
Chapter 5 Detailed description of the Silurian region of the Southern Uplands

I. The Central Belt

Typical sections of the Moffat Black Shale Series

The typical sections of the Moffat series in Dobb's Linn and Craigmichan Scaurs selected by Professor Lapworth, and described by him in his paper on "The Moffat Series", illustrate the lithological and palaeontological sub-divisions of the different groups. The exposures of the two higher groups (Birkhill and Harden) in Dobb's Linn are complete, only a small development of Glenkiln Shales being there visible. This hiatus is, however, partly supplied by the section in Craigmichan Scaurs, where the members of the Glenkiln group are well displayed. Even there, however, the base of the latter group is not seen, their relations to the Arenig volcanic rocks not being clearly defined within the Moffat region.

Dobb's Linn, Moffatdale (Figure 5)

This famous section occurs at the head of Moffatdale [NT 19638 15662]; it is about ten miles from Moffat, five miles from St. Mary's Loch, and about half a mile from Birkhill Cottage on the watershed between Moffat valley and one of the tributaries of the Yarrow. At this spot, three streams unite to form the Moffat Water, two of them draining the eastern side of the valley, while the third (Dobb's Linn), flowing down the western slope, has cut a deep gorge through the black shale series.

Ascending the latter stream, which there runs parallel to the strike of the Silurian rocks, the observer finds a magnificent exposure of the black shale series rising along an anticlinal fold in the Tarannon greywackes and shales. About 350 yards up the stream it is joined by a small tributary, draining the high grounds to the west, which forms a conspicuous lateral gorge, traversing the black shales more or less at right angles to their strike. At the head of the lateral gorge there is a fine waterfall, where the stream leaps over the Tarannon greywackes and shales on to the softer beds of the Upper Birkhill group. Admirable exposures, too, occur in the corrie north of the lateral gorge, and particularly in the Main Cliff to the south of that gorge. On the 6-inch map, the name "Dobb's Linn" is applied to the main stream, though originally restricted to the waterfall at the head of the lateral gorge. The upper portion of the main stream is termed the Long Burn.

The members of the Moffat series, in the Dobb's Linn section, as Professor Lapworth has shown, are not arranged in a normal anticline. For example, towards the southern limit of the arch, the black shales and the Tarannon greywackes dip uniformly to the north of west as if there were an ascending sequence from east to west (Figure 6), Sec. 4 in ground-plan). Again, on the western limit of the fold, the Tarannon greywackes and shales at the waterfall dip east at high angles, below the Birkhill beds that are exposed in the lateral gorge, thus indicating an apparent upward succession from west to east ((Figure 7), Sec. 2 in ground-plan). It is obvious, therefore, that the strata along these two lines of section are partly inverted, and hence no reliance can be placed on mere superposition. Indeed, it is only by following the outcrops of the various sub-divisions of the series and determining their horizons by means of the graptolites that their physical relations can be satisfactorily established.

It is further observable that a prominent fault runs along the crest of the arch in a N.N.E. direction ((Figure 5), West Fault), forming an important structural line. For at the base of the Main Cliff, near the southern termination of the fold, it brings the Glenkiln black shales into contact with the Barren Mudstones ((Figure 8), Sec. 3 in (Figure 5)), while towards the north-east it places the Harden black shales in conjunction with the Lower Birkhill Shales ((Figure 9), Sec. 1 in (Figure 5)). A second dislocation (East Fault in ground plan, (Figure 5)) runs for a short distance along the west slope of the Long Burn. Another fault, of minor importance, however, occurs in the lateral gorge between the Barren Mudstones and Lower Birkhill Shales. Notwithstanding these dislocations the zones established by Professor Lapworth can be readily identified, and the graptolites can, in most cases, be obtained in excellent preservation.

Taking, first, the section in the lateral gorge, showing the strata in inverted order ((Figure 7), Sect?, in (Figure 5)), we find the flags and green shales at the waterfall dipping at angles from 70°–80° below the grey shales, with four thin black

seams belonging to the zone of *Rastrites maximus* (Carr). The latter form the highest fossiliferous zones of the Upper Birkhill beds in this section. The following fossils have there been obtained from this horizon ((Figure 7), 4m"):

Monograptus Sedgwicki (Portl.)

Monograptus turriculatus (Barr.)

Monograptus Hisingeri (Carr.)

Monograptus attenuatus (Hopk.)

Rastrites maximus (Carr.)

Petalograptus folium (His.)

Peltocaris aptychoides (Salt.)

Next in order come grey shales and clays yielding no fossils, succeeded by black and grey shales with white clays, forming the zone of *Monograptus spinigerus* (Nich.), containing the following fossils ((Figure 7), 4III'n):

Monograptus Sedgwicki (Portl.)

Monograptus = spinigerus (Nich.)

Monograptus attenuatus (Hopk.)

Monograptus Clingani (Carr.)

Monograptus Hisingeri (Carr.)

Monograptus spiralis (Geinitz.)

Monograptus leptotheca (Lapw.)

Rastrites hybridus (Lapw.)

Climacograptus normalis (Lapw.)

Petalograptus folium (His.)

Diplograptus tamariscus (Nich.)

Diplograptus Hughesi (Nich.)

Dicinocaris browniana (Woodw.)

Peltocaris aptychoides (Salt.)

Grey mudstones and clays with a thin seam of black shale are then met with, followed by pyritous black shales representing the zone of *Cephalograptus cometa* (Geinitz), yielding the fossils given below ((Figure 7), 4III'm)

Cephalograptus cometa (Geinitz.)

Monograptus lobiferus (M'Coy.)

Monograptus leptotheca (Lapw.)

Monograptus cyphus (Lapw.)

Monograptus argutus (Lapw.)

Monograptus Hisingeri (Carr.)

Monograptus tenuis (Portl.)

Rastrites hybridus (Lapw.)

Rastrites capillaris (Carr.)

Diplograptus tamariscus (Nich.)

Diplograptus sinuatus (Nich.)

Diplograptus Hughesi (Nich.)

Petalograptus folium (His.)

To the foregoing strata succeed black Baggy shales and mudstones with clays and occasional ironstone nodules, forming the upper members of the Lower Birkhill group. These beds are of considerable thickness and belong to the zone of *Monograptus gregarius* (Lapw.). From the exposure of this horizon in the main stream the following fossils were obtained ((Figure 7), III'1):

Monograptus gregarius (Lapw.)

Monograptus cyphus (Lapw.)

Monograptus Sandersoni (Lapw.)

Monograptus triangidatus (Hark.)

Monograptus leptotheca (Lapw.)

Monograptus lobiferus (M'Coy.)

Monograptus attenuatus (Hopk.)

Monograptus tenuis (Portl.)

Climacograptus innotatus (Nich.)

Climacograptus normalis (Lapw.)

Diplograptus (Dimorphograptus) confertus (Nich.)

Rastrites peregrinus (Barr.)

Petalograptus folium (His.)

Discinocaris browniana (Woodw.)

Dawsonia campanulata (Nich.)

The lower zones of the Birkhill black shales are not satisfactorily seen in the lateral gorge, owing to the presence of a small fault crossing that stream in a north and south direction; but in the corrie to the north they are well displayed, with

their characteristic fossils. The hard black flaggy shales representing the zone of *Diplograptus vesiculosus* (Nich.) there yielded the following forms ((Figure 9). 4III k):

Diplograptus vesiculosus (Nich.)

Diplograptus acuminatus (Nich.)

Dimorphograptus Swanstoni (Lapw.)

Climacograptus rectangularis (M'Coy.)

Monograptus attenuatus (Hopk.)

Monograptus tenuis (Portl.)

Monograptus gregarius (Hopk.)

Underlying the foregoing beds in the corrie are the shattery black and brown shales belonging to the horizon of *Diplograptus acuminatus* (Nich.), which have yielded also *Dimorphograptus Swanstoni* (Lapw.), *Climacograptus rectangularis* (M'Coy), *Datesonia campaniata*

The various zones just described constitute the Birkhill division of the Moffat black shale series. The lowest zone (*D. acuminatus*, Nich.), resting directly on the Barren Mudstones, forms the base line of the Llandovery formation.

Returning to the lateral gorge, we meet with the Barren Mudstones ((Figure 7), 3II') in conjunction with the lower members of the Birkhill group, but owing to the small fault already referred to the highest bands with *Dicellograptus anceps* (Nich.) are absent. They are found, however, in good exposures in the corrie north of the gorge and also in the Main Cliff, where the thin black seams in the mudstones have yielded *D. anceps* and *Climacograptus bicornis* (Hall). To these beds succeed the mass of pale-coloured mudstones, with occasional limestone nodules, which, near their base, include a thin seam of black shale containing *Dicellograptus complanatus*, *Diplograptus socialis*, *Climacograptus scalaris* ((Figure 7), 3II'h). Underneath the Barren Mudstones come black slaty shales with *Pleurograptus linearis* (Carr) — the highest zone of the Harden black shales ((Figure 7), 3IIg). This important horizon can be traced up the cliff to the north of the lateral gorge and along the Main Cliff to the south of that section. From these various exposures the following forms have been obtained:

Pleurograptus linearis (Carr.)

Amphigraptus divergens (Hall.)

Leptograptus capillaris (Carr.)

Leptograptus flaccidus (Hall.)

Retiolites (Neurograptus) fibratus (Lapw.)

Dicellograptus morrisi (Hopk.)

Dicellograptus elegans (Carr.)

Diplograptus foliaceus (March.)

Diplograptus quadrimucronatus (Hall.)

Climacograptus tubuliferus (Lapw.)

Siphonotreta micula (M'Coy.)

Next in order we find the black slaty shales of the *Dicranograptus Clingani* zone ((Figure 7), (Figure 8), (Figure 9), 31le) visible in the lateral gorge, in the cliff to the north and also in the Main Cliff, which have yielded the following forms:

Dicranograptus Clingani (Carr.)

Dicranograptus Nicholsoni (Hopk.)

Dicranograptus ramosus (Hall.)

Dicellograptus Forchhammeri (Geinitz.)

Dicellograptus caduceus (Lapw.)

Dicellograptus moffatensis (Carr.)

Amphigraptus radiatus (Lapw.)

Lasiograptus margaritatus (Lapw.)

Leptograptus flaccidus (Hall.)

Diplograptus truncatus (Lapw.)

Diplograptus foliaceus (Murch.)

Climacograptus bicornis (Hall.)

Climacograptus caudatus (Lapw.)

Corynoides calycularis (Nich.)

Hyalostelia fasticulus (M'Coy), glass-rope sponge.

Acrotreta Nicholsoni (Dav.)

The lowest zone of the Hartfell black shales (*Climacograptus Wilsoni*) is best seen on the slope at the foot of the Main Cliff-an exposure to be referred to presently. On the south bank of the lateral gorge, where it joins the main stream, there is a small rocky knoll at the edge of the alluvium, composed of black flinty shales with cherty bands resembling lithologically the Glenkiln Shales. The forms obtained from them include *Dicranograptus zic-zac* and *D. ramosus*. Here the main or west fault crosses the burn, on the east side of which the evidence is obscured by the alluvium. Eastwards along the section line No. 2 of (Figure 5) the observer crosses the east fault (Figure 7) and traverses the eastern limb of the arch, which there displays the *Monograptus gregarius* bands in a highly contorted form, and the various zones of the Upper Birkhill Shales, followed in normal order by the greywackes and shales of Tarannon age.

A section across the arch near the south end of the Main Cliff ((Figure 8), Sec. 3 in (Figure 5)) shows on the west limb a regular descending sequence from the Upper Birkhill zones to the Glenkiln black shales, with a normal dip to the W.N.W. Here the representatives of the Glenkiln Shales are met with; indeed, it is the only clear exposure of the latter division in the Dobb's Linn anticline. At the foot of the scar the *Climacograptus Wilsoni* band, the lowest zone of the Hartfell black shales, can be followed for several yards along its line of outcrop, where it yields fine examples of that zonal form, together with *Climacograptus bicornis*, *C. Schärenbergi*, *Diplograptus foliaceus*, *Glossograptus Hincksi*, *Cryptograptus tricornis*. This zone is underlain by nearly three feet of black shales, which, from their organic remains, may be regarded as the highest zone of the Glenkiln division. From this band the following forms were obtained:

Climacograptus bicornis (Hall.)

Climacograptus caelatus var. *antiquus* (Lapw.)

Dicranograptus zic-zac (Lapw.)

Dicellograptus sextans (Hall.)

Cryptograptus tricornis (Carr.)

The foregoing subdivision has been recognised in the sections at Craigmichan Scaurs and Hartfell, where it occupies a similar position, that is, immediately below the *C. Wilsoni* band, and above a zone of mudstones and cherts with radiolaria.

At the foot of the Main Cliff at Dobb's Linn, a zone of grey mudstones and cherts with radiolaria, four feet thick, appears below the highest sub-division of the Glenkiln Shales ((Figure 8), 2lc), and it there rests on a band of black shales eight feet in thickness, which have yielded the following forms characteristic of the Glenkiln division:

Dicranograptus zic-zac (Lapw.)

Dicranograptus formosus (Hopk.)

Dicranograptus ramosus (Hall.)

Dicranograptus Nicholsoni (Hopk.)

Dicranograptus sp.

Dicellograptus patulosus (Lapw.)

Dicellograptus divaricatus (Hall.)

Dicellograptus sextans (Hall.)

Dicellograptus sp.

Cryptograptus tricornis (Carr.)

Lasiograptus bimucronatus (Nich.)

Didymograptus serratulus (Hall.)

Clathrograptus cuneiformis (Lapw.)

Diplograptus foliaceus (Murch.)

Diplograptus euglyphus (Lapw.)

Diplograptus angustifolius (Hall.)

Diplograptus perexcavatus (Lapw.)

Climacograptus bicornis (Hall.)

Climacograptus caelatus var. *antiquus* (Lapw.)

Climacograptus Schärenbergi (Lapw.)

Climacograptus peltifer (Lapw.)

Corynoides calycularis (Nich.)

The Glenkiln black shales just described are truncated by the main or west fault, which brings them in contact with the Barren Mudstones ((Figure 8), 3II'), succeeded by the black shales of the Lower Birkhill group, with *Diplograptus vesiculosus* and *Monograptus gregarius* (4III). Eastwards they are followed by the clays and black shales of the Upper Birkhill group with their characteristic forms (4III', 4III''), though, owing to the weathering of the *beds* on the east cliff, the fossils are not so readily obtained. These pass normally upwards into the greywackes and shales of Tarannon age.

The Long Burn (Figure 5) shows an excellent section of the members of the Birkhill division. At its northern limit the black flags of the *D. resticulosus* zone are exposed; bounded on the east side by the *M. gregarius* bands, which are inverted. Down stream, the beds belonging to the latter horizon are always succeeded on the east side by the Upper Birkhill Shales: the higher zones appearing at intervals underneath the greywackes and shales of Tarannon age. On the west bank of the Long Burn a thin lenticular band of black grit is intercalated in the *Monograptus gregarius* zone. which is traceable for some distance along the cliff. Apparently it dies out rapidly, for it has not been detected on this horizon in any other part of the Dobb's Linn anticline.

On referring to Section 1 of the ground-plan (Figure 5) and (Figure 9), which shows the relations of the strata in the lower part of the Long Burn and in the corrie to the north of the lateral gorge, it will be seen that on the west limb of the fold there is a descending section, in inverted order, from the Tarannon greywackes and shales, through the various zones of the Birkhill division and the Barren Mudstones to the Hartfell black shales. Here the main fault in the core of the arch appears, which truncates the Hartfell Shales (3II) and brings in to the east, in normal order, the three zones of the Lower Birkhill group (4III in section). Between the main fault and the Long Burn the structure along this line of section is interesting, for the Barren Mudstones (3II') with the *Dicellograptus anceps* band come to the surface evidently along a minor fold in the Birkhill Shales, on the rocky slope on the west bank of the Long Burn. At the northern limit of this exposure of Barren Mudstones the *D. acuminatus* and *D. vesiculosus* bands can be traced round the end of the fold (Figure 5) till they are abruptly cut off by the east fault, which for a short distance runs parallel to the course of the main or west fault.

Passing eastwards along the same line of section, across the Long Burn, where the *Monograptus gregarius* bands are puckered and inverted, the observer finds the Upper Birkhill shales (4III' 4III''), (Figure 9)) followed in normal order by the greywackes and shales of Tarannon age.

The north-easterly extension of Dobb's Linn anticline is obscured by peat and drift, but it probably terminates not far to the north of the present visible exposure of black shales.

Summary. — From the foregoing descriptions it will be seen that a detailed examination of Dobb's Linn section proves the accuracy of Professor Lapworth's conclusions regarding the sequence and geological relations of the strata. The various subdivisions of the Moffat series (Birkhill, Hartfell, and Glenkiln), which are lithologically and palaeontologically distinct, are there arranged in the form of an arch, the highest zones of the Birkhill Shales being in contact with the overlying Tarannon greywackes and shales on both limbs of the fold. As the observer passes towards the centre of the anticline, the different zones are met with in descending order, till on the Western limb at the foot of the Main Cliff there is an exposure of the Glenkiln Shales with an intercalated band of radiolarian cherts and mudstones. The natural sequence is, however, interrupted by the main or west fault running along the crest of the arch, which brings different horizons in contact with each other. It is further clear that at the southern limit of the arch ((Figure 6), Sec. 4 in (Figure 5)) the axial plane of the fold dips towards the west, and hence the strata on the east limb are inverted; while in the lateral gorge (Figure 7) the strata on the west limb are inverted.

It is of importance, also, to note that the lowest zone of the Birkhill Shales marks the base of the Upper Silurian rocks of the region, and that while this boundary line coincides with a distinct palaeontological break, there is nevertheless a perfect passage from the underlying Hartfell group (Caradoc) into the overlying Birkhill sediments (Llandovery).

The order of succession indicated in Dobb's Linn is confirmed in a remarkable manner by the fine section in Craigmichan Scaurs [NT 16237 06083], which is traceable along the strike for three-quarters of a mile (Figure 10). In addition to the Birkhill and Hartfell divisions, there is here an excellent exposure of the Glenkiln black shales and the associated mudstones and cherts. The Craigmichan Scaurs occur on the south-east flank of Capel Fell (2223 feet) at the head of the Selcoth Burn, which joins the Moffat Water about seven miles south-west of Dobb's Linn. Though the strata are considerably shattered, and in some instances repeated by reversed faults, the general order of succession can be clearly followed.

On referring to the geological map of the region (Sheet 16) it will be seen that about two miles up the Selcoth Burn from its point of junction with the Moffat Water there is a marked bend in its course. Below this bend it flows northwest towards the Moffat Water; above it, for nearly half a mile, its course is about south-west and north-east, or nearly parallel to the strike of the strata. About half a mile above this bend, the Selcoth Burn is joined by a small tributary (the Rae Grain, (Figure 11), ground plan) draining the south-east slope of Capel Fell. Between the Rae Grain and the great bend in the Selcoth Burn, a deep and rough gorge has been carved in the Moffat series, the members of which form a prominent escarpment on the north-west side of the stream.

In the Selcoth Burn and on the slopes of Capel Fell, the representatives of the black shale series appear along several isoclinal folds dipping to the north-west.. The main fold occurs furthest south, its axis nearly coinciding with the course of the stream between the Rae Grain and the great bend in the Selcoth Burn. The physical relations of the strata, so clearly unfolded by Professor Lapworth, may be readily grasped by a study of the various sub-divisions exposed in this great isocline. The lowest beds forming the core of the arch occur in the bed of the Selcoth Burn and along the base of Craigmichan Scaurs, north-eastwards to the foot of the Rae Grain. The relations of the Glenkiln group to the overlying Hartfell division in Craigmichan Scaurs are illustrated by the accompanying horizontal section (Figure 10), which is drawn across the gorge above the waterfall in Selcoth Burn.

Beginning on the north cliff, on the horizon of the *Climacograptus Wilsoni* band (3II) at the base of the Lower Hartfell group, we find beneath that band about 2½ feet of black shales which here yield forms similar to those in the thin black shale zone at the top of the Glenkiln group) in the Dobb's Linn section. They likewise rest on a prominent mass of mudstones and cherts with radiolaria, the thickness of which cannot be safely estimated owing to the presence of faults. They present the following lithological characters in descending order:

1. Alternations of grey cherty ribs and mudstones
2. Zone of blue-grey mudstones weathering yellow
3. Grey ribbed cherts with radiolaria
4. Yellow, spotted, ashy band, resembling a fine volcanic tuff

The foregoing succession of cherts and mudstones is apparently much thicker than the corresponding zone in the Dobb's Linn section, but it here rests on a similar mass of black shales with characteristic Glenkiln fossils, which with the mudstones and cherts is repeated by minor folds (Figure 10). The following assemblage of forms was obtained from these exposures:

Caenograptus pertenuis (Lapw.)

Thamnograptus typus (Hall.)

Dicranograptus zic-zac (Lapw.)

Dicranograptus minimus Gall.

Dicranograptus ramosus (Hall.)

Diplograptus angustifolius (Hall.)

Climacograptus peltifer (Lapw.)

Dicellograptus patulus (Lapw.)

Diplograptus foliaceus (Murch.)

The members of the Glenkiln group are succeeded on both sides of the gorge by the Lower Hartfell black shales. As the observer descends the Selcoth Burn from the Rae Grain, towards the bend in the former stream, he finds that the Glenkiln Shales disappear and pass underneath the overlying zones. The succession however, is not undisturbed, for there seems to be a reversed fault truncating the strata along this part of the stream course — a structural feature to be referred to presently (Figure 10), (Figure 11), and (Figure 12).

On the north limb of the fold, on Craigmichan Scaurs, the following forms have been obtained from the *Climacograptus Wilsoni* zone, at the base of the Hartfell group:

Climacograptus Wilsoni (Lapw.)

Climacograptus bicornis (Hall.)

Dicranograptus ramosus (Hall.)

Glossograptus Hincksi (Hopk.)

Diplograptus foliaceus (Murch.)

Corynoides calycularis (Nich.)

Next in order come the black flaggy shales of the *Dicranograptus Clingani* zone, containing the following assemblage of fossils:

Leptograptus flaccidus (Hall.)

Dicranograptus ramosus (Hall.)

Dicranograptus Nicholsoni (Hopk.)

Dicellograptus Forchhammeri (Geinitz.)

Dicellograptus moffatensis (Carr.)

Diplograptus foliaceus (Murch.)

Climacograptus bicornis (Hall.)

Climacograptus caudatus (Lapw.)

Retiolites (Neurograptus) fibratus (Lapw.)

Corynoides calycularis (Nich.)

To these beds succeed the black slaty shales that form the highest zone of the Lower Hartfell group, yielding the characteristic forms:

Pleurograptus linearis (Carr.)

Leptograptus flaccidus (Hall.)

Dicellograptus Morrisi (Hopk.)

Dicellograptus elegans (Carr.)

Climacograptus tubuliferus (Lapw.)

Diplograptus quadrimucronatus (Hall.)

Overlying these fossiliferous zones comes a fine development of the Barren Mudstones, which can be traced from the bend in the Selcoth Burn along the north-west limb of the anticline for half a mile. Owing to their peculiar mode of weathering, their outcrop can readily be followed along this magnificent crag, where they are overlain by the members of the Birkhill group. When the Hartfell black shales and the Barren Mudstones are followed along the strike south-westwards along Craigmichan Scaurs to the great bend in the Selcoth Burn, they are there seen to be truncated by a reversed fault which is probably the continuation of that at the foot of the Rae Grain. A few yards north of the bend this dislocation is succeeded by several small reversed faults trending towards the north-west, which repeat slices of the Hartfell black shales and the overlying Barren Mudstones ((Figure 13), 3II 3III■).

Next in order, above the Barren Mudstones, come the members of the Birkhill group, which are exposed on both sides of the arch. On the south limb of the main isocline, near the bend in the Selcoth Burn, the black flaggy shales of the lower division yielded specimens of *Diplograptus vesiculosus* (Nich.), *Climacograptus innotatus* (Nich.), *C. normalis* (Lapw.), *Monograptus tenuis* (Portl.); while the overlying sub-zone there furnished *Monograptus gregarius* (Lapw.), *M. lobiferus* (M'Coy), *M. triangulatus* (Hark.), *M. spiralis* (Geinitz), *Climacograptus normalis* (Lapw.).

The greywackes and shales of Tarannon age are found in regular order above the highest zone of the Birkhill Shales in Craigmichan Scaurs, and also on the south-east limb of the anticline. High up on the slope of Capel Fell and along the great crag of Craigmichan Scaurs, a second isoclinal fold of no great breadth can be traced, revealing only the Birkhill Shales.

The evidence regarding the relations of the Moffat series to the overlying greywackes and shales obtained from the section in Rae Grain still further confirms the foregoing order of succession (Figure 11) and (Figure 12). The axis of the great isoclinal fold on Craigmichan Scaurs is prolonged north-eastwards to the foot of the Rae Grain, where the Glenkiln black shales and the associated mudstones and cherts with radiolaria are exposed (2, 2I in section, (Figure 12)). On the south side they are truncated by a reversed fault, whereby they are made to overlie the Lower Hartfell black shales on the south limb of the fold (3II) Northwards in the Rae Grain the members of the Glenkiln group are overlain by folded and crumpled slaty black shales with characteristic Lower Hartfell forms (3II, (Figure 12)), followed by an exposure of decomposing brown and grey shales and mudstones representing the Barren Mudstones. Next in order come the black flaggy shales charged with *D. vesiculosus* (4III, (Figure 12)) succeeded by the Upper Birkhill zones, which plunge underneath the greywackes and shales of Tarannon age. On retelling to the ground-plan (Figure 11), it will be seen how the latter are thrown into sharp synclinal folds to the north-west of the main isocline, being there underlain by the *liastrites maximus* zone of the Upper Birkhill Shales. It is evident, therefore, that no great thickness of Tarannon greywackes and shales intervenes between the successive isoclines of the black shale series in Craigmichan Scaurs and Capel Fell.

Turning now to the south limb of the fold at the foot of Rae Grain (Figure 12), we notice that the Lower Hartfell black shales, which are there much shattered and contorted, are succeeded by the Barren Mudstones. Next in order come the members of the Birkhill division (4III, 4III■) with an inverted dip to the north-west, followed by the Tarannon greywackes and shales.

One of the striking features in the section in the Selcoth Burn below the great bend is the repetition of the Birkhill Shales by a succession of sharp isoclinal folds in the midst of the Tarannon greywackes and shales, which have been figured and described by Professor Lapworth in his paper on "The Moffat Series".<ref>Quart. Jour. Cool. Soc., Vol. xxxiv., p. 261.</ref> The accompanying ground plan and series of horizontal sections (Figure 13) illustrate the relations of the strata. Here there are six isoclinal folds, each dipping to the north-west, revealing some of the Birkhill zones amid the overlying flags and shales. The south-east limb of each arch is truncated by a reversed fault whereby different zones of the Birkhill Shales are made to overlie the Tarannon flags and shales. The most northerly isocline occurs about 600 yards down stream from the great bend in the Selcoth Burn (Section 1, (Figure 13)), where on the north side of the arch

about 24 feet of stained shales appear, which are streaked with white clays and dark seams, the latter being charged with *Rastrites maximus*. These are underlain by lower zones of the Upper Birkhill division, which are abruptly truncated by a reversed fault. In Sections 3 and 4 (Figure 13) the Lower Birkhill Shales are likewise represented in the centre of the isoclines, many forms characteristic of the *Monograptus gregarius* and *Diplograptus vesiculosus* zones being here obtainable. Indeed the horizons of the various bands in the successive anticlines can be readily determined by the included fossils, though in some instances the individual zones are thrust against each other. The following forms have been obtained from the black seams associated with white clays belonging to the *M. spinigerus* zone of the Upper Birkhill division in one of Apse isoclinal folds:

Monograptus spinigerus (Nich.)

Monograptus Hisingeri (Carr.)

Monograptus jaculum (Lapw.)

Monograptus Sandersoni (Lapw.)

Monograptus leptotheca (Lapw.)

Monograptus tenuis (Portl.)

Monograptus Clingani (Carr.)

Diplograptus sinuatus (Nich.)

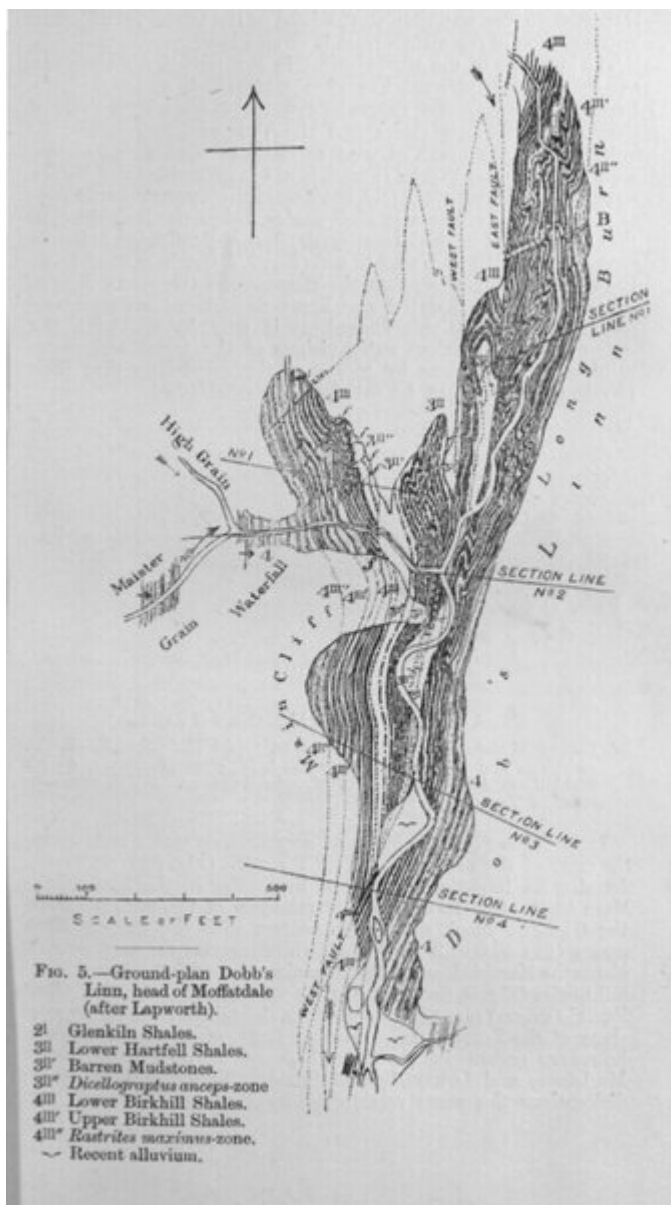
Diplograptus tamariscus (Nich.)

Petalograptus folium (His.)

Peltocaris aptychoides (Salt.)

In describing these isoclines, Professor Lapworth called attention to the fact that the angle of inversion of the axial planes "decreases in proportion as we pass outwards from the chief anticlinal line", or, in other words, as we descend the stream towards the northmost fold.

From the evidence supplied by the great anticlinal fold in Selcoth Burn and Craigmichan Scaurs, it is clear that the sequence of the Moffat series described in the foregoing paragraphs is placed beyond dispute. The distinctive lithological and palaeontological features, so apparent in Dobb's Linn, are no less marked in the sections just described. As yet there is no indication of any change in the physical conditions which mark certain zones to the north-west and south-east of the typical Moffat area.



(Figure 5) Ground-plan Dobb's Linn, head of Moffatdale (after Lapworth). 2I Glenkiln Shales. 3II Lower Hartfell Shales. 3II' Barren Mudstones. 3II'' *Dicellograptus anceps*-zone 4III Lower Birkhill Shales. 4III' Upper Birkhill Shales. 4III'' *Rastrites maximus*-zone. [Alluvium symbol] Recent alluvium.

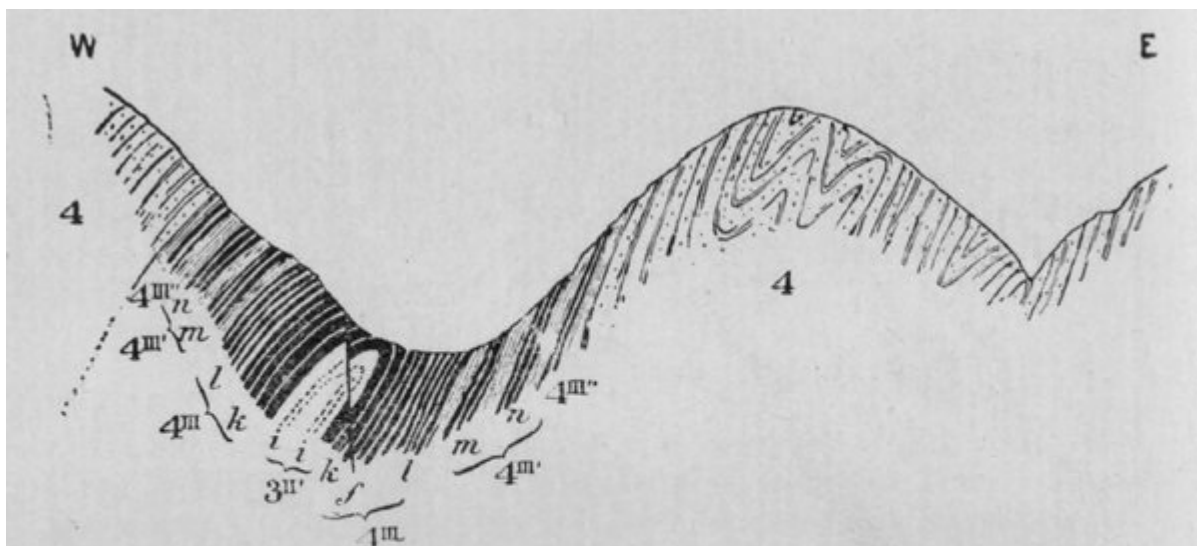


FIG. 6.—Section in Dobb's Linn (No. 4 of Fig. 5).

3II' Barren Mudstones—i. *D. anceps*-zone. 4III L. Birkhill—k. *D. vesiculosus* and *D. acuminatus* zones—l. *M. gregarius*-zone. 4III' U. Birkhill—m. *D. cometa*-zone—n. *M. spinigerus*-zone. 4III'' *R. maximus*-zone. 4 Tarannon.

(Figure 6) Section in Dobb's Linn (No. 4 of (Figure 5)). 3II' Barren Mudstones—i. *D. anceps*-zone. 4III Lower Birkhill k. *D. vesiculosus* and *D. acuminatus* zones 1. *M. gregarius*-zone. 4III' Upper Birkhill—m. *D. cometa*-zone n. *M. spinigerus*-zone. 4III'' *B. maximus*-zone. 4 Tarannon.

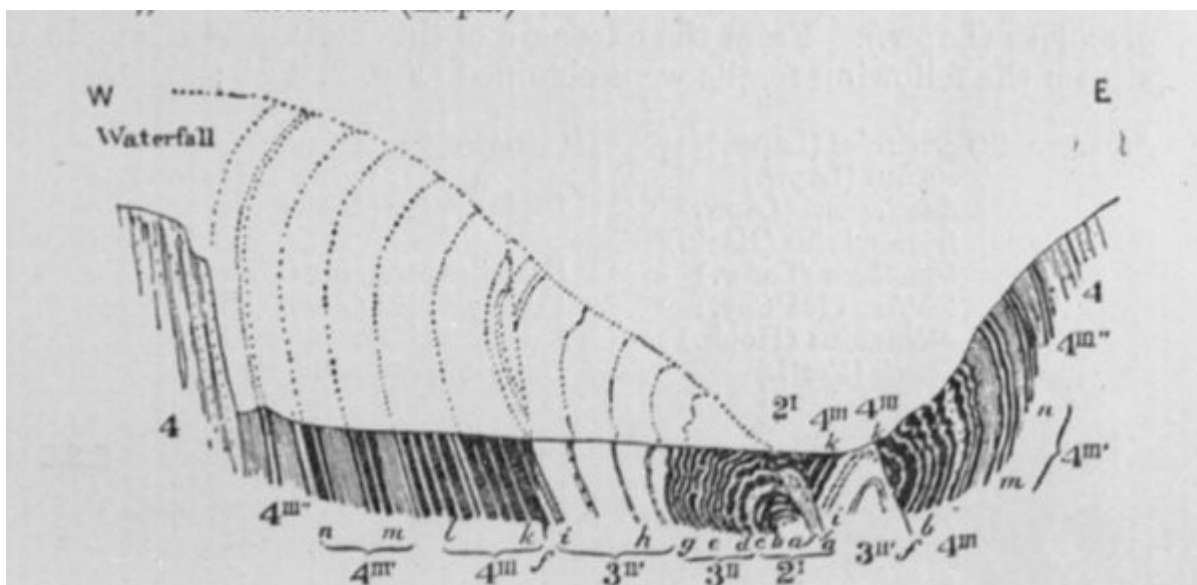
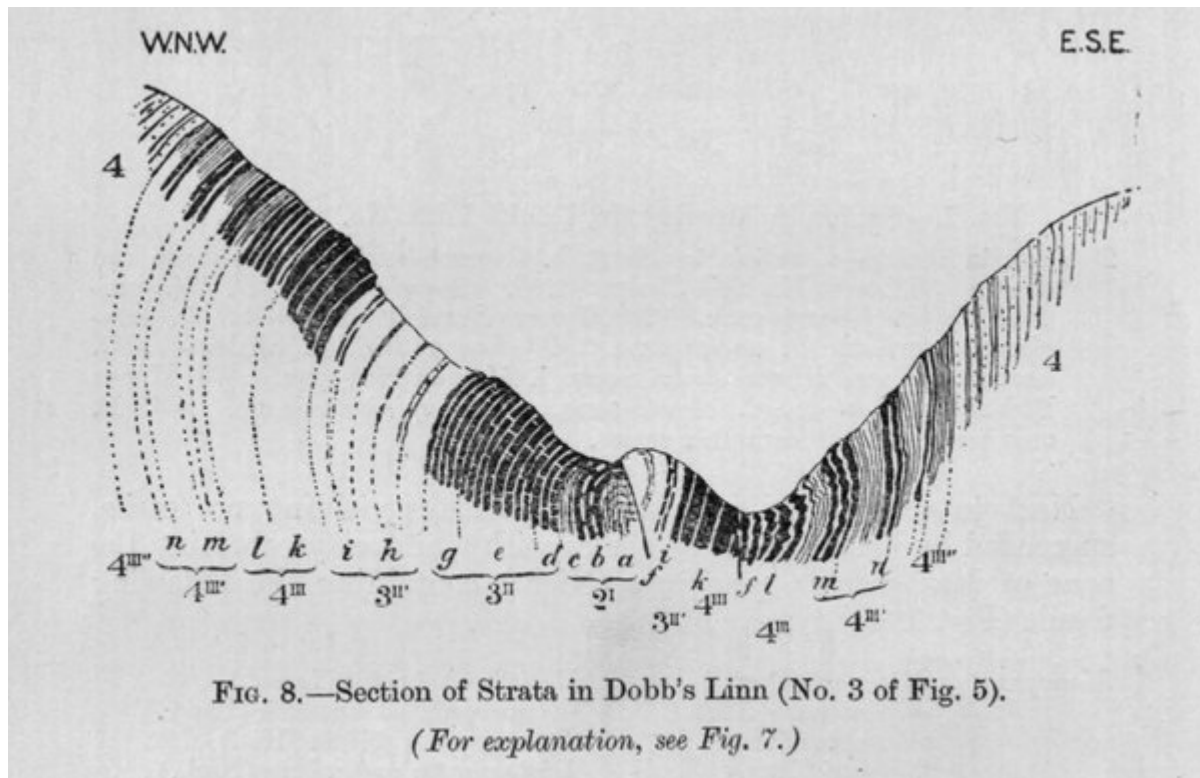


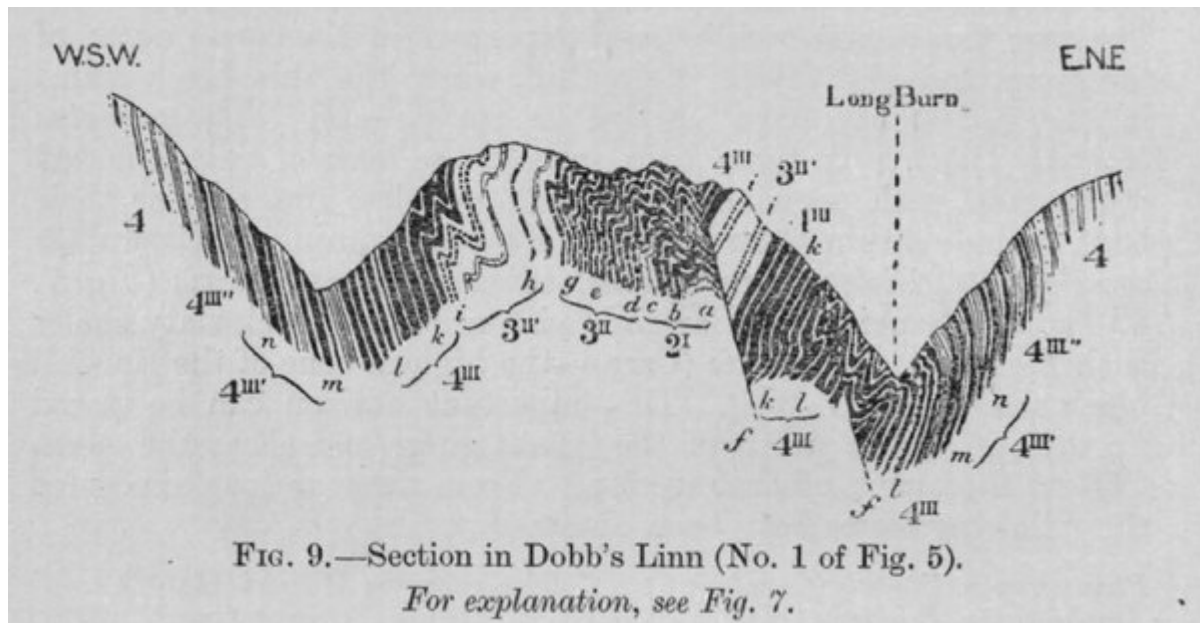
FIG. 7.—Section in lateral gorge, Dobb's Linn (No. 2 of Fig. 5).

2I Glenkiln Shales—a. radiolarian chert, b. *C. gracilis*-zone, c. mudstone and chert. 3II Lower Hartfell Shales—d. *C. Wilsoni*-zone, e. *D. Clingani*-zone, g. *P. linearis*-zone. 3II' Upper Hartfell Shales—h. *D. complanatus*-zone, i. *D. anceps*-zone. 4III Lower Birkhill Shales—k. *D. acuminatus* and *D. vesiculosus* zones, l. *M. gregarius*-zone. 4III' Upper Birkhill Shales—m. *C. cometa*-zone, n. *M. spinigerus*-zone. 4III'' *R. maximus*-zone. 4 Tarannon series. f. Faults.

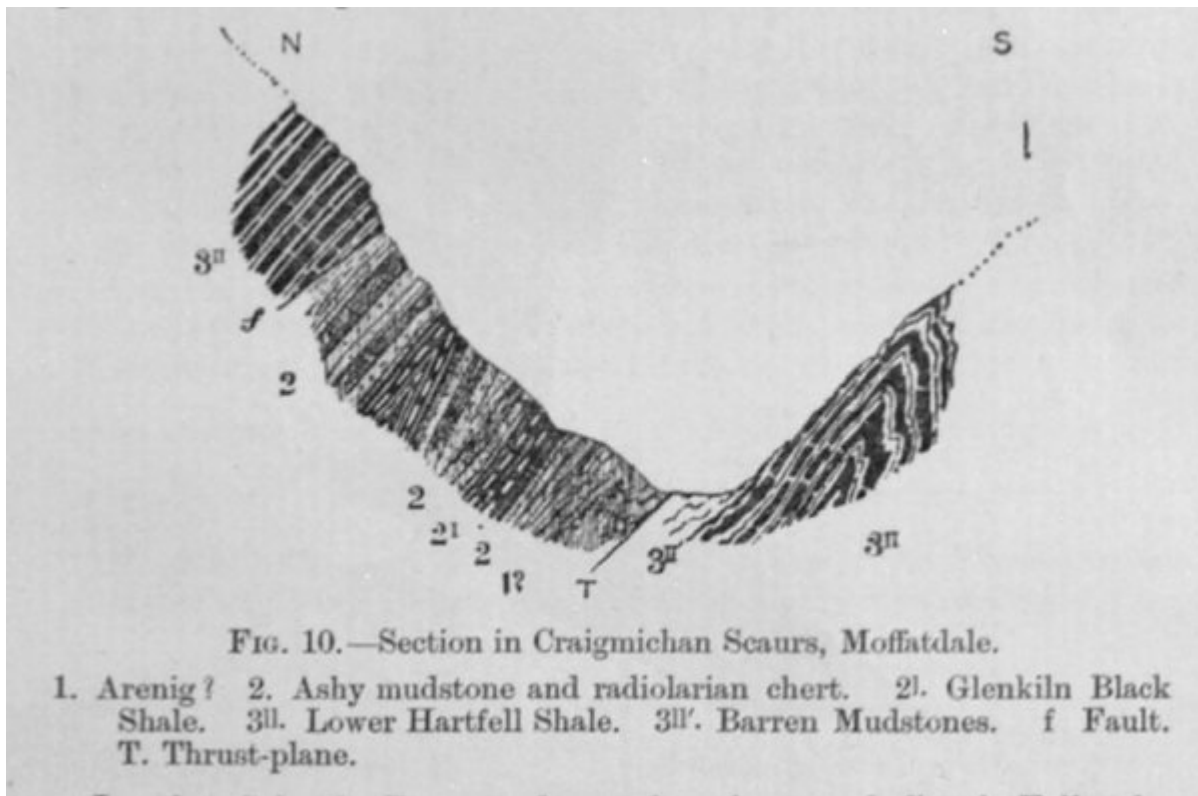
(Figure 7) Section in lateral gorge, Dobb's Linn (No. 2 of (Figure 15)). 2I Glenkiln Shales a. radiolarian chert, b. *C. gracilis*-zone, c. mudstone and chert. 3II Lower Hartfell Shales d. a *Wilsoni*-zone, e. *D. Clingani*-zone, g. *P. linearis*-zone. 3II' Upper Harden Shales h. *D. complanatus*-zone, i. *D. anceps*-zone. 4III Lower Birkhill Shales k. *D. acuminatus* and *D. vesiculosus* zones, 1. *M. gregarius*-zone. 4III' Upper Birkhill Shales m. *C. cometa*-zone, n. *M. spinigerus*-zone. 4III'' *R.*



(Figure 8) Section of Strata in Dobb's Linn (No. 3 of (Figure 5)). (For explanation, see (Figure 7))



(Figure 9) Section in Dobb's Linn (No. 1 of (Figure 5)). For explanation, see (Figure 7).



(Figure 10) Section in Craiginichan Scaurs, Moffatdale. 1. Arenig ? 2. Ashy mudstone and radiolarian chert. 2l. Glenkiln Black Shale. 3ll. Lower Hartfell Shale. 3ll'. Barren Mudstones. f Fault. T. Thrust-plane.

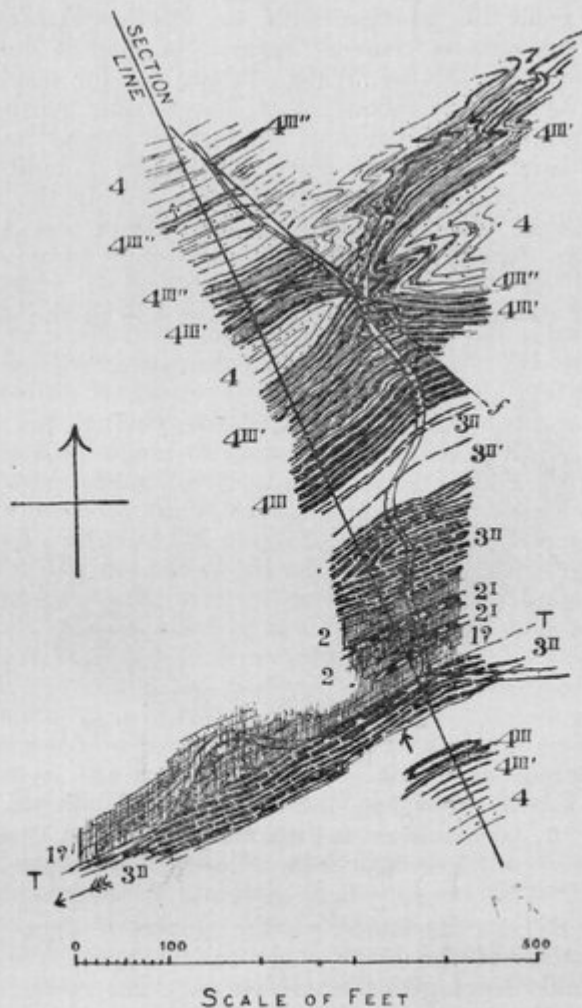
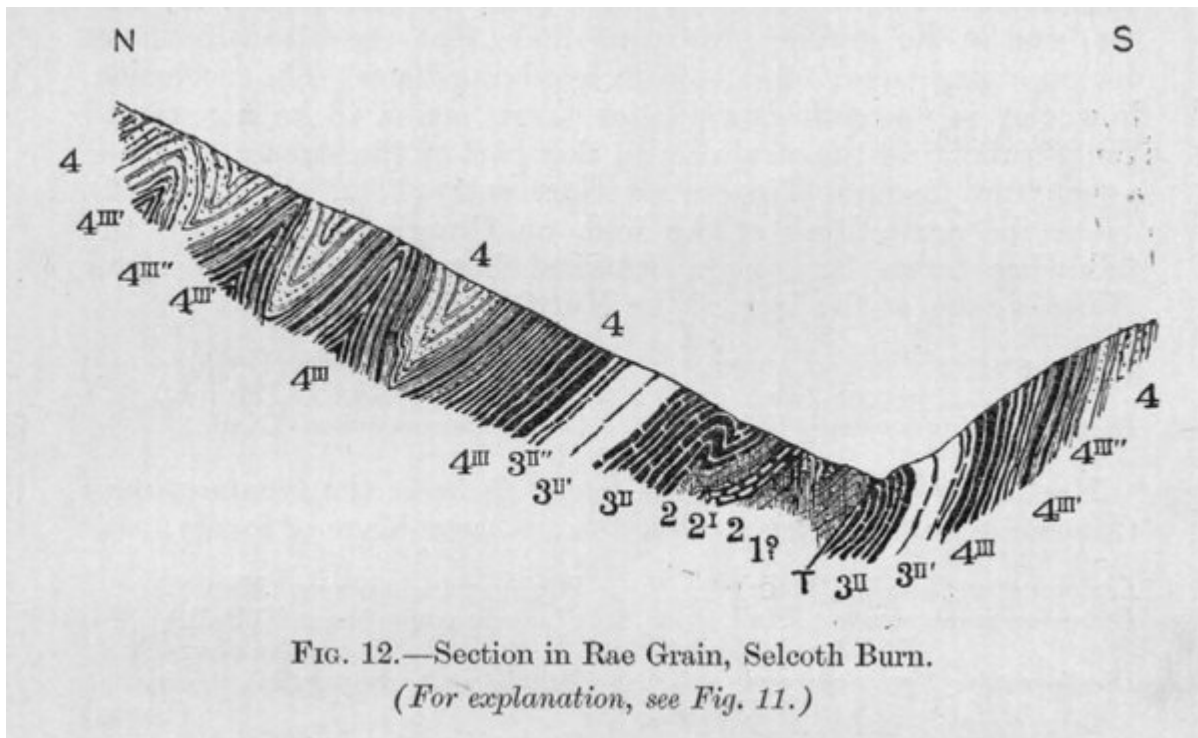


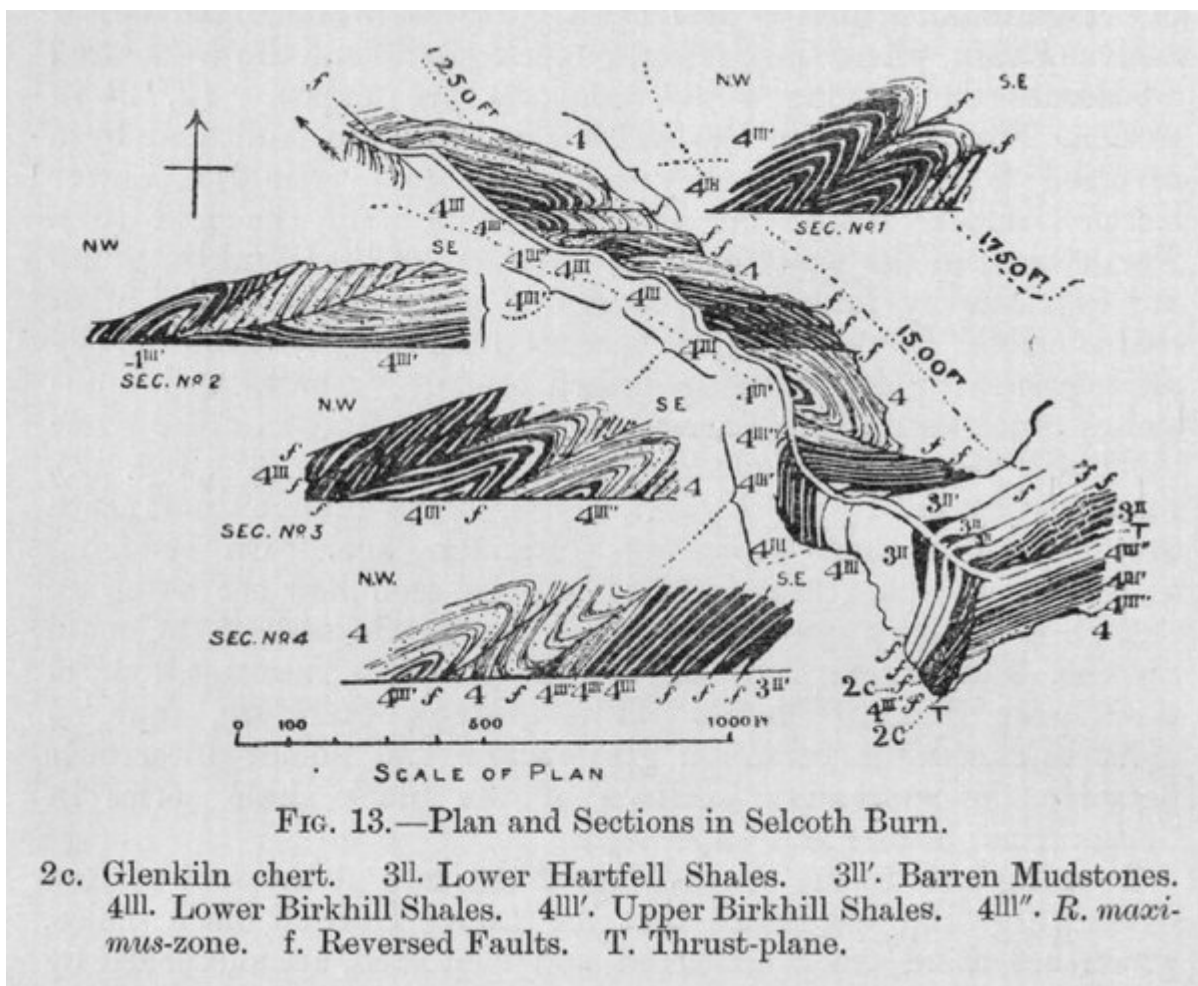
FIG. 11.—Plan of Strata in Rae Grain, Selcoth Burn.

Arenig ? 2. Ashy mudstone and chert. 2l. Glenkiln Shales. 3ll. Lower Hartfell Shales. 3ll'. Barren Mudstones. 3ll''. *D. anceps*-zone. 4lll. Lower Birkhill Shales. 4lll'. Upper Birkhill Shales. 4lll''. *R. maximus*-zone. 4. Tarannon series. f. Fault. T. Thrust-lane.

(Figure 11) Plan of Strata in Rae Grain, Selcoth Burn. 1. Arenig ? 2. Ashy mudstone and chert. 2l. Glenkiln Shales. 3ll. Lower Hartfell Shales. 3ll'. Barren Mudstones. 3ll''. *D. anceps*-zone. 4lll. Lower Birkhill Shales. 4lll'. Upper Birkhill Shales. 4lll''. *B. maximus*-zone. 4. Tarannon series. f. Fault. T. Thrust-lane.



(Figure 12) Section in Rae Grain, Selcoth Burn. (For explanation, see (Figure 11).)



(Figure 13) Plan and Sections in Selcoth Burn. 2c. Glenkiln chert. 3II. Lower Harden Shales. 3II'. Barren Mudstones. 4III. Lower Birkhill Shales. 4III'. Upper Birkhill Shales. 4III''. *R. maximus*-zone. f. Reversed Faults. T. Thrust-plane.