Chapter 20 The Old Red Sandstone

Introductory

The Upper Paleozoic succession in Anglesey opens with a group of rocks that present a striking contrast to all the older systems. Resting unconformably upon member after member of those systems, and overlain by the lowest beds of the Carboniferous, is a series of purple-red sandstones, red mudstones, cornstones, and limestones, with conglomerates, that must be referred to some portion of the Old Red Sandstone. They are well exposed along the coast between Dulas and Lligwy Bays, in the precipitous escarpment of Coed-y-gell, and in the elevated tract between Mynydd Bodafon and the sea. As bed after bed laps round the eastern crags of that ancient hill, their outcrop rapidly narrows, and is reduced in half a mile to less than half its former width. Thence, along its course to the south-west, it further dwindles, and just before reaching Llangefni is completely overstepped by the Carboniferous. There is also a small outlier on the foreshore of Trwyn-cwmrwd, opposite the tower of Ynys Dulas.

Petrology

There is rather a remarkable variety of sedimentary types for a formation of such limited extent, every gradation being traceable between such extremes as coarse conglomerate and clean grey limestone.

Conglomerate

The conglomerates are well bedded, and for the most part not very coarse, though their boulders of quartzite are occasionally a foot in diameter. They are generally red. The pebbles are derived both from the Mona Complex and the Ordovician, and include vein-quartz, quartzite, Bodafon moor-schist, Gwna Green-schist, jasper, hornfels, and gneiss, with dark grits and hard mudstones of various Ordovician horizons. A few seem to be (see Chapter 19) from the pyritised rocks of Parys Mountain. They are markedly local in character, and have not travelled far. Around the skirts of Mynydd Bodafon the fine Bodafon quartzite is the dominant pebble, at Trwyn-cwmrwd it is gneiss.

Sandstone

The sandstones are of the well-known purple-red colour that is general in this formation throughout the British Isles. Pale-green reduction spots and bands occur, but are not common. The rocks are evenly and in general somewhat thinly bedded, sometimes well banded, the partings often being bright with clastic mica; but are perhaps rather finer than is usual in the Old Red Sandstone, and there is not much current-bedding. Their chief component is quartz in small subangular grains, with abundant white mica, in a reddish muddy matrix that appears to be chiefly kaolinised and micacised felspar debris. The hiematitic dust that gives the colour is partly disseminated through this matrix, partly in the form of definite pellicles, in which it is much more dense than in the matrix. Heavy minerals appear to be rare.

Mudstone, marl, or dust-rock

More prevalent, however, is a type that may be called a red sandy mudstone, though its difference from the normal sandstone, except for the presence of a little carbonate, is less in composition than in texture. Arranged, on the large scale, in beds quite as definite and even, though usually thicker than those of the normal type, there is within each bed a lack of lamination, so that the rock breaks in an irregular and 'cake-like' manner. The minerals are the same, with more quartz than would be expected, but finer, while the micas do not lie in any particular direction. The conditions of deposit were evidently rather different. Now, the kaolinous matrix, with its admixture of carbonates, the fine angular quartz, the little flakes of mica, and, above all, the unlaminated attitude of these micas, with its resultant lack of internal stratification, are all characters of the Loess of China, so vividly described by Richthofen, who draws special attention to the two last-named characteristics. The Loess is now generally admitted to be of aeolian origin, which suggests wind rather than water as the distributing agent in the present case. If the shallow waters of a sandy lagoon be dried away in parts from time to time, then blowing dust can speedily fill up the desiccated pools. Richthofen, in fact, regards the sediments of the great desiccated lakes of Central Asia as a fruitful source of the ever-drifting dust of those regions. To some such conditions, many times repeated, we may perhaps look for an explanation of this large mass of fine material, arranged as it is in even beds, but internally un-laminated.

Cornstones

By increase in the proportion of carbonate the rocks just described pass, often rapidly, into red calcareous mudstones, in which the calcite (for there is but little magnesium) has segregated in small irregularly oval or tube-shaped concretions, usually pale-green, and sharply delimited from the micaceous red matrix. Such rocks become extremely cellular by weathering. Increase of the size and number of the nodules brings us to a type quite half of which is composed of calcite, and may be truly called a cornstone; while this again may pass into a nodular calcite-rock with only a separating network of mudstone. The mudstone meshes have the usual texture and composition, the pale nodules being chiefly composed of rather fine dusty calcite, with many little angular grains of quartz. Such rocks as these, though bounded by well defined bedding-planes, are totally devoid for the most part of lamination, and are highly complex. They are of all grades of thickness, from one or two inches to 20 feet or more, and very massive. The crags of the great escarpment of Coed-y-gell, which is 200 feet in height, show no bedding of any kind, and they tower for some 60 feet above the dense bush of the steep slopes at their foot. In spite of the complexity of the rocks, it may be discerned that the nodules have a general tendency to stand at right angles to the bedding, as if <ref>In 'The Country Around Carmarthen' (*Mem. Geol. Surv.*), 1909, pp. 72–3, a precisely similar suite of strata in the Lower Old Red Sandstone is described. See also several other recent Geological Survey Memoirs on South Wales, such as those on the countries around Abergavenny, Newport, Ammanford, and Haverfordwest.</ref> they had grown upwards concurrently with the accumulation of the ferruginous mud around them. Yet, when overlain by a fine ordinary sandstone, the junction is surprisingly sharp and even. Calcareous nodules, with vertical tubules about which nodules could easily develop, are also, it may be recalled, a feature of the Loess. The origin of these cornstones, indeed, is bound up with that of the mudstones or dust-rocks just discussed.

Limestones

The last-named type may pass, by vanishing of the red mechanical sediment, into clean, massive, grey limestone, much like many of the beds in the overlying Carboniferous, and showing a similar mottling, but Dr. G. J. Hinde could detect no microscopic organisms. Here and there pale-green glistening aggregates may be seen. The rock is a variable mosaic of calcite, some fine and dusty, some clearer but not so fine, disposed in nodular aggregates, each type enclosing each. The glistening aggregates are full of clastic quartz and mica. An interesting feature is that certain tracts of the fine dusty calcite are penetrated by numbers of perfect idiomorphic crystals of quartz, some of them doubly- terminated, and with the angles of the prism sharply developed. They are full of inclusions, chiefly calcite-dust, but marginally clear, and optically undisturbed. They lie in all directions, and the largest are nearly 0.5 mm. in length.

Chemical analyses

The following analyses have been made:

	I.	II.	III.
Residues insoluble in HCl	84.91	15.67	9.08
$Al_2O_3+Fe_2O_3$	8.25	2.37	0.92
CaO	1.23	41.91	50.19
MgO	2.08	3.07	nil
CO_2	3.55	36.72	39.62
	100.02	99.74	99.81
Percentage $CaCO_3$	2.19	74.83	89.62
Percentage $MgCO_3$	4.37	6.42	

I. Purple-red mudstone, north side of Traeth yr Ora (E10299) [SH 489 887]. Anal. J. O. Hughes.

II. Purple cornstone, 900 yards east-north-east of Pentre-eirianell, between footpath and escarpment. (Same characters as (E10435) [SH 492 884] Anal, J. O. Hughes.

III. Grey limestone, coast Aouth of Traeth yr Ora, east of Penrhyn farm (at 'a' of 'Ordinary' on six-inch map) (E10300) [SH 491 884]. Anal. J. O. Hughes.

It will be seen that, in the mudstone, magnesium is in excess of calcium; that with the substitution of carbonates for insoluble matter and iron in No. II, though slightly increasing absolutely, it decreases greatly in proportion to calcium; and that in the grey limestone it has disappeared altogether.

Staining

The underlying formations have been considerably stained. We have already seen that the delicate rose-colour of the Bodafon quartzite (see p. 80) must be assigned to this cause; besides which, the Bodafon moor-flags, the hornfels, and the Deri mica-schists (see p. 335) are affected, a maximum being reached in the Nebo gneisses (see p. 327, further details being given in Chapter 21), anlong which it is intense. The pebbles in the Old Red conglomerates themselves are coated with a pellicle of haematite and are penetrated for some distance, their more unstable minerals being occasionally pseudomorphed.

The different degrees of susceptibility to staining exhibited by the minerals of the Grneisses are interesting, and would repay further study. The quartz is merely penetrated along its cracks, but haematite dust is substituted for the kaolin of the decaying felspars. The greatest sufferer is the biotite, which had evidently become peculiarly susceptible<ref>The remarkable bleaching of this biotite (see pp. 135, 328) seems to be antecedent to the staining, and if so, must be of Lower Palaeozoic age.</ref> and has often been (Plate 12), Fig. 3 completely pseudomorphed in haematite. Very striking is the stability of the slender sillimanite, which, even where haematisation is at a maximum, is not in the least affected, but retains its delicate sea-green tint.

The general distribution of the phenomenon "has interesting bearings. If we protract the dip of the base at Trwyn-cwmrwd across the horizontal extent of the tract of staining, it -will appear that the iron solutions have penetrated the gneisses (whose foliation is locally vertical) to a depth of about 100 feet. Noteworthy also is the circumstance that the staining, feeble or absent about Llangefni, waxes greatly north-eastward, in which direction the Old Red Series is thickening and its floor deepening. The intensity of the staining is therefore conditioned by the thickness of the formation, and by the direction of percolation of underground waters. Finally, if, bearing this in mind, we return to the present subject after having considered the relations of the Carboniferous to the Old Red of Trwyn-cwmrwd (see p. 589; and Chapter 21, 'Trwyn-cwmrwd') we shall see reason for believing that the greater part of the staining was effected in Pre-Carboniferous times. If so, it may have been brought about while the formation was still saturated with the waters of its own basin of deposit.

Contemporaneous erosion and disturbance

Here and there, as at the north end of Traeth yr Ora, a cornstone shows internal bedding, and in such beds the nodules are more like small isolated balls, about a third of an inch in diameter. Dr. Strahan suggests that they may have been detached from an older bed, and rolled, during a local episode of contemporaneous erosion.<ref>See also 'The Country around Newport' (*Mem. Geol. Surv*)1909, pp. 15, 19.</ref> On the southern cliffs of the same little bay there is one of the curious contemporaneous disturbances that are occasionally met with among sedimentary deposits, and which are not easy to explain. Between thick and rather massive brownish-red sandstones dipping steadily south-east at about 30°, are some nine inches of a laminated reddish sandstone which is rapidly crumpled without the beds either above or below being in the least disturbed ((Figure 281), p. 585). Nor is there any sign of sliding. The phenomenon resembles those of the Torridon Sandstone, and also some seen in the Caithness flagstones a few miles to the west of Thurso.<ref>Compare also the contorted 'Skerries' in the Keuper Marls. B. Smith, *Geol. Mag.* 1910, p. 306. Also the paper by Arnold Heim quoted on p. 434.</ref> There is an inch or two of erosion below the contorted bed: and it will be seen in Chapters 22, 23, that contemporaneous disturbance and erosion appear to be in some way connected. But this case may perhaps be a result of desiccation.

Succession

Such being the materials of the series, the following summary may serve to convey a picture of the proportions in which they compose it, and of its aspects on the large scale. Two main divisions can be recognised, the lower consisting of mudstones with cornstones, while the upper is composed chiefly of sandstones. In the lower, calcareous beds of varying thickness alternate rapidly with the mudstones, and amount to a third, perhaps even to a half, of that portion. Conglomerates, confined for the most part to the base, do not exceed 150 feet anywhere. The cornstones may be of any thickness up to 20 feet, but they are apt to occur in groups, of which the largest, that of Coed-y-gell, exceeds 200 feet in thickness. Of the clean grey limestones six or seven are known, one of which is about eight feet thick. The limestones and cornstones vary greatly in thickness, and die out rapidly along the strike, sometimes by decrease of lime in one and the same bed of mudstones, sometimes ((Figure 279), p. 584) by wedging out or sudden thinning<ref>To represent the real proportion of cornstone inland upon the maps has been a serious difficulty.</ref>; and other beds are also impersistent.

In the upper division, there are still a good many cornstones, but they are thin, and have now become quite subordinate to the Sandstones. The top of the system is nowhere seen.

General view of the Old Red Sandstone

The lowest beds accessible are the conglomerates of Trwyn-cwmrwd, somewhat higher than which must be the beds that emerge at the foot of the Coed-y-gell escarpment (Figure 275), after which there is a rising succession along the coast almost as far as Lligwy Bay. The beds, as will be seen from that figure, are thrown into a large fold that is nearly monoclinal, but whose further limb, curving up into a gentle syncline, brings in the higher, arenaceous division. The middle limb of the monocline is vertical.

On the first page of this chapter the existence of an overlap was briefly alluded to. This is perceptible directly to the eye when we face the escarpments that look down upon the Vale of Dulas. Bed after bed of the Coed-y-gell cornstone runs out south-westward past Pentre-eirianell and disappears against the curving base, until its highest beds, which at Coed-y-gell form the crest of the escarpment, come to rest upon the Ordovician at the City Dulas road below the Inn. The beds of the Pentre-eirianell escarpment now act as local base, running out in their turn near Bodafon-isaf farm. The matter is somewhat complicated by the impersistence of the beds, which replace each other as above described; but even when allowance has been made for that, it becomes evident that the lower members of the series are disappearing rapidly by overlap as we approach Bodafon Mountain.

Before that is quite reached, however, a great bend in the strike sets in, with dips to the north-east of 20°–25°, and about 140 feet of strong conglomerate appear (Figure 278). The base of the Old Red (still rising on the overlap) then passes off the Ordovician, and crossing the Bodafon thrust-plane, which it then buries (Figure 276), (Figure 154), comes to rest directly upon the steep eastern crags of the ancient quartzite. It thus becomes evident that the verticality of the middle limb of the monocline cannot continue for more than half-a-mile; for its inclination must lower as the strike bends round. The tract between Bodaf on and the sea is therefore compounded of a monocline and a semi-syncline, whose south-eastern limb is nearly abolished by the Lligwy fault which brings down the Carboniferous.

The strike then curves again, this time to the south and southwest, and the Old Red Series, still with a conglomerate at the base, and the overlap still going on, passes round the mountain's eastern slopes ((Figure 277), (Figure 155), (Figure 156), (Figure 157), (Figure 158), Grraig-fryn (Figure 296) and four other small inliers of quartzite now interrupt the normal south-westerly trend of the beds, which rise around them. Thence to the final Carboniferous overstep at Llangefni, it is the upper arenaceous division, with, however, a few cornstones, that is represented, and (Figure 280) with good basal conglomerates composed of local Gwna schists; the dips being now all easterly at moderate angles.

Tectonics

Molar movements — That the movements by which these rocks have been affected were of no mean power is manifest. It will appear that they were not all of the same nature.<ref>The Dulas and Lligwy faults (see Chapter 21) are Post-Carboniferous.</ref> Let us return to the sea-section. A south-easterly dip of some 200–30° is maintained from Traeth Dulas as far as the southern side of Porth-y-môr, beyond which it rises rapidly to 90°, and then drops again (Figure 275), constituting thus the great monoclinal fold already alluded to. The further limb has a gentle northerly dip, and in this part there are structures of an isoclinal character. At one little creek a sharply over-driven anticline (Figure 282) may be seen, and further south a similar syncline (Figure 283). Thrust-planes (Figure 284) begin to appear, and in some places the beds are almost as much cut up as in many of the grit-and-shale sections of the Ordovician rocks not far away. The thrusts often truncate several beds in their course, and the calcareous nodules have been dragged out and deformed.

Internal modifications — The rocks have not escaped internal re-arrangement. Upon such beds as were susceptible to it a somewhat rude but often conspicuous cleavage has been impressed. Most susceptible have been the finer micaceous red (whose unlaminated micas would lend themselves to re-arrangement) next to them the cornstones, and least of all the sandstones, while the conglomerates are not cleaved at all. Massive beds inland often show no other structure, but on the coast its independence of the bedding is perfectly clear (Plate 34). A measure of its intensity may be obtained as follows. In the sandy mudstones it is quite strong enough to destroy all tendency to part along the bedding, but the laminated sandstones can be split along either set of planes. Yet it never succeeds in imparting a smooth or shiny surface, the cleavage-planes being irregular, and rough to the finger. Slides have been made of two of these cleaved rocks, a red laminated sandstone and a mottled red and green mudstone. The first shows, under the microscope, no trace of cleavage; but in the second there is a decided re-arrangement of the micas, especially in the pale red parts adjacent to the green areas. The cornstones cleave much more readily than might have been expected from their coarse and rugged aspect. This is due to the susceptibility of their haematitic and micaceous mudstone matrix. Their calcareous nodules are somewhat compressed; but the planes of cleavage bend round and have never been seen to pass through them, from which it is evident that their segregation was complete before the commencement of the movements. Even the massive grey limestones have not escaped. Their little sea-green aggregates have been drawn out into narrow strings, and have often acquired a slightly schistose aspect, which is due to a shredding-out of their clastic micas along planes a little oblique to the course of the string.

The general intensity varies locally; being strong near the sea, waning somewhat about Penrhoslligwy Church, waxing again at Plâss Bodafon, and then waning gradually southwards, though perceptible at intervals as far as Erddreiniog, beyond which no cleavage has been detected. Nowhere has the pressure been severe enough to disturb the internal optics of the quartz; or (*cf.* footnote on p. 88) to cause any paling of the red rocks.

Cleavage and movement — The strike of this cleavage is east by south–west by north at Lligwy Bay; but it slowly bends round to east by north—west by south inland, and also towards Traeth Dulas. Its relations to dip, folding, and thrusting are in some ways exceptional and of considerable interest. Throughout the district, with the exception of one zone, it is inclined at a high angle to the north-northwest. In the zone of overfolding on Lligwy Bay it is (Figure 282), (Figure 283) parallel to the axes of the isoclines, and must be referred to the movements to which they are due. To the great monocline, however, its relations are quite different. As the inclination of the beds rises on the middle limb, that of the cleavage moves round with them and falls (Figure 285)a–(Figure 285)*e,* so that as they approach the vertical, it approaches the horizontal. But when they become quite vertical it never becomes quite horizontal, but still retains a slight northward inclination; which may be attributed to its being driven somewhat out of its natural position on the inner side of the fold, a view that finds confirmation in a slight curvature that it is then apt to acquire. The great monocline is. therefore later than the isoclines, since it carries round with it the cleavage which was induced by them.

Now, if we refer to (Figure 284), we shall see that the minor thrusts of Lligwy Bay must also be later than the cleavage, for they are at lower angles, and truncate it. Therefore, however nearly related to the adjacent isoclinal folding, they must be subsequent to that, representing (see pp. 545, 555–6) another phase of the same southward impulse. Can we; then, connect them in any way with the mono-cline, dynamically different from them though that certainly appears to be? Let us consider the dynamical significance of this depression of the cleavage-dip. Depression of cleavage-dip may be seen in the Ordovician rocks (Figure 267), (Figure 268), (Figure 270), (Figure 271), and it takes place at thrust-planes, along planes, that is, where there is an impulse with a large horizontal component. But the monocline (Figure 275) is ascribable to a southward impulse, which was pushed far enough to raise the middle limb to 90° but not far enough to overturn it. That it failed to do so was probably due to the pre-existing southerly dip of the northern limb, which would not facilitate an overturn.<ref>The nearest approach that we get is the production of a few small thrusts across the vertical middle limb.</ref> Had it succeeded in producing a major isocline or thrust-plane, that would be on a higher tectonic horizon than the structures along Lligwy Bay; and higher tectonic horizons are in general subsequent to those they over-ride.

It thus becomes possible to assign all these phenomena to successive stages of one and the same impulse. First, we have isoclinal folding, but with sufficient resistance to induce a compressive cleavage, which was followed by a disruptive stage with minor thrusting, and that by an attempt at a major isocline, arrested, however, before it passed beyond the stage of monocline.

This southward impulse is of the same nature and from the same direction as those by which both the Lower Palaeozoic rocks and the Mona Complex are affected throughout the north of Anglesey; and yet there cannot be a moment's doubt of the complete unconformity of this Old Red Sandstone to all the older systems. It passes transgressively across their outcrops and contains fragments of them in the condition in which they now exist *in situ.* We have already seen (pp. 558–9) that a similar relation obtains between the Ordovician and the Mona Complex, which are similarly folded and yet completely unconformable. So persistent was the tendency in this region to the exertion of a southward impulse, that it set in for a third time, with comparative feebleness, however, and never since repeated.

Thickness

The two upper lines in the following table are taken from the coast, the next three from the Coed-y-gell escarpment and the coast, and the lowest one from the eastern flanks of Mynydd Bodafon.

	Feet.	
Sandstones with thin cornstones	450	Arenaceous Division
Muds with a few cornstones	250	
Cornstone zone of Pen-y-braich	150	Calcareous Division
Muds with cornstones	150	
Corn stone zone of Coed-y-gell	200	
Sandstones and conglomerates	140	Basal
	1,340	

The basal beds, measured across Traeth Dulas to the hither side of the Dulas fault (see Chapter 21), would not be less than 500 feet if the dip shown in (Figure 275) continues. But as they are invisible, a measurement of the basal beds on Bodafon has been substituted, though, owing to the overlap, these are (see p. 584) on a higher horizon. There is little doubt, therefore, that the total is an under-estimate, probably by some 300 feet. Moreover, the top of the system is nowhere seen.

Age of the series

What, now, is the true horizon of this formation? Is it to be assigned to the Lower or Upper division of the system? No palaeontological evidence, unfortunately, is available, though the most promising members of the series have been searched by Mr. Muir; but Dr. Strahan, as a result of an examination of the strata made with this special object in view, finds that the lithological character of the various sandstones, marls, and cornstones are identical with those of the Lower Old Red Sandstone of South Wales<ref>'The Country around Carmarthen' (*Mem. Geol. Surv.*), 1909, pp. 72, 73; and The Country around Newport' (*ib* .), 1909, pp. 13–18.</ref>,whereas they cannot be matched either in the Upper Old Red Sandstone of that region or in the red Carboniferous Basement Beds of North Walps and North-West England. Further, between their deposition and that of the earliest Carboniferous rocks of North Wales, there intervened a period of over-folding and thrusting accompanied by cleavage. Though themselves much faulted at a later date, the Carboniferous rocks exhibit no trace of disturbance of this type. The movements had ceased before the Carboniferous period commenced. Little doubt, therefore, can remain that the beds must be assigned to the Lower member of the Old Red

Sandstone,

Relations to the Carboniferous Series

The pronounced unconformity thus made manifest is masked in various ways. Between Llangefni and Bodafon both systems dip at moderate angles in the same general direction, and the unconformity simulates a mere overlap. Between Bodafon and the sea there are dips in opposite directions, and the beds on the curve strike (as does the cleavage) at the Carboniferous. Unfortunately the base of that system is let down by the Lligwy fault, and the original junction is invisible. But on the other side of the Old Red altogether, across the Dulas estuary, there is a little outlier of the Carboniferous basement conglomerate, which is on the same level as, and strikes at the Old Red base on Trwyn-cwmrwd. We need therefore have no difficulty in mentally reproducing the transgressive sweep of the Carboniferous base across all the folded beds of the Penrhoslligwy monocline, till, passing across the base of the Old Red Series<ref>The Old Red of Trwyn-cwmrwd must therefore be a thin plate, which barely escaped being swept away *by* the Pre-Carboniferous denudation. It is far too thin to have supplied the iron which has stained the underlying gneisses with such intensity (see Chapter 21). That staining must have been effected when the full thickness of the formation still rested on the gneiss, a state of affairs that did not survive the Oprboniferous erosion. It follows, therefore, as was foreshadowed on p. 581, that by far the greater part of the staining must have taken place in Pre-Carboniferous time.</ref>, it comes to rest upon the Ordovician of Dulas.

Physiography

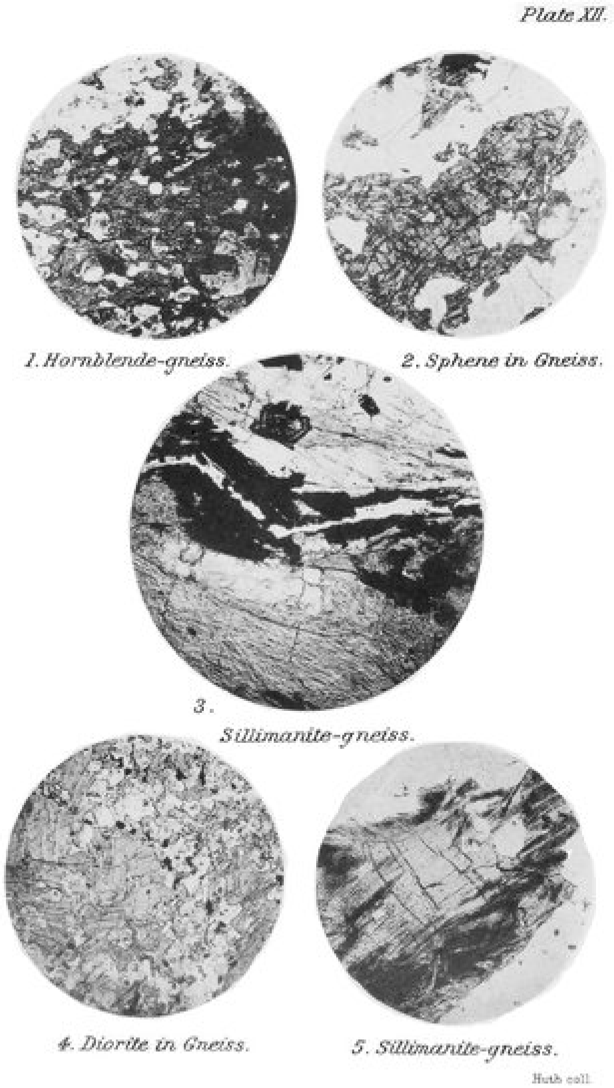
At Llangefni, Bodorgan, Llangaffo, Berw, and throughout the Straitside and Penmon Areas (for which terms see Chapter 22), the Carboniferous rocks repose directly upon the Mona Complex and the Ordovician, and we have already seen that the rocks of Parys Mountain were exposed at that time. In the Carboniferous period, therefore, the horizontal extent of the Old Red Sandstone cannot have been great. This might, in view of the unconformity of which we now know, be ascribed to Sub-Carboniferous denudation, and is no doubt largely due to that. Nevertheless, there is reason to suspect that, in the districts just mentioned, the formation was never deposited at all. From the south-westward overlap within it, there can be no doubt that it is thinning, and that the old land was gaining in elevation, in that direction. The conglomerates of Llangefni (Figure 280) show that it was rising westward as well. Further: the feebleness of the staining except in the north-east indicates that the formation was never very thick in other directions. Combining all these sources of information, we may infer that the Old Red Sandstone of Anglesey was deposited in a long hollow that deepened and opened out to the north-east, but was closed in every other direction.

That Bodafon Mountain formed an island in the waters of that time is shown by the rapid overlaps around its sides; but it must have been covered in the end, for the persistent staining of the Bodafon quartzite indicates an extension over it of some thickness of the higher beds. The same staining also shows (see p. 581) that the quartzite has been but little cut into by erosion since (probably in late Tertiary time — see Chapter 34) the cover of red beds was removed therefrom. In its present features, accordingly, it is likely that we see, not seriously modified, a little of the scenery of Devonian time. Graig-fryn (Figure 296) and the four adjacent small inliers appear to be the summits of lesser islands. On the floor of that ancient valley, therefore, the harder members of the Mona Complex rose into rugged hills at least 500 or 600 feet in height.

We shall see in Chapter 22 that there is good reason for believing the Mona Complex to have been far more extensively buried beneath Ordovician rocks in Carboniferous times than it is to-day; and, if so, then that Ordovician cover must have been even more extensive in the period of the Old Red Sandstone. Ordovician fragments are, accordingly, more plentiful in the Old Red than in the Carboniferous conglomerates. Yet, except at Dulas and Tregaian, the Old Red Series rests directly upon the Mona Complex. If, however, it were deposited in a long, deep hollow, this becomes intelligible. For such a hollow might well cut down through the relatively thin cover on the Ordovician anticlines, laying bare the Mona Complex all along its course, except over the deep infolds of Dulas and Llangwyllog. The higher beds of the formation may, even on the anticlines, have spread out on to Ordovician rocks.

Recapitulation

The Old Red Series of Anglesey must be assigned altogether to the Lower division of the Old Red Sandstone. It consists of red conglomerates, sandstones, mudstones, and cornstones, with some grey limestones, and has an aggregate thickness of more than 1,300 feet. Resting unconformably upon all the older systems, it is itself overlain unconformably by the Carboniferous rocks. Under the pressure of a third and final outbreak of the ancient southward impulse of the region, a rude cleavage has been induced, and some parts have been folded isoclinally, following upon which came an episode of minor thrusting. Finally, a large monoclinal fold was developed, on whose middle limb the cleavage was brought into a horizontal position. All these movements are of Pre-Carboniferous date. The formation seems to have been deposited in a long and rugged hollow, deepening and opening towards the north-east.



(Plate 12) Microphotographs of the Mona Complex. 1. Hornblende-Gneiss. 2. Sphene in Gneiss. 3. Sillimanite-Gneiss. 4. Diorite in Gneiss. 5. Sillimanite-Gneiss. See Appendix 3.

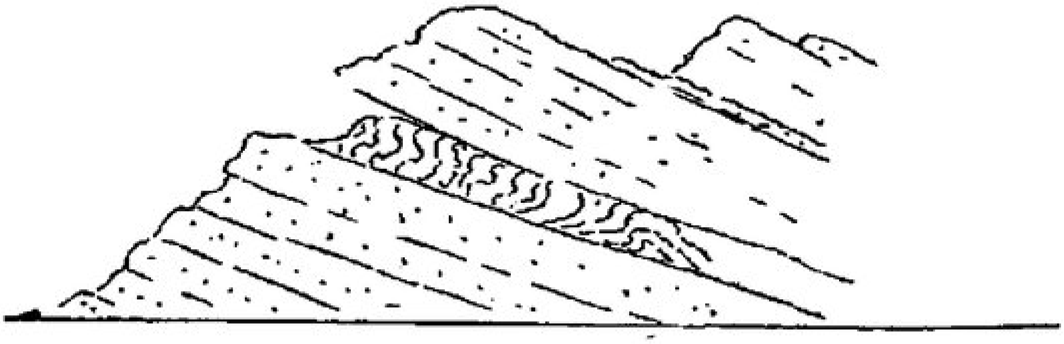


FIG. 281.—CONTEMPORANEOUS CONTORTION IN OLD RED SANDSTONE.

(Figure 281) Contemporaneous contortion in old red sandstone. Traeth-yr-ora.

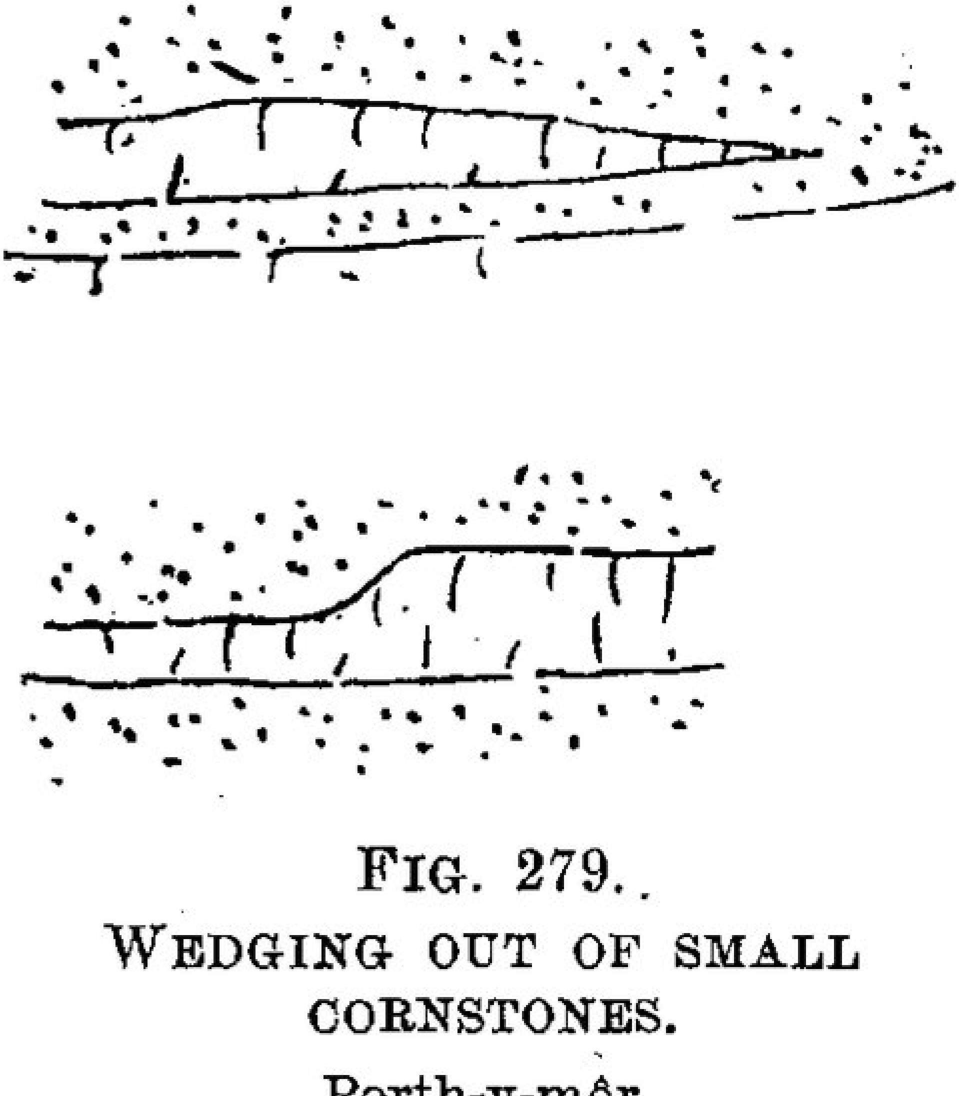


FIG. 279.

WEDGING OUT OF SMALL CORNSTONES.

Porth-y-môr.

(Figure 279) Wedging out of small cornstones. Porth-y-môr.

FIG. 275.—SECTION THROUGH THE OLD RED SERIES FROM COED-Y-GELL TO LLIGWY BAY.
Scale: eight inches = one mile.

M = Bodafon Moor Schists } Mona
MQ = Bodafon Quartzite } Complex.
b = Ordovician.

Symbols used in Figs. 275, 276, 277, 278.
c = Old Red Sandstone Series.
c' = " " Cornstones.
d = Lligwy Sandstone (Carboniferous).

d_2' = D_1 Subzone of Carboniferous Limestone.
d_2'' = D_2 " " "
BT = Bodafon Thrust-plane.

(Figure 275) Section through the Old Red Series from Coed-y-gell to Lligwy Bay. Scale: eight inches = one mile. Symbols used M = Bodafon Moor Schists, Mona Complex, Mq = Bodafon Quartzite, Mona Complex. b = Ordovician. c = Old Red Sandstone Series. c = cornstones d = Lligwy Sandstone d2■ = D1 Subzone of Carboniferous Limestone. d2■ D2 Subzone of Carboniferous Limestone. BT = Bodafon Thrust-plane.

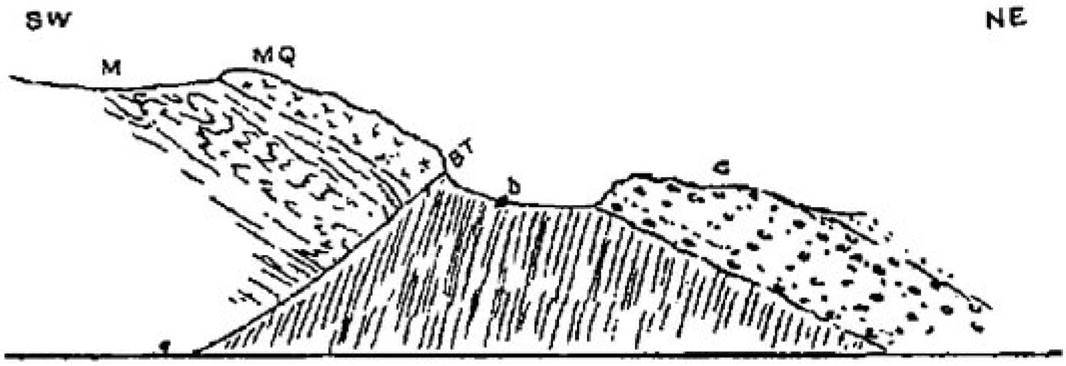


FIG. 278.—SECTION PARALLEL TO PART OF FIG. 276, ALONG A LINE 266 YARDS FURTHER TO THE WEST-NORTH-WEST.

(Figure 278) section parallel to part of (Figure 276), along a line 266 yards further to the west-north-west. Scale: 8 inches = 1 mile. Symbols used M = Bodafon Moor Schists, Mona Complex, Mq = Bodafon Quartzite, Mona Complex. b = Ordovician. c = Old Red Sandstone Series. c = cornstones d = Lligwy Sandstone d2■ = D1 Subzone of Carboniferous Limestone. d2■ D2 Subzone of Carboniferous Limestone. BT = Bodafon Thrust-plane.

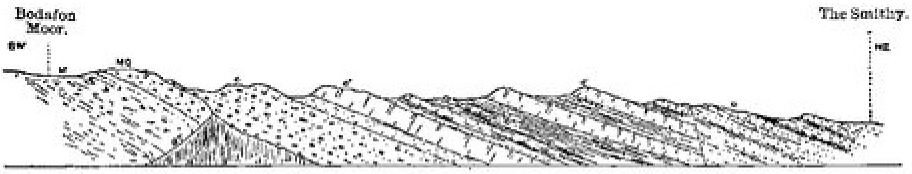


Fig. 276.—SECTION FROM THE NORTH END OF BODAFON MOOR, THROUGH THE OLD RED SERIES, TO THE SMITHY.
Scale: eight inches = one mile.

M = Bodafon Moor Schists } Mona
MQ = Bodafon Quartzite } Complex.
b = Ordovician.

Symbols used in Figs. 275, 276, 277, 278.
c = Old Red Sandstone Series.
c' = " " Cornstones.
d = Lligwy Sandstone (Carboniferous).

d_2' = D_1 Subzone of Carboniferous Limestone.
d_2'' = D_2 " " "
BT = Bodafon Thrust plane.

(Figure 276) Section from the north end of Bodafon Moor, through the Old Red Series, to the Smithy. Scale: eight inches = one mile. Symbols used M = Bodafon Moor Schists, Mona Complex, Mq = Bodafon Quartzite, Mona Complex. b = Ordovician. c = Old Red Sandstone Series. c = cornstones d = Lligwy Sandstone d2■ = D1 Subzone of Carboniferous Limestone. d2■ D2 Subzone of Carboniferous Limestone. BT = Bodafon Thrust-plane.

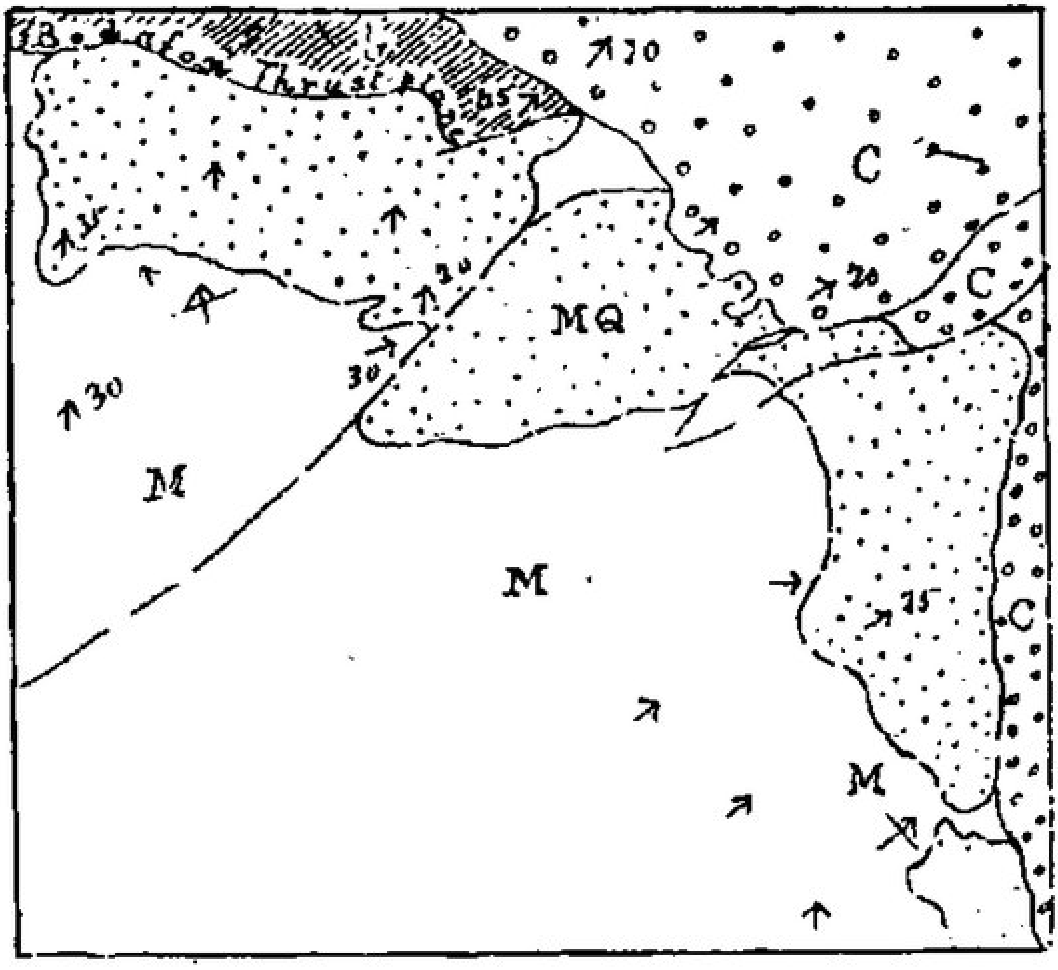


FIG. 154.

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. 277.—SECTION FROM THE NORTHERN SUMMIT OF MYNYDD BODAFON, ACROSS THE VALE OF LLIGWY.
Scale: 7·5 inches = one mile.
Symbols used in Figs. 275, 276, 277, 278.

M = Bodafon Moor Schists } Mona
MQ = Bodafon Quartzite } Complex.
b = Ordovician.

c = Old Red Sandstone Series.
c' = " " Cornstones.
d = Lligwy Sandstone (Carboniferous).

d_2' = D_1 Subzone of Carboniferous Limestone.
d_2'' = D_2 " " "
BT = Bodafon Thrust plane.

(Figure 277) Section from the northern summit of Mynydd Bodafon, across the Vale of Lligwy. Scale: 7.5 inches = one mile. Symbols used M = Bodafon Moor Schists, Mona Complex, Mq = Bodafon Quartzite, Mona Complex. b = Ordovician. c = Old Red Sandstone Series. c = cornstones d = Lligwy Sandstone d2■ = D1 Subzone of Carboniferous Limestone. d2■ D2 Subzone of Carboniferous Limestone. BT = Bodafon Thrust-plane.

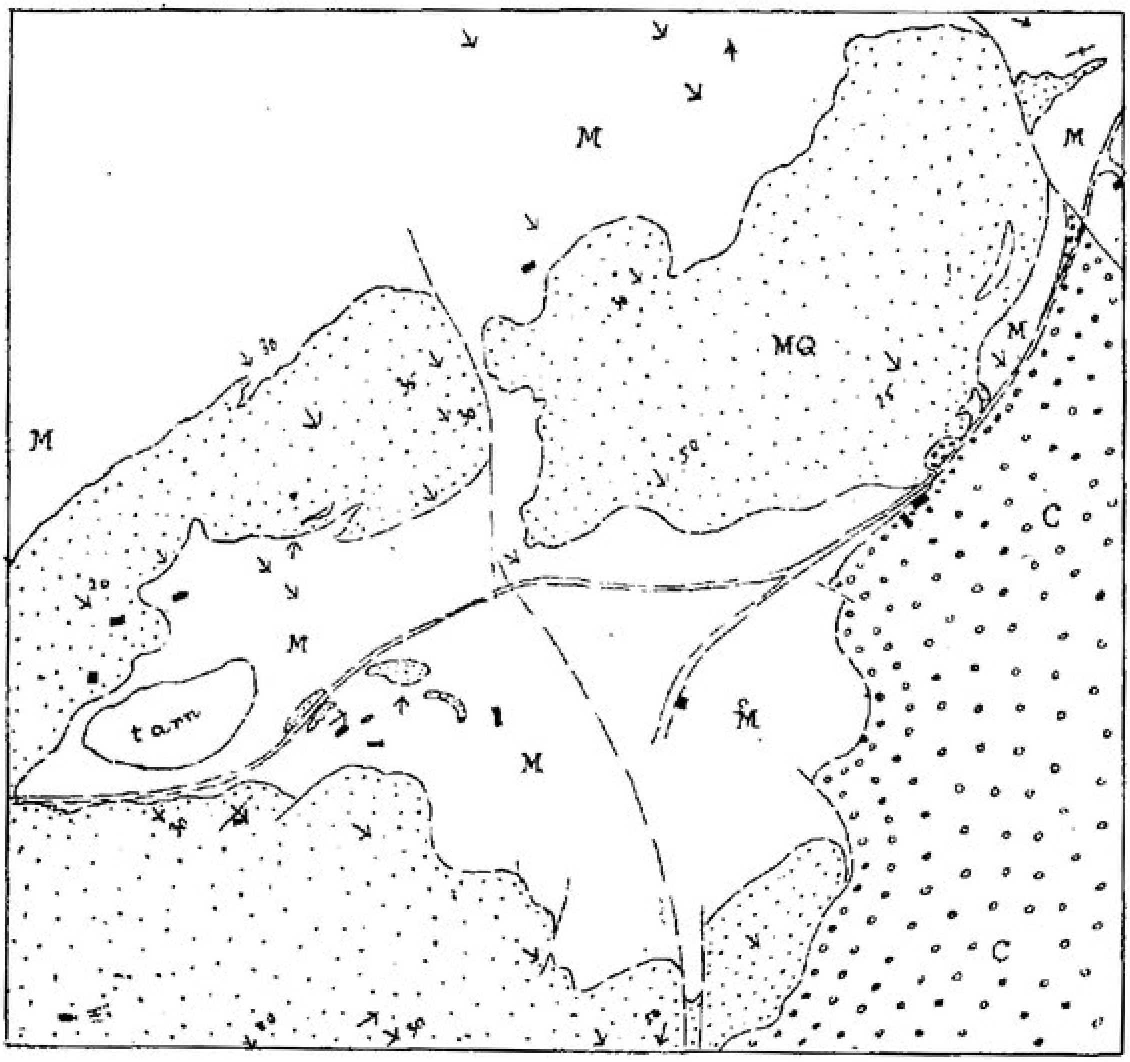


FIG. 155.—THE CENTRAL PARTS OF MYNYDD BODAFON.

(Figure 155) The central parts of Mynydd Bodafon. From the six-inch maps. M = Bodafon Moor Schists. MQ = Bodafon Quartzite. C = Old Red Sandstone.

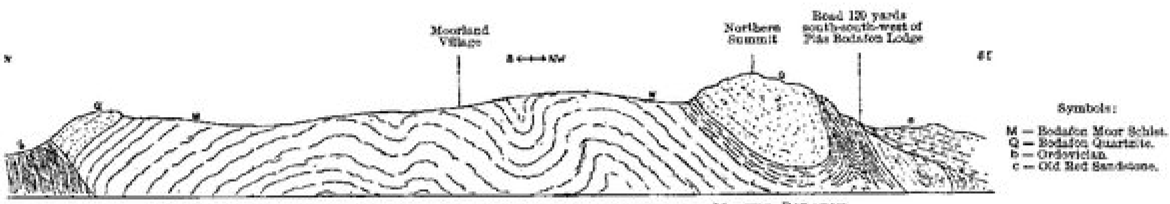


FIG. 156.—SECTION ACROSS BODAFON MOOR AND THE NORTHERN SUMMIT OF MYNYDD BODAFON.

(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.

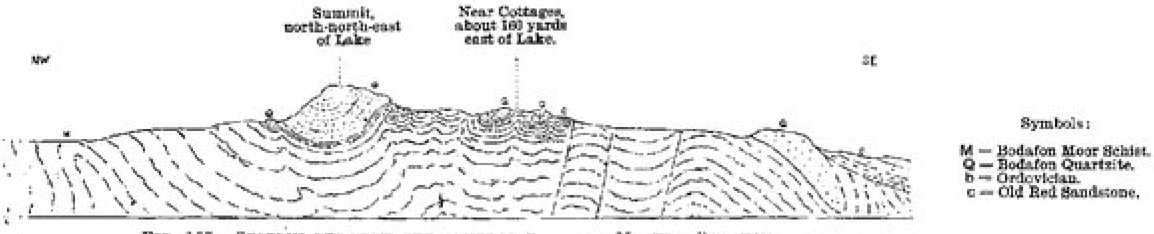
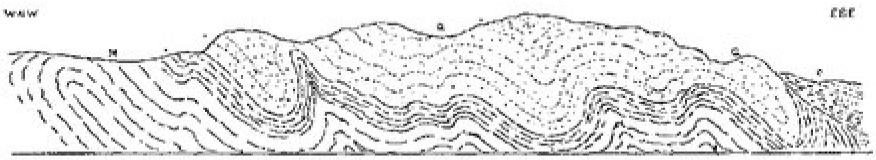


FIG. 157.—SECTION THROUGH THE CENTRAL PARTS OF MYNYDD BODAFON.

(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.



M = Bodafon Moor Schist.
Q = Bodafon Quartzite.
b = Ordovician.
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.

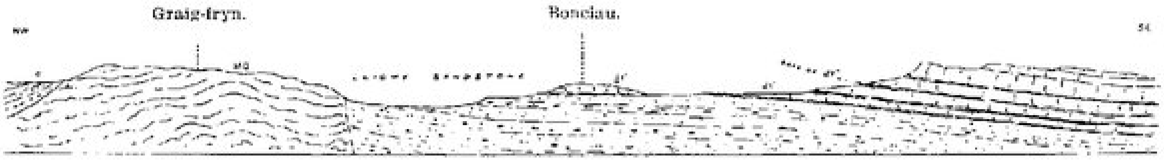


FIG. 296.—SECTION ACROSS THE GRAIG-FRYN INLIER AND THE VALE OF LLIGWY.
Scale—Eight inches = one mile.
MQ = Bodafon quartzite. C = Old Red Sandstone. d′₂, d″₂ = D₁ and D₂ sub-zones of Carboniferous Limestone

(Figure 296) Section across the Graig-fryn inlier and the vale of Lligwy. Scale eight inches = one mile. MQ = Bodafon Quartzite. C = Old Red Sandstone. d■2, d■2 = D1 and D2 sub-zones of Carboniferous Limestone

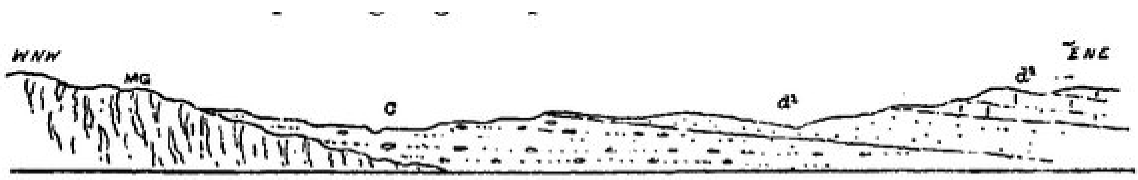


FIG. 280.—SECTION ABOUT A MILE NORTH-EAST OF LLANGEFNI.
Scale: 12 inches = one mile.
MG — Gwna Mélange. C = Old Red Sandstone.
d^2 = Lligwy Sandstone (Carboniferous).
d^2_4 = Carboniferous Limestone.

(Figure 280) Section about a mile north-east of Llangefni. Scale: 12 inches = one mile. MG = Gwna Mélange. C = Old Red Sandstone. d2 = Lligwy Sandstone (Carboniferous) d2 = Carboniferous Limestone.

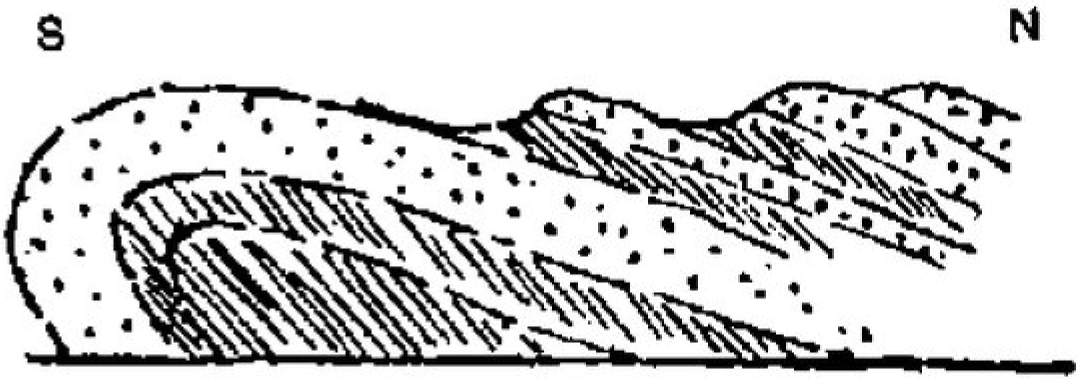


FIG. 282.

ISOCLINAL ANTICLINE IN OLD RED SANDSTONE.

(Figure 282) Isoclinal anticline in Old Red Sandstone. Lligwy Bay.

FIG. 283.

ISOCLINAL SYNCLINE IN OLD RED SANDSTONE.

(Figure 283) Isoclinal syncline in Old Red Sandstone. Lligwy Bay.

FIG. 284.—THRUSTING IN OLD RED SANDSTONE.

(Figure 284) Thrusting in old red sandstone. Lligwy Bay.

(Plate 34) Cleavage and bedding in Cornstones and Mudstones of the Old Red series. Porth-y-mor.

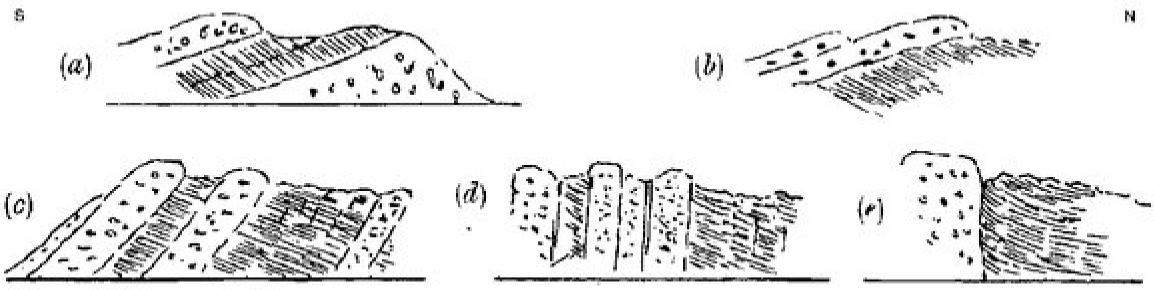


FIG. 285 (a—e).—THE TURNING OF THE CLEAVAGE ROUND THE MONOCLINAL FOLD IN THE OLD RED SERIES.
Coast between Porth-y-môr and Lligwy Bay.

(Figure 285) (a–e) The turning of the cleavage round the monoclinal fold in the Old Red Series. Coast between Porth-y-môr and Lligwy Bay.

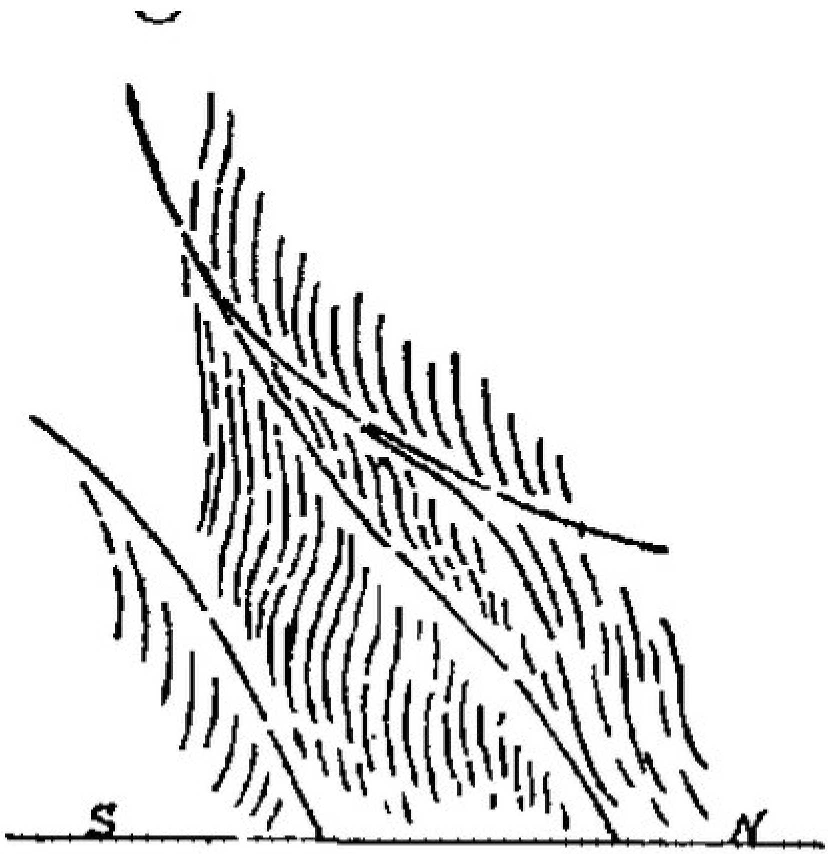


FIG. 267.

MINOR THRUSTS IN SHALE. PORTH Y GWICHIAID BEACH.

(Figure 267) Minor thrusts in shale. Porth y gwichiaid beach. Height about 10 feet.

FIG. 268.

HORIZONTAL THRUST IN SHALE. NORTH CLIFF OF PORTH Y GWICHIAID.

(Figure 268) Horizontal thrust in shale. North cliff of Porth y gwichiaid. Height: about 10 feet.

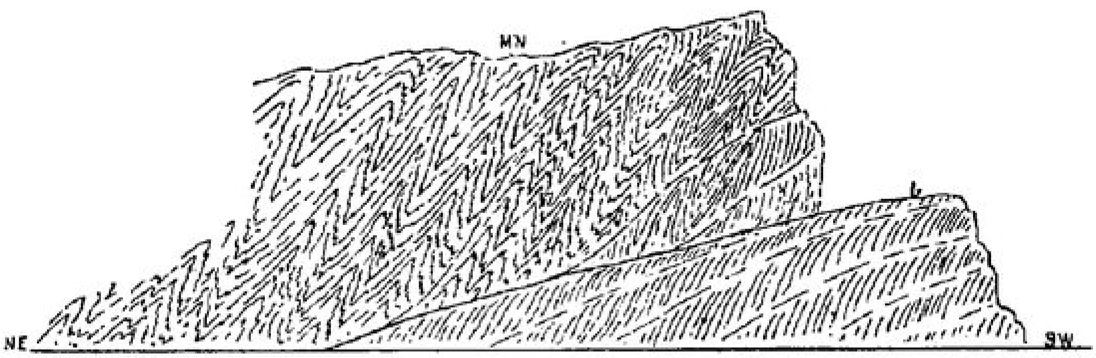


FIG. 270.—THE CARMEL HEAD THRUST-PLANE AT CARMEL HEAD.
MN = Amlwch Beds. b = Cleaved Ordovician Shale.

(Figure 270) The Carmel Head Thrust-plane at Carmel Head. MN = Amlwch Beds. b = Cleaved Ordovician Shale.

FIG. 271.

MINOR THRUSTS AT THE CARMEL HEAD THRUST-PLANE, CARMEL HEAD.

Depth: about one foot.

CHT = The Main Thrust.

(Figure 271) Minor thrusts at the Carmel Head Thrust-plane, Carmel Head. Depth: about one foot. ChT = The Main Thrust.