Chapter 8 General view of the Mona Complex

Sketches will first be given of the developments, the condition, and of what are believed to be the structures of the Complex in the several regions and inliers; and then an attempt will be made to unify these into something like a connected picture. But the interpretations put forward in this chapter are for the most part based on the views as to the succession and the tectonics adopted in the preceding chapters, and are therefore subject to the reservations and cautions expressed on pp. 152, 170, 176.

Developments in the several regions

Holy Isle

As the evidence for the existence of the maximum recumbent folding was derived from Holy Isle, the most salient points in its structure had to be described to some extent in Chapter 7, thereby anticipating much of the present. summary. Those points, therefore, will be taken for granted now, and only so much added as is necessary to an elucidation of the major secondary folds.

The members of the Complex that are present are the Holyhead Quartzite, the South Stack Series, the thin spilitic tuff at the junction, the New Harbour Beds, and the serpentine-suite of intrusions. Both divisions of the South Stack Series are developed on a great scale, especially at the north end of the Isle; the Stack Moor Beds appearing only at the Stack Moor, the Breakwater coast, and Rhoscolyn. Most of the wide extent of the New Harbour Group south-west of the Namarch fault belongs to the fissile Celyn beds, the Soldier's Point beds having been recognised, so far, only along the Tre-Arddur alluvium; but they occupy nearly the whole of the tract north-east, of that fault.

The Isle falls into four structural parts (as shown in the chart, (Figure 100)); the lower limb of the Rhoscolyn Fold, south-west of the North Stack fault; the upper inverted limb of the same fold, from Cymyran Bay to Tre-Arddur Bay; the lower limb of the Holyhead Fold, from Tre-Arddur to the North Stack Signal Station,; and the Nappe of Holyhead, north-east of the Namarch fault.

The pitch is persistently to the north-east; while both major and minor secondary folding are (save one or two exceptions) isoclinal with a southward overdrive. The major secondary folds are as follows*:*

Country South-West of the North Stack fault — Of prime interest are those which are exposed in the magnificent sea-cliffs that look down upon the South Stack (Plate 1), Frontispiece; and (Folding-Plate 1), for they are the only major folds in the Complex that are visible directly to the eye.<ref>For the means of obtaining access to the Stack, see p. 257.</ref> They have been described on p. 183. It is interesting to note how the resistance of the massive beds to the southerly impulse raises the axial inclination, and with it the foliation-dip in the grits, locally to 90°. The net effect of the great folds is on the whale synclinal, for the Stack Moor beds descend to sea-level, though the north limb of the syncline has been destroyed by the sea. To that syncline we owe the fortunate preservation of the two little infolded outliers of Quartzite (Figure 28) on the very crest of the Stack Moor. Probably a steep anticline, followed by a syncline 500 feet deeper, lie beneath Gigorth Bay, for the Llwyn beds just appear at the foot of the south walls of the Bay, so it is likely that the North Stack fault clings to the land, leaving the North Stack itself on its west at the base of another Quartzite infold. With the rise of the Llwyn beds near Pen Las Rock the folding becomes completely isoclinal, the isoclines having a vertical amplitude of more than 200 feet. When Henborth is passed, this diminishes, and about Porth Rhwydan we see the curious phenomenon of nearly vertical beds thrown into many small isoclines with foliation dipping at rather low angles northward (Figure 36). Judging by the characters of the beds, the net effect of the whole series of isoclines appears to be a gradual rise, but the base never appears, for the sea cuts away this limb from Porth y Post to Rhoscolyn.

The major secondary folds at Rhoscolyn (Folding-Plate 2) are isoclinal from Bwa Du to Rhoscolyn Head, and then follows a broad low anticline at Maen y Fran, succeeded by a powerful syncline, isoclinal, but facing sharply northward—the only powerful isocline in the Isle with a northerly overdrive. One of the most remarkable features is that, no matter what be the

dip of the massive beds, no matter in which direction the major isoclines be overdriven, the rapid minor isoclines developed in the fissile partings face persistently south-east. Even in the cliffs between Maen y Fran and Rhoscolyn Beacon, where the beds are nearly vertical, the minor isoclines are still arranged as in (Figure 38), showing what an overmastering impulse there was from the northwest. It is, unfortunately, difficult to decide the interesting question as to whether all these great folds be secondary, or whether, in the north-westward-facing isocline, we have the true closing core of the Rhoscolyn maximum Recumbent Fold itself. In favour of that view is the fact that the minor isoclines ignore its inclination and cross it. Yet they may still be later than, and equally ignore, a major secondary fold. And, further, it is not easy to believe that the throw of the North Stack fault can have diminished so much as the hypothesis requires.

Country between the two Main Faults — Turning now to the country between the two great faults (Folding-Plate 3), the apposition of the Rhoscolyn anticline to that of Maen y Fran suggests that they are on the same secondary major axis, the Rhoscolyn anticline being the roof, brought down by the North Stack fault. But the strong southerly dips are absent, and there is no suggestion of a synclinorial structure. The Rhoscolyn anticline does not seem to be completely isoclinal, but its northern limb is a very gentle dip for some two miles, on which the New Harbour Beds (chiefly of Celyn horizon) are driven together by innumerable minor isoclines and little foliation-thrusts. Into them, after the maximum recumbent, but before the major secondary folding (see pp. 109, 211), was intruded the complicated serpentine-suite. There can be no serious rupture on the south, where the old thermal aureole remains; but between Cao'r-sais and Porth y Garan the New Harbour Beds are driven over the intrusions on a powerful thrust, which may be called the Garan Thrust-plane, while the intrusive rocks themselves are much deformed, converted into crystalline schists, and their foliation corrugated by the minor folding. Away from the thrust-plane, the resistance they offer gives rise to a considerable deflection of the strike (see (Figure 101) p. 239). The vertical foliation-dips that prevail both in and around the larger intrusions (on the main Island as well as on Holy Isle) point to their being stocks or bosses that rose (before the secondary folding—see pp. 109, 211) almost at right angles to the tectonic horizons established by the recumbent folding.

This upper limb of the Rhoscolyn Recumbent Fold is a northward, the lower limb of the Holyhead Recumbent Fold, a southward over-roll; and, as the Skerries Group is pinched out, the New Harbour Beds of the two folds being folded on themselves, there must be a powerful thrust at the roll-over. Precisely where the tectonic horizon changes is not yet known, but from the presence of Soldier's Point beds and of innumerable minor thrusts (Figure 62), (Figure 63), it is taken to be about the. Tre-Arddur gap. Until, however, the Soldier's Point horizon can be identified with confidence wherever present, greater exactitude cannot be attained. For, not only are New Harbour Beds brought against New Harbour Beds, but the Tre-Arddur thrust itself, being a plane of the primary recumbent folding, must have been powerfully folded by the major secondary, and further corrugated by the ternary minor isoclines, so that it would appear at several places. Besides, there may be more than one thrust, t the zone, all similarly folded, thus yielding a multiplicity of thrust outcrops. Finally, being older than the maximum metamorphism, re-crystallisation would have been set up along them, so that they would now appear, not as mylonising ruptures, but as planes of pure foliation, scarcely distinguishable from all the other countless, corrugated, foliation planes.

In any case, we pass, beyond the Tre-Arddur gap, into the lower, uninverted limb of the next great recumbent fold, the Holyhead Fold. Soldier's Point beds can be recognised for about a quarter of a mile, after which they do not reappear upon this limb. The net effect of the incessant isoclines is still a general northward . inclination, by virtue of which the major infolds begin, a mile from the gap, to take in the lower part of the South Stack Series, though the pitch confines that series, for a mile and a half, to the eastern side of the tract, until, in the deep infold that begins near Gorllas, it is allowed to reach across to the North Stack fault. An interesting effect of the pitch is the way in which the little spilitic tuff, clinging to the base of the South Stack Series, but always just within the Celyn beds, keeps bending to and fro round the rising ends of the minor isoclines.

To come to the major folds; there is no means of gauging the amplitude of those near Tre-Arddur; but from Gareg-fawr to Llain-goch it is clear that the recumbent limb is thrown into a series of great isoclines that, close to the Namarch fault, must have amplitudes (measured from the pitch-angle) of 1,100 feet in some cases. One anticline, just beyond Stryd, brings up the Celyn beds all the way to the fault. About Capel Gorllas the dip steepens and steadies, indicating a plunge to a still deeper infold. So steep are the dips, that in the valley beyond the last appearance of the Llwyn beds there is room for a complete outcrop of the Stack Moor beds, whose top is just seen along the roadside at the base of the Quartzite, which is now brought in by this deep infold. The other side of that infold has been destroyed by the sea, but the

bedding seen over the great caves near the North Stack suggests that the South Stack Series is once more about to rise. The structures in the Quartzite are very hard to read (Plate 16), but such bedding as can be made out indicates that it has been packed into the great syncline (which may be called the Mountain syncline) in a succession of folds with amplitudes of more than 700 feet, tentatively shown in (Figure 91), which is the result of a number of re-drawings made in favourable lights. It will be seen that the folds are not persistently isoclinal, the massive Quartzite having offered more resistance than usual to the south-ward impulse.

Country North-east of the Nantarch Fault — The country to the north-east of the Namarch fault is all on the upper, inverted limb of the Holyhead Recumbent Fold (Folding-Plate 3), being the first appearance of the vast Nappe of Holyhead; and is composed almost entirely of New Harbour Beds, of Soldier's Point horizon. They are thrown into the most beautiful minor isoclines that are known in the Mona Complex. But at the Breakwater, Celyn beds (in which is the little basic tuff) appear, and are quickly followed, as we cross the cove, by both divisions of the South Stack Series. The Quartzite also appears three times, and is twice visibly intercalated in the Stack Moor beds, in cakes varying from 30 to 270 feet thick. Now it is manifestly impossible that the 30-foot quartzite cake of Porth Namarch can be the continuation of the vast mass of the mountain, against which it is brought by the Namarch fault. Therefore the Breakwater tract cannot be the true core of the Holyhead Recumbent Fold. It is interpreted as a subsidiary recumbent core (Figure 92), pushed back southward into the gape (which must be multiple) of the Holyhead Recumbent Fold. The amplitude of the Breakwater fold is unknown. It must be full of ruptures, for not only is the Quartzite cut down to thinner and thinner cakes, but the South Stack and Celyn beds are greatly cut down also. These are primary thrusts ancillary to the Breakwater fold itself; they roll over on a major secon- n dary anticline which brings up the Breakwater core from under the Soldier's Point beds of the great Nappe of Holyhead (Figure 93).

Holy Isle is therefore a fragment, sculptured out of the cores of two maximum recumbent folds, the Holyhead and the Rhoscolyn Fold, with the subsidiary Breakwater fold; which are accompanied by folded foliation-thrust-planes ancillary to the recumbent folding, ail heing thrown into great secondary major isoclines, and the whole mass packed, by a south-eastward impulse, into innumerable minor isoclines, to which minor thrust-planes are in their turn ancillary.

The Western Region

The members present are the New Harbour Beds, the Church Bay Tuffs, and the Gwna Beds. Of the New Harbour Group, the Soldier's Point beds alone are known to be present, and they contain a fine development of the spilitic lavas and also of the bedded jaspers and jaspery phyllites. The Church Bay Tuffs are nearly undeformed at their northern end, but become schistose to the south. The Gwna Beds consist of typical green-schist and mélange, with strong developments of quartzite, limestone, and graphitic phyllite, and some good ellipsoidal spilites with nodular jasper. Some of the serpentines and their associates also fall within the district. The New Harbour Beds are holocrystalline schists, though less perfect than in Holy Isle (p. 48); but metamorphism falls off rapidly in the other two formations, and almost vanishes in the northern outcrops of the Church Bay Tuffs, whose great homogeneous mass doubtless offered exceptional resistance.

The whole region is regarded as lying on the inverted Nappe of Holyhead (the reasons for which view are given on p. 176), and if so, then the succession must be an inverted one. Whether any part is upon a lower limb depends upon the course of the Namarch fault, but such portion could in no case extend as far as the railway. From Tre-gof creek south-eastward the course of the fault has not been ascertained with precision, as there is evidence of several parallel fractures, which are shown upon the maps. It is most probable, however, that the main fault passes along the Strait of Holy Isle, whose features are evidently determined by faulting. To keep strictly to the channel involves curves near Fadog and Cvmyran, and it may pass across the Fadog promontory and east of Cymyran; but as it can be seen to curve pretty sharply at Porth 1\amarch, such curvature is no serious obstacle. The fault raises important questions concerning the stratigraphical position of the serpentine-suite, for whatever course be assigned it, some of that suite are left on either side, and therefore on different tectonic horizons. Had they been sills injected before the maximum recumbent folding, it is incredible that they could now be grouped as they are. There is, however (pp. 109, 208), independent petrological and other evidence that they were injected at an interval or intervals in the movements. The stratigraphical evidence, therefore, indicates that the intervals were after the maximum folding, and that the intrusions then found their way across different tectonic horizons; but before the major secondary folding and shearing, to which they owe their metamorphism.

It has been shown on pp. 196–8 how, near Valley, the old isoclinal folding of Holy Isle is overpowered by a minor thrusting coming from the opposite direction, upwards from the south-east, and that these new planes are in their turn folded. Now this thrusting is one with the general foliation of the Western Region, which must therefore be later than the isoclines of Holy Isle. Isoclines overdriven from the north-west are seen here and there; but the dominant structure is the new foliation, which has a persistent (though not universal) dip to the south-east, and must be regarded as due to an upward shear from that direction. With it a few true bedding-dips, as on Clegyr-mawr, agree.

The major structures — It will be seen from the map that, if the succession be inverted, the recumbent nappe must be thrown into a broad secondary syncline, the northern secondary limb being truncated by the Yr-ogo-goch fault that brings down the Ordovician rocks (close to which the bedded jaspers suggest that the New Harbour Beds are about to rise); that the syncline must be pitching eastward and that it must be compound, a number of large anticlines within it bringing up the Church Bay Tuffs. Now, to obtain a correct picture of the structures as a whole depends upon obtaining a true reading of the forms of these major folds, and of their relations to the dominant secondary foliation. The prevalent southerly dip of that raises a presumption that they are isoclines with a northward overdrive. At Clegyr-mawr the bedding of the tuffs dips 20°–30° south-east, to pass below the first nip of Gwna Beds (which, evidently pitching eastward, fails to reach the sea). On both sides of that nip are also south-easterly dips, and the same is the case again in the narrow anticline of Tuff that follows, and in the succeeding Gwna Beds of Foel. That the dips coincide with true dip is shown by the Tuffs on the south limb of the narrow anticline turning round on the sea-cliff to pass below the Foel Gwnas, as well as reappearing to pitch under them on the ebb-reefs of Porth Swtan. It therefore appears that the folds must be isoclinal, with the northward overdrive suspected, and that the secondary foliation is a product of the same stresses. Whether, however, any of their limbs are free from rupture may be doubted, for three reasons. The great homogeneous mass of tuff would not readily lend itself to folding; the Gwna Beds are shattered into mélange; and the tendency to rupture was very strong even about Valley (Figure 71), (Figure 72), (Figure 73), (Figure 74), (Figure 75), at a lower tectonic horizon. It is to be supposed that the major folds about Llanrhyddlad are for the most part thrust out along the dominant foliation, except at the sea-ward ends, where, on the rise of the pitch, there would be relief of strain. One such rupture, which may be called the Bodfardden Thrust-plane, is evident upon the maps, for along it the Gwna Beds as well as the Church Bay Tuffs are brought against the New Harbour Beds. It is dynamically connected with the pitch, for as the infold subsided eastwards, it ruptured, and the New Harbour Beds of the southern limb were driven over it. The thrust itself is doubtless a true foliation-plane, and if exposed would probably show no cataclastic structures, for the Gwna Beds and Church Bay Tuffs as they approach it show perceptible progressive metamorphism. Seawards it wanes with the' rise of the pitch, and at Porth Defaid must have passed into the New Harbour Beds or died out, for there is a passage into the Tuffs (p. 157) at that place. At Brwynog it must begin to wane again, for the Tuffs reappear. But all their central parts are missing, being evidently cut out, and only the top and bottom left. The section (Folding-Plate 4) expresses the foregoing views of the structure of the region. The wide-spreading New Harbour Beds are probably disposed in countless ruptured isoclines of small amplitude and low undulating pitch, for the lavas and jaspers are repeated all across, as if the general effect were approximately horizontal. The low pitch is due to the eastward waxing of the Bodfardden thrust-plane. The combined effect is to spread out the New Harbour Beds in both directions, thus accounting for their large area. But. there may be deeper infolds at Penial and Llanddeusant, where tuff-like beds occur. Near Glan-alaw the strike swings, round somewhat, and the contents of the Ordovician conglomerates indicate that the Tuffs and Gwna Beds come on below them in the Cors y Bol country.

The reversal of the direction of thrust and overfold is most remarkable, and there is no sign whatever that the region is riding upon any single great thrust above the isoclines of Holy Isle. None can be seen in the section on the estuary of the Alaw, and the evidence of that section and of those at Llanfair-yn-neubwll (Figure 71), (Figure 72), (Figure 73), (Figure 74), (Figure 75), (Figure 76), points clearly to the change of overdrive being effected by means of a zone of innumerable minor thrusts.

The Northern Inliers

The Garn and Fydlyn Inliers afford important evidence as to the succession in the Complex; the Gader Inlier, the finest section in the Gneisses. They raise problems as to dynamics that are not easy of solution, for the southerly dip so persistent in the Western Region disappears, and is replaced once more by northerly foliation-dips and south-ward

thrusts and isoclines. As there is clear evidence at Fydlyn (pp. 214, 289) that the succession is inverted, as the evidence on the Garn points to the same conclusion, and as that in the other inliers is in harmony therewith so far as it goes, they are all supposed to be still on the inverted Nappe of Holyhead, the major secondary isoclines, however, being here of great amplitude.

At the ***Garn Inlier*** (Folding-Plate 9), New Harbour Beds of the Soldier's Point Group (in the condition of green-mica-schist) are succeeded by comparatively thin Church Bay Tuffs, and those by Gwna mélange, metamorphism waning rapidly in that direction. The New Harbour Beds are isoclinally folded with a southward impulse.

At the ***Fydlyn Inlier*** (Folding-Plate 10), (Folding-Plate 13), the stratigraphically lowest and tectonically highest member is the Fydlyn felsitic suite, succeeded by Gwna mélange with quartzite, limestone, spilite, and diabases, and those by Church Bay Tuffs. Anamorphism is low, but not at a minimum. The Gwna Beds are seen (pp. 176, 289) to rise from below the Fydlyn rocks on an isoclinal anticline, so the succession is undoubtedly inverted. The inlier is nearly split by two ruptured Ordovician infolds, but their thrusts and slips appear to nearly neutralise one another, thus introducing less confusion than might have been feared. Ignoring that, its ancient isoclinal structure consists of a pair of synclines, each taking in the Fydlyn Beds. The southern one is compound, with rolls that brim,-$_r$' up the Gwna Beds, and the northern one is complicated by the Hwch lower thrust-plane, which drives its northern limb (p. 291) right across its core and on to its southern limb. Between the two major synclines is an anticline bringing up the Church Bay Tuffs.

Over the Ordovician shale that bounds the Fydlyn Inlier on the north, the Gader Gneisses (Folding-Plate 10), (Folding-Plate 13) are driven on the Post-Ordovician Hwch thrust-plane. If the Mona succession be inverted, with the Gneisses uppermost and riding on the Gwna Beds on an ancient folded thrust (pp. 216, 221) then the Gader Gneiss, now the denuded core of a thrust Ordovician anticline, must have been the core of a secondary isoclinal Mona syncline. That syncline was probably not the same as the one which we see at Porth-yr-hwch in the Fydlyn Inlier, but one from further north, for there is reason to suspect (Chapter 14) that the Hwch thrust-plane has considerable horizontal displacement and has carried this gneiss for some distance to the south. A small fragment of Gwna mélange is brought up against the gneiss on the coast, but the Fydlyn Group is cut out.

The ***Corwas Inlier*** is composed of New Harbour Beds of Soldier's Point type, which pitch towards a thrust that parts them from a tract of Gwna Beds. But the vicinity of the thrust is obscure, and the Church Bay Tuffs may be but partly cut out, and the thrust of no great magnitude. Metamorphism falls off eastward.

No more than suggestions can at present be offered in explanation of the structural contrasts between the Western Region and the three north-western inliers. Yet the contrast is not as violent and immediate as it seems at first sight. For the inliers are all riding upon Post-Ordovician thrust-planes, and have been brought much nearer (how much nearer is unknown) both to the Western Region and to one another than they were at the time when their structures were being produced. They have also been carried upwards. The Garn Inlier has been brought upward upon the Garn fault and both upward and southward upon the Garn thrust-plane (Chapter 14). The tendency of the structures of the Western Region would be to ride somewhat upwards in a northerly direction, and it is probable, therefore, that the contrasts are those of differing tectonic horizons, now brought close together and to the same level. The isoclines of the Garn may be a survival of the old isoclines of Holy Isle, below or between planes of the secondary foliation of the Western Region. More than this it is not yet possible to indicate.

The Northern Region

The succession is unusually complete in this region, the Coeden, Amlwch, Skerries, and Gwna Beds all outcropping, as well as the Gneisses, and there are a number of small intrusions of the serpentine-suite. The South Stack Series, New Harbour, and Skerries Groups are all represented by northern facies that are unknown elsewhere, and the same is the case, though but locally, with the Gwna Beds. The Coeden beds appear only on the southern margin. The Amlwch Beds occupy some two-thirds of the region, and their bedded jaspers, jaspery phyllites and spilitic lavas are finely developed, especially about Amlwch. There, also, their alternating type is most pronounced, but westward and southwestward rather less so, the lavas and jaspers at the same time dwindling somewhat. A number of large phyllitic tracts, most of them in Bodelwyn beds, have been delimited on the one-inch map, though not given a separate colour. The Skerries Group is

represented only by the Grits proper along the central band, in which are The Skerries themselves (where the conglomerates are found), the West Mouse, and the long tract ranging from Llanrhwydrys to Llanfechell. In the Trwyn Bychan tract, between Hell's Mouth and Bull Bay, the Sherries Grits are seen to lie between the Amlwch Beds and the Church Bay Tuffs, which are finely developed along the northern coast. The Gwna Series is complete, alternating beds (now mostly mélange and green-schist), quartzite, limestone, graphitic phyllite, spilitic lavas, and jaspers being all present. The quartzite, limestone, and black beds are at a maximum, the lavas rather feebly developed: while in parts of Gynfor (as the district on either side of Llaulleiana may be called) vulcanism is at a minimum, the lavas being very thin and local, the alternating beds grey and free from pyroclastic matter, a condition unknown elsewhere in the group.

There is progressive anamorphism from the Gwna to the Coeden Beds, and, in a less degree, from north to-south upon corresponding horizons; the Gynfor Gwnas (which have undergone great mechanical destruction but only a minimum of reconstruction) being in Van Hise's 'Zone of fracture', the rest of the region in various depths of his 'Zone of flowage'.

The whole region (Folding-Plate 5) is riding, at a generally low angle, upon the Post-Ordovician Carmel Head thrust-plane, by which (Chapter 18) it has been brought a long distance from the north. Its own structure is persistently isoclinal with, also, a steady south-ward overdrive, but these folds are far older (see p. 244 and Chapter 18) than the Post-Ordovician movements, by which they are broken, and belong to the ancient movements of the Mona Complex. The pitch is low . and variable, sometimes east, sometimes west, while in the middle there may be none at all. The major isoclines are on a great scale, so that the form of most of them is not directly visible. Reasons have, however, been assigned (see p. 177) for supposing the succession to be inverted, the Coeden beds being tectonically lowest, the Gwna Beds and Gneisses tectonically highest, and for considering the whole region to be upon the Nappe of Holyhead.

The Lanfairynghornwy Belt — This will be a convenient name for the marginal belt that can be traced from Carmel Head to Llanifiewyn, emerging from beneath the rest of the region. Lowest of the tectonic horizons of this belt is the wedge of Amlwch Beds that (Folding-Plate 13) at Carmel Head itself, rides upon the Carmel Head thrust-plane, at which its ancient minor isoclinal folds are cut and shattered. This wedge is quickly cut out by another thrust (that may be either of Pre-Cambrian or Palaeozoic date) which, from the name given on the .0004 and six-inch maps to the next cove, may be called the Porth-y-wig or 'Wig' thrust-plane. It must be at a lower angle than the axis of the major isocline, and must be powerful, as it eliminates the whole of the Skerries Group, but its course land-wards is cut short in only 100 yards by the Carmel Head thrust-plane, on to which it laps, as if it were of older date. The Gwna Beds brought forward by it then come on to the Cannel Head thrust-plane, upon which they ride all the way to Llanffiewyn. They are of interest because of their spilitic lavas, which are the best development, in that group, in the Northern Region.

Involved with these Gwna Beds, the junctions all being evident ruptures (thus cutting out the Fydlyn Group), are the four strips of the Mynachdy Gneiss. Now, if the succession be inverted, the Gneisses must be uppermost, and the relations must be those of an ancient folded thrust-plane (Figure 94), broken in its turn both by the later mylonising movements of the Complex, and by those which have let in the wedge of Glenkiln shales- and (see Chapters 14, 18) torn their base to pieces. So the Mynachdy Gneiss is, as might have been expected, hardly more than a shattered and decayed wreck of a once crystalline formation.

The sinuous line along which these Gwna rocks and Gneisses are succeeded by the Amlwch Beds (once more cutting out the Skerries Group) is the tipper boundary of the Llanfairvnghornwv Belt, and must be the outcrop of another powerful thrust, which may be called the Caerau Thrust-plane. This fails to reach the coast, being there cut out by the Post-Ordovician Mynachdy thrust-plane, but its sole is laid bare at Llanfflewyn, where it is almost horizontal. There is reason to think that it is an ancient rupture of the Mona' Complex, for the old thermal alteration at Caerau, which (see pp. 108–9, 320) belongs to an interval in the production of the Complex, does not seem to be cut up by it, but to obscure the outcrop of the thrust. As we approach the lake, a wedge of Church Bay Tuff is admitted below it, but, beyond the Geirian fault, it laps on to the Carmel Head thrust-plane, and the remarkable dynamic effects produced between the two great thrusts where close together are described in Chapter 18. The Caerau thrust-plane has not been traced beyond Gwaen-ydog.

The Llanfairynghornwy Belt is thus to be regarded as a long *lambeau,* nearly horizontal, that is caught between the Carmel Head and Caerau thrust-planes. Its thickness at Mynachdy marsh is not likely to exceed 500 or 600 feet. Its

internal structures are at higher angles than its bounding planes, and are to be regarded as the remains of a deep isoclinal infold of the major series, which has been truncated both upwards and downwards. The Gwna Beds and Church Bay Tuffs of Llyn Llygeirian (Folding-Plate 5) must be part of the northern limb of this infold, while the Mynachdy Gneiss is in its core, which was therefore multiple. The Amlwch Beds of Carmel Head doubtless rose upon its southern limb, but that limb has been cut through by the Wig thrust-plane, driving forward the Gwna Beds and leaving a subordinate *lambeau* below them that can only be some 50 feet in thickness. The Wig and Caerau thrust-planes (if of the Complex) belong to the major secondary structures, but the ancient folded thrust-plane of Mynachdy to the primary recumbent structures.

The major folds and thrusts in the main body of the region — The Coeden beds now appear from below the Amlweh Beds in the curve of the thrusts; and, riding first upon the one and then upon the other, take their place for some five miles as the tectonic base of the main body of the Northern Region. They are powerfully folded, the folds having a larger sweep than is usual in the thinner-bedded Amlwch Series. The isoclines are very steep, with even a few symmetrical folds (Figure 132); revealing thus an approach to dynamic equilibrium, from which a steep cleavage-foliation might have been expected, but there is only a strain-slip (Figure 70) in some thin lepidoblastic beds. The pitch is low and undulating, and is westerly at the west and easterly at the east end, indicating a rise from below the Amlwch Beds on a large major anticline.

Between them and the Skerries Grits of Bwlch there can hardly be room for the whole Amlwch Series, the spilites and jaspers, moreover, being almost absent. Their local development may have been poor, but there is reason (p. 316) to suspect thrusting west of Bwlch, and there are probably undetected thrusts in the Amlwch Beds themselves, cutting out most of the Lynas beds.

That the major isoclines of the region must be of great original amplitude (though now cut off at no great depth by the Carmel Head thrust-plane) has already been remarked. That which here takes in the Skerries Grits is boat-shaped (pp. 177, 317). Possibly, therefore, the West Mouse and The Skerries lie in another infold that is nearly but not quite on the strike of it. But neither of these infolds is deep enough to take in the Church Bay Tuffs. The infold of Llanrhwydrys is overthrust from the north-east (p. 317), and the thrust-plane must be at a low angle. But its age is unknown, it may be an ancient one, possibly even folded and cut by later ones, and must be supposed to pass into the Amlwch Beds in the obscure ground east of Llanfechell.

The broad tract of Amlwch Beds that follows must be anticlinal, probably bringing up the Bodelwyn phyllites from Tre-gele to Rhydgroes, but with innumerable corrugations. To the east of Amlwch are some of the most beautiful isoclinal folds in Anglesey (Figure 49), (Figure 52), but towards Cemlyn folding is largely replaced by thrusting that is almost parallel to the bedding and that is healed up ' by crystalline foliation.

The Trwyn Bychan tract is to be regarded as a second infold of the Skerries Group, deep enough to take in the Church Bay Tuffs and even the Gwna Beds; and is compound, seeing that it takes the latter in on three distinct ranges of nips. This statement is, however, an extreme simplification, for in the Trwyn Bychan syncline almost every fold must be ripped out by thrusting. The high-dipping foliation of the Tuffs themselves is thrown into sigmoidal curves by innumerable ancient thrust-planes of the Complex, four of which are large. The greatest of them, which is horizontal at one place, and is cut by steeper ones, may be called the Trwyn Bychan thrust-plane ((Figure 95) and pp. 185, 314). The Tuffs are then driven on to the Gwna Beds by the Trwyn Bychan lower thrust-plane (*loc. cit.*), and it is evident, from the different beds that come against the junctions, that nearly all the nips are thrust. Further complications are introduced by the presence of Ordovician infolds, themselves torn out by the Porth Pridd and other thrust-planes. From Porth Wnol to Cemaes Bay the Skerries Group is once more cut out by a thrust (Figure 96) which may be called the Wylfa thrust-plane, shattered Gwna Beds of a deep infold being driven, at a lower angle than the dip, on to the Anawch Beds. But on both sides of the Hell's Mouth fault the structures are extremely difficult to interpret with consistency, owing to the anomalous behaviour of that fracture. It is a down-throw to the north-west, for on that side it introduces nips of Ordovician rocks a mile further to the south-west than they are found on the other side. Producing several feet of breccia (p. 311) it cannot but be powerful. Yet it scarcely seems to displace the Ordovician base-line at Hell's Mouth. That may be partly explained by the nearly vertical Ordovician clip at that place. But neither does it appear to displace the Wylfa thrust-plane at Neuadd, and it is possible that the Gwna nip east of the fault, which must lie in a deep ruptured infold (possibly thrust southward as well)

may not be resting on that same plane. The sudden thickening of the quartzite on Dinas Cynfor suggests that it is doubling over, possibly on a fold above the Nappe of Holyhead, brought down by the Hell's Mouth fault, which may be Pre- as well as Post-Ordovician, recurrent movement accounting for the great width of breccia. That a higher fold is coining on to the north is confirmed by finding that on the Middle Mouse the Skerries Beds underlie the Amlwch Beds. Whether this be the beginning of the Bodorgan Recumbent Fold, or some subsidiary one, is not known. It is known, however, that the Gwna quartzite, in spite of the Pre-Ordovician shattering of the group, was (Chapter 14) locally horizontal in Ordovician times, though its horizontality was probably of the nature indicated in (Figure 97). It is now repeatedly broken, and at high angles, or even vertical. To restore, in such case, ancient planes of movement whose original angle is unknown to us, is a problem that seems insoluble at present. But it is clear that the anomalies of the Hell's Mouth fault are the net result of the superimposition of Post-Ordovician thrusting and faulting upon the inversions, foldings, and thrustings of the ancient Complex.

The Middle Region

The members present are the Gneisses, the Coedana granite with its hornfels (which appears to he largely an altered condition of the Church Bay Tuffs), the Penmynydd Zone with Gwna sediments, the Gwna Beds in very full development and including both the north-western sedimentary and the eastern volcanic facies (pp. 155, 179), and the Tyfry Beds.

The Gneisses, of all types, are finely developed, and it is evident from the map that not only the small inliers among the Ordovician rocks but the large Nebo Inlier are continuous with the Middle Region tract itself, and that a great crescent of gneiss (indicated by the broken lines in (Figure 101)) extends all through the middle of the Island from the Tywyn Trewan to the north-east coast. Xenoliths of crystalline hornfels are numerous within the Coedana granite, which is partly fringed on both sides by the crypto-crystalline type. Passing to the Penmynydd Zone; a persistent fine and flaggy belt adjoins the hornfels, then flaggy and flaky flaser belts alternate. The hornblende-schists are small and thin, and glaucophane has not been found. The triple Gwna Group of quartz-schist, limestone, and graphitic-schist appears in small outcrops all across and along the Zone, as well as in its inliers to the east, and is of purely western facies. There is decisive evidence (see p. 385) that the Zone develops at different stratigraphical horizons. A considerable tract of it is hidden by the Ordovician of Llangwyllog. The Gwna rocks proper (as distinct from those in the Penmynydd Zone) consist first of typical Gwna Green-schist, in which lie the great Engan spilites, now completely converted into chlorite-epidote-actinolite-schists with their jaspers deformed and bleached (pp. 77, 88). East of them is a prodigious mass of autoclastic mélange with vertical divisional planes, in which are numerous nips of quartzite, all very slightly reconstructed, and also the Llanddwyn spilites of Ceinwen, which are not much deformed. They are associated with large ashy rose-limestones, whereas the Engan spilites are almost free from limestone. The Engan and Llanddwyn spilites, therefore, cannot be the same, but must be on different horizons; and as the Llanddwyn lavas are surmounted by the Tyfry Beds, they must be the later of the two great flows. The large epidiorites of Bodorgan may (see pp. 109, 321, 348) be of approximately the same age as the dolerites of the Northern Region. The Tyfry Beds occur in the Ceinwen country and as a series of strips along the eastern margin of the Region, where they pass into the Gwna mélange. The great outcrops of quartzite in the extreme north-east at Mynydd Bodafon are an important circumstance in the stratigraphy.

Now, ignoring the Penmynydd metamorphism, and considering original material only, it is evident that the western Gwna facies, with its clean grey limestones, carbonaceous shales, and thin or no lavas, is well-developed in the western part of this region; that the eastern Gwna facies, with its great spilites, ashy rose-limestones, and complete absence of the carbonaceous shales, is fully developed in the eastern parts; and that die two facies come close together. Further: if the Church Bay Tuffs be represented in the hornfels, then both the western and eastern (Tyfry) facies of the Skerries Group are also present.

The region differs from all the others in the comparative rarity of rapid visible folding; instead of which we find persistent high or even vertical foliation-dips, with remarkably steady north-easterly strike (especially in the Gwna mélange). Along the eastern margin both deformation and metamorphism are comparatively low or moderate. Thence there is a generally progressive metamorphism westwards, but with sudden rises in and west of Gwna Vale.

The major folds and thrusts to the west of Gwna Vale — Structurally, the region is the most complex in the Island, and is extremely perplexing, more than ono hypothesis being possible, while difficulties attend all that have been, so far,

devised, most of which arise from the relations of the Penmynydd Zone. What follows (Folding-Plate 6) must therefore be understood, hardly as a theory, but rather as a suggestion in aid of a structural theory of the region.

The western part, it will be recalled, is considered to lie upon the great inverted Nappe of Holyhead, the Nappe of Bodorgan appearing in the eastern parts. There is independent evidence that the succession in the western part really is inverted, for the passage-beds from the Gwna sediments to the Church Bay Tuffs (see p. 64) undoubtedly pass under the Bodafon quartzite (pp. 160, 336) showing that the Gwna Group is resting there upon the Skerries Group. Towards an interpretation of the major secondary folds, one fact stands out as of prime importance, and that is the existence of a great compound anticline at Mynydd Bodafon. Its nature is shown in (Figure 154), (Figure 156), (Figure 157), (Figure 158), (Figure 159), and detailed evidence for it is given on pp. 336–40. It pitches to the north-east.

Now, if the succession be inverted, the Gneisses must be uppermost, and this view finds confirmation in their position to the west of the axial line of the Bodafon anticline, where a complementary syncline might be expected. They may be supposed to lie in a vast crescent-like depression, which may be called the Caradog syncline, some three miles wide, that sweeps past the shores of Cors y Bol to the Nebo Inlier. It has already (pp. 168, 184) been suggested that, as the rocks originally adjacent to them are missing, they must be lying on an ancient rupture, most of whose outcrop has been flooded by the Coedana granite, for that intrusion, it will be recalled (p. 167) is evidently later than the primary recumbent folding. The ancient primary rupture thus postulated may be alluded to as the Gwyndy Thrust-plane. The Gwyndy thrust-plane must be folded by the major secondary flexures, and sink down deeply into the Caradog infold. The Bodafon Moor Flags (see p. 336) that rise on the Bodafon anticline, must be some of the upper Gwna Beds. They are converted into hornfels near the (destroyed) cromlech, and the long zone of hornfels to their south-west, referred on petrological grounds to the Church Bay Tuffs, might be expected to rise from below them on the pitch. The Coedana granite points directly to the core of the anticline, under which it seems to sink, as its hornfels-effects diminish to the north-east, beyond its outcrop. It would therefore appear to be a great sill, rising into or on the anticline. If so, another- great syncline should be expected along its south-east flank, and as the foliation- and bedding-dips there are either steeply to the south-east or vertical, the granite may be supposed to plunge down almost vertically. Now it is here that we find the Penmynydd Zone of metamorphism. That it should appear on this tectonic horizon is perplexing, but reasons have been given on p. 200 for supposing that there has been a transfer from the zone of fracture to the zone of flowage, explicable by the roll-over of a still higher *nappe de récouvrement,* making the Penmynydd alteration possible (see also footnote, p. 227). We have seen that alteration to be later than the intrusion of the granite. We know, too, that the impulse here was from the southeast. If we suppose rocks lying in or let down into a profound synclinal depression with nearly vertical axis, whose further side was a wall of granite cased in hornfels and backed by a deep syncline of gneiss; if we suppose them still granite-heated (thus facilitating chemical re-adjustments), and, in that condition, driven against the unyielding north-western wall, then the Penmynydd metamorphism becomes intelligible. Much of them, further, we know to be highly alkaline (pp. 112, 122–7), and probably rhyolitic dust, a material that would lend itself to re-crystallisation.

The zone, of course, is not an horizon. Yet stratigraphy is traceable within it. We have seen reason to suspect that the Church Bay Tuffs, inverted, plunge down into this infold, which may be called the Bodwrog syncline. We know that Gwna quartz-schist, graphitic-schist, and limestone are repeated many times both across and along it. The dominant material of the surface is more than suspected to represent the Fydlyn rhyolitie group. If, then, the great infold be compound, filled in the main by the Fydlyn Beds with Gwna sediments appearing here and there on the crests of subsidiary anticlines, the stratigraphy can be made, so far, consistent. There can be but little pitch, for the limestones are found far inland to the north-east. Connected with that, probably, is the fact that the Bodafon quartzite fails to run along the western margin of the Gwna rocks of the Penmynydd Zone, as it should do if plunging unbrokenly down into the syncline. It must be cut out by a north-westward thrust, raising the rocks of that infold and thus abolishing their pitch.

Major folds and thrusts of the Nappe of Bodorgan — On their further side is a long tract of Gwna Green-schist, with many trains of lenticular tracts of Penmynydd schist. On the theory just propounded, it is unlikely that these are merely "capricious" local alterations, they are more likely to be the upper parts of the Penmynydd Zone brought up, a view confirmed by the singular fact that they are often more strongly folded than the principal tract of the zone. Almost at the same time the great Engan spilite-schist appears, and with remarkable suddenness. For the basic rocks of the Penmynydd Zone are thin hornblende-schists and amphibolites probably all intrusive, and if any spilites at all are associated with the local Gwna sediments of the zone (which is doubtful) they must be quite thin, just as they are in

Gynfor, whereas the Engan spilite is the greatest of all the lavas of the Island. Yet its first infolds occur on the same strike as, and its main body only five-eighths of a mile from the western Gwna facies, from which circumstance the change of tectonic horizon from the Nappe of Holyhead to the Nappe of Bodorgan (ushered in really by the Bodorgan thrust-plane) is inferred to come on somewhat below its base. The Bodorgan thrust-plane is regarded as folded, and as rising again on the major secondary anticlines which, about Plâs-bach, Bodwrdin, and elsewhere, bring up inliers of Penmynydd mica-schist in which are nips of Western-Gwna limestone with graphitic films. Only 160 yards beyond one of these inliers the Llanddwyn spilites of the Ceinwen infold come on, quite unreconstructed and in great part even undeformed, with ashy rose-limestones, and followed by the Tyfry Beds. So the western and eastern facies of the Gwna Group, each in full development, lie close together, and are interfolded with each other on the major secondary flexures.

It has not been considered wise to lay down the Bodorgan thrust-plane on the maps (though this has been done, approximately, on the small chart of (Figure 100) and on the Folding-Plate section), but it cannot be far from the margins of the Penmynydd Zone tracts, rolling over and over, possibly also cut by vertical secondary slides along the strike. The plane itself is doubtless now masked by crystallisation, so as to appear on its outcrop merely as one among countless foliation-planes in a zone of anamorphism. As it passes eastwards, it eliminates one by one the lower members of the Nappe of Bodorgan; first the Gneisses, and then the Fydlyn Beds, having been cut out by the time it has descended to the present level of erosion. Still rising to higher and higher horizons, it thins the Gwna Beds, and by the time we reach the Pliis-bach anticline, it has risen almost to the base of the Engan spilites. Passing still further east, the Engan spilites themselves fail to reappear. They are not repeated by the Plâs-bach anticline, on whose south-eastern limb, instead of them, appear the Llanddwyn spilites. The Gwna Green-schist on the two limbs must therefore be on two different horizons, that on the west being below the Engan, that on the east below the Llanddwyn spilites. The effects of the secondary anticline are thus quite abnormal, which is accounted for by supposing that the Bodorgan thrust-plane, where it rolls over, is in the act of cutting out the Engan and lower beds: But at this place, the great thrust seems to have attained its highest position. For, as the western Gwna facies never reappears, the Bodorgan thrust-plane cannot emerge on the further side of the Ceinwen infold, and is therefore supposed, after having risen almost up to the Llanddwyn spilites, to be returning to lower horizons, allowing the beds between the Llanddwyn and Engan spilites to appear upon an anticline.

The tract thence to the Carboniferous is regarded as a compound anticline of mélange, called the Hermon anticline, though it is somewhat. difficult to realise that any major folding at all can be hidden within this eleven-mile tract in which hardly anything is to be seen but lenticular masses all standing vertically. There is a Tyfry nip at Cefn-cwmmwd, and finally the Tyfry Beds come in along the margin of the Complex, tucked in under the great fold. They graduate into the Gwna Beds, and yet the Llantldwyn spilites and limestones are but feebly represented, and in many places absent, being doubtless cut out along some of the countless planes of rupture.

The section (Folding-Plate 6), which must be understood: is a suggestion merely, may serve to render the hypothesis here set forth intelligible. The positions regarded as probable for the Gwyndy and Bodorgan thrust-planes (omitted on the maps) are indicated. But the section has been simplified exceedingly, only the larger folds being shown. Itll be seen that the arrangement of the major secondary folds, and of the resulting foliation-dips, is fan-like. It cannot be called synclinal, for the deepest infold of all is at the south-eastern margin where the large tract of Tyfry Beds is taken in; so that the general inclination of the region is at a considerable angle to the south-east.

The Gneissic Inliers

The Nebo Inlier, as well as the small ones about Llanerehymedd and Bryngwran, are undoubtedly in continuity with the Gneiss of the Middle Region, and thus on the inverted Nappe of Holyhead, cut by the Gwyndy thrust-plane, itself infolded into the Caradog major syncline.

The Deri Inlier

The rocks are evidently those of Mvnydd Bodafon, but more foliated, and must be on the south limb of another anticline, whose core is invaded by the granite and whose north limb is concealed below the Ordovician.

The Pentraeth Inliers

These, caught between and broken by the Berw faults, are closely related to each other. They consist almost entirely of Gwna Beds, with one small inlier of the Penmynydd Zone, a number of large infolds of the Tyfry Beds, and one small serpentine. The CWIIa Beds are wholly of the eastern facies, being Green-schist and mélange, with a great development of the spilitic lavas, and especially the limestones, as well as jaspers, jaspery phyllites, and albite-diabases, the latter on a greater scale than usual. But the Engan spilites and the quartzite appear to be absent. Some of the most perfect examples of the variolitic structure, both glassy and felspathic, have been found in these inliers. Several of the rose-limestones are very ashy. The Tyfry Beds are typical, with much purplish phyllite as well as ashy grit, and their bedding is in unusual preservation. In both inliers, however, the rocks have been excessively torn up, and the spilites, though so beautifully preserved in certain cores, are for the most part sheared into dull green and purple schists, and their junctions with the albite-diabases obliterated. Except in the little inlier of the Penmynydd Zone, the metamorphism is of a low order, but somewhat higher in the Western than in the Eastern inlier. Folding is rarely seen, dips at moderate angles are but few, and the dominant structure is a vertical schistosity.

Both inliers are supposed to lie, like the eastern Middle Region, on the Nappe of Bodorgan; the sequence being normal, with the Tyfry Beds uppermost.<ref>It is possible, however, that they may be on the tectonic horizon of the Llanddwyn Wedge (p. 228).</ref> But the major secondary folds are probably ripped out in every case. Their positions may be roughly indicated, thus:

The Western Inlier must be crossed obliquely by an anticlinal axis near the Smithy, up into the core of which the Penmynydd rocks are driven between a pair of slides; and by a broad compound syncline with slight northerly pitch about Tan-y-graig, taking in the Tyfry Beds. The Eastern Inlier must be synclinal south-west of Pentraeth, the principal tract of Tyfry Beds lying in a symmetrical infold that is probably both deep and steep-sided. East of it, near Tyfry, three smaller synclinal nips occur. There must be a slight south-westerly pitch from the sea-ward end as far as Tyfry. The inners are complicated by superimposition of powerful faulting, not only Post-Ordovician but Post-Carboniferous, upon the already excessive secondary ruptures of the Nappe of Bodorgan, and the direction of the throw of faults has been reversed in later times (Chapter 27). But the lines of the old Mona movements can be distinguished. They strike more northerly, meeting the Berw faults at angles of as much as 20°, thus carrying the bands obliquely across the inliers.

The Aethwy Region

The members present are the Penmynydd schists, the Gwna Group, and the Tyfry Beds. Some basic gneisses which occur among the Penmynydd rocks near the western margin are correlated with the Gneisses of the other regions. The Penmynydd Zone is chiefly mica-schist, with large masses of hornblende- and glancophane-schist, no quartzite, limestone, or graphitic schist being known within it here. The Gwna rocks of Aethwy proper are chiefly green-schist and mélange, with large masses of basic schist, jaspers, limestones, and quartzites (the last being rare). The basic schists are known to be in great part reconstructed spilitic lava, but may be partly after albite-diabase. In what may be called the Llanddona Highlands, little nips of them are extremely numerous. Ashy rose-limestones are associated with the lavas, and so the only Gwna facies present is the eastern one.

In a narrow tract on the north-western margin, between the Aethwy Region proper and the Berw fault, which may be called the Llanddwyn Wedge (see the chart, (Figure 100)), Gwna rocks reappear, now accompanied by Tyfry Beds. This wedge is distinct from the rest of the region, and may be on a higher tectonic horizon. It is the type-district of the eastern volcanic facies of the Gwna Beds. Mélange and green-schist are subordinate, while the ellipsoidal spilites are developed on a great scale, often, too, in perfect preservation (even retaining their augite), with their inter-ellipsoidal jaspers. Spilitic tuffs, albite-diabases, and ashy rose-limestones accompany them. They are the type-spilites of the Island. Though the Llanddwyn wedge is cut by lines of powerful shearing, and the spilites locally converted into dull spilite-schist, anamorphism is not found on Llanddwyn or in the dunes of Newborough, but only in the narrow north-eastern part, and even there is of a low order.

In the Aethwy Region proper, the Gwna Beds have undergone more metamorphism. than anywhere else in the island (outside the Penmynydd Zone). Original spilitic structure survives at a few places only, the lavas being almost

everywhere converted into chlorite-epidote-schists with a good deal of actinolite and with ternary albite. Not only the Green-schist, but even the matrix of the Autoclastic Mélange, has been considerably reconstructed, with tolerably well-developed mica, and the stages reached along the Menai Strait are as high as any. Quartz has segregated on an enormous scale. Bedding has disappeared, and nemablastic texture is intense. In fact, all the higher characters of the Green-schist, described on pp. 67–9, are in reality the characters of this region. Connected with this is the rapid folding, not only of green-schist but even of mélange, which presents a strong contrast to the persistent high dips of the mélange in the Middle Region. The polyclinal type is developed on a great scale, and is peculiarly characteristic of these rocks. The existence of cross-folding, which produces a continual unsteady wavering of strike, presents a similar contrast. Two tracts of specially gritty mélange run, from Pen-y-parc to the Bulkeley Memorial, and from Cadnant to Llansadwrn; and so, as tracts of highly siliceous nemablastic schist (at the Suspension Bridge and at Llanddona) are found at each end of the larger of these tracts, it is evident that they are an altered condition of these gritty beds.

In the Penmynydd Zone, the flaser type is dominant. The survivals of original material, and the passages from the Gwna Beds, have been described (pp. 122–5). The rocks are perhaps more highly crystalline than in the Middle Region. But the differences from that region' are chiefly (as in the Gwna Beds) that there has been a much greater segregation of quartz; and that instead of a persistent high dip with subordinate visible small symmetrical folds, rapid folding, chiefly isoclinal but often poly-clinal, is conspicuous, and is the rule everywhere, both in acid and in basic schists. Basic rocks are present on a vastly greater scale} and glancophane-schist is abundant. With regard to the horizons present in the zone, the acid mica-schists have been (pp. 122–6, 162) correlated with the Fydlyn Group, which must be very thick; and it is possible that the glancophane-schist may represent the great Engan Pitch being to the north-east, the Fydlyn must pass under the Gwna Beds, and the succession must be uninverted. theasons have been given (p. 180) for supposing the whole region except the. Llanddwyn wedge to lie upon the Nappe of Bodorgan.

It is disconcerting, undoubtedly, to find that the high Penmynydd grade of metamorphism has mounted from the Nappe of Holyhead to that of Bodorgan.<ref>Disconcerting, because these highly altered Penmynydd rocks have thus to be placed on a higher tectonic horizon than that of the Church Bay Tuffs and Gwna Beds of the Nappe of Holyhead, which are but slightly altered (see notes on pp. 200, 210). It is natural to suppose that, both in the Middle and Aethwy Regions, the Penmynydd anamorphism must be upon a tectonic horizon lower than that of the Nappe of Holyhead. Yet, if we attempt to place them upon the lower limb of the Holyhead Recumbent Fold, or upon either limb of the Rhoscolyn Fold, we find that the same difficulty reappears in a new form, and that we have placed slightly altered rocks under highly altered rocks. For we have then placed the slightly altered Gwna and Tyfry Beds of the Middle and Aethwy Regions under the Green-mica-schists of the Nappe of Holyhead. Stratigraphical difficulties as to inversion also emerge. Most serious of all, it will be found that the facies of the Skerries and Gwna Groups do not then develop in the right directions. Thus, we have to encounter difficulties of some kind whichever arrangement we adopt, and the one adopted as a working hypothesis appears to be, on the whole, that which presents the least embarrassments.</ref> Yet the ascent is less real than apparent, for the anamorphism in question does not, after all, reach the base of the Llanddwyn spilites, though it seems to involve the Engan spilites, thus mounting somewhat, though not greatly, higher than in the Middle Region. The Bodorgan thrust-plane, we may recall, was, when last seen, passing to lower horizons; and here the vast mass of the Pydlyn Group has been admitted above it; the base of the nappe having thus descended rather than the metamorphism having ascended. Concordantly with this we may note that the general inclination of the Middle Region is at a considerable angle to the south-east; and that the Aethwy Region has undoubtedly been raised on the Berw fault from a depth of at least 2,300 feet (Chapter 27) while its more crystalline parts had already been raised an unknown distance on the Newborough slide (see below). It has, moreover, been shown (pp. 198–200) that the Aethwy rocks have been transferred from the zone of fracture to that of flowage, and that this is explicable by the rolling over them of another large *nappe de récouverment.* A difficulty remains, however, in that there is no sign of the Coedana granite, whose influence has been appealed to in partial explanation of the Penmynydd metamorphism in the Middle Region (p. 222). Yet we may reflect that, but for the denudation of the core of the Bodafon anticline, the existence of the Coedana granite would have remained unknown. That there are plutonic intrusions in the Aethwy Region is certain, for, whatever be the relations of tho basic gueisse$_s$ (p. 231), diorites are exposed in Llangaffo cutting.

The whole question is more difficult, for the foliation-planes have been folded, and their original position, with the original direction of impulse, is unknown.

The major folds and thrusts — Let us now consider the nature of the major secondary folds and ruptures (Folding-Plate 7), (Folding-Plate 8). The Llanddwyn wedge comes in quite suddenly, and must be brought against the Penmynydd Zone by a powerful rupture, which may be called the Newborough slide, evidently now at a high angle, but probably folded. Now as the rocks of the wedge contain much less altered cores than any known parts of the Nappe of Bodorgan, far less altered than the other Aethwy Gwnas, it is probable that they belong to the upper limb of the Bodorgan Fold, in which case they would be the highest tectonic horizon of the Complex known in the Island, and would be inverted. Little can be made out of their own major folds, which being in the zone of fracture, are evidently all ruptured along powerful shear-lines, and the dips at high angles. There seem to be two parallel anticlines, with Tyfry Beds in the core of each, one. running east of Bryn Llwyd, the other through Llanddwyn Island, the great ellipsoidal spilite being taken in on a syncline between them. Their axes must be approximately vertical, and their strike is obliquely across the wedge, more northerly than that of the Berw fault, but approximately parallel to the Newborough slide. As these unaltered rocks are at the south-west end, the pitch is presumably in that direction, but there is a reversal near Cerig Mawr. The Newborough slide is cut off by the Berw fault at a point west of Llangaffo Church.

Turning to the Aethwy Region proper, it is evident from the map that the major secondary folds must be on a great scale, and a generally anticlinal structure, is at once suggested, with the western limb truncated by the Newborough slide-and the Berw fault. As soon, however, as the structures are examined, a number of anomalies appear. They will best be grasped by means of the following summary, aided by the simplifications of the map given in (Figure 98).

1. The anticline that is obvious from the dips is really a foliation-anticline.
2. Coincident with it, however, is an anticline of the axes of minor opposing isoclines.
3. Yet the disposition of the glaucophane-schists about the margins of the Penmynydd Zone tract indicates a true stratigraphic anticline.
4. To some extent at any rate, especially along Mynydd Llwydiarth, foliation-dip certainly coincides with mass- or true-dip.
5. The axes of the stratigraphic and foliation anticlines do not coincide—are indeed a considerable distance apart even where nearest.
6. Nor are they parallel. That of the stratigraphic anticline strikes north-east—south-west, that of the other north — south, a divergence to the south of sonic 45°, so that at Llandysilio and Newborough they are eight miles apart.
7. The axis of the stratigraphic anticline must begin on the western side of Mynydd Llwydiarth (about a mile within the Penmynydd Zone tract), running thence by Penmynydd Church, Gaerwen, and Llangaffo to Newborough, where it is cut off by the Newborough slide.
8. The axis of the foliation-anticline keeps close to the eastern margin of the Penmynydd Zone, but is usually about three-eighths of a mile within the Gwna tract.
9. At the axis of the stratigraphic anticline folial dips are often confused, but where distinct are north-westerly.
10. At the axis of the foliation anticline folial dips, instead of being horizontal, are vertical.
11. Yet their verticality is usually not a true plane verticality, but is thrown into a series of a-clinal corrugations.
12. In the same' axial tract there may be no dip at all, but polyclinal folding, or mere bundles of nemablastic siliceous pencils.
13. About a quarter of a mile west of the same axis there is in places violent horizontal contortion about vertical axes (Figure 61), so that severe torsion must have taken place.
14. Folding transverse to the dominant strike is common all over the Gwna tract, and for some distance into the Penmynydd tract. It is usually a horizontal wrench, but sometimes isoclinal with a northward overdrive.
15. Near the axis of the great foliation-anticline, the nemablastic lineation crosses the crests of small anticlines obliquely, another evidence of torsion.
16. The pitch is on the whole north-easterly in the main Penmynydd area, northerly in the Gwna area; and is high on the western margin.
17. The strike of the Gwna Beds curves round in a crescent concave to the west. Their prevalent dip is to the right when walking northward on that crescent.

18. The Penmynydd Zone rises at several places within the Gwna tract, but", apparently, at different stratigraphical horizons.
19. There are subsidiary rolls both of pitch and foliation-isoclination dip.

It is evident that in Aethwy there must be excessive complication in the secondary and minor folding, unusual even for the Mona Complex.

The existence of a great foliation-anticline that is asymmetrical stratigraphically, recalls the great foliation-anticline of Cowal in the Scottish Highlands, described by Mr. Clough in the Geological Survey Memoir on that region.<ref>"Geology of Cowal" ((fig. 47), pp. 84–87).</ref> But that of Aethwy differs from that of Cowal in the vertical dips at its axis, in the opposition of the facing isoclines, and in the development of a great real anticline to the west of the foliation-anticline. Now a general stratigraphic syncline, with a foliation-anticline, opposition of isoclines, and vertical dips at the axis, are essentially the features of a synclinorimn; and there can be no doubt that the Aethwy foliation-anticline is, in a way, synclinorial, for the Penmynydd Zone rises on both sides of it (see item 17 of summary above). But in a true synclinorium folial symmetry should coincide with stratigraphical; whereas in Aethwy, the vertical dips are some way to one side of the only possible synclinal axis, in addition to which the Aethwy verticality is not plane but is a-clinally contorted. And powerful horizontal torsion has also taken place along the Aethwy axis, in which it resembles the axes of later movement in the Lewisian Gneiss of Scotland. The nemablastic pencilling at the axis appears to be a special character.

On the whole, the Aethwy Region appears to be somewhat as in the horizontal sections (Folding-Plate 7), (Folding-Plate 8), which are of course greatly simplified. The pitch is away from the observer. On the left, the upper inverted limb of the Bodorgan Recumbent Fold appears on the (folded) Newborough slide; the rest of the section being on the lower limb (the Nappe of Bodorgan). The leading features are, from west to east; the main Aethwy (real) anticline, all in Penmynydd rocks; then what may be called the Llanddona syncline (in which, on the map, appear the numerous nips of basic schist); then subsidiary rises of the Penmynydd Zone (though on higher horizons eastward); then the Llaniestyn syncline (apparent on the maps, but not reached in the sections), taking in the highest lavas with limestone. The main Aethwy anticline is isoclinal, and has been driven eastwards over the Llanddona syncline, which is also isoclinal but in an opposite direction. Between these opposing overdrives the Llanddona syncline has become synclinorial, but the axis of the foliation-anticline became established in it a-symmetrically. Its vertical dips may once have been plane, but are now a-clinally contorted, probably from oscillations during the conflict between the major opposing isoclines, under a permanent load from above. Rotation, under the same influences, probably produced the nemablastic pencilling. But the pencils are not merely rotated, they are powerfully drawn-out, or they would not be nemablastic. This would be due to the torsion in the vertical dimension, of which independent evidence has been set forth above. The wrenching along east and west lines (with some amount of northward overdrive) is later, and is the last movement that was accompanied by crystalline anamorphism. The two diverging ruptures of Mynydd Llwydiarth (described on pp. 373–6), which look like thrusts on the limb that is common to the Llanddona synclinorimn and the main Aethwy anticline, may really be connected with the torsion in the horizontal dimension.

The position of the basic gneisses is perplexing. They may be merely deep-seated cores of the intrusions from which came the sills that are now hornblende-schist, as the Llangaffa diorite seems to be. But it is curious that they should all appear along the western margin; that they should be banded, heterogeneous, with occasional north-westerly foliation-strike, full of coarse albite-pegmatites, and that a strip of coarse, acid albite-gneiss appears along the margin of one of them. One would hardly expect such characters in the mere cores of the basic intrusions. They are rather those of an ancient gneissic floor. In either case these rocks must, if on this uninverted limb, be rising. from below. The contrast which they always present to the adjacent rocks shows that their boundaries are slides, one of which may be in part Post-Ordovician (Chapter 17). But they are crushed and mylonised, and can hardly have come up from the lower parts of the Pemnyuydd–anamorphic zone. It is more likely that they are shattered catamorphic nips like those of Mynachdy, brought in on infolds of the (primary) Newborough slide from the inverted upper limb of the Bodorgan Fold.

Considered as a whole, the Aethwy Region must be anticlinal. The western limb is brought in by the Newborough slides, and the rest has a gradual eastward inclination which must be bringing in the same horizons not far beyond the Menai Strait.

Developments over the island considered as a whole

Probable thickness

No reliable measurements have been obtained. But by combining several methods it is possible to arrive at a general idea of the thicknesses. One of these is by means of the pitch. Now, if the meaning of pitch be that corrugated instead of plane sheets rest on each other with an inclination in the direction of the greatest axes of the corrugations, it follows that the pitch-angle is also the true dip of the sheets as a whole. Errors may be introduced in several ways, most serious (though least likely) being a possibility that the minor isoclines on which the angle is measured may have been imposed on pre-existing major folds that had a different strike. They may arise from uncertainty as to the relation of foliation to bedding, from impersistence of the folds, from a spiral tendency, and other sources.

In Holy Isle and other districts, however, the pitch is remarkably steady; and as the results obtained from it show no serious divergence from those obtained by other methods in a case where that is possible, it seems better to make some attempt at estimates of thickness than to leave the question wholly nebulous, as a first attempt may lead the way to more successful ones in future, provided the difficulty of the subject be fully realised.

If the section in (Figure 91) be correct, then the thickness of the Holyhead. Quartzite must be about 700 feet. Some 400 feet of the Stack Moor beds are seen in the cliff opposite the South Stack, and with a pitch of 15°, 800 feet more must come in between the cliff-top and the Quartzite outlier, making a total of 1,200 feet. The group measured by dip across the valley on the south side of the mountain is 1,100 feet, which agrees well with the result obtained from pitch. From Penrhymnawr to the North Stack fault the same pitch gives 1,500 feet of Llwyn beds, but as neither base nor top is visible, they are unlikely to be less than 2,000 feet. The top of the Celyn beds appears at Holyhead, but they widen at Trefignath, giving 1,800 feet on an average pitch of 14°, and as the base is not reached they are probably 2,000 feet. The Soldier's Point beds, from the Namarch fault to Salt Island, with an average pitch of 14°, measure 1,250 feet, but the top never appears, so this must be an under-estimate. Assuming the same pitch to continue, 1,750 feet more would come in by the time we reach Penial, but it is very doubtful whether the Penial rock be the Church Bay Tuff, and higher beds probably occur in the wide Llanddeusant country, so 3,000 feet is probably less than the total of the group. The Church Bay Tuffs at Clegyr-mawr are dipping at 30°, and such dips as can be seen to the north are higher. If, however, we assume only 30°, we obtain 2,000 feet as far as Yr-ogo-goch, where there are indications of the New Harbour Beds. The Sherries Grits may be as much as 800 feet in Bull Bay, and can hardly exceed 700 feet in the large infold. No estimates have been made of the Coeden or Amlwch Beds. The beds at Fydlyn cliff are dipping at 40°, so the Gwna Beds between the Fydlyn and the Hwch do not seem to exceed 350 feet, but they widen eastward where the sills appear, and may reach there 970 feet. At Llanfaethlu they are certainly pitching eastward (though greatly broken) off the Church Bay Tuff, and if we assume a pitch of 10°, 1,500 feet would have come on by the time the Ordovician base is reached. But the northern Gwna facies is likely, by its nature, to be attenuated in comparison with the south-eastern. Accordingly, if the section in (Folding-Plate 6) represents something like the truth, the mélange between the Malldraeth and the Llanddwyn spilites at Ceinwen, doubled vertically on itself, must include some 4,500 feet of beds. The Ceinwen spilites would be, from the same section, about 375 feet (and they must be thicker at Llanddwyn). In the same way the Engan spilites and their underlying sediments would be about 1,200 feet. The Gwna quartzite in Gynfor cannot be less than 180 feet thick, as it and the Ordovician rocks are locally conformable, and the purple conglomerate fillsold hollows in it to that depth (Chapter 14). The thickness of the quartzite at Bodafon (Figure 156), (Figure 157), (Figure 158), is 300 to 400 feet. The Fydlyn Group must approach 200 feet, the base, however, being nowhere seen. But the rocks of the Penmynydd Zone of metamorphism, correlated for the most part (pp. 127, 162) with the Fydlyn Group, must be vastly thicker, especially in the Aethwy Region. In that region (pp. 228–30) there is reason to believe the major secondary folds to be of great amplitude, in which case the group could not occupy the space it does unless it were some 4,000 feet in thickness. The total thickness of the Mona succession, exclusive of the Gneisses, appears therefore to be about 20,000 feet. But it must be understood that these estimates are put forward with the greatest reservation, and largely to serve as a starting-point for further research.

Facies and physiography

The changes of facies already alluded to afford a certain amount of evidence as to the physiography of the period, immeasurably remote though that is. But the present positions of the several facies are by no means to be taken as their positions at the time of deposition. The operation of the recumbent folding of the Complex, upon which is superimposed that of the Carmel Head thrust-plane, has brought about extraordinary changes of position, and even reversals of direction, and must be allowed for in every case. (Figure 35) and (Figure 100) should be consulted, and combined with a working-model of the folding. The view of the tectonics advocated in Chapter 7 is of necessity assumed here. But as the physiographical results of the assumption are self-consistent, and much more probable, as such, than might have been hoped for under such circumstances, they afford some degree of confirmation to the tectonic views assumed.

Nothing can be made out concerning any principle governing the distribution of the types of gneiss. At present, there is an increase of basic gneiss in a southerly direction, but when we consider the tectonic succession, the original distribution appears merely sporadic.

What remains of the Fydlyn Group at the Fydlyn Inlier is so limited both horizontally and vertically that we have but scanty data for a study of the facies. Yet the great development of acid mica-schist in the Penmynydd Zone, especially in Aethwy, points to a thickness of acid volcanic rocks that seems incredible at Fydlyn. If the tectonic horizons be correctly determined, this thickening would have been to the north, and we may therefore look in that direction for the focus of the felsitic eruptions.

The facies of the Gwna Beds that are at present western and eastern evidently represent, respectively, attenuated thalassic and thickening hypo-littoral sedimentation. The spilitic eruptions thicken with the sediments, so that the volcanic centres appear to have been, as is so often the case, distributed along the margins of the land. When the tectonic horizons are allowed for, it would seem as if that laird, with its volcanic fringe, is to be looked for somewhere to the north-west.

The Church Bay Tuffs are thickest about Llanrhyddlad, indicating proximity of the volcanic centres of those eruptions, which, therefore, allowing for the tectonics, appear to have been somewhere to the north-west as before. In the Northern Region, their upper parts are replaced by the Skerries Grits, which, though largely volcanic (see p. 59), have undergone some degree of water-sorting. In this case, we have better evidence than usual of the direction and even the position of the land, for the great igneous boulders of The Skerries cannot be far from their source. The land, then, must still have lain somewhere to the north-west, though not in the present position of The Skerries, for we must remember that (besides the recumbent folding of the Complex) the Northern Region is riding on the Carmel Head thrust-plane, and is *sans racine.* The Tyfry Beds, regarded as equivalents of the Church Bay Tuffs, must, according to the tectonic scheme adopted, have been deposited far to the north of where we (save possibly on the Middle Mouse) now see them. They contain fragments derived from an old land, and confirm the conclusion, therefore, that, throughout the period represented by the Skerries Group, it lay somewhere to the north or north-west.

In the New Harbour Group, the Lynas beds contain both more and thicker grits than do the Soldier's Point beds, and there are a few (*see* pp. 51, 303, 304) land-derived fragments of some size. The Amlwch facies was undoubtedly deposited far to the north of the New Harbour facies, and the land, therefore, must once more be looked for in a northerly direction. The spilitic lavas (like those of the Gwna Beds) thicken in the same direction. The Bodelwyn beds, however, are of much the same texture as the Celyn beds.

Both divisions of the South Stack Series thin from the South Stack to Rhoscolyn, but they seem to thicken again on the lower limb of the Holyhead Fold, thinning again at the Breakwater tract, and at the seine time losing their coarser grits, while the Coeden beds are decidedly thinner-bedded and finer than the Llwyn beds of any part of Holy Isle. Perhaps we are, in this case, on the successive tectonic horizons, crossing, not following, the direction of the land. The close resemblance, between the Bodelwyn and the Celyn beds may foreshadow this change in physiography.

The Holyhead Quartzite seems to change in the same directions as the South Stack Series, but the evidence is very scanty.

Thus, throughout the period represented by the Bedded Succession of the Mona Complex, as far up as the middle of the New Harbour Group, the direction of the land, and also of the foci of volcanic activity, seems to have been somewhere towards the north-west. Then come signs of change, suggesting that, for the rest of the period, it is to be looked for rather to the south-west or the northeast. This change, it is most interesting to note, was accompanied by extinction of the long-continued vulcanicity of the period.

Geographical distribution of the stratigraphical and tectonic members of the complex

The Bedded Succession occupies by far the greater part of the exposed area, the Gneisses occupying only about one-eighteenth, though if their probable extension on the Sub-Ordovician floor (indicated by the broken lines in the chart, (Figure 101)) be taken into consideration, they may occupy as much as one-sixth of the Island. With regard to the distribution of the several members, it is to be noted that the Holyhead Quartzite is the most, the Gwna Beds (which besides their visible outcrop must occupy much of the Sub-Ordovician floor in the Cors y Bol country) the least restricted both as to extent of outcrop and of distribution; that, in fact, there is a tendency to increase of extension as we descend in the chronological succession. The Gneisses, in spite of their moderate outcrop, are distributed all over the Island, from the north-eastern coast to the Tywyn Trewan and from the Carmel Head Gader to the Aethwy Region. The Penmynydd Zone appears only in the Middle and Aethwy Regions.

The distribution of the tectonic (see chart, (Figure 100), p. 238) is the reverse of that of the stratigraphieal horizons, for the lower occupy vastly less space than do the higher ones. There is a notable leap in matter of extent from the lower to the upper limb of the Holyhead Recumbent Fold, the latter (called the Nappe of Holyhead) being the most extensive of all the tectonic horizons. This contrast between the distribution of the stratigraphical and of the tectonic horizons, taken in connexion with the north-easterly pitch, points of itself to the existence of widespread inversion and of powerful primary thrust-planes. From the same chart (combined with (Figure 35)) it will be seen that the succession must be inverted over some two-thirds of the extent of the outcrops in the Island. The Post-Ordovician Carmel Head thrust-plane has also exerted most important influence upon the distribution of the horizons, whether stratigraphical or tectonic, and must never be forgotten in any study of the Complex.

Arrangement of the post-recumbent foldings

The major secondary folding is isoclinal in Holy Isle, in the Northern Inliers, and in the Northern Region, its impulse being southward. In the Western Region it is also isoclinal, though with a northward impulse. In the Middle Region it is fan-like or symmetrical. In the Aethwy Region it is again isoclinal, but with opposing impulses about a syncli-norial axis. An abstract of the general arrangement of the major folds upon the Main Island is shown in (Figure 99), but it is to be remembered that the major folds of Holy Isle (Folding-Plate 3) pitch under those displayed in that figure, and are not shown in it.

The minor folding is very strongly isoclinal, with a southward impulse, in Holy Isle and in the Northern Region. In the Western Region it is largely inconspicuous, a flaggy foliation-dip to south-east at moderate angles being very general. In the Middle Region it is still less conspicuous, vertical foliation-dips being dominant. In the Aethwy Region it is isoclinal to east and west, with opposing impulses, and is a-clinal and polyclinal about the synclinorial axis. Its impulses thus agree on the whole, though not strictly, with those of the major folding; In the Western Region, the Northern Inliers, the Northern Region, and the eastern Aethwy Region it slowly dies out as we pass to higher tectonic horizons, and gives place, first to thrusting, and finally to autoclastic mélange. The same change takes place as we cross the Middle Region from west to east and pass into the Pentraeth Inliers, such minor folding as is visible dying out and being replaced by mélange, whose development attains a maximum in the eastern Middle Region. In eastern Aethwy it was re-imposed (see pp. 198–200) upon the lower parts of the Autoclastic Mélange which had once replaced it.

Pitch, dip, and strike throughout the island

The pitch, where visible, is usually to the north-east, save in the Northern and in the eastern Aethwy Regions, where it undulates. The pitch-angle is moderate except along the western Aethwy margin.

The foliation-dip is usually at moderate angles elsewhere than in the Middle Region, where it is vertical or nearly so. Its prevalent direction is northerly, save in the Western, and on the eastern margins of the Aethwy Region.

In considering the, strikes, the Gneisses must be discounted, as they have (see p. 168) irregular strikes of their own, discordant from those of the adjacent rocks. The dominant strike of the foliation (as also of the bedding where that survives) in the Bedded Succession is north-easterly. To this (apart from a few merely local divergences) there are several exceptions of importance. In part of the Northern Region the strike is north-westerly; on the eastern edge of the Western Region there is a bend round, as if to pitch under the concealed rocks of the sub-Ordovician floor; and in the eastern part of the Aethwy Region it is northerly with a sweep round to north-north-west. But all these strikes may be seen at a glance in the chart (Figure 101), which shows also the plunge of the isoclines, the dip, and the pitch. The discordances at the Carmel Head thrust-plane are clearly apparent on this chart.

Distribution of the metamorphism

The distribution of the metamorphism is at first sight so irregular as to seem actually capricious, high and low degrees of it being met with here and there all over the Island. Yet this apparent caprice is really due to the varying circumstances of the tectonics. The determining laws of the metamorphism are steadily the same, and can be made out in almost all the cases. First; variable anamorphism is a feature of the Bedded Succession, not of the Gneisses. They are (as pointed out on p. 168) not merely far more coarsely and plutonically crystalline, but they are uniformly so. In whatever connexion they appear, they are, all over the Island, a thing *sui generis,* always in essentially the same crystalline condition. They can therefore be removed from the discussion, which is thereby greatly simplified.

Now the variations of crystalline anamorphism in the Bedded Succession are as follows. In Holy Isle it is at a maximum, and is approximately uniform throughout the Isle. In the Western Region it gradually wanes northward, until about Llanrhyddlad it has almost died away. It repeats the process, and rather more rapidly, in the Northern Inliers.- In the Northern Region it begins once more at a high grade<ref>Though this maximum has been brought far nearer to that of Holy Isle than it once was, by the Cannel Head thrust-plane.</ref>, and once more wanes northward in a most pronounced manner until in Gynfor it is at a minimum, and in some spots has died out altogether.

There seems at first sight to be an exception in the Llanfairynghornwy Belt (pp. 216–17), most of which is but slightly anamorphic. But this belt is caught between the Cannel Head and Caerau thrust-planes, and is to be regarded as really a tract of high tectonic horizon, over which the rest of the region has been driven.

Within itself, moreover, the belt repeats the same process, for anamorphism wanes northward in it from the Amlwch Beds of Carmel Head.

In the Middle Region we must exclude the hornfels, which is a local product of the Coedana granite. Anamorphism is resumed in the Penmynydd Zone at about the same grade as in Holv Isle. It then wanes eastward (interrupted only at the Plâs-bach and other inliers), until along the base of the Carboniferous rocks it is once more at a minimum and has nearly died away. At the Pentraeth Inliers it resumes a high grade for a few yards near Bryn-gwallen, but wanes at once rapidly to north-east and east.

In the Penmynydd. Zone of the Aethwy Region crystalline anamorphism is once more at a maximum, being perhaps more intense than even in Holy Isle, and for a third time wanes eastward, never, however, sinking to quite so low an ebb as in the Middle Region or at Pentraeth. The Llanddwyn wedge is quite distinct, and differs from all the other tracts. Where it begins, at Llangaffo, the grade is that of Gwna Green-schist, but anamorphism wanes rapidly till in the Newborough Dunes and on Llanddwyn it reaches a minimum as low as at Gynfor, and has died out in places altogether. This is the only case where the waning is in a southerly or westerly direction, and goes to confirm the view that the Llanddwyn wedge is on a tectonic horizon of its own.

We have thus four maxima, Holy Isle, Llanfflewyn, and the Penmynydd Zones of the Middle and Aethwy Regions; and four minima, Llanrhyddlad, Gynfor, the Malldraeth slope, and Llanddwyn. Throughout the north-western parts of the Island, anamorphism wanes northward; throughout the south-eastern parts it wanes eastward, save in the Llanddwyn

wedge, where it wanes to the south-westward (Figure 101)B.

Note — To bring out the waxings and wanings, delicate gradations of stipple would be required that could not be applied to a small-scale chart. The chart here given ignores all gradations and minor complications, but shows at a glance the general distribution of the metamorphism.

What, now, is the significance of these phenomena? In the first place, it is evident that anamorphism is completely independent both of stratigraphical horizon and of geographical direction. But it is equally evident that it is conditioned strictly by tectonic horizon. In every single case throughout the Island, it wanes as we ascend from lower to higher tectonic horizons.<ref>In Chapter 7, pp. 176–80, waning anamorphism was occasionally appealed to in confirmation of the views there advocated; so that, to that extent, this argument is open to the charge of being a circular one. But the appeal was in confirmation only. The real evidence on which the tectonic succession is based is, throughout, stratigraphical, and is quite independent of metamorphic states. So strictly stratigraphical, indeed, that in two cases (those of the horizons on which the Penmynydd anamorphism is placed) it is relied upon in spite of actually waxing anamorphism.</ref> Its approximate uniformity in Holy Isle shows, however, that when a certain depth is reached, it begins to wax more slowly. Further; concurrently with the waning of crystallisation, folding is replaced by rupture, minor folding in particular giving place to autoclastic mélange. Connected with this is the somewhat singular circumstance that the best preservation of original bedding is on the lowest tectonic horizons that are laid bare.<ref>On lower ones still, nevertheless, we may expect obliteration of the bedding from general plasticity, and flowage under stress. Incidentally, this confirms the view that the crystallisation of the Gneisses is their own. For they appear in all cases on tectonic horizons far higher than those of Holy Isle.</ref> The law thus emerges<ref>Long ago expressed, I believe, by Dr. Teall.</ref> that, given equal dynamical conditions, anamorphism is a function of depth. Dynamical conditions did not, however, continue to be equal throughout the processes to which we owe the Mona Complex; and to their inequality is due the apparently formidable exception to the above generalisation that the Penmynydd anamorphism appears on higher tectonic horizons than the two older maxima of Holy Isle and Llanfflewyn. The exception is but apparent. Reasons have been given (see pp. 198–200) for believing that we are dealing with the recurrence of similar dynamical conditions, inducing similar effects, upon what was once a zone of steadily upward-waning metamorphism, leaving the lower and older ones rigid and unaffected. And in the Penmynydd Zone itself, both in the Middle and Aethwy Regions, anamorphism wanes as we ascend in tectonic horizon, thus fulfilling the law of depth, apd leaving the generalisation unimpaired.

There may thus be said to be three different successions in the Mona Complex, a stratigraphic, a tectonic, and a metamorphic succession.

Stratigraphic succession	**Tectonic succession**	**Metamorphic succession**
Holyhead Quartzite		Minima of the East
South Stack Series	Bodorgan Fold	Zone of Upward Waning
New Harbour Group		Penmynydd Maxima
Skerries Group	Holyhead Fold	Minima of the North
Gwna Group		Zone of Upward Waning
Fydlyn Group	Rhoscolyn Fold	Maxima of Holy Isle andp Llanfflewyn
Gneisses		The Gneissic Metamorphism

The first column is entirely independent of the other two; indeed, from the combined accidents of inversion, thrusting, and erosion, such coincidence as it has with them tends to be in inverse order. Between the second and third columns there is coincidence as far up as the base of the Penmynydd maxima (which appears high up in the Holyhead Fold); then there is a breach, after which there is another coincidence to the tops of both columns.

Recapitulation

The Mona Complex, as presented to us to-day, is therefore to be pictured, not as a stratigraphic but as a tectonic succession; and the dispositions that appear upon a one-inch map as resulting from the action of the major folding upon such a succession; most of the dispositions that are perceptible in the field being effects of the minor upon the major

folding; while the crystalline condition in which we find its rocks is referable to their position in the metamorphic succession that is indicated in the third column. By combining these ideas a view can be reached that seems for the present satisfactory, unless it be in the high position that has had to be assigned to the Penmynydd anamorphic maximum, above tectonic horizons that contain rocks that are but slightly altered.<ref>See, however, footnote on p. 227. [reproduced here]: Disconcerting, because these highly altered Penmynydd rocks have thus to be placed on a higher tectonic horizon than that of the Church Bay Tuffs and Gwna Beds of the Nappe of Holyhead, which are but slightly altered (see notes on pp. 200, 210). It is natural to suppose that, both in the Middle and Aethwy Regions, the Penmynydd anamorphism must be upon a tectonic horizon lower than that of the Nappe of Holyhead. Yet, if we attempt to place them upon the lower limb of the Holyhead Recumbent Fold, or upon either limb of the Rhoscolyn Fold, we find that the same difficulty reappears in a new form, and that we have placed slightly altered rocks under highly altered rocks. For we have then placed the slightly altered Gwna and Tyfry Beds of the Middle and Aethwy Regions under the Cl rem-mica-schists of the Nappe of Holyhead. Stratigraphical difficulties as to inversion also emerge. Most serious of all, it will be found that the facies of the Skerries and Gwna Groups do not then develop in the right directions. Thus, we have to encounter difficulties of some kind whichever arrangement we adopt, and the one adopted as a working hypothesis appears to be, on the whole, that which presents the least embarrassments.</ref>

It is hoped that the foregoing attempt at interpretation may serve at any rate as a clue to the labyrinth. But much work will have to be done (very likely with the aid of methods that are as yet undevised) before an adequate, or even a correct mental picture is gained of this wonderful Complex, as is doubtless also the case with others that resemble it.

Note — There is some evidence as to the respective parts that were played by the recumbent and the post-recumbent movements in the production of the dynamic metamorphism. Pertaining to the Chronology of the Foliation, it ought to have been given on page 205. Its omission escaped notice until too late for insertion in that chapter, and it has therefore been placed in Appendix 9.

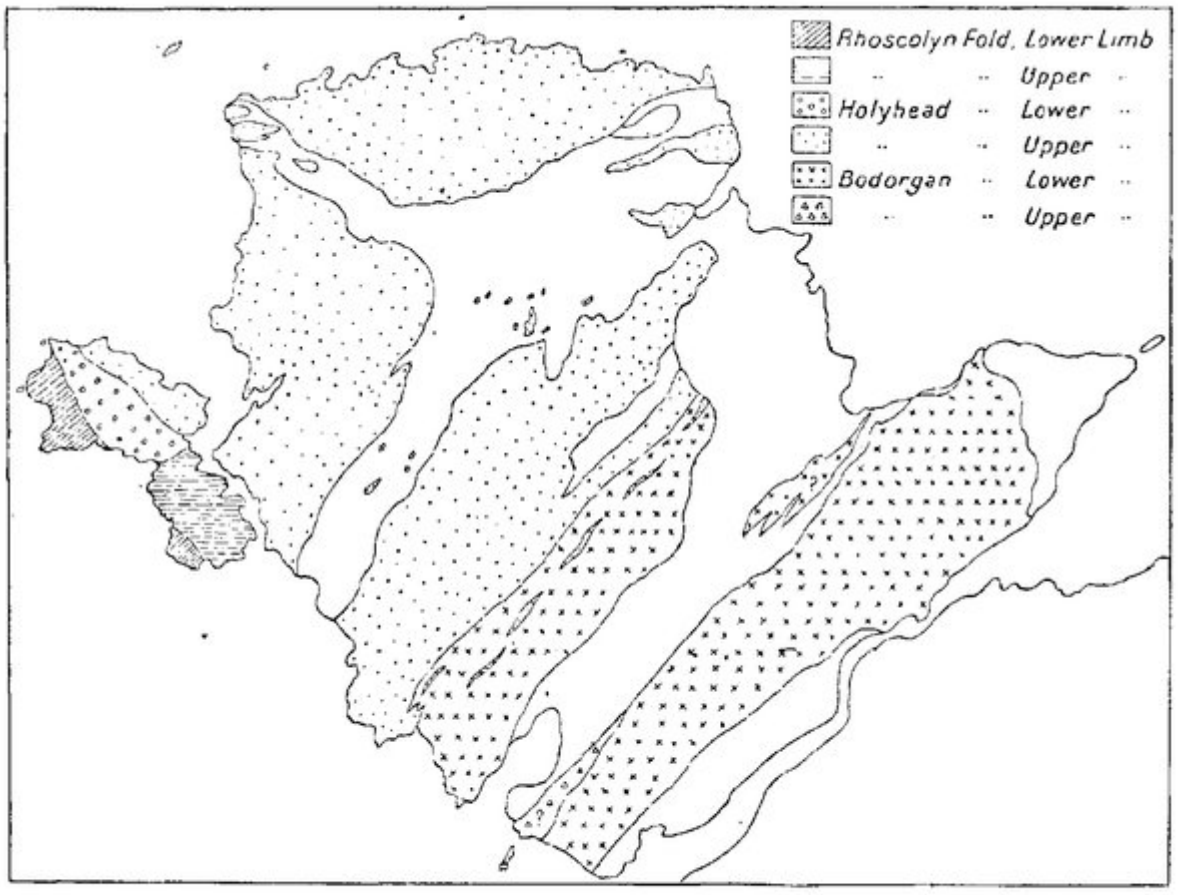
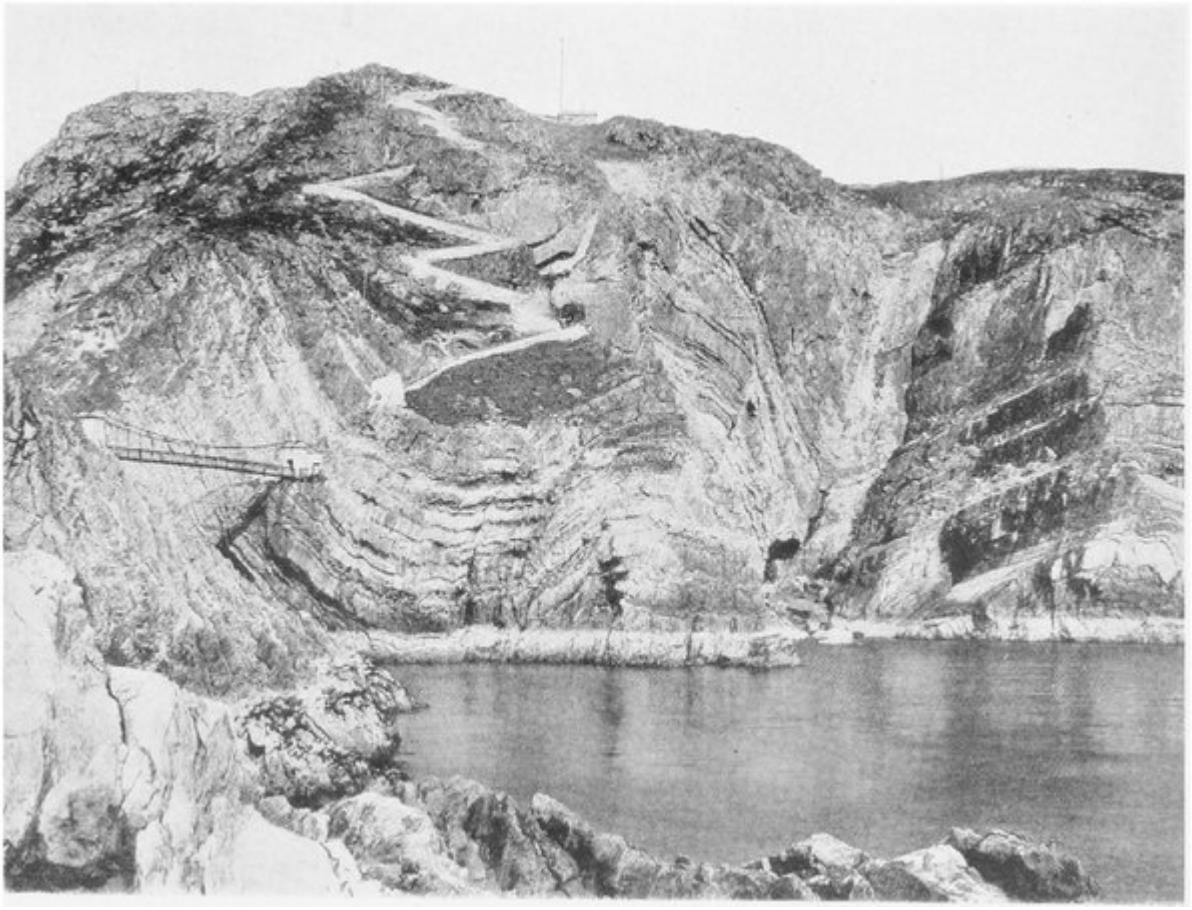


FIG. 100.—CHART SHOWING THE DISTRIBUTION OF THE TECTONIC HORIZONS OF THE MONA COMPLEX.
Scale: 1 inch = 6 miles.

(Figure 100) Chart showing the distribution of the tectonic horizons of the Mona Complex. Scale: 1 inch = 6 miles.



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

(Folding-Plate 1) Section along the sea-cliffs from the South Stack to Henborth. Scale 16 inches = 1 mile

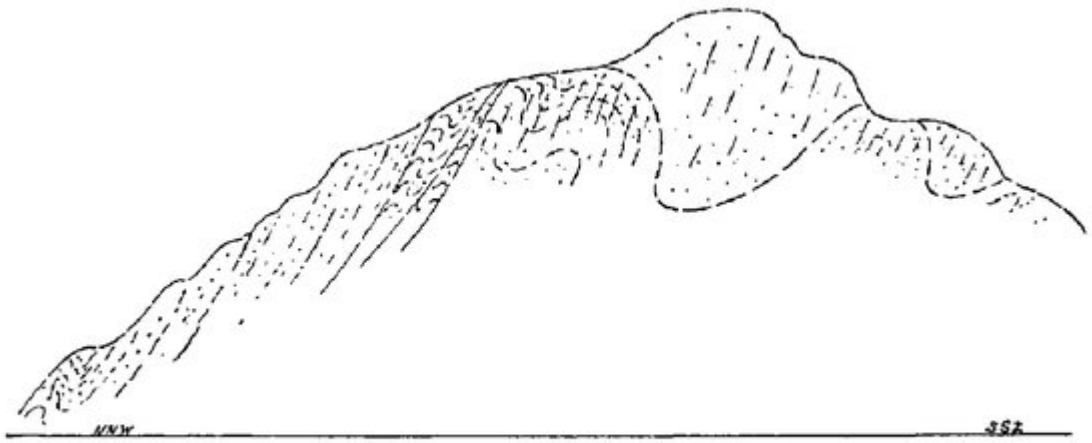


FIG. 28.—INFOLDED OUTLIER OF HOLYHEAD QUARTZITE ON THE SOUTH STACK MOOR.

(Figure 28) Infolded outlier of Holyhead Quartzite on the South Stack Moor. At the 500 foot contour. Height of section, 60 feet.

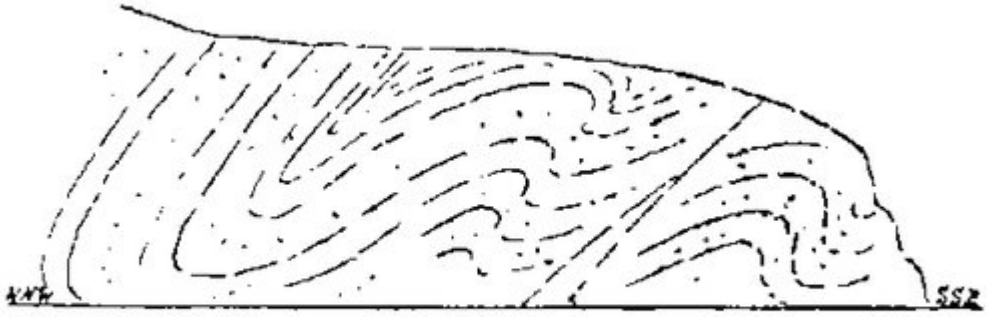
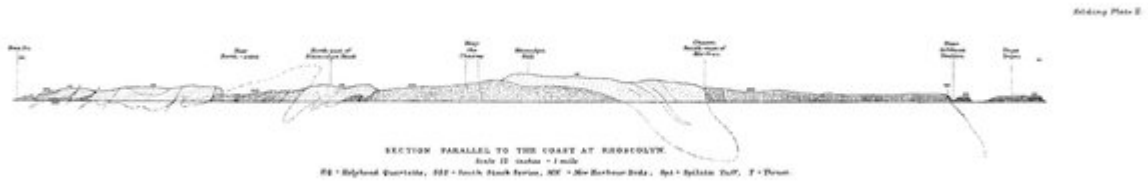


FIG. 36.

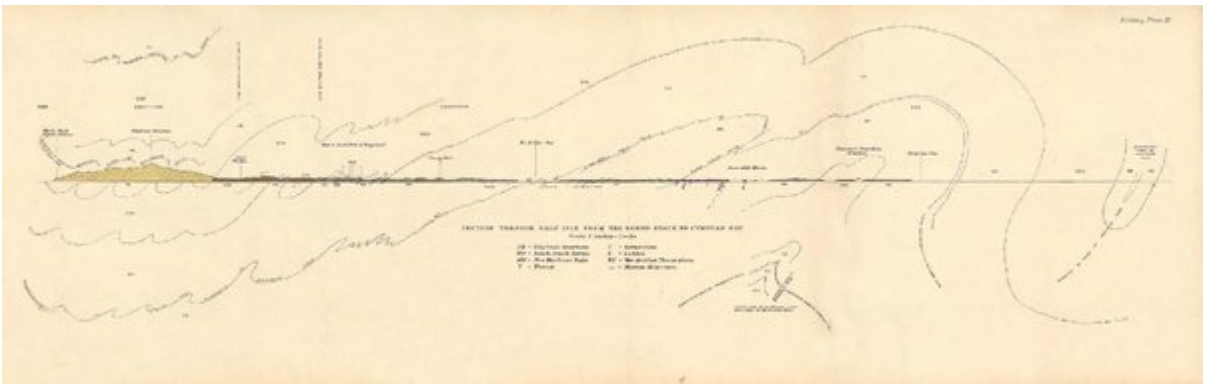
(Figure 36) Major isoclines in Llwyn Beds In the chasm of the dyke. North cliffs of Henborth. Height, about 200 feet.



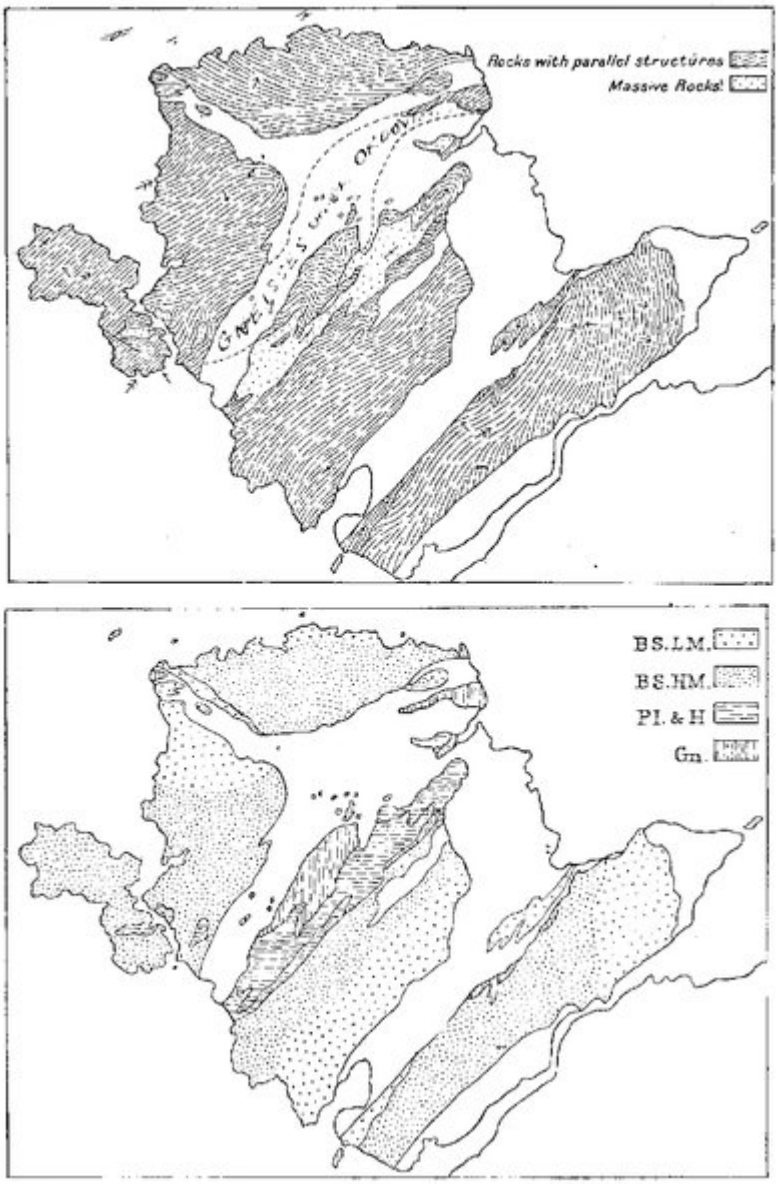
(Folding-Plate 2) Section parallel to the coast at Rhoscolyn. Scale 12 inches = 1 mile. HQ = Holyhead Quartzite, SSS A South, Stack Series, MN = New Harbour Beds , Sp.t Spilitic Tuff, T Thrust.

FIG. 38.—FOLIATION IN MASSIVE AND FISSILE BEDS.

(Figure 38) Foliation in massive and fissile beds. Cliff opposite the South Stack.



(Folding-Plate 3) Section through Holy Isle from the North Stack to Cymyran Bay. Scale 3 inches = 1 mile HQ = Holyhead Quartzite. SSS A South, Stack Series, MN = New Harbour Beds T = Thrust. U Serpentine. E Gabbro, TrT Tre-Arddur Thrust-plane [symbol Marine Alluvium.]



(Figure 101) a. Chart showing the general directions of strike and other structures in the Mona Complex. Scale: 1 inch = 6 miles. 101B Chart showing the distribution of the metamorphism in the Mona Complex. Scale: 1 inch = 6 miles. BS. LM. = Bedded Succession, Low Metamorphism. BS. HM. = Bedded Succession. High Metamorphism. PI. & H. = Plutonic Intrusions and Hornfels. Gn. Gneisses. Note: To bring out the waxings and wanings. delicate gradations of stipple would be required that could not he applied to a small-scale chart. The chart here given ignores all gradation, and minor complications, but shows at a glance the general distribution of the metamorphism.

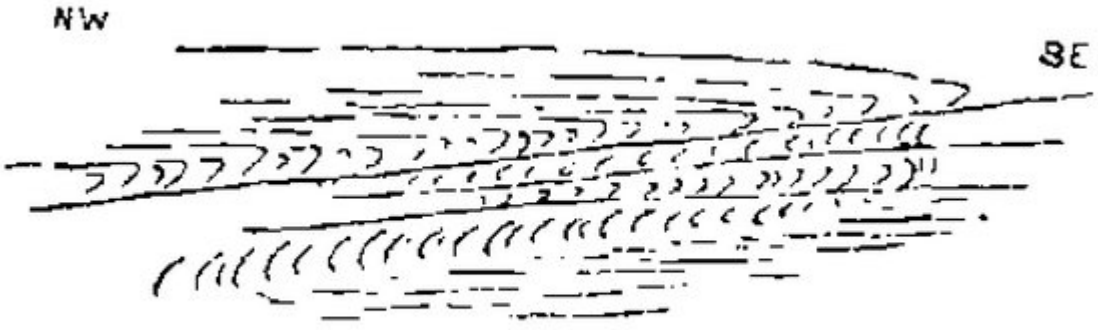


FIG. 62.

(Figure 62) Minor thrusts in the Tre-Arddur zone. Cliffs west of Castell.

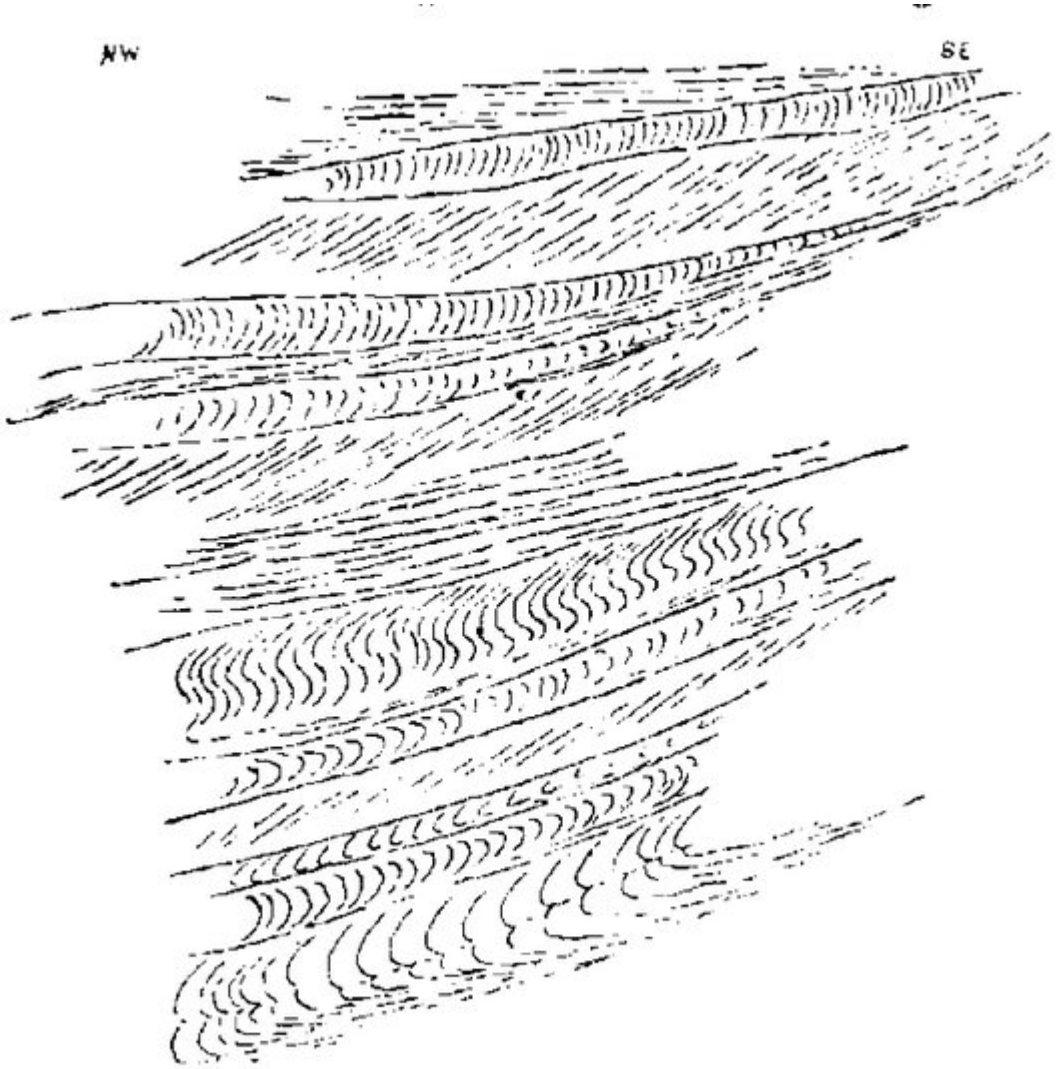


FIG. 63.

(Figure 63) Minor thrusts in the Tre-Ardour Zone. Foot of crag, south-east of Gareg-fawr. Height about nine inches.

(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.*

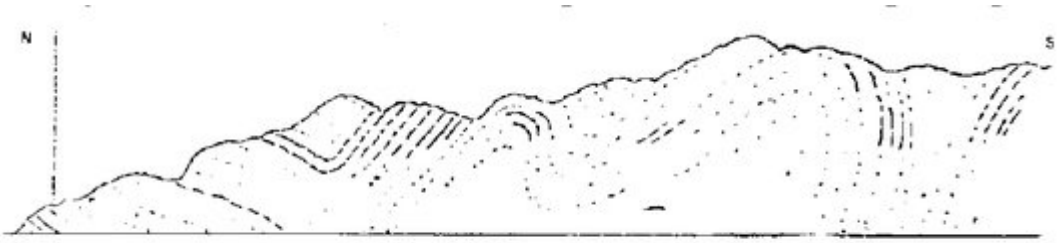


FIG. 91.—MAJOR FOLDS OF THE QUARTZITE ON THE GREAT SEA CLIFFS.

(Figure 91) Major folds of the quartzite on the great sea cliffs. Bedding obscure where lines are dotted. Height, about 500 feet.

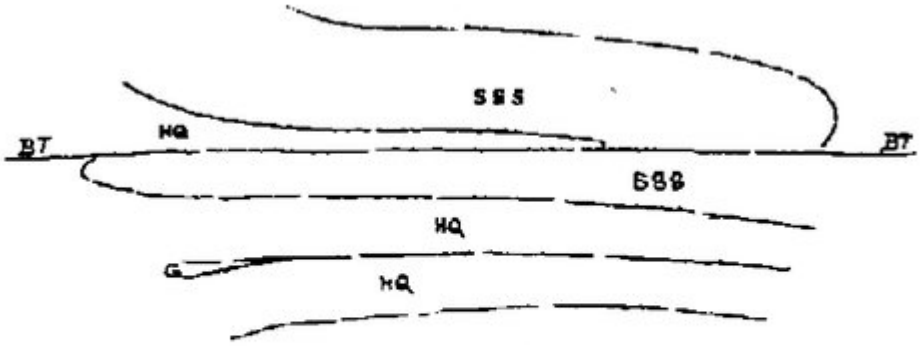


FIG. 92.

DIAGRAM OF RECUMBENT BREAKWATER FOLD.

(Figure 92) Diagram Breakwater Fold. HQ=Holyhead Quartzite. SSS=South Stack Series. BT=Breakwater Thrust-plane. G=Direction of gape of Holyhead Fold.

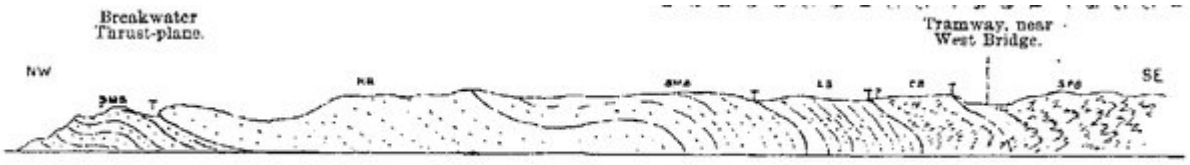


FIG. 93.—SECTION ACROSS THE BREAKWATER TRACT.

(Figure 93) Section across the Breakwater Tract. About three-eighths of a mile east of Porth Namarch. Scale 24 inches = one mile. HQ = Holyhead Quartzite. SMB = Stack Moor Beds. LB = Llwyn beds. CB = Celyn beds. SPB = Soldier's Point Beds. TT = Thrust

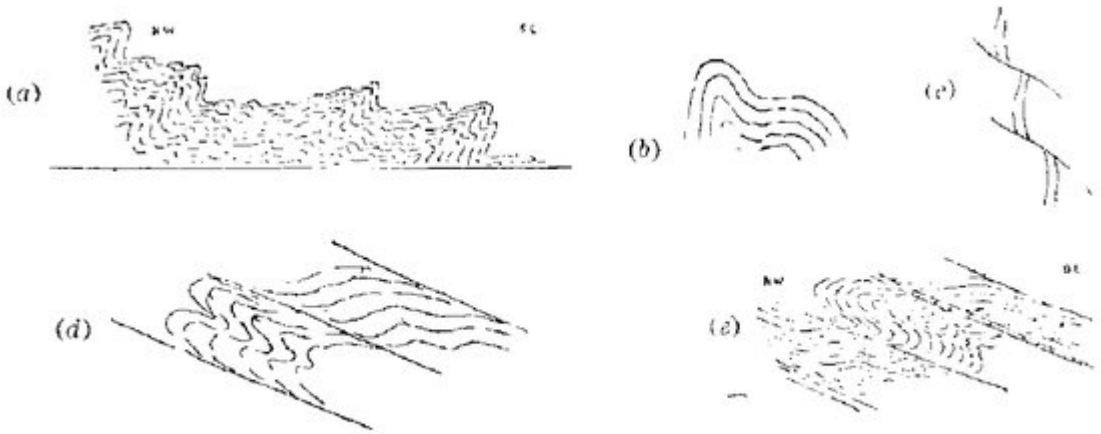


FIG. 71.

CHANGE OF STRUCTURE ALONG THE ESTUARY OF THE ALAW.

(Figure 71) Change of structure along the estuary of the Alaw. Amplitudes one foot or less. Nos. a to e in order eastwards, from Valley Foundry to Gored Footpath.

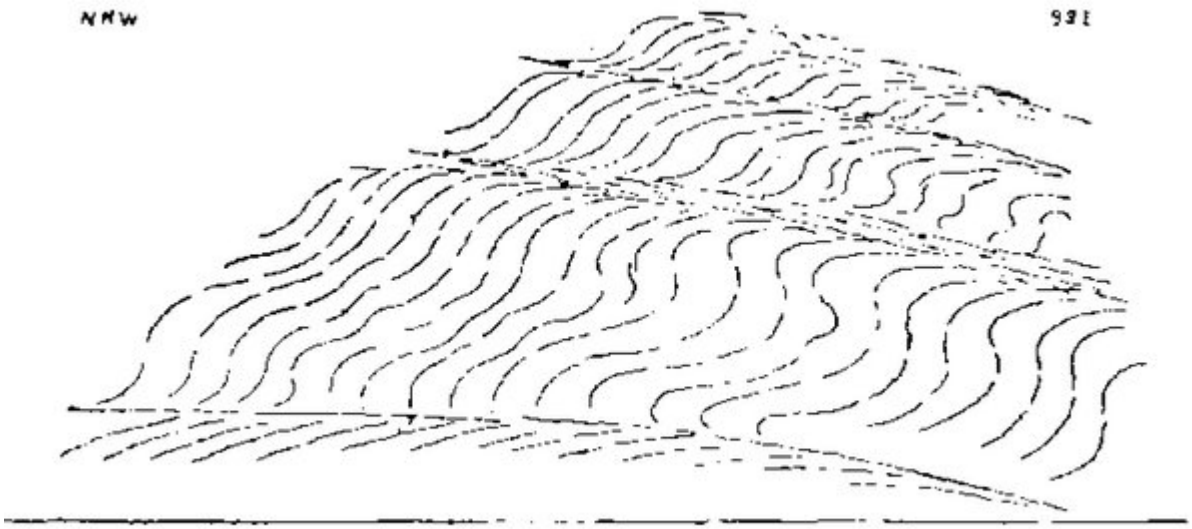


FIG. 72.—THE VALLEY THRUST-PLANES.

(Figure 72) The valley thrust-planes. Crags above the railway, east and south-east of Llanfair-yn-neubwll Church.

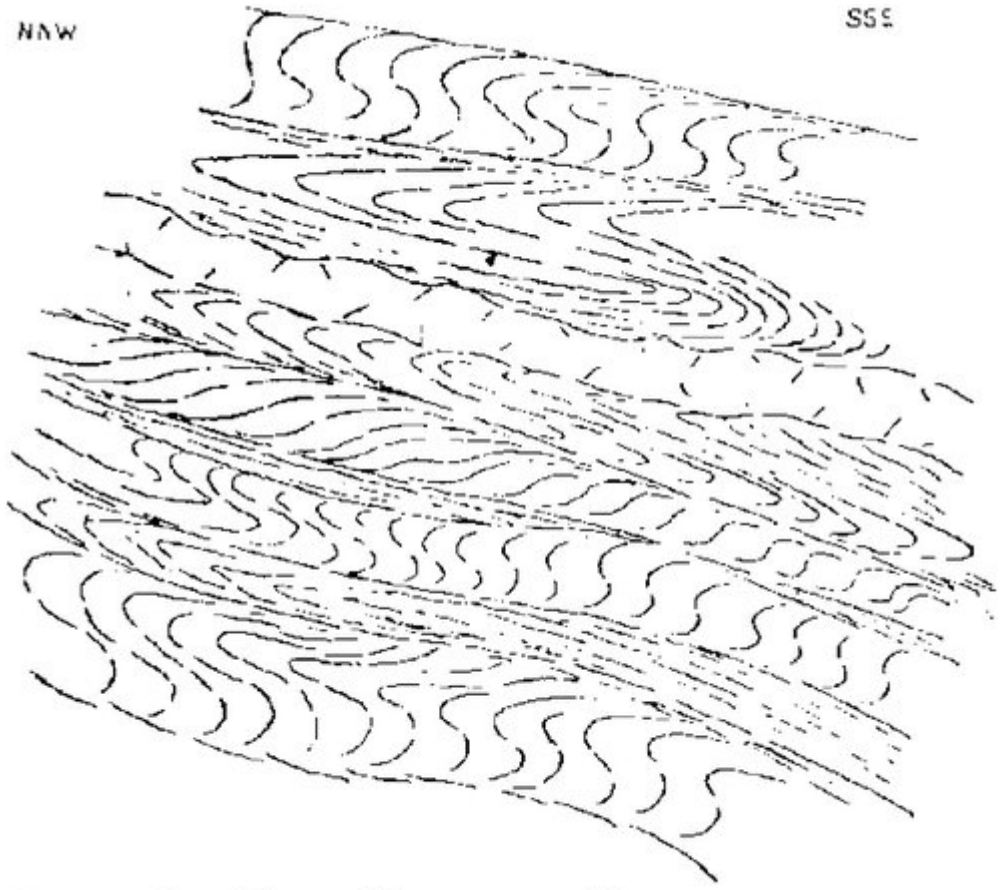


FIG. 73.—THE VALLEY THRUST-PLANES.

(Figure 73) The valley thrust-planes. Further stage, and with vein-quartz. Crags above the railway. east and south-east of the same Church.

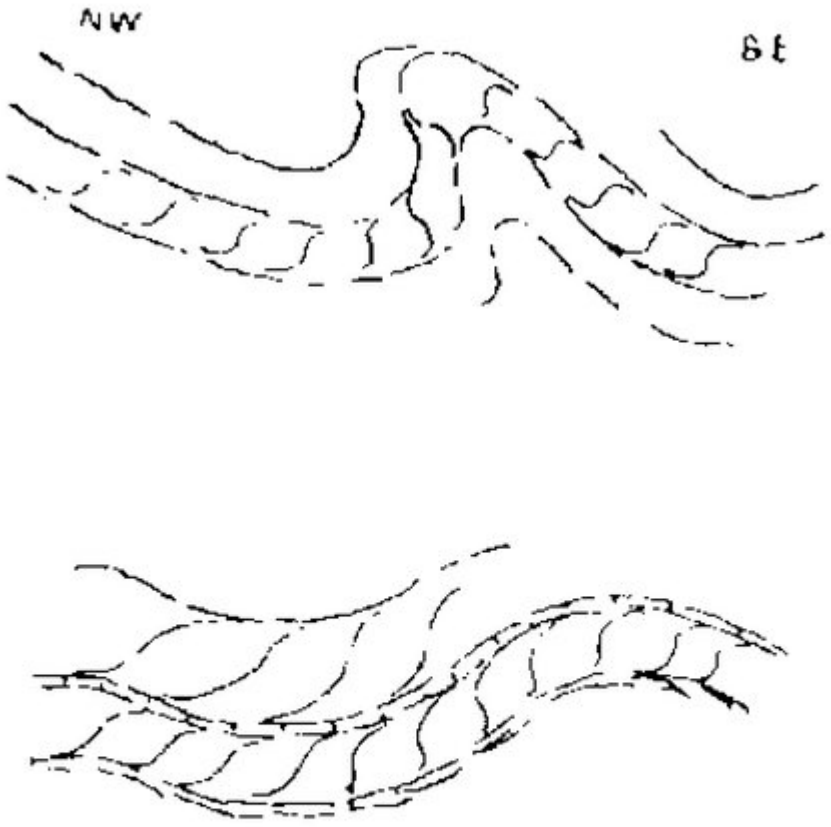


FIG. 74.—UNDULATIONS OF THE VALLEY THRUST-PLANES.

(Figure 74) Undulations o' the valley thrust-planes.

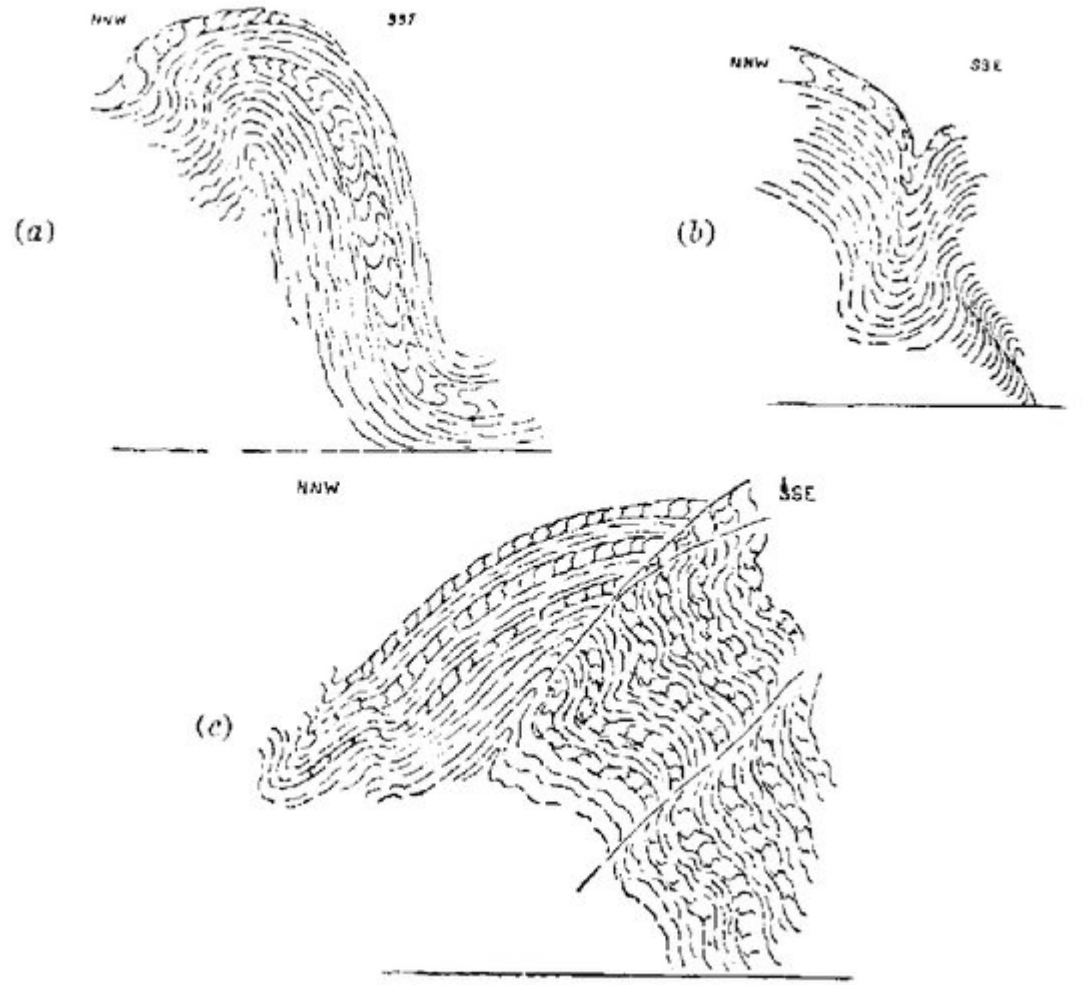
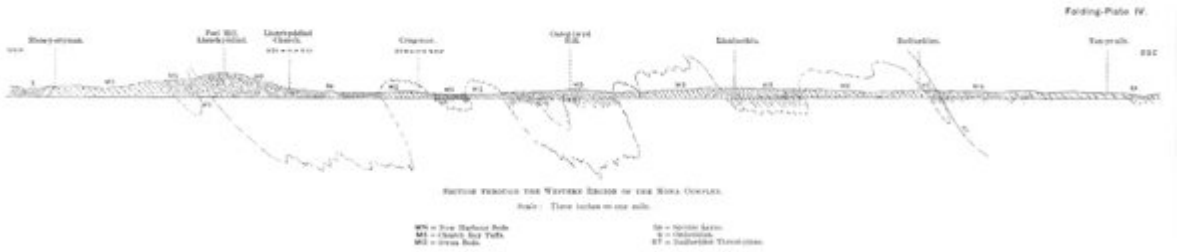


FIG. 75.—THE FOLDING AND THRUSTING OF THE VALLEY THRUST-PLANES.

(Figure 75) The folding and thrusting of the valley thrust-planes. Amplitudes up to four feet. Crags above the railway, north-east and east of the Church.

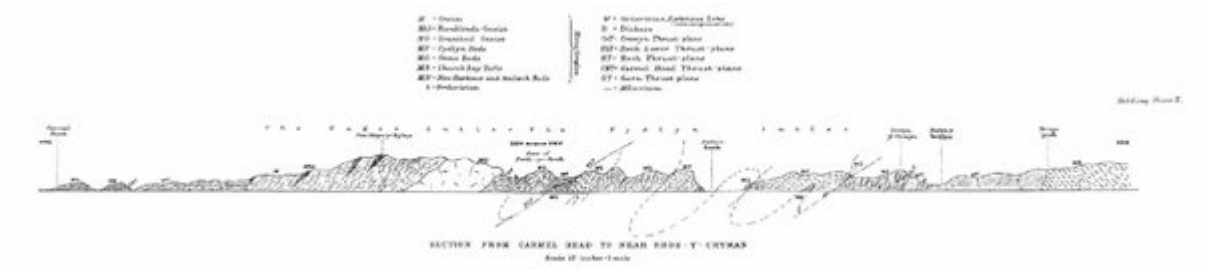


(Folding-Plate 4) Section through the western region of the Mona Complex. Scale: three inches = one mile. MN = New Harbour Beds. SP = Spilitic Lavas. MS = Church Bay Tuffs. B = Ordovician. MG = Gwna Beds. BT = Bodfardden Thrust-Plane.

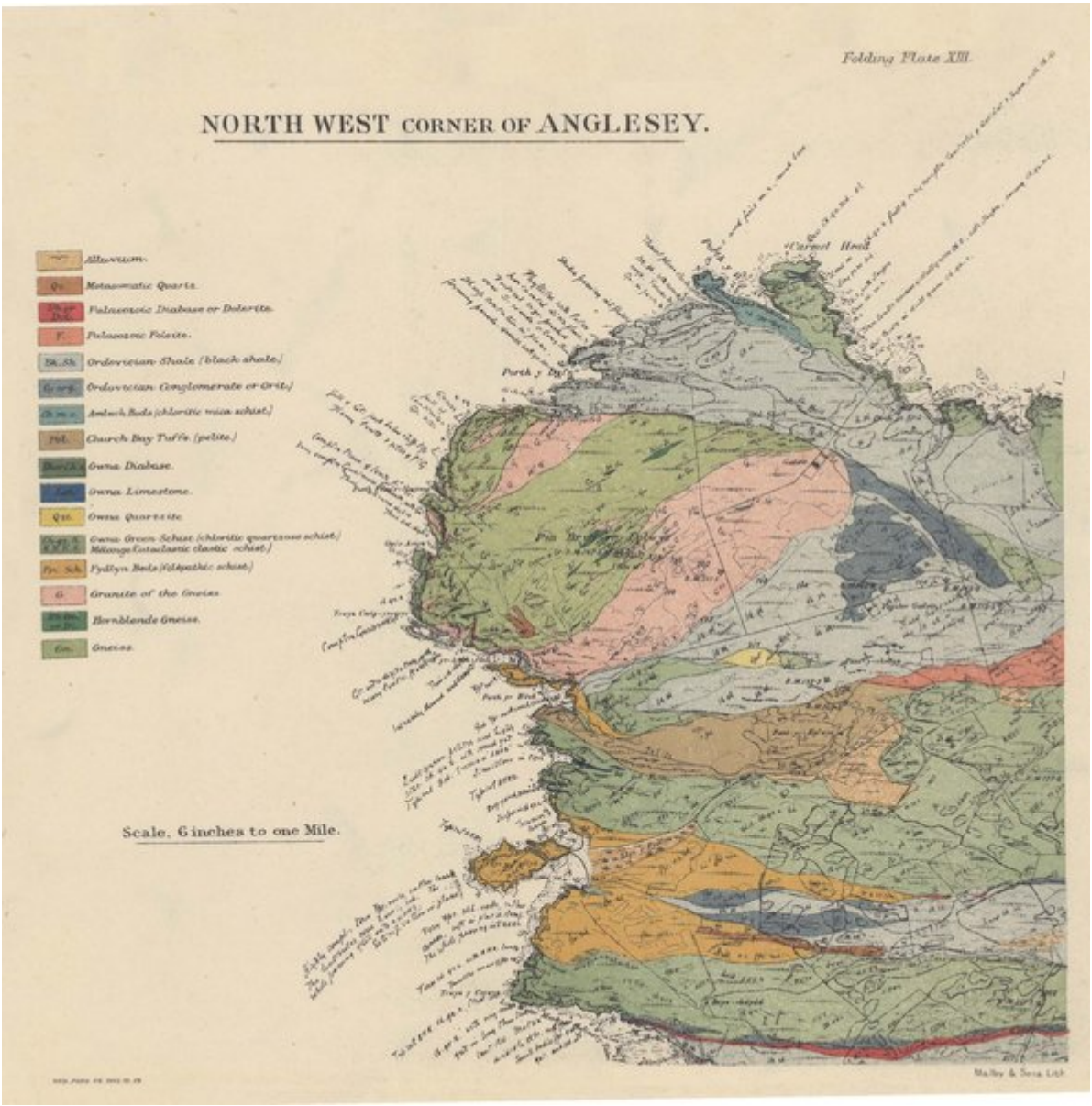
FIG. 76.—DIAGRAM TO ILLUSTRATE THE CHANGE FROM THE ISOCLINES OF HOLY ISLE INTO THE FOLIATION OF THE WESTERN REGION.

(Figure 76) Diagram to illustrate the change from isoclines of Holy Isle into the foliation of the Western Region.

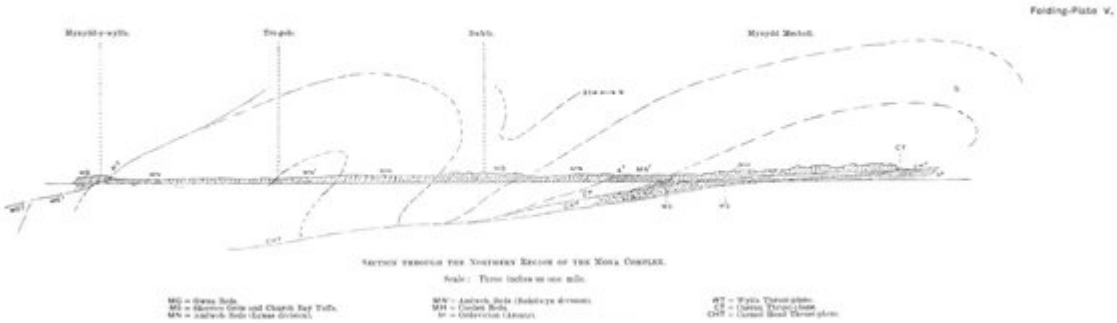
(Folding-Plate 9) Section through Mynydd-y-garn. Scale 12 inches = 1 mile.



(Folding-Plate 10) Section from Carmel Head to near Rhos-y-Cryman. Scale 12 inches = 1 mile.



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



(Folding-Plate 5) Section through the Northern Region of the Mona Complex. Scale: Three Inches = One Mile. MG = Gwna Beds. MN= Amlwch Beds (Bodelwyn Division). WT = Wylfa Thrust-Plane. MS = Skerries Grits and Church Bay Tuffs. MH = Coeden Beds. CT= Caerau Thrust-Plane. MN = Amlwch Beds (Lynas Division). BC = Ordovician (Arenie). CHT = Carmel Head Thrust-Plane.

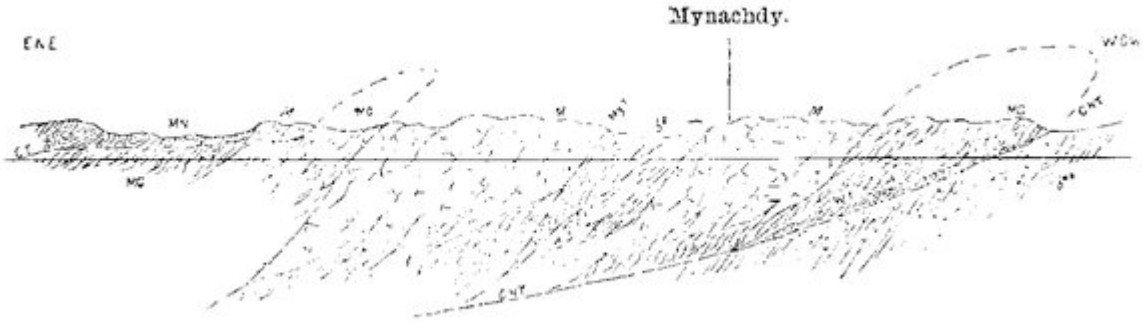


FIG. 94. SECTION AT MYNACHDY.

(Figure 94) Section at Mynachdy. Scale: Nine inches = one mile. MN = Amlwch Beds. MG = Gwna Beds. M = Gneiss. beb = Lower Ordovician Beds. be = Glenkiln Beds. CT = Caerau Thrust-plane. MyT Mynachdy Thrust-plane. WT = Wig Thrust-plane. CHT = Carmel Head Thrust-plane.

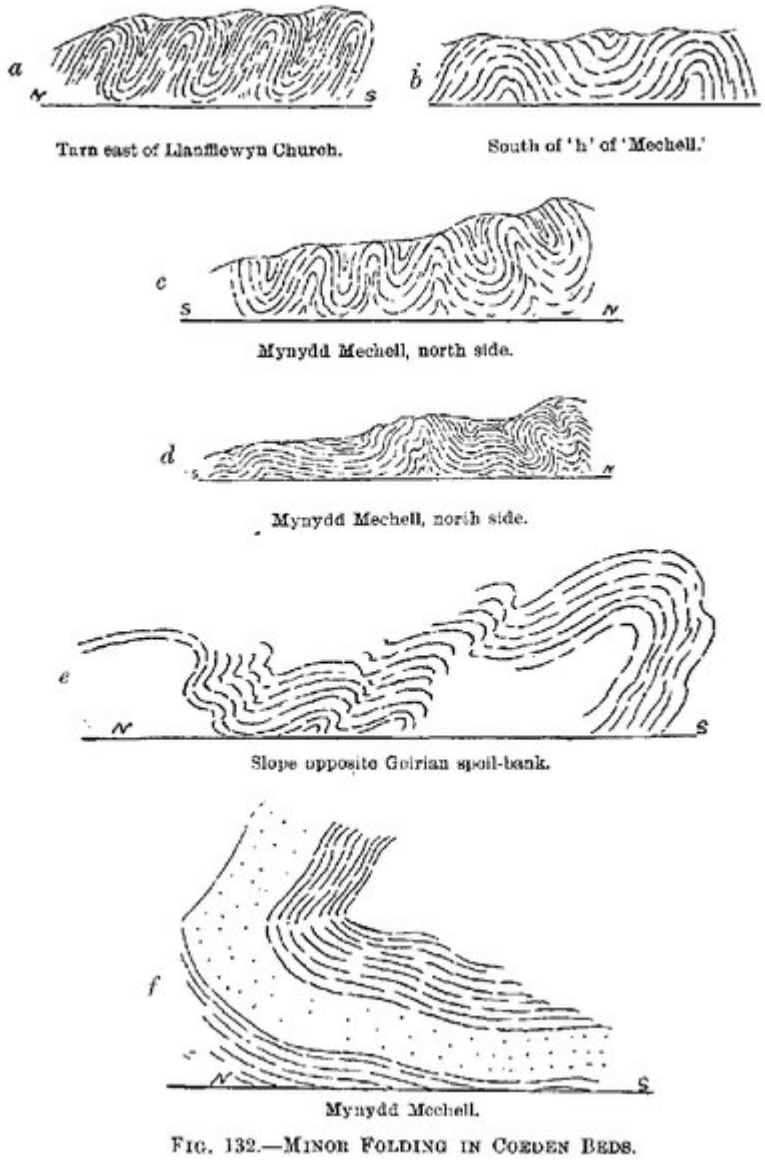


FIG. 132.—MINOR FOLDING IN COEDEN BEDS.

(Figure 132) minor folding in Coeden Beds. a. Tarn east of Llanfflewyn Church. b. South of 'h' of 'Mechell'. c. Mynydd Mechell, north side. d. Mynydd Mechell, north side. e. Slope opposite Geirian spoil-bank. f. Mynydd Mechell.

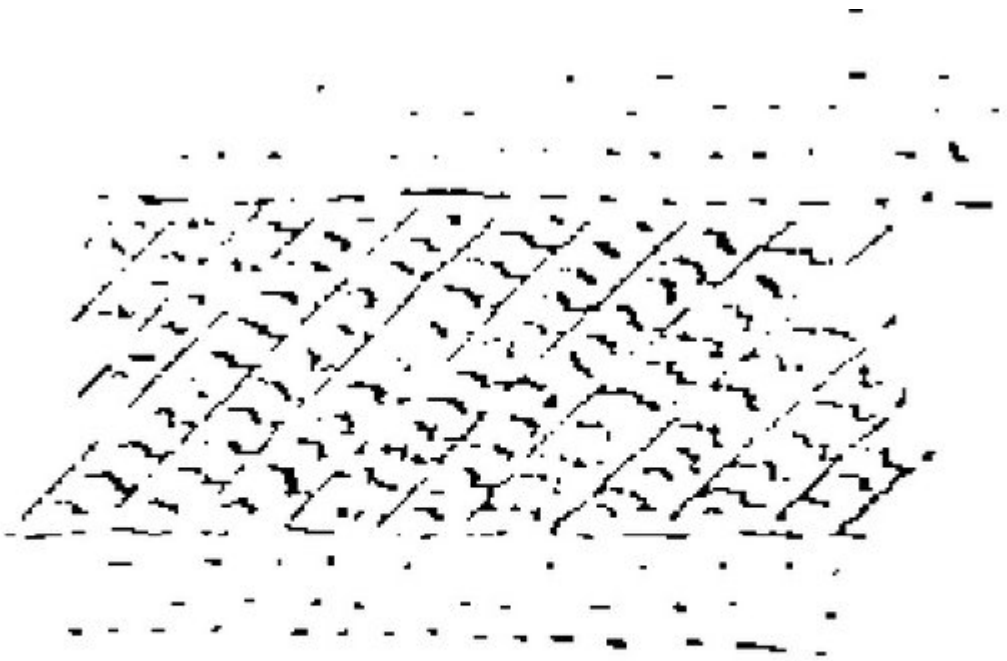


FIG. 70.—STRAIN SLIP.

(Figure 70) Strain slip. Quarter of a mile west of Minffordd Windmill

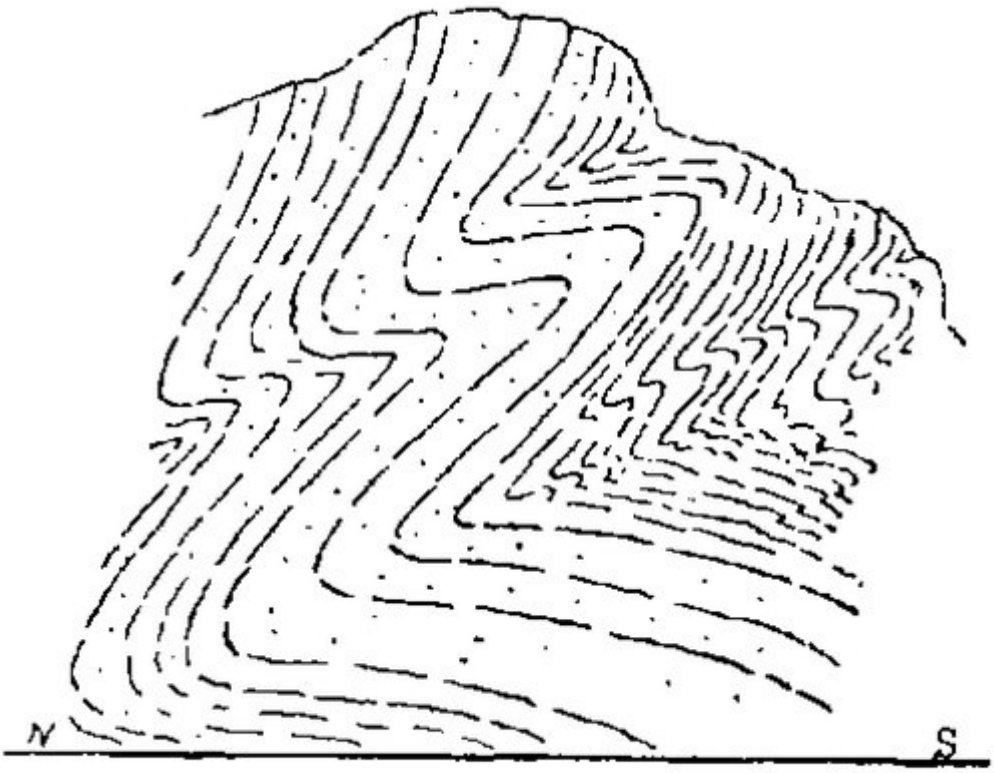


FIG. 49.

(Figure 49) Folding in Amlwch Beds. Half-a-mile west of Bryn-eilian. Height about two feet.

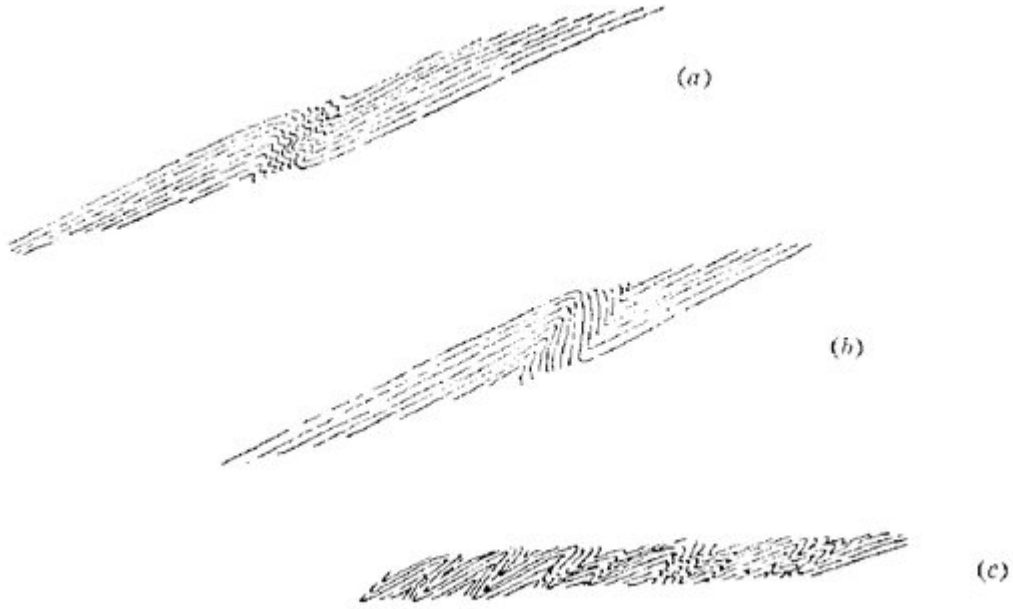


FIG. 52.—STRAIGHT-LIMBED ISOCLINES.

(Figure 52) Straight-limbed isoclines. Western Cliffs of Point Lynas. (a), (b) Limbs 30 to 40 feet in length. (c) Limbs three feet in length.

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.

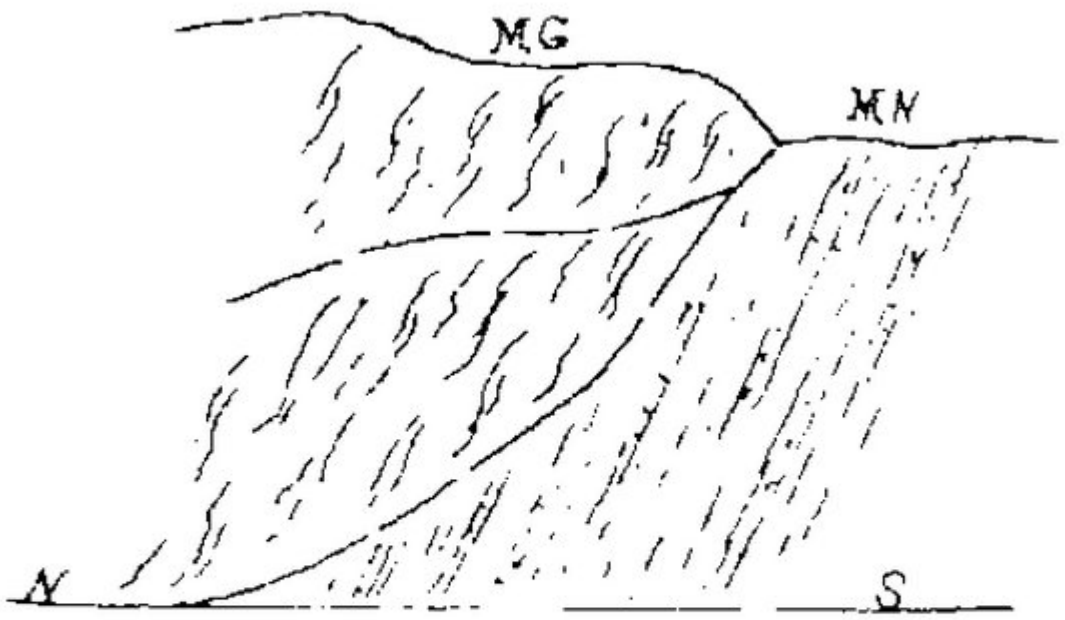


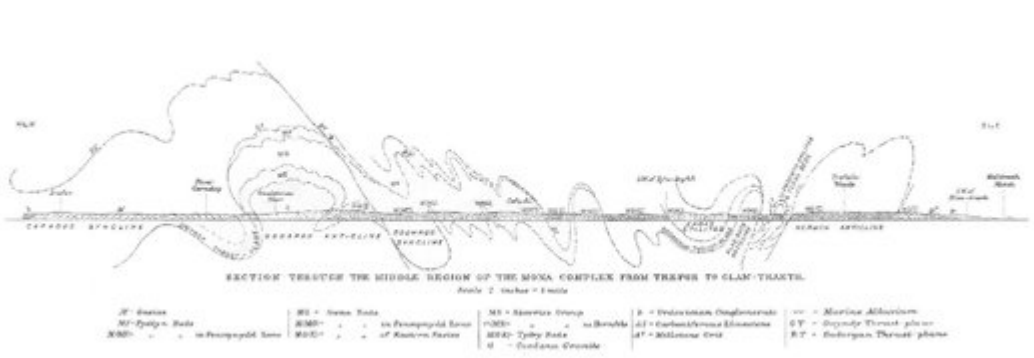
FIG. 96.

THE WYLFA THRUST-PLANE,
Porth Wnol.

(Figure 96) The Wylfa Thrust-Plane, Porth Wnol. Cliff about 80 feet in height. MG = Gwna Mélange. MN = Amlwch Beds.

FIG. 97.—DIAGRAM OF SUPPOSED ORIGINAL RELATIONS OF THE GLENKILN CONGLOMERATES TO THE MONA COMPLEX IN THE GYNFOR DISTRICT.

(Figure 97) Diagram of supposed original relations of Glenkiln Conglomerates to the Mona Complex in the Gynfor District, b'= Pale conglomerate. b = Purple conglomerate. MQ = Gwna Quartzite.



(Folding-Plate 6) Section through the middle region of the Mona Complex from Trefor to Glan-traeth. Scale 2 inches = 1 mile

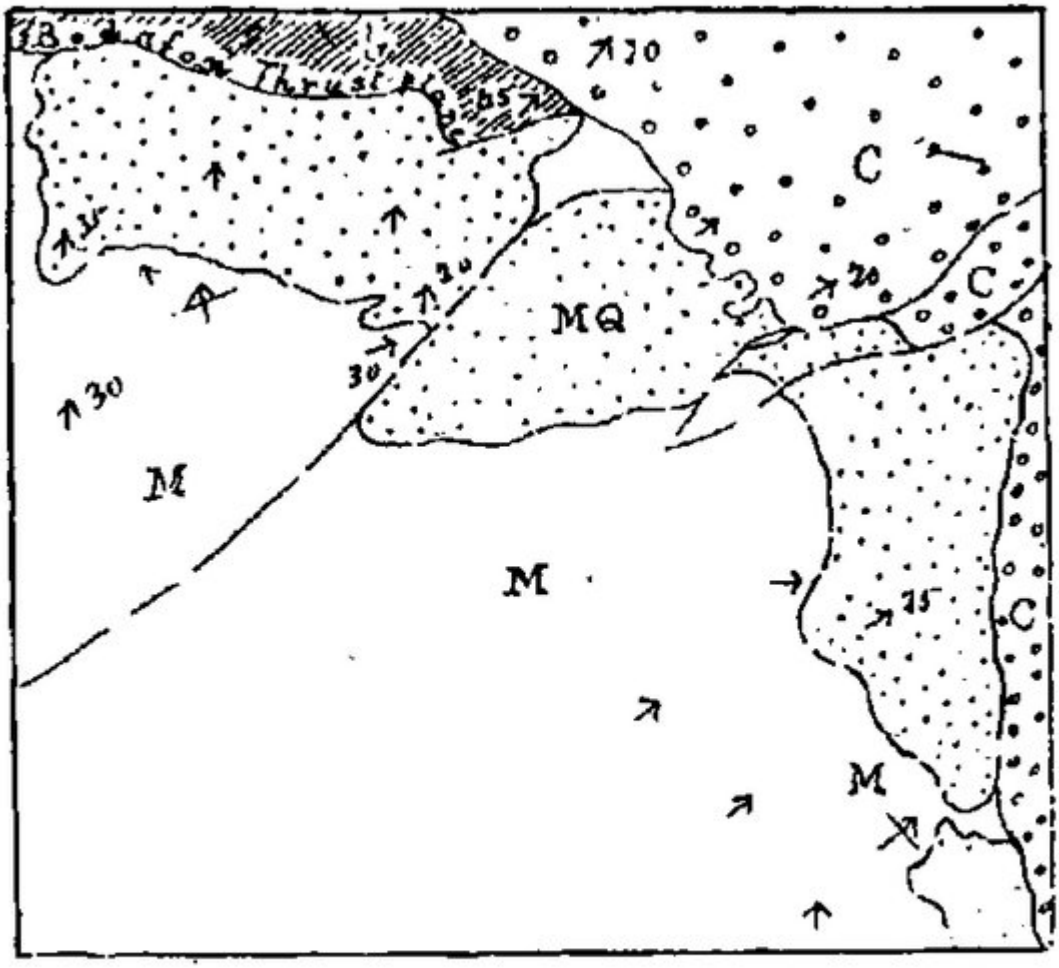


FIG. 154.

NORTHERN PARTS OF BODAFON MOOR.

(Figure 154) Northern parts of Bodafon Moor. From the six-inch maps. M = Bodafon Moor Schist. MQ = Bodafon Quartzite. b= Ordovician Shale. c = Old Red Sandstone.

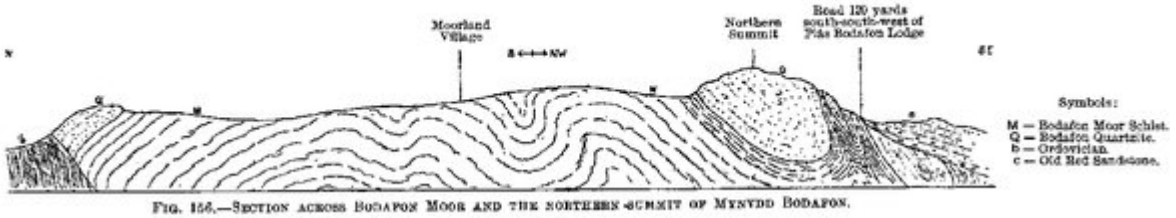


FIG. 156.—SECTION ACROSS BODAFON MOOR AND THE NORTHERN SUMMIT OF MYNYDD BODAFON.

(Figure 156) Section across Bodafon Moor and the northern .summit of Mynydd Bodafon. Scale: Eight inches = one mile. Symbols: M = Bodafon Moor Schist. Q = Bodafon Quartzite. b= Ordovician Shale. c = Old Red Sandstone.

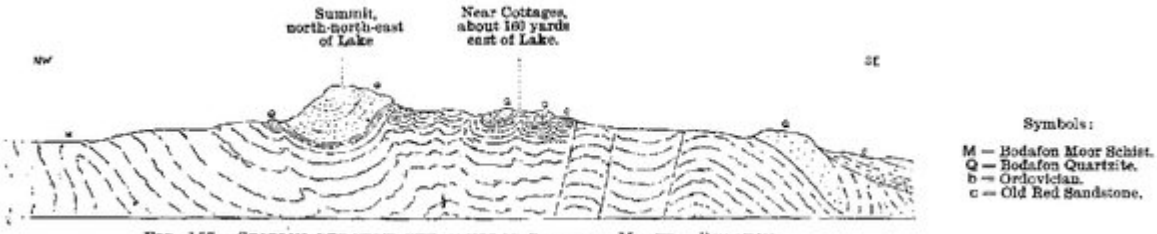


FIG. 157.—SECTION THROUGH THE CENTRAL PARTS OF MYNYDD BODAFON.

(Figure 157) Section through the central parts of Mynydd Bodafon. Scale: Eight inches = one mile. Symbols: M = Bodafon Moor Schist. Q = Bodafon Quartzite. b= Ordovician Shale. c = Old Red Sandstone.

FIG. 158.—SECTION THROUGH THE SOUTHERN PARTS OF MYNYDD BODAFON.

(Figure 158).-Section through the southern parts of Mynydd Bodafon. Scale: Eight inches = one mile. Symbols: M = Bodafon Moor Schist. Q = Bodafon Quartzite. b= Ordovician Shale. c = Old Red Sandstone.

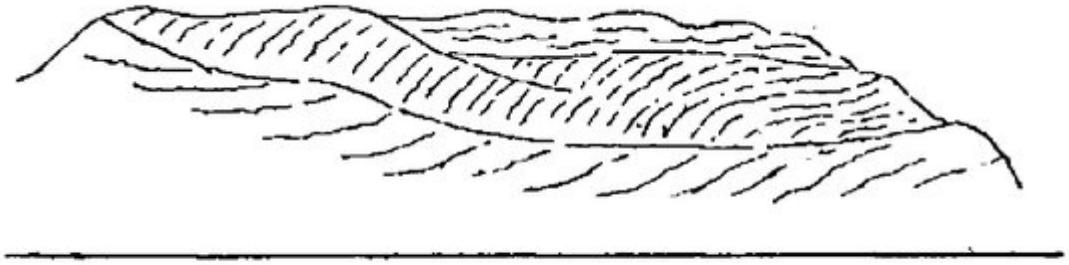
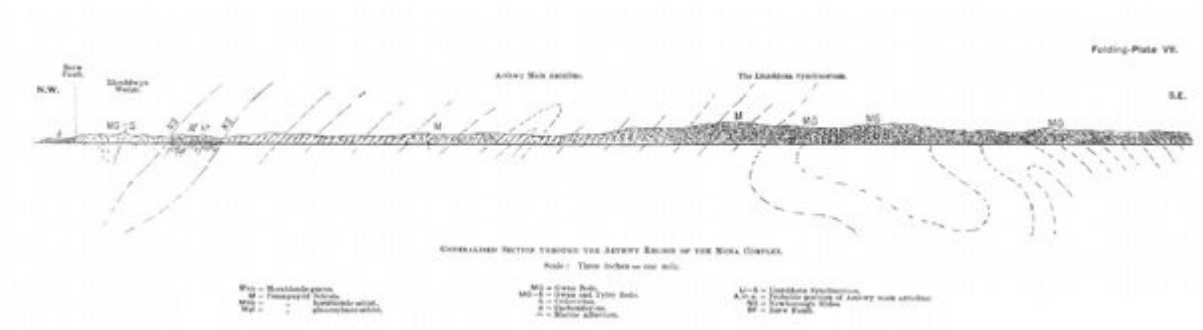
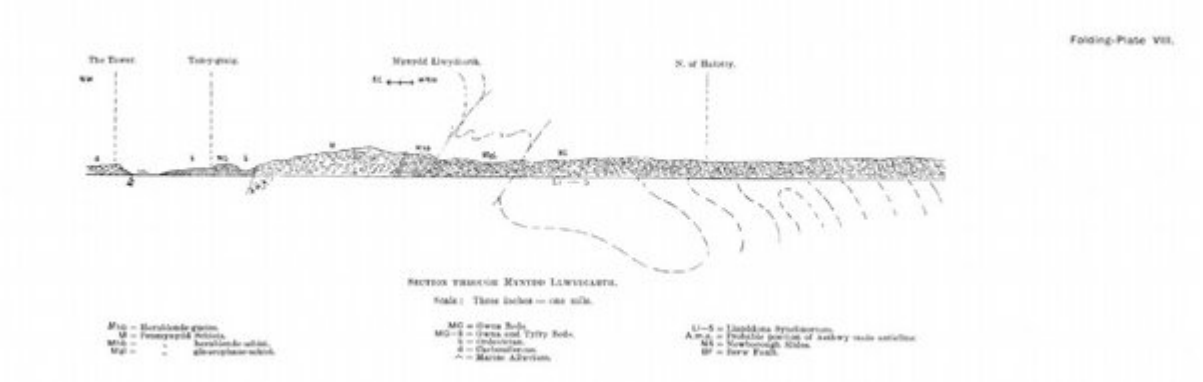


FIG. 159.—LATE THRUSTS ON YNYS MEIBION.

(Figure 159) Late thrusts of Ynys Meibion. height: about nine feet.



(Folding-Plate 7) Generalized section through the Aethwy Region of the Mona Complex. Scale: Three inches = one mile



(Folding-Plate 8) Section through Mynydd Llwydiarth. Scale 3 inches = 1 mile.

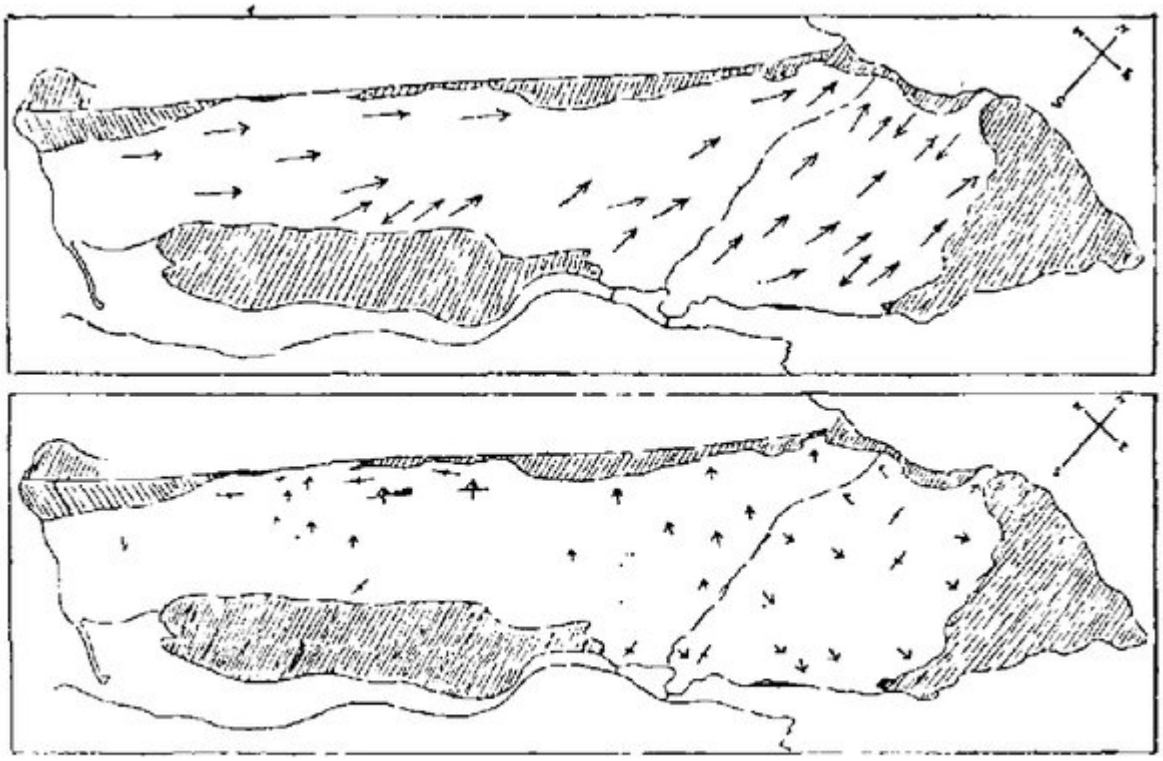


FIG. 98.—STRIKE, DIP, OVERFOLDING, AND PITCH IN THE AETHWY REGION.

(Figure 98) Strike, dip, overfolding, and pitch in the Aethwy region. Scale: Six miles = one inch. Broken line junction of Penmynydd Schist and Gwna Green-schist. Long-tailed arrows = Pitch.

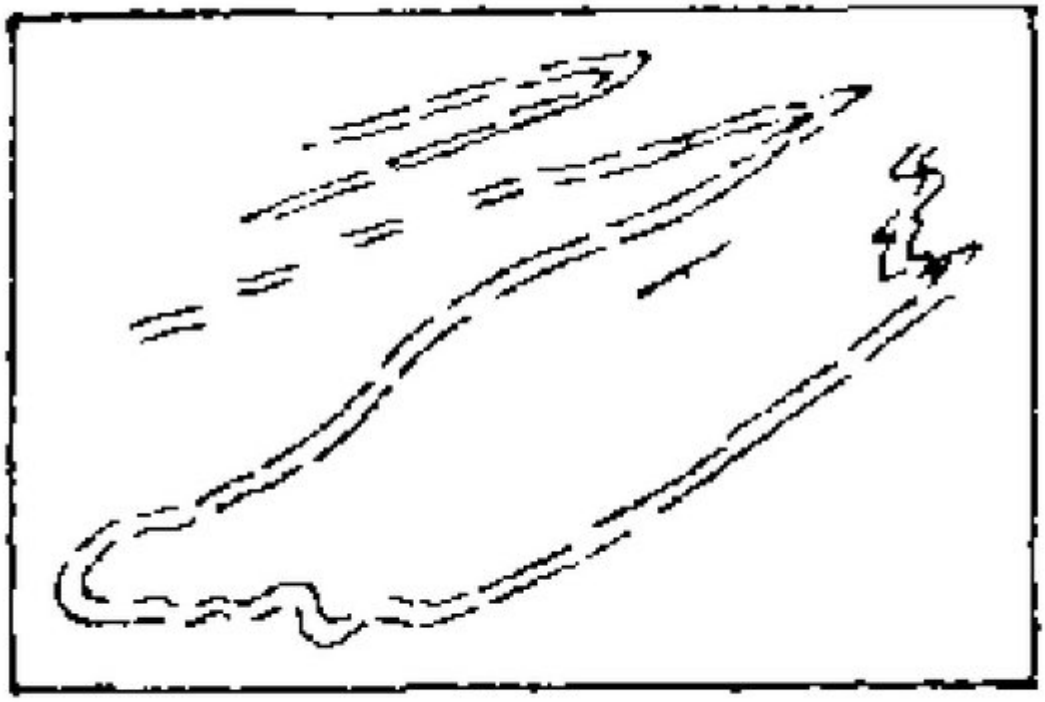


FIG. 61.

(Figure 61) Plan of five-foot folds in hornblende-schist. About 100 yards north-east of Gigfran, Mynydd Llwydiarth.

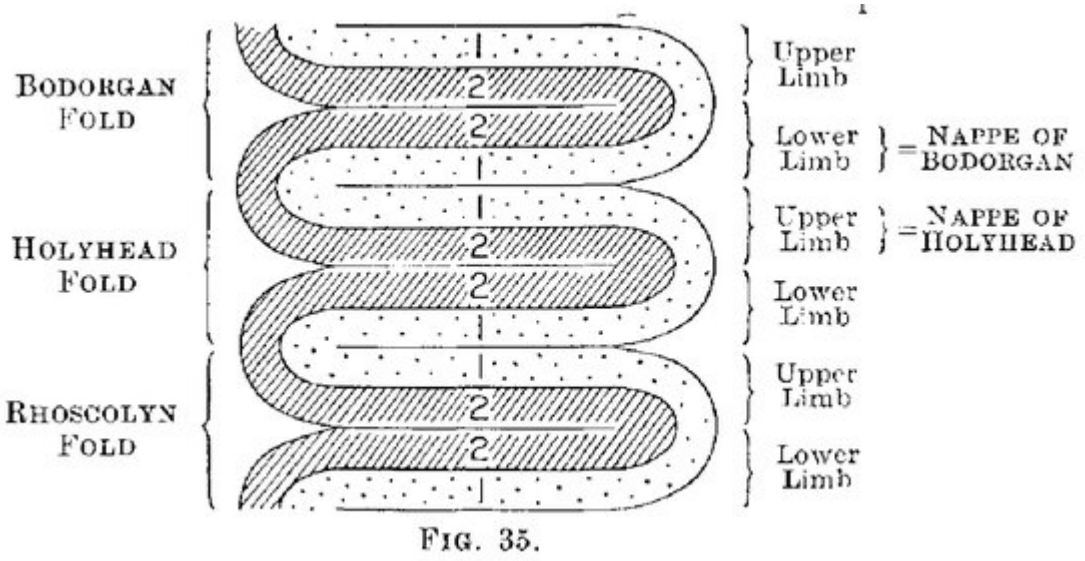


FIG. 35.

(Figure 35) Diagram of the recumbent folds of the Mona Complex.All thrusts omitted.

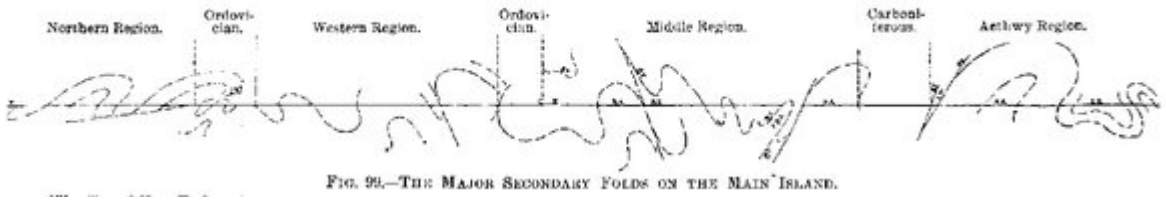


FIG. 99.—THE MAJOR SECONDARY FOLDS ON THE MAIN ISLAND.

(Figure 99) The major secondary folds on the main island. XX = Top of New Harbour Beds. CHT = Carmel Head Thrust-plane. CS = Caradog Syncline. BA = Bodafon Anticline. BS = Bodwrog Syncline. BT = Bodorgan Thrust-plane, BA = Plâs-bach Anticline. HA = Hermon Anticline. BF = Berw Fault. LW = Llanddwyn Wedge. NS = Newborough Slide. AA = Aethwy Anticline. LS = Llanddona Synclinorium.