-slipping. Massive tuffs with a foliation dipping steeply seaward are traversed (Figure 64), (Figure 95), (Figure 141) by slickensided thrust-planes also dipping seaward, but at low angles, as well as by strong vertical joints running north and south. The rock parts along the joints and foliation, and then slides off down the thrust-planes. A great slip took place in 1910, about three-eighths of a mile east of Trwyn-bychan. The general profile of the land, which is ice-worn, slopes to the sea from the 100-foot contour at about 16°, but land-slipping and marine erosion, combined, are cutting it back into vertical cliffs (Figure 342). If, now, the general angle of the slopes be protracted, allowance being made for the curvature due to glaciation, some idea can be obtained of the amount that has been-lost, as shown by the dotted line, for slopes of this kind still survive down to the water's edge at several points, and must once have been continuous all the way along.

Between Trwyn-bychan and the Cave, however, the cliff is, forsome distance, 100 feet in height, so that the sea has cut away a rudely triangular prism of the tuff, whose vertical side is 100 feet and whose horizontal side is 150 to 250 feet in width. And, as the other side of this prism was an ice-worn slope, we have here a measure of Post-Glacial marine erosion in hard rock.

Holyhead Breakwater — The ravages of the sea upon Holyhead Breakwater are of 'general geological interest. It runs along just within the 50-foot submarine contour, to a concave curve in which contour it has been compelled to conform, so that it is only 200 yards from deep water. When a long storm-wave breaks full upon its outer reach, a curtain-like mass of white foam half a mile in length may be seen to rise 30 or 40 feet into the air. Concerning the effects of such waves upon the structure, Mr. F. E. Cotton (resident engineer to the port) and the late Admiral Burr (harbourmaster) have kindly furnished me with the following particulars. From time to time, during heavy north-westerly gales, many great breaches and caverns have been made, several hundred tons of stonework (for the nature of which see Chapter 38) having sometimes been torn away in a single tide: In 1912–13, £55,000 were spent in putting down heavy rubble ' to protect the foundations. To protect the exposed outer end, with its Lighthouse, 12 blocks of concrete weighing 100 tons each were deposited<ref>Thin iron shells were floated to the spot, and then filled with concrete at low water.</ref>, but most of these were soon moved from their places, and the engineers have therefore deposited blocks of twice that weight (Plate 59)<ref>In that plate, blocks of both sizes are shown, the 200-ton blocks being those upon which men are standing. The plate (reg. No. 1,722) is one of six photographs of the subject (reg. Nos. 1,722–7) kindly presented to the Geological Survey by Mr. H. E. Spencer.</ref>. One of the 100-ton blocks was displaced as much as 35 feet in a single night. One of the 200-ton blocks<ref>It may be recalled that the largest block mentioned by Sir Arch. Geikie ('Textbook of Geology', ed. iv, 1903, p. 568) as having been moved by sea-waves weighed 50 tons.</ref>, which rested on 100-ton blocks at high-water mark of ordinary tides, was, in December, 1914, driven three feet along a slight incline upwards. Several of the blocks were in motion, and some of them sawed off a foot or two of the corners of their neighbours. Finally, in a subsequent storm of the same tempestuous winter, another of the 200-ton blocks was thrown down altogether.

Chronological sketch of the development of the land-surface

Long ago, apparently in Early Pliocene time, the region surrounding the old Welsh Highland had become reduced by erosion to a base-level, upon which there stood one small monadnock. This plain (the 'Monadnocks' platform of to-day) was then raised about 200 feet.<ref>For the alternative possibilities as to the nature of the episode represented by the Tregarth shelf, see p. 783.</ref> Erosion once more set in, and went on until only nine fragments were left of the platform of that time, everything between them being swept away, and a new base-level reached. This, in its turn, carrying nine fragments of the first one as monadnocks on its back, was elevated some 275 feet, and became the Menaian Platform.

At that time it extended far beyond its present limits, but its outer portions were composed of softer materials, chiefly Mesozoic. Gradually these disappeared, leaving a hard nucleus of older rocks, at whose margins the rate of marine erosion received a considerable check. This was the first appearance in British physiography of what may be called 'Anglesey'. But it was not then an island; it was a peninsula, continuous with the landward portion of the Platform.

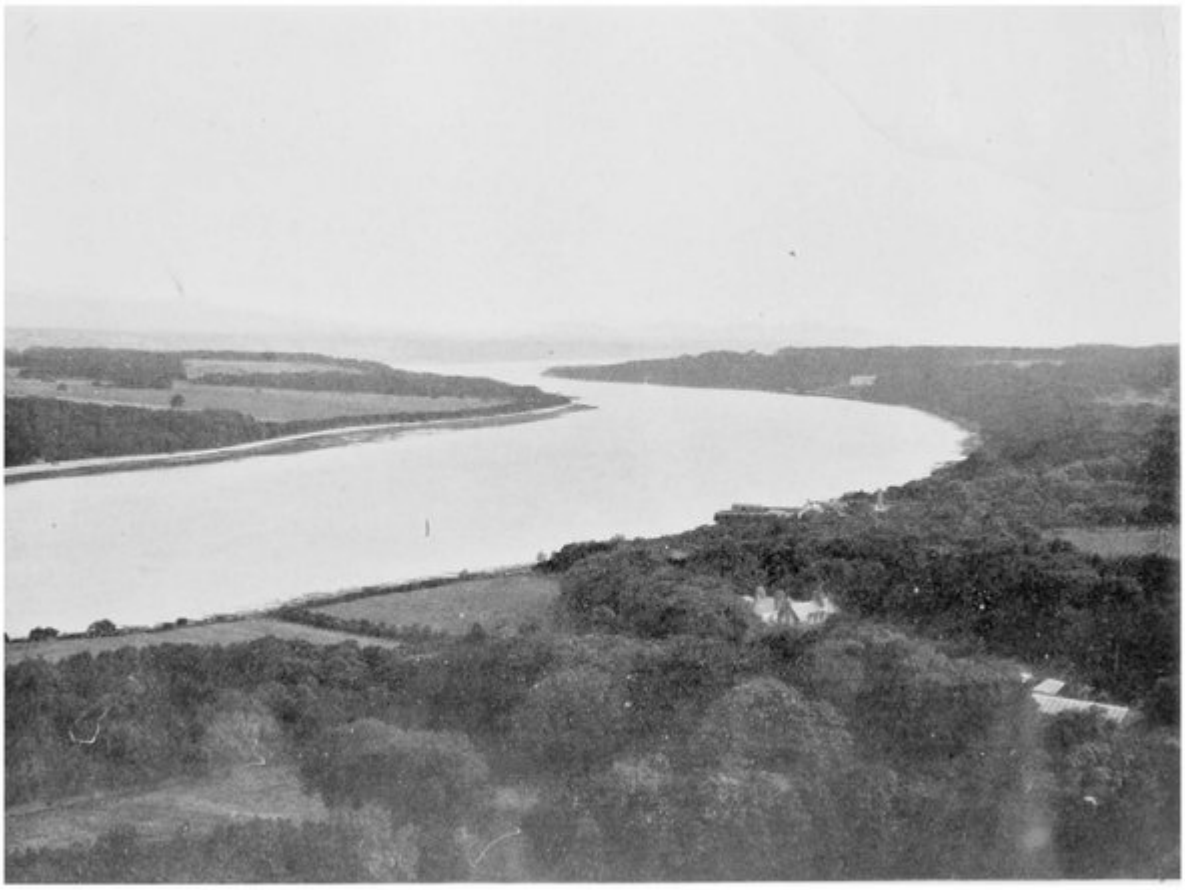
In the meantime, sub-aerial erosion of the platform had been proceeding. The main watershed had become established; and drainage therefrom, finding out lines of weakness, initiated the greater valleys of the dominant longitudinal series. Then, drainage into them from the broad intervening ridges initiated the transverse valleys, and drainage into these again produced a few secondary longitudinal valleys. Erosion went on along the whole system until the greater channels had been cut down between 200 and 1100 feet, the watershed narrowed, and one branch of it thinned into the Northern Barrier.

Then the whole region was remodelled by the ice. Ancient rugged features were smoothed away, and the rounded aspect of all ice-worn regions was imparted not only to the minor asperities of the Menaian Platform, but even to the great monadnocks. The old drainage of late Pliocene times was remodelled, the longitudinal valleys accentuated, smoothed, and straightened, the watershed lowered, and the country dimpled with lake-basins. Extensive low-lying tracts, especially in the north and west, were loaded with boulder-clay so heavily as to bring them nearly to the level of the adjacent portions of the rocky platform. Generally, it may be said that the net effect of the great glaciation was to even up the surface, and to check for a long time the work of sub-aerial waste upon the old plateau. Eventually, fluvio-glacial erosion, uniting two valleys of the longitudinal system, gave rise to the continuous hollow of the Menai, into which the sea was admitted in consequence of the subsidence that let down the Forest-bed, so that, this last touch added to the long process of development, the Menai became a Strait, and Anglesey an island.

(Plate 51) The Eastern Reach of the Menai Strait. From the Suspension Bridge.

(Plate 50) The Menaian Platform and the Bodafon monadnock. From the roadside at Mynydd-mwyn-mawr, Llanerchymedd.

(Plate 52) The Menai Strait at the submerged watershed. Looking towards the Mountain-Land of Wales. From the top of the column..



(Plate 53) The Middle Reach of the Menai Strait. From the top of the column.

(Plate 54) The Western Reach of the Menai Strait. From above Port Dinorwic.

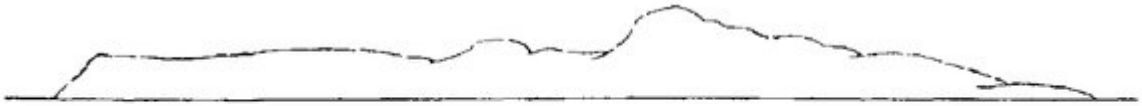


FIG. 339.—HOLYHEAD MOUNTAIN AND THE SOUTH STACK MOOR: SKETCHED FROM THE BWA GWYN, RHOSCOLYN.

(Figure 339) Holyhead Mountain, from Rhoscolyn, and the South Stack Moor: sketched from the Bwa Gwyn, Rhoscolyn.

(Plate 16) The North Stack and the sea-cliffs of the Holyhead Quartzite From the South Stack Moor. Height seen = 582 feet. ***Note****.—The feature determined by the North Stack fault runs on, from sea-cliff, up the mountain-side, below the sky-line.*

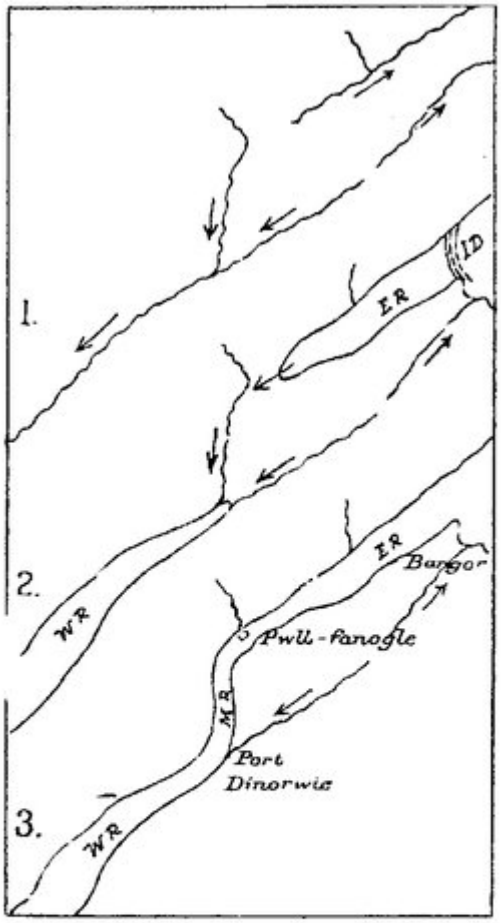


FIG. 340.

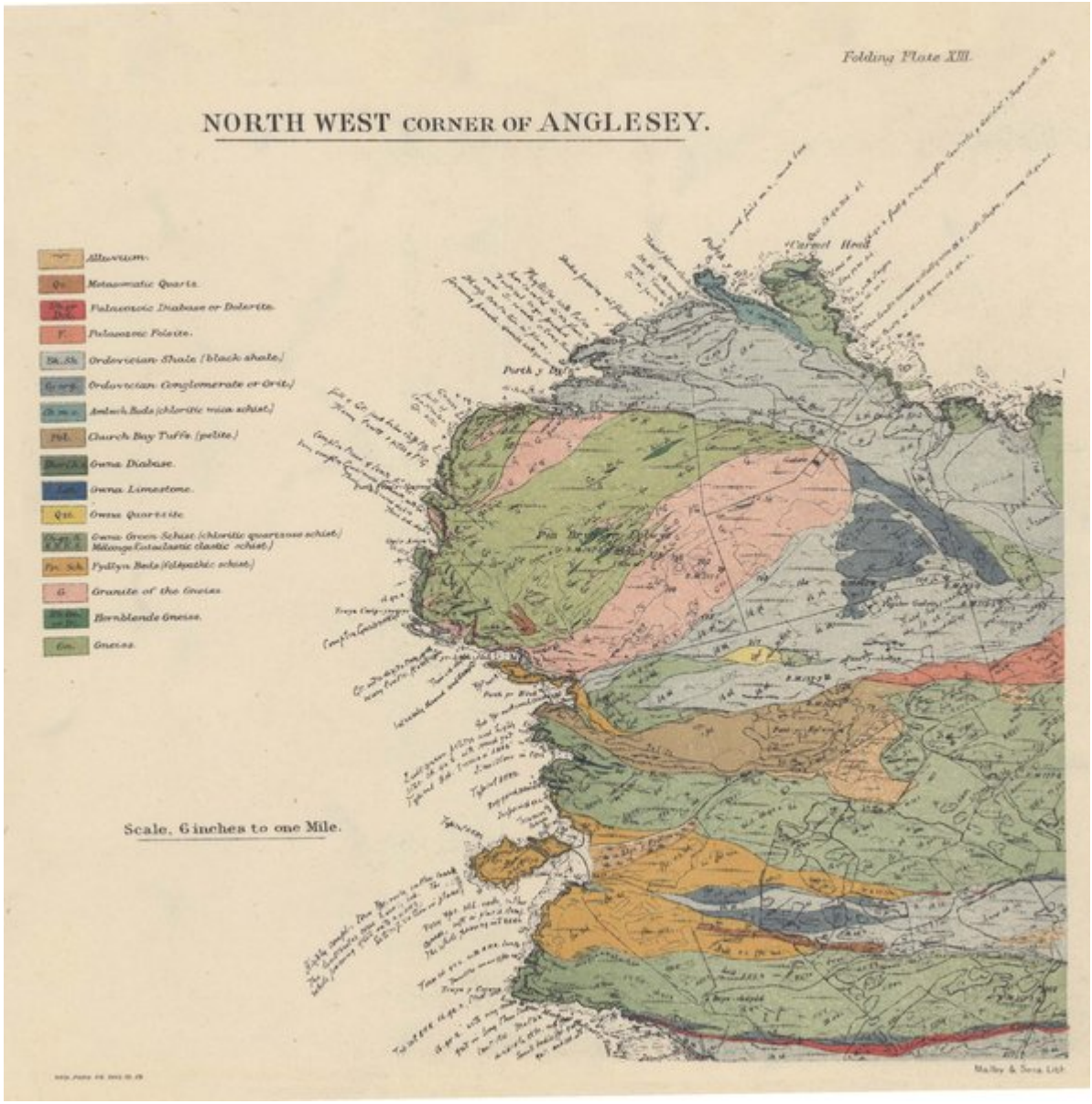
STAGES OF THE MENAI STRAIT.

Scale: four miles = one inch.

1. PRE-GLACIAL. 2. LATE-GLACIAL.
3. POST-GLACIAL.

W R = Western Reach.
M R = Middle Reach.
E R = Eastern Reach.
I D = Ice-Dam.

(Figure 340) Stages of the Menai Strait. Scale: four miles = one inch. 1. Pre-glacial. 2. Late-glacial. 3. Post-glacial. W R = Western Reach. M R = Middle Reach. R = Eastern Reach. I D = Ice-Dam.



(Folding-Plate 13) The North-West corner of Anglesey. Reproduction of manuscript six-inch map.

(Plate 55) Typical scenery of the Mona Complex. Amlwch Port Moor.

(Plate 56) Rock table of Carboniferous Limestone. Near Marian-glas.

(Plate 41) Undercut cliff of Carboniferous Limestone. Trwyn-dinmor, Penmon.

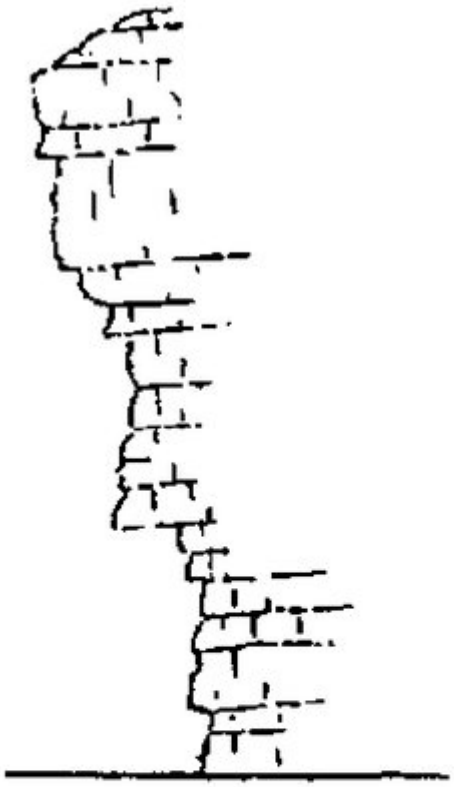
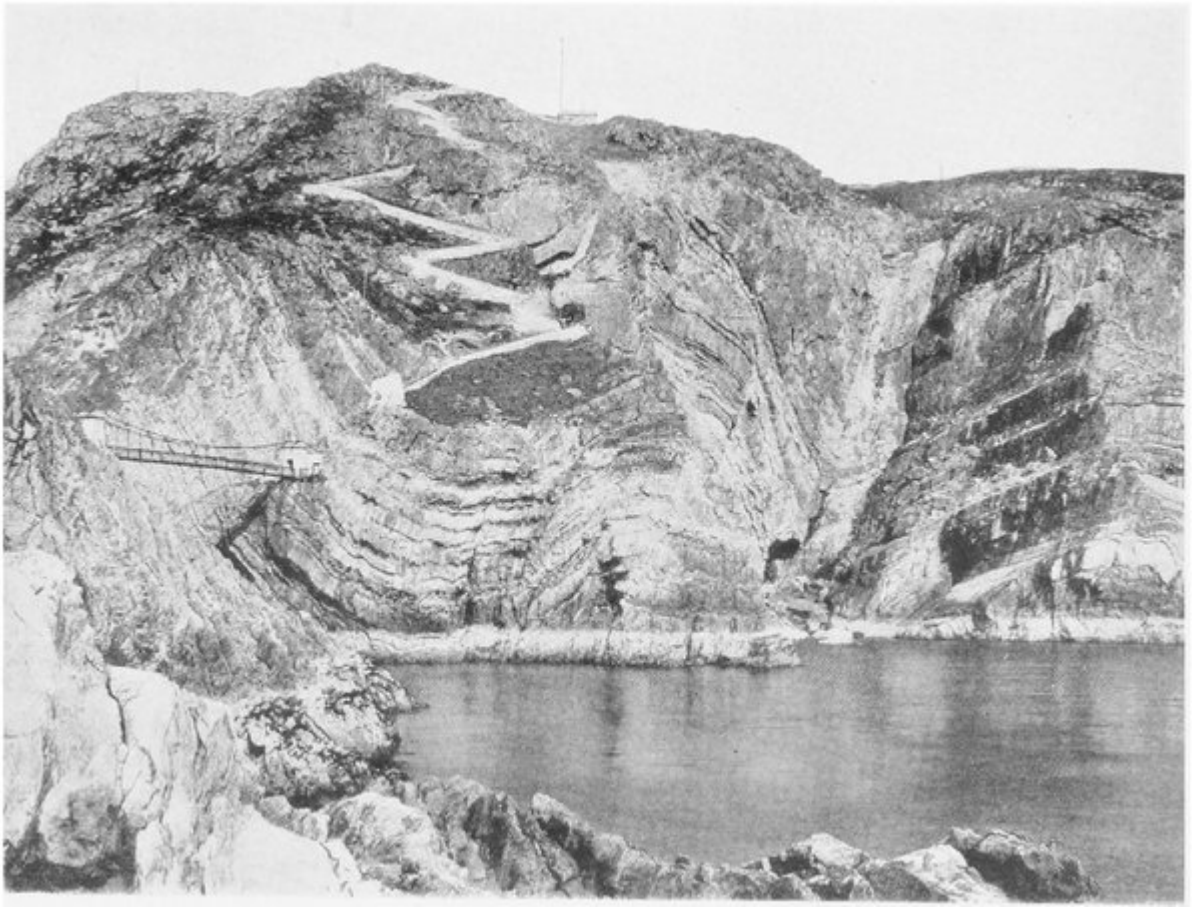


FIG. 341.

UNDERCUT CLIFF
AT
TRWYN-DINMOR.

(Figure 341) Undercut sea-cliff, Trwyn-dinmor.



(Plate 1) The Folding of the Mona Complex, as viewed from the South Stack, Holyhead. Height seen: 445 feet. Frontispiece to Vol 1..

(Plate 15) The Banded Gneisses. Henblâs, Llandrygarn.

(Plate 49) Desert scenery. Dunes of Newborough.

(Plate 6) Rose-Limestone with ellipsoidal structure. Dunes of Newborough.

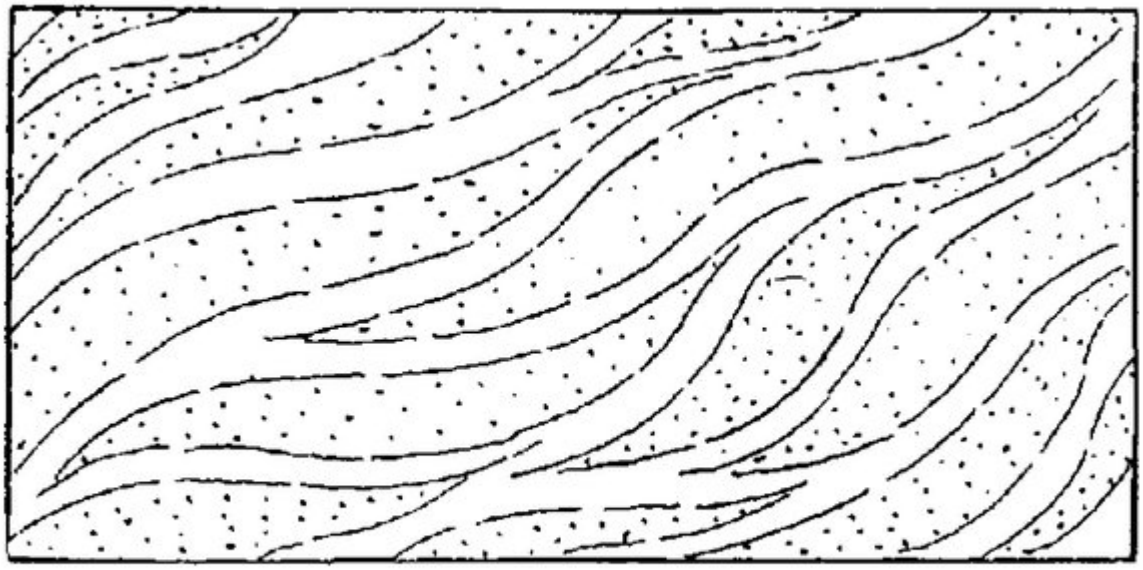


FIG. 69.—DIAGRAM OF AUTOCLASTIC MÉLANGE.

(Figure 69) Diagram of autoclastic melange.

FIG. 166.—LIMESTONES IN GWNA GREEN-SCHIST.

(Figure 166) Limestones in Gwna Green-schist. About four feet and three feet thick. Roadside, about 200 yards west of bathing house.

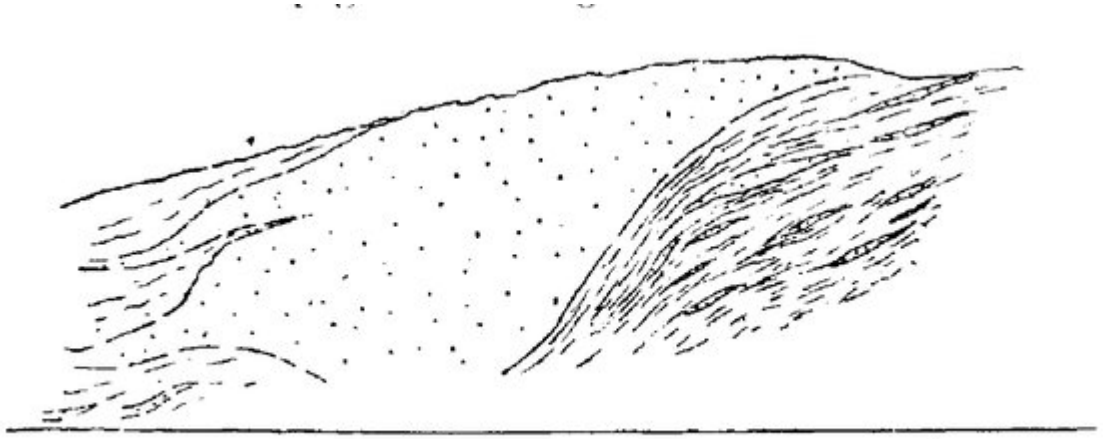


FIG. 169.—LENTICULAR QUARTZITE.

(Figure 169) Lenticular quartzite. Three and a half feet long. In Gwna Mélange, Llansadwrn.

(Plate 22) Lenticular quartzites in Autoclastic Mélange, with late basic dyke. Porth Wnol.

(Plate 7) Autoclastic Melange. Coast near Porth Cadwaladr, Bodorgan.

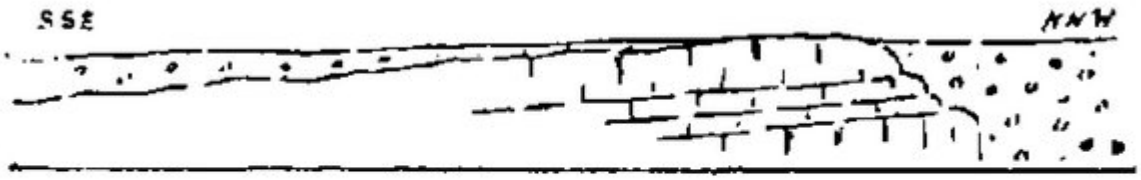


FIG. 334.

BURIED ESCARPMENT AT CROES-FRYN.

(Figure 334) Buried escarpment at Croes-fryn.

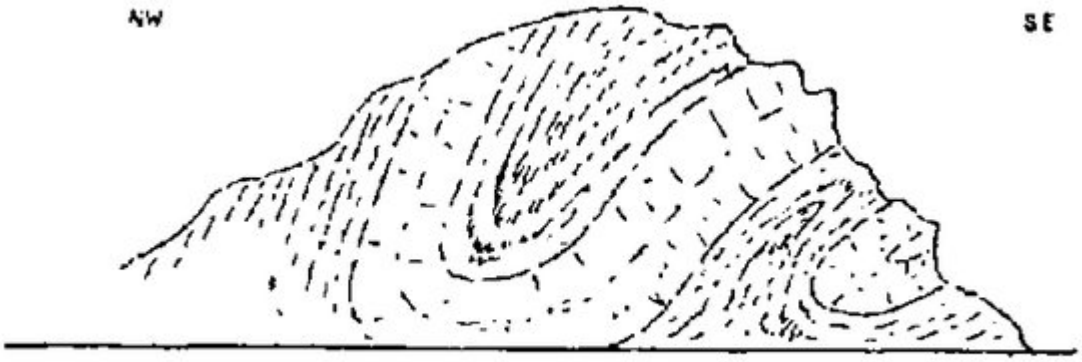


FIG. 30.

(Figure 30) Spilitic Tuff and Passage Beds, Bodwradd. 500 yards north of west of Bodwradd. (LIwyn Beds taken in on pitch immediately to north-east.) Height, about 20 feet.

(Plate 57) Llangwyfan Church Islet at half-tide.

(Plate 58) The same. [Llangwyfan Church Islet at half-tide] From the headland.

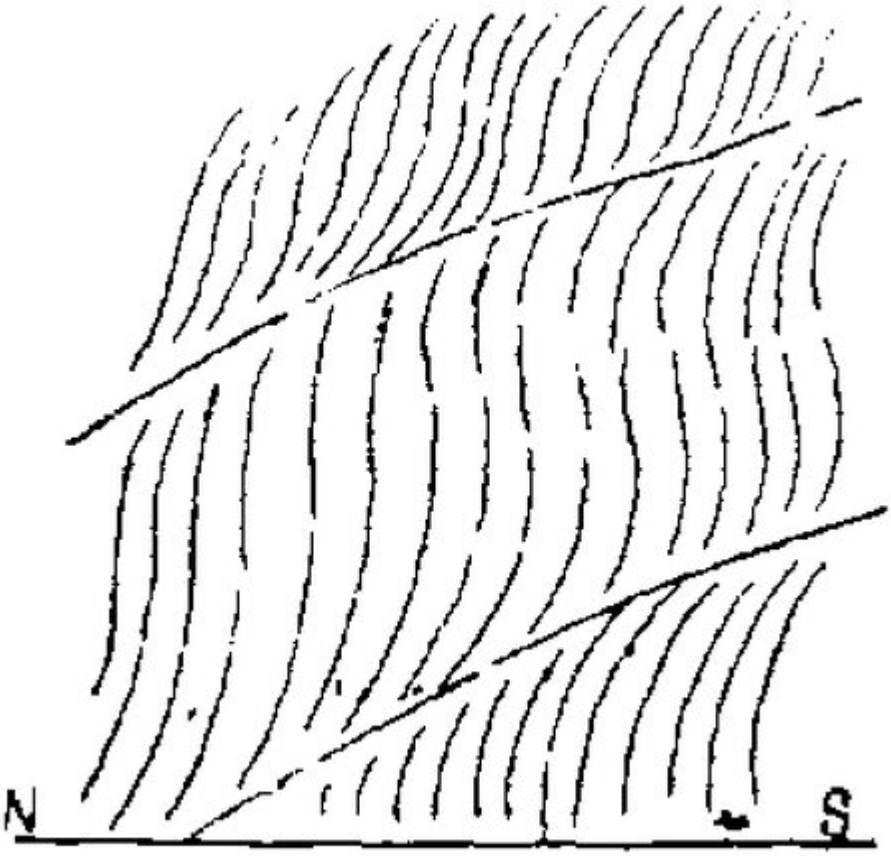


FIG. 64.

(Figure 64) Sigmoidal foliation with thrusts at one-foot intervals. East bluffs of Trwyn Bychan.

FIG. 95.—THE THRUST-PLANES AT TRWYN BYCHAN.

(Figure 95) The thrust-planes at Trwyn Bychan. Sketched from a boat. Cliffs about 100 feet in height. MS = Church Bay Tuffs. MG = Gwna Melange. b = Nemagraptus Shales.

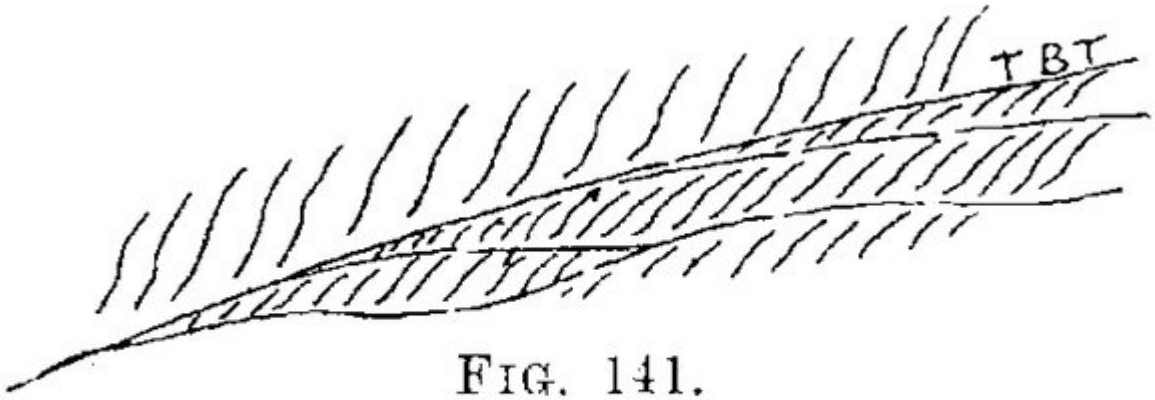


FIG. 141.

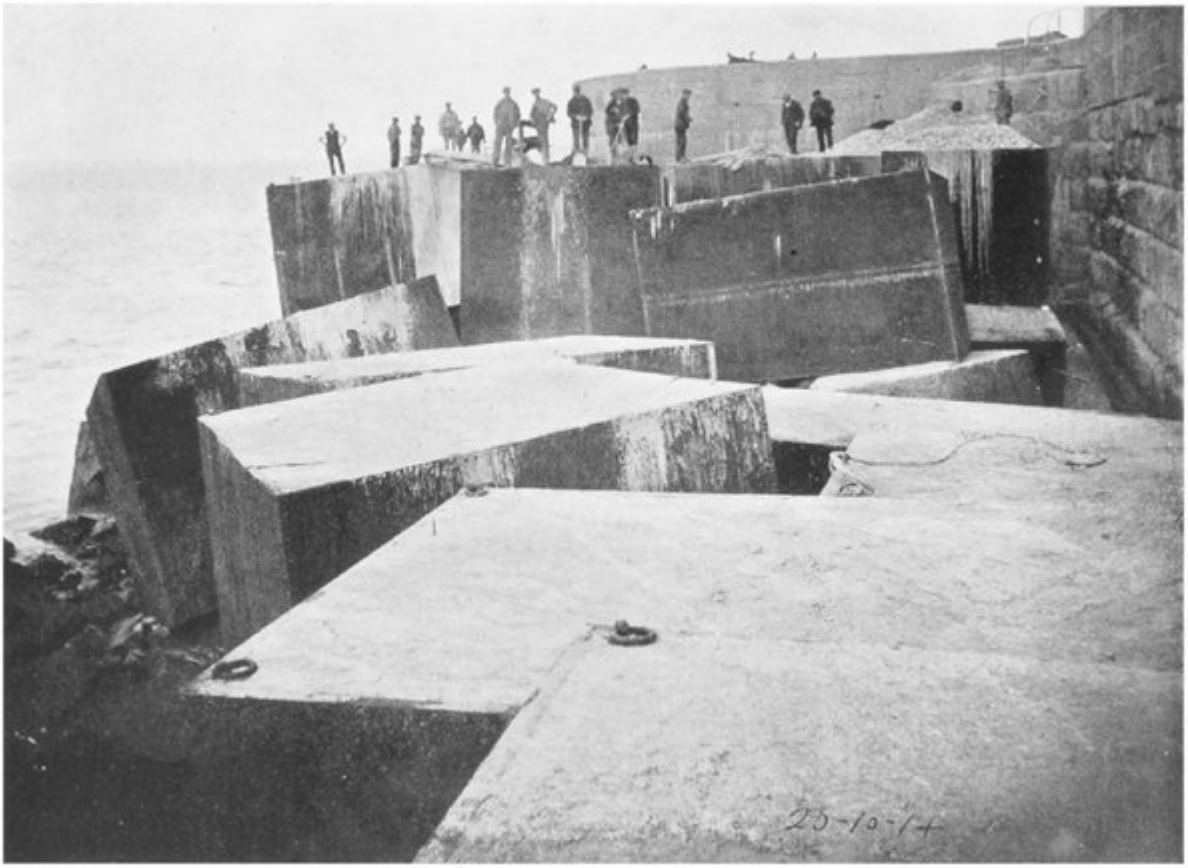
DETAIL AT THE TRWYN BYCHAN THRUST-PLANE.

(Figure 141) Detail at the Trwyn Bychan Thrust-Plane.

FIG. 342.

POST-GLACIAL MARINE EROSION: COAST NEAR TRWYN-BYCHAN.

(Figure 342) Post-glacial marine erosion: coast near Trwyn-bychan.



(Plate 59) Blocks moved by the Sea. Holyhead Breakwater.