
Chapter 13 The Northern Belt — continued. Arenig, Llandeilo, and Caradoc formations in the district between Wrae, Peeblesshire, and the Lammermuir Hills.

A belt of Caradoc strata extending down Tweeddale from Glencotho and Wrae, by Drummelzier and Stobo Castle, to Hamilton Hill and Winkston, north of Peebles (Sheet 24 of the Survey Map), is of special interest, not only on account of the presence of fossiliferous limestone and conglomerate, but also from the occurrence of a remarkable series of interbedded lavas and tuffs, which, as shown in Chapter 4, differ in certain aspects from the earlier volcanic rocks of Arenig time. That these igneous materials were undoubtedly contemporaneous with their associated strata is proved by their relation to the fossiliferous limestones and conglomerates and by the occurrence of fossils in calcareous volcanic tuff. This development of volcanic activity during Caradoc time seems, however, to have been comparatively local, for though the distance between Glencotho and Winkston is only about fifteen miles, the lavas and tuffs have not been traced continuously between these points. Neither have they been found elsewhere throughout the Caradoc strata of the Southern Uplands, save in a few instances in the Sang uhar and Leadhills district.

The fossiliferous limestones, conglomerates, and contemporaneous volcanic rocks are associated with a prominent band of shales and slates, admirably displayed in the Stobo slate quarries. In these excavations a small arch of Hartfell black shales appears and reveals the fossils of *Pleurograptus linearis* zone. The occurrence there of the highest sub-zone of the Hartfell black shales helps to confirm the correlation of the Stobo Slates and Lowther Shales with the Barren Mudstones of the Moffat region. Hence the boundary marking the northern base-line of the Llandovery Rocks in Sheet 24 has been drawn along the southern limit of this belt of strata.

In the following paragraphs, we shall first describe the development of fossiliferous limestones, conglomerates, and contemporaneous volcanic rocks between Wrae and Winkston, and proceed thereafter to indicate their relations to the Stobo slates and Hartfell black shales.

Wrae Quarries. — On the eastern slope of Wrae Hill [NT 11766 32499], overlooking the Tweed, a series of quarries has been opened for different purposes — one for slates, a second for building stone, and others for limestone. In the eastmost quarry — that opened for building stone — near the Powder Magazine, slates are visible on the north side, and coarse pebbly grit in the centre of the excavation. On the south side, the brecciated material is embedded in the slates, with curious nests of small rounded pebbles of quartz and quartzite, which, owing to the decomposition of the enclosing matrix, can easily be removed by the hammer. In some instances, the pebbles of quartzite reach a considerable size; one in particular, resembling that type of rock in the Perthshire Highlands, measures nine inches across.

At the 1000-foot contour line the lower limestone quarry has been excavated for a distance of 30 yards along, and about 20 yards across, the strike. The higher portion of the quarry is covered with debris, but in the centre an excellent section shows the relations of the lavas and tuffs to the slates, and the presence of fossiliferous limestone in the tuff. Beginning at the north side, we find blue and grey slates protruding through the turf, and close to the north edge of the quarry, dipping to the N.N.W. at high angles. Southwards these slates are succeeded by 18 feet of grey tuff, in which the fossiliferous limestone nodules are embedded. Part of this tuff is coarse, with recognisable fragments of soda-felsite, while other parts are comparatively fine., composed largely of lapilli of soda-felsite lying in a calcareous matrix. A remarkable feature of the rock is the mode of occurrence of its included limestone, in the form of nodules, lenticles, and oval masses, which are not cleaved. Many of these are fossiliferous; some being abundantly charged with encrinites, others with trilobites, brachiopods, &c. This tuff is succeeded by grey slates with thin intercalations of fine tuff. In the centre of the quarry two bands of fine-grained vesicular lava are separated by a thin parting of grey slate — the bands measuring two feet and four feet thick respectively. They are followed by grey calcareous tuff. Southwards the section is obscured by debris, but at the southern edge cleaved slaggy lava and tuff appear.

The higher limestone quarry is in reality an excavation of the rocks much in the same line of strike as that of the lower; the tuff with limestone bands and nodules occurs on the south side, while the centre and north side are occupied by slates. An important section is displayed by the side of the old roadway leading from the Old Limekiln to this quarry. On the west side of the path grey and blue slates, dipping south-eastwards at high angles, are followed by a bed of

fine-grained soda-felsite-lava, forming a prominent rib which extends down the slope into the lower quarry and up the slope in a westerly direction. Under the microscope this rock No. [\(S7199\)](#) shows "phenocrysts of felspar, probably anorthoclase. Groundmass spotted in ordinary light, finely crystalline with small microlite of felspar". By the side of the road this lava-flow is from eight to ten feet thick, but it gradually widens when traced up the slope, and becomes more vesicular. Eastwards, on the farther side of a talus of debris, an exposure of tuff with calcareous nodules is visible also on the south side of the quarry. At this point the following fossils were collected during the visit of the Geological Survey in 1896, viz.: *Lingula attenuata*, *Strophomena grandis*, *Discina perrugata*, *Iliaenus Bowmani*, and *Sphaerexochus mirus*.

Westwards from the limestone quarries, the volcanic tuff can be traced for a distance of about 300 yards to a point near a stone fence, where it has been excavated for dyke-building. Midway between these localities, a section visible in a small quarry-hole shows cleaved slaggy lava and tuff with slates and breccia containing some volcanic material. Nodules of limestone occur in the tuff, one of which yielded an *Orthoceras*.

The following list of fossils from the limestone and tuff at Wrae and Drummelzier [NT 13645 34149] has been collected by the Geological Survey:

Glyptocrinus basalis (M'Coy.)

Crinoid stems.

Asaphus sp.

Cheirurus sp.

Iliaenus Bowmani (Salt.)

Iliaenus Davisi, var. *B. involutus* (Salt.)

Sphaerexochus mirus (Beyr.)

Discina perrugata (M'Coy.)

Discina sp.

Leptaena (Plectambonites) transversalis (Wahl.)

Lingula attenuata (Sow.)

Lingula longissima (Pand.)

Orthis actoniae (Sow.)

Orthis calligramma (Dalm.)

Orthis sowerbyana (Dav.)

Cyclonema sp.

Cyrtoceras scoticum (Blake.)

Orthoceras arevoliratum (Hall.)

Orthoceras sp.

The volcanic zone has not been observed in place west of the stone fence on Mossfennan Brae, but as blocks of tuff occur on the west slope of that hill the rock may not improbably be *in situ* somewhere on that hill.

Glencotho. — [NT 08400 29952] About two and a half miles to the south-west of the Wrae Quarries, a similar development of contemporaneous volcanic rocks is associated with the well-known fossiliferous limestone of Glencotho. This locality is situated in the basin of the Holms Water, about half a mile to the south-east of Glencotho Farmhouse [NT 08967 29360], where the Glencotho Burn — an affluent of the Holms Water — receives a small tributary rivulet that drains the western slope of the Benshaw. Hill. The volcanic rocks are exposed in this tributary and in quarries on the adjacent slope.

The eastmost quarry affords clear evidence of the association of the limestone with volcanic tuff. At the southern edge of the quarry grey calcareous tuff is seen resting on a tolerably solid mass of limestone, underlain by tuff with limestone nodules and at the northern limit of the quarry by tuff. The total thickness of beds, which there dip to the S.S.E. at high angles, is 38 feet. Here the tuff contains blocks and lapilli of soda-felsite, embedded in a calcareous matrix. Not far to the south fine-grained lava protrudes through the turf, followed on the south-east side by tuff with limestone lenticles and nodules. The lapilli in the tuff are highly vesicular and are set in a matrix of crystalline calcite.

About 100 yards to the south of the eastmost quarry, an interesting section is visible in the streamlet that drains into the Glencotho Burn. At the south or upper limit of the volcanic series, grits and shales are faulted against a fine-grained lava (soda-felsite) with phenocrysts of felspar in a grey matrix. Northwards this bed of lava is followed by grey shales and greywackes with thin bands of tuff. Again, the westmost quarry supplies an excellent section of calcareous tuff, which can be followed south-westwards along the slope overlooking the Glencotho Burn, where it appears to occupy two separate folds. The following list of fossils has been obtained from the solid limestone and nodules in the tuff:

Crinoid stems.

Glyptocrinus basalis (M'Coy.)

Illaenus (young of)

Phacops alifrons (Salt.)

Sphoerexochus mirus (Beyr.)

Discina sp.

Lingula attenuata (Sow.)

Leptaena sericea (Sow.)

Leptaena sp.

Orthis actoniae (Sow.)

Orthis biforata (Schl.)

Orthis calligramma (Dalm.)

Meristella (*Whitfieldia*) *tumida* (Dalm.)

Triplesia incerta (Dav.)

Modiolopsis orbicularis (?) (Sow.)

Orthonota undata (?) (Sow.)

Cyclonema (?)

Bellerophon (*Euomphalus*) *sculptus* (Sow.)

Holopea concinna (M'Coy.)

Lituities (Trocholites) coornu-arietes (Sow.)

Loxonema sp.

Orthoceras pendens (Blake.)

Orthoceras sp.

Drummelzier. — The volcanic zone of Wrae and Glencotho is prolonged to the east side of the valley of the Tweed, where, south from the Old Castle of Drummelzier [NT 14148 34430], various quarries have been opened in the tuff containing the limestone. In the westmost excavation 45 feet of volcanic ash have been laid open, all more or less highly cleaved,. Strange to say, though the volcanic matrix is schistose, the nodules, lenticles, and oval masses of limestone embedded in it are not cleaved. Here, as at Wrae, Glencotho, and Winkston, the limestone yields encrinites in abundance, together with trilobites, brachiopods, &c.

The calcareous tuff is succeeded southwards by shaly greywackes and shales which dip to the S.S.E. About 45 yards to the south of the quarry, a brecciated grit, resembling that in one of the Wrae quarries, appears. By means of various exposures the volcanic ash can be traced along the hill elope to the north-east for a distance of three-quarters of a mile from the westmost quarry.

The tract along which these contemporaneous volcanic rocks have been followed between Glencotho and Drummelzier is about four and a half miles in length. Beyond it to the north-east, for a distance of about seven miles, no trace of them has been observed, save in certain exposures of grit in the Stobo slate quarries, which contain fragmental volcanic material. They reappear, however, on Hamilton Hill to the north of Peebles.

Hamilton Hill, Peebles. — This locality is situated about a mile and a half to the N.N.W. of Peebles on the west side of the Eddleston Valley. A road skirting the hill about the level of the 1000-feet contour line, leads to a slate quarry on the northeast declivity about 200 yards distant from the gateway bounding the cultivated ground [NT 23759 42408]. The strata in the centre and on the south side of the quarry consist of grey shales repeated by folds and nearly vertical. On the north side a pebbly grit contains fragments of grey shale, black shale, rounded quartz pebbles, and small nodular masses of limestone. In contact with this pebbly grit, and forming the north bank of the quarry, comes a bed of decomposing lava, vesicular in places, with porphyritic felspars referred by Mr. Teall to the type of the soda-felsites. By means of debris on the slope, this volcanic rock can be traced in an E.N.E. direction to another quarry below a stone fence at the corner of a field, where it forms the face of the quarry for a distance of eleven yards. Here the soda-felsite is highly vesicular, the cavities being filled with carbonate of lime; it also contains porphyritic felspars. On the south side of the quarry, shale debris occurs, and on the north side pebbly grit and shales are found.

About 150 yards further to the west, another small excavation has been opened in a band of grit, containing large fragments of black shale — one over a foot across — from which the following fossils were collected: *Climacograptus bicornis*, *C. caelatus* var. *antiquus*, *C. Schärenbergi*, *Dicranograptus ramosus*, *Diplograptus foliaceus*, *Obolella*.

This part of the hill slope is strewn with fragments of black cherty shales, from which the late Mr. Robert Mathieson obtained specimens of *Diplograptus rugosus* and *Discina Portlocki*. These fragments may probably indicate the occurrence of an outcrop of black cherty shales in this portion of Hamilton Hill which is concealed by the turf.

In a W.S.W. direction across Hamilton Hill, slaggy lava, likewise of the type of the soda-felsites, occurs apparently on three separate folds. Of these the most important is that seen on the north-west slope just within the cultivated ground and about a mile and a half S.S.E. from Upper Kidston Farmhouse. Here the outcrop of, lava, about 20 yards broad, is bounded on the south side by grey shales, striking E. 20° N. and nearly vertical, while on the north side oval masses and fragments of fossiliferous limestone are in contact with and even included in the lava. On the latter side also, pebbly grit with small nodules of limestone, occurs close to the soda-felsite. Under the microscope, the volcanic rock, containing angular fragments of white crystalline marbly, shows "phenocrysts of an acid plagioclase and probably also sanidine in a

ground-mass of microlitic felspars. The calcareous grit, on the north side, is full of fragments of lava, which, under the microscope, are identical with and closely allied to the adjoining rock in the quarry.

Several blocks of limestone were observed in a stone fence bounding this field, and from these blocks the following collection of fossils was chiefly obtained:

Crinoid stems.

Cheirurus bimucronatus (Murch.)

Cheirurus gelasinosus (Portl.)

Sphcerexochus mirus (Beyr.)

Discina perrugata (M'Coy.)

Discina sp.

Lingula attenuata (Sow.)

Lingula Ramsayi (Salt.)

Obolella or *Kutorgina*.

Siphonotreta micula (M'Coy.)

Leptaena sericea (Sow.)

Meristella (*Whitfieldia*) *tuntida* (Dalm.)

Orthis actoniae (Sow.)

Orthis calligramma (Dalm.)

Orthis sowerbyana (Dav.)

Orthis vespertilio (Sow.)

Orthis sp.

Orthis like *girvanensis* (Dav.)

Strophomena deltoidea (Corr.)

Winkston. — [NT 24440 43027] On the eastern side of the valley of the Eddleston, the well-known fossiliferous conglomerate and calcareous breccia of Winkston occurs about two miles to the north of Peebles. Good exposures, still to be met with in quarries by the road-side and in the road-cutting, show the rock to be variable in character, though in general it may be described as a calcareous breccia, charged with sub-angular fragments of various materials, including grey shale, black shale, quartz, &c., with innumerable small nodules of crystalline limestone arranged in parallel lines. The latter vary in size from pea-shaped masses to nodules from two to six inches across, which frequently decompose and leave cavities, giving the rock a curious pitted appearance. By an increase in the calcareous matter, the rock merges into a tolerably solid mass of limestone, as, for example, in the section at the road-side, a few yards south of an old quarry, where, also, graptolites (including *Climacograptus bicornis* and *Diplograptus*) were found in a fragment of black shale in the calcareous breccia.

In the old quarry the calcareous breccia dips to the S.S.E. about 60°. Here, after a careful search for fossils during a recent visit of the Geological Survey, the species were obtained that are given in the following list. The smaller limestone nodules consist mainly of a mass of encrinites, the larger blocks yield forms similar to those at Wrae and Glencotho:

Favosites cristatus (Blum.)

Turrilepas sp.

Cheirurus bimucronatus (Murch.)

Iliaenus Bowmani (Salt.)

Discina perrugata (M'Coy.)

Lingula attenuata (Sow.)

Lingula Ramsayi (Salt.)

Lingula sp.

Leptaena (Plectambonites) transversalis (Wahl.)

Leptaena quinquecostata (M'Coy.)

Leptaena (Plectambonites) sericea (Sow.)

Meristella (Whitfieldia) tumida (Dalm.)

Orthis actoniae (Sow.)

Orthis vespertilio (Sow.)

Orthis calligramma, (Dalm.)

Siphonotreta micula (M'Coy.)

Strophomena like *shallochensis* (Dav.)

Strophomena (Rafinesquina) deltoidea (Conr.)

Strophomena sp.

Triplesia sp.

In an old quarry [NT 24831 43734]? about 250 yards further to the east an excellent section may be seen of the brecciated grit containing fragments of grey and blue shale, black shale (one fragment yielding *Climacograptus* sp.), chert, greywacke, and various igneous rocks.

Further up the slope, and about 500 yards E.N.E. of Winkston old quarry, the breccia with limestone nodules is well seen. Indeed, it can be traced at intervals, by means of exposures on the slopes and hill-top, as far as Collie Law, where a brown grit with *Orthis* occurs. On the northern slope of Winkston Hill [NT 25094 43896] an interesting development of volcanic rocks evidently represents the volcanic zone of Hamilton Hill, Wrae, and Glencotho. They form a narrow band running in an E.N.E. direction from the main road at Winkston Quarry for a distance of about 1200 yards. Their greatest breadth is about 200 yards. Along their northern margin the relations of the volcanic rocks to the surrounding strata are obscured by drift, while on the south side, though the lavas occur close to the sediments, the actual junction has not been detected. The best exposures are to be seen on the north slope of the Winkston Hill, about half a mile E.N.E. of the

Winkston Quarry. Here small knobs of pink felsitic lavas appear, one in particular having a red mottled appearance. A microscopic section No. [\(S7152\)](#) of the latter variety is thus described by Mr. Teall: "This is a most beautiful perlitic felsite. All the well-known details of perlitic structure are perfectly illustrated. The perlitic cracks are marked out by ferrite. The most striking feature of this rock is the occurrence of irregular patches of calcite, giving uniform extinction over large areas, in which the perlitic structure is as perfectly shown as it is in the normal felsitic matrix. The main mass of the rock is an extremely fine crystalline aggregate largely composed of very minute felspar microlites. A few of the larger felspar laths occur in the calcite patches".

About 100 yards to the west of the knob composed of the mottled perlitic felsite, pink fine-grained felsite appears in debris, evidently due to the breaking up of the solid rock underneath. Eastwards at a distance of 250 yards an old quarry near a stone fence furnishes a good section of felsitic lava. To the south of it, fossiliferous crystalline limestone is visible in a small exposure, which, for a distance of 200 yards, can be traced along the southern margin of the felsitic lavas by means of a bright green grassy hollow.

In the stone dykes bounding these fields, large blocks of felsitic lava show beautiful fluxion structure, contortion of the igneous lamin, and brecciation, of the rock. It is highly probable that this structure was produced when the rock was molten and flowing as a viscous mass along the sea floor. Towards the east the felsitic lavas disappear, but south-westwards they can be traced by means of debris on the fields as far as the high road north of Winkston Quarry.

We will now proceed to indicate the relations which the fossiliferous limestone and breccia, with their associated volcanic rocks, between Glencotho and Winkston bear to the-Lowther Shales and Stobo Slates, and to:the black shale zones of the Moffat series.

Stobo Slate Quarries. — [NT 15753 36371] Professor Nicol was the first to call attention to the occurrence of the Wrae limestone in blue slates or shales, which can be traced continuously to the southwest towards tie valley of the Clyde and the Lowther Hills, and north-eastwards to Stobo. To the west of Stobo Castle, and on the north side of the valley of the Tweed, the ground is trenched by deep quarries which have been opened along the strike of the beds. The westmost quarry — the largest of the series — exposes a fine section of grey and blue slates with one or two bands of brecciated grit containing fragmental volcanic material, the whole series dipping to the S.S.E. at high angles. In a small quarry immediately to the south, three sharp arches reveal black shales, of which the eastmost outcrop is the most important. These strata consist of alternations of thin black flinty ribs and black shale, much slickensided along movement planes, so that fossils are difficult to obtain. In a prolonged search the following fossils were collected:

Pleurograptus linearis (Carr.)

Dicellograptus Morrisi (Hopk.)

Dicellograptus elegans (Carr.)

Dicellograptus sp.

Climacograptus bicornis (large forks.)

Climacograptus tubuliferus (Lapw.)

Cryptograptus tricornis (Carr.)

Lasiograptus margaritatus (Lapw.)

Retiolites (Neurograptus) fibratus (Lapw.)

Diplograptus foliaceus (Murch.)

Diplograptus sp.

This assemblage indicates the position of the highest sub-zone of the Hartfell black shales of the Moffat region (Lower Caradoc), and hence the Stobo Slates that overlie this band may naturally be regarded as the equivalents of the Barren Mudstones of Moffat (Upper Caradoc).

Holms Waterhead, Glencotho (Sheet 24 of Survey Map). — Various arches of the Moffat Shales appear not far to the north of the volcanic zone in the Glencotho quarries. In the Hare Burn [NT 07158 28392] (which joins the Holms Water at Holms Waterhead), above Holms Waterhead, grits and sandy micaceous shales occupy the water-course as far up as the branching of the stream, where black shales come to the surface. A few feet above the fork [NT 07186 28233], cleaved black shales visible on the bank yielded *Corynoides calycularis*, *Dicellograptus elegans*, *Leptograptus flaccidus*, *Diplograptus foliaceus*. Further up stream radiolarian cherts and black shales are visible on the west bank. The shales being cleaved, fossils are difficult to obtain from them, but *Diplograptus euglyphus* was found in the band next the grey cherts, and *Corynoides calycularis* was collected from the outer zone. Massive grey grits occur on the hill slope not far from the exposure of the black shales at this locality. Near the head of the Hare Burn much cleaved and shattered black chert and shale are met with.

On the south side of the valley, in another small tributary of the Holm Burn further to the south-west, grey cherts and black flints and shales appear near the head of the burn, followed northwards by brown shales and decomposing greywackes with dark blue seams. On the south-western side of the watershed between the Holms Water and one of the branches of the Culter Water, near the Holm Nick (N.W. corner of Sheet 16) [NT 05744 26591], a considerable display of radiolarian cherts and black shales may be seen in the Nout Craig [NT 05920 26318], and in the gully formed by the Nout Craig Burn. These strata are here brought into contact with the greywackes by a fault.

Basin of the Eddleston near Winkston. — [NT 24504 43069] Similar evidence is obtained near Winkston, indicating that no great thickness of strata can intervene between the outcrops of Arenig cherts and Moffat black shales on the one hand, and the position of the fossiliferous limestone and breccia of Winkston on the other. At the head of a small stream traversing the eastern portion of the Winkston volcanic rocks, and immediately to the south of the lavas, a continuous section of blue shales may be followed for a distance of 250 yards across the strike, and near to this locality debris of Moffat black shales occurs. Again, to the north of Winkston, midway between Old Milkieston and Windylaw [NT 24229 45391], black shales and debris of chert are visible in the fields.

About two miles and a half to the north-east of Winkston evidence has been noted of the existence of folds of the Moffat Shales near the fossiliferous grits. On the slopes of the valley formed by the stream named the Black Cleuch [NT 27248 45852] on the six-inch map, that rises between the Cardon Law and Whiteside Edge, three outcrops of the Moffat series may be examined. The two more northerly exposures display the Arenig charts and black shales, while the most southerly one reveals only debris of black shales. Along the northern declivity of the Whiteside Edge [NT 27064 45556] debris of radiolarian chert can be traced for a short distance. The crest of the Whiteside Edge is formed of grits lying between two folds of the Moffat Shales; these merge in places into a breccia charged with angular fragments of shale and calcareous nodules with encrinite stems, resembling the fossiliferous calcareous breccia in Winkston Quarry [NT 24831 43737]?

Head Waters of the Leithen, East of Eddleston. — In the higher part of the Leithen Water, west of Bowbeat Hill (2049 feet), several folds of the Moffat series display the radiolarian cherts and some of the members of the overlying black shales. The most important series of arches occurs in the Leithen Water, about 2¼ miles due east of Eddleston Station, and also due east of Hog Knowes [NT 27503 47095] — a heathery hill rising to a height of 1682 feet on the west side of the Leithen. On the east side of the valley a scar of black shales on the slope of the Bowbeat Rig [NT 27965 47265], from which a small stream flows to the Leithen Water, forms a good base-line for studying the structure of the immediately surrounding ground.

About thirty yards north of the junction of this streamlet, black shales appear in the Leithen Water [NT 27731 47203], and occupy the watercourse for several yards. They are much shattered and veined with quartz and do not yield fossils readily. They are succeeded northwards by brown greywackes and shales which dip south-easterly. At the northern limit

of this mass of greywackes and shales a band of pebbly grit exposed in the bed of the stream contains lenticles of black shales, and is followed by black shales associated with black cherty ribs. From these black shales graptolites have been obtained, some of which belong to the middle sub-zone of the Lower Harden black shales, including *Diplograptus foliaceus*, *Dicellograptus*, *Corynoides calycularis*, *Climacograptus caudatus*. Fossils are neither abundant nor in good preservation. These black shales are followed northwards by the grey radiolarian cherts, which occupy the bed of the stream for 23 yards, and show the typical features of this zone. Both the nodular and well-banded varieties occur, charged with radiolaria in abundance. North of this outcrop of charts another exposure of black shales occupies the stream for nine yards, succeeded by cherts for a distance of sixteen yards, and thereafter by black shales associated with black cherty ribs, which pass outwards into sandy black shales and pebbly greywackes with masses of black sandy micaceous shales. These lenticular masses of black shale in the grits yield *Diplograptus foliaceus*, *Corynoides calycularis*, and *Dicellograptus*.

The grits just mentioned extend in the water-course for a distance of twenty-three yards northwards, when black sandy shales reappear, yielding specimens of *Lasiograptus margaritatus*. The grits then once more come to the surface and are followed immediately by another sharp fold of the black sandy shales.

The evidence supplied by this Leithen. Water section shows that the beds are repeated by a series of compound folds.

Bowbeat Rig, Leithen Water. — [NT 28122 47298] The eastern slope of the Leithen. Valley is trenched by a stream that rises high up on Bowbeat Rig, the north-west continuation of Bowbeat Hill, and forms a scar in the upper part of its course. Though no section is visible in the lower part of the stream, important evidence is obtained from the scar in the higher part of the slope. Here a series of compound folds of the radiolarian cherts and overlying black shales is followed by greywackes and shales. These compound folds are abruptly truncated on the south side by a fault that runs E.N.E. and brings greywackes and shales successively in contact with the cherts and black shales. On the north side of the scar a considerable mass of black shale is repeated by numerous rapid folds. The bands are much decomposed, but at the line of junction with the greywackes the decomposed black shales have furnished the following forms characteristic of the *Pleurograptus linearis* zone: *Pleurograptus linearis*, in great abundance, *Diplograptus quadrimucronatus*, *Leptograptus flaccidus*, *Diplograptus foliaceus*, *Hyalostelia*, &c. It is thus apparent that the highest sub-zone of the Lower Hartfell black shales of the Moffat series is still represented as a black shale in the district of the head-waters of the Leithen.

Leithen Water South of Bowbeat Rig. — [NT 27753 46953] About 250 yards south of the junction of the streamlet on Bowbeat Rig with the Leithen. Water, two small anticlines of the black shales appear. Fragments of cherts and black shales are found on the north slope of Cardon Law, indicating other exposures in that neighbourhood. The general character of the strata, however, exposed in the Leithen Water resembles that of the Caradoc type in the northern area, consisting of greywackes, pebbly grits, and shales.

An important band of conglomerate is visible in the Leithen Water at a point about a quarter of a mile north-east of the top of Cardon. Law [NT 28088 46257], and about half a mile south of the section in the scar on Bowbeat Rig. At one locality on the north bank of the Leithen Water, opposite a sheep-fold [NT 28067 46264]?, where the best exposure met with, the conglomerate appears along the back of an arch, which is truncated by a small fault on its northern side. At the broadest part the conglomerate is five feet wide, and consists of a grey grit with pebbles of various rocks and lenticular masses of black chert, the latter sometimes four feet long. Blocks or masses of grey and red radiolarian chert likewise occur, and pieces of black shale containing *Dicellograptus* and *Diplograptus foliaceus*. The rounded pebbles are composed of calcareous greywacke, quartzite (one at least ten inches across), and of quartz-felsite, one nine inches across. The grey shales and mudstones are seen folding over the conglomerate on the face of the bank. Other bands of pebbly grit, not so coarse in texture, occur in the immediate neighbourhood.

This band of coarse conglomerate lies a little to the north of the line of strike of the band of fossiliferous conglomerate on Winkston Hill, believed to be of Caradoc age. It is unfossiliferous, but as the *Pleurograptus linearis* zone (the highest sub-zone of the Hartfell black shales, Lower Caradoc) occurs in black shales not far to the north, on Bowbeat Rig, it may be of Upper Caradoc age. A probable continuation of it is exposed on the hill slope, from 400 to 500 yards to the south-west, near the watershed between the Leithen and Eddleston Waters.

Bowbeat Burn. — [NT 28490 46741] This stream rises between the Bowbeat Hill and Bowbeat Rig, and flows south into the Leithen Water. At a point about 300 yards up from the junction of the two streams the radiolarian cherts of Arenig age are exposed on both sides of the valley. On the west side of the valley the black shales and black cherts are seen in contact with the grey radiolarian cherts, the width of the exposure measuring 16 yards. From the black shale bands at this locality, in immediate contact with the cherts, the following forms were obtained: *Didymograptus superstes*, *Dicellograptus*, *Diplograptus foliaceus*, *Climacograptus bicornis*. On the east side of the valley the green mudstones of Arenig age are visible in contact with the cherts, and yield the conodont-like organism which occurs with the Arenig mudstones at Ravengill (Abington.).

On the eastern slope of the valley the black shales and cherts make their appearance along the line of strike. Their outcrop can be traced by means of debris to the Leithen Water, near to the point where the coarse conglomerate is visible.

To the south of this band of cherts and black shales two additional exposures of the black shales may be seen on the east slope of Cardon Law one at the head of a small gully on the north-east face of that hill, the other about 300 yards further to the south at a height of 1750 feet [NT 28293 45543]. The more southerly displays alternations of black shales and black cherty bands, from which have been obtained *Diplograptus foliaceus*, *Climacograptus bicornis*, *Dicellograptus Morrisi* — evidently belonging to the Lower Hartfell horizon.

Excellent sections of rusty brown Lowther Shales are visible in the streams that drain the col between Cardon Law and Lamb Law [NT 28574 45386], also in the burns forming the sources of the Craighope Burn, east of Bowbeat Hill.

Gladhouse Water (Bowbeat Shepherd's House). — [NT 29648 48547]? At the south-western end of the Moorfoot Hills, near the ruins of Bowbeat shepherd's cottage, two small burns from east and west join the Gladhouse Water, which flows northward into the South Esk. In the eastern stream the Arenig cherts and black shales for a distance of 800 yards are repeated by folding. At the very head of the scar the width of the exposure of cherts and black shales is 66 yards, the cherts being repeated about fifteen times. The black shales are succeeded on both sides by the grey sandy shales and greywackes. The black shales and black cherts are crushed, shattered, and much veined with quartz; hence fossils are difficult to obtain from them. The following forms were collected from these strata: *Diplograptus foliaceus*, *Leptograptus flaccidus*, and *Climacograptus bicornis*.

Similar outcrops of cherts and black shales are seen in the small tributary on the west side of the valley. These anticlines lie much in the same line of strike as, and are probably continuous with, the bands of black shale at the head of the Leithen Water, which can be traced across Bowbeat Rig by means of debris underneath the peat.

Black shales and cherts are again visible in two small burns close to the county boundary. In the stream that drains the north slope of the Emly Bank (1980 feet) [NT 29761 47447] three isoclinal folds of the Moffat series may be detected, two exposing the cherts and black shales and one merely the black shales. In one of the branches of the burn, draining the northern slope of the Bowbeat Hill (2049 feet) [NT 29209 47331], there is a good exposure of the cherts and black shales, much shattered. Excellent sections of the brown shales, which overlie the Glenkiln–Hartfell Shales, also occur in these streams.

Basin of the Heriot Water

In the various streams which unite to form the Heriot Water (in the north-east corner of Sheet 24) several anticlines reveal representatives of the Moffat Shales, with, in some instances, the radiolarian cherts, accompanied at one locality by vesicular lava. The tributary streams that drain the watershed of the Moorfoot Hills between Mauldslee Hill and Blackhope Scar display numerous folds of the black shale series, which unfortunately, however, yield few fossils, owing to the shattered condition of the strata.

Blackhope Water. — [NT 33886 51625] In this stream, at the Blackhope Farmhouse, and for a short distance westwards, grey pebbly grits appear, like the Haggis Rock. Black shales are seen first at a point about 400 yards west from the farmhouse, and in the next 500 yards there are six anticlines of greatly crushed and shattered black shales, from

which no fossils have been obtained. Dark and black cherts are associated with these black shales.

On the west side of a small tributary of the Blackhope Water, named the Fernie Syke [NT 32860 50758], three-quarters of a mile south-west of Blackhope Farmhouse, at a point about 150 yards up, an anticline of much shattered black shales, seamed with veins of white quartz, may be seen, from which no fossils have been obtained.

In a small scar (in the line of strike of the outcrop of the cherts and black shales near Bowbeat in the Gladhouse Water), at the head of one of the tributaries of the Blackhope Water, the cherts and black shales are visible. [NT 31819 48556]?

Hope Burn. — [NT 32899 48639] In the higher reaches of this burn a fine exposure of brown micaceous shales with pebbly grits occupies the stream for a long distance. At a point about a mile and a quarter up stream from Garvald Farmhouse a fine development of black shales, much crushed and shattered, affords graptolites in fair preservation [NT 33830 50370]. The grey cherts are not visible, but black cherts occur, and thin seams of white clay are intercalated in the black shales. The following forms were here obtained: *Corynoides calycularis*, *Diplograptus foliaceus*, *Climacograptus caudatus* (?), *Climacograptus bicornis*, *Dicellograptus caduceus*, *Dicellograptus* sp. On the south side, where the black shales are brought into contact with the grey and brown shales by means of a fault, the grey shales bound the black shales on the north (Figure 63). In this exposure there must be several folds of the black shales.

Down the stream grey shales appear for a few yards to the north of the band of black shales.

About 100 yards to the E.N.E. of the last exposure of black shales, a gully, which indents the east side of the Hope Burn, and the lower part of which is occupied by a cone of debris, displays an arch of cherts and black shales, followed by decomposing brown-weathering shales and greywackes. A few yards up from this point a very small arch of black shales may be observed with the greywackes folding over them (Figure 63). From that point upwards, the north wall of the gully is occupied by grey shales and greywackes almost to the head of the scar, while in the bottom of the gully cherts and black shales, too much crushed to yield fossils, are laid bare. Near the head, the gully forks; and just below the branching a very small exposure of highly vesicular lava, much decomposed, occurs with the cherts. Here both the cherts and the lava are truncated by a fault which runs nearly east and west, with a hade towards the north, and therefore a reversed fault (Figure 63) and (Figure 64). Above the fork, in the main gully, a second small exposure of the vesicular lava is associated with the charts, and truncated in like manner by the fault. The beds on the south side of the fault consist of brown greywackes and shales (3 in (Figure 63) and (Figure 64)).

At the road-side between Edinburgh and Innerleithen, on the watershed of the Moorfoots [NT 34938 54215], a good section shows the rapid reduplication of the Arenig cherts and overlying sediments, which have a general dip to the south-east at 40°. At the south end, the radiolarian cherts are seen on two compound folds on both sides of the road, the mudstones and shales folding over the cherts. These mudstones, which are violently puckered, contain some of the strains of black shales with fragments of graptolites. They are followed by black shales — from ten inches to a foot thick — with *Diplograptus foliaceus* in abundance, and *Lasiograptus margaritatus*. These shales are in turn succeeded by greywackes and pebbly grits, with lenticular patches and seams of black shale with *Dicellograptus*, followed by dark micaceous and grey shales. The whole section is probably not longer than 100 yards. The radiolarian cherts here present their normal characters, the Glenkiln horizon is represented probably by the mudstones and dark strains, while the overlying black shales and sediments may belong to the Hartfell horizon.

Garvald Farmhouse. — [NT 35529 51279] In a small burn which joins the Blackhope Burn due east of Garvald Farmhouse, several folds of the Moffat black shales may be examined. About 200 yards up from the road a scar shows a good exposure of the cherts and overlying black shales, the cherts being associated with brown decomposed shales, containing at one point a thin dark or black seam. On the south side the yellow cherts and mudstones are succeeded by shattery black shales and black cherts, followed by grey shales. On the north side, a black shale band likewise occurs. It is visible in a small exposure, and is followed by grey shales. Further down the stream, the black shales are met with on separate folds overlain by grey shales.

About 200 yards north of the mouth of this burn [NT 35223 51365], the radiolarian cherts are visible, followed by the black shales, and further north by a succession of greywackes and shales; but on the south side of the radiolarian cherts,

in the intervening space towards the mouth of the burn, several small exposures of the black shales indicate the rapid reduplication of the strata — a feature which is further illustrated by the puckering of the black shale bands.

Eastwards, in the direction of the mouth of the Crookmill Burn, the black shales may be seen at intervals on different anticlines.

At the northern edge of the alluvium of the Heriot Water north of Little Dod [NT 36930 51497], the radiolarian cherts are visible together with the black shales. On the farther side of the Carcant Burn [NT 36996 52004]?, a series of folds reveals the black shales, and in some instances the radiolarian cherts. The most northerly anticline of the black shales is associated with a felsite dyke which has been traced for a considerable distance to the north-east.

Raeshaw Wood, Ladyside. — [NT 35777 50611] The sediments which overlie the black shales in this part of the basin of the Heriot Water consist mainly of greenish grey sandy shales, weathering brown and yellow, associated with thin greywacke bands and occasional pebbly grits. The occurrence of these grits is perhaps the most interesting feature of the series. An excellent exposure of them has been laid open in a quarry at the road-side below Raeshaw Wood [NT 35845 50378], on the north side of Heriot Water above the junction of Ladyside Burn. Here they contain numerous pieces of black shale yielding fragments of graptolites, of which the following species were identified during a recent visit to the quarry: *Climacograptus Schärenbergi*, *C. bicornis*, *Cryptograptus tricornis*, *Dicellograptus*, *Didymograptus superstes*. This grit, which points to local elevation and erosion of the cherts and black shales, closely resembles the brecciated grit associated with the fossiliferous limestone of Wrae and Glencotho; it is abundantly charged with small rounded quartz pebbles and occasional chert fragments.

Further down the valley of the Heriot Water, opposite the mouth of Ladyside Burn [NT 36253 50411], the pebbly grit or conglomerate becomes coarser, and contains pebbles of a grey micaceous granitoid rock. In a quarry at the road-side the following graptolites were obtained from fragments of black shale in this bed; *Diplograptus euglyphus*, *Climacograptus Schärenbergi*, *C. bicornis*, *Cryptograptus tricornis*, *Dicellograptus*. A similar band of pebbly grit or fine conglomerate is exposed near the black shales on the Heriot Water opposite the farmhouse of Little Dod [NT 36808 51462].

Gala Water

Among the head-waters of the Gala, several exposures of the Moffat series may be observed, but few of importance. At the extreme north-west corner of Sheet 25 of the Survey Map, some of these outcrops are recognisable merely by their debris on the surface. They occur on the cultivated ground west of Sandyknowe [NT 40346 54044], and again to the north-east of Hangingshaw [NT 41292 54646], on the crest of Hangingshaw Hill, and near the county boundary at the northern edge of Sheet 25. The black shale debris is sometimes associated with cherts, both zones occurring in the midst of red-crustured greywackes, grits, and greenish shales.

Corsehope. — [NT 41039 52701] About a mile and a half to the south of Heriot Station, on the west side of the valley of the Gala Water, and about 250 yards to the south of the Corsehope Burn, red jasper and cherts with radiolaria are well displayed. Grey mudstones are associated with the cherts and jaspers, which yield a doubtful shell.

Not improbably these mudstones may be the equivalents of the shelly mudstones of Arenig age in the Abington district. Debris of flinty black shales met with to the north on the ridge yielded the following fossils: *Diplograptus foliaceus*, *Cryptograptus tricornis*, *Dicellograptus sextans*, *Diplograptus euglyphus*, *Climacograptus Schärenbergi*, *C. bicornis*.

Again, to the east of the valley, on the mossy ground between the Armet Water and the tributaries of the Leader, debris of chert and much crushed and shattered black shales may be found. These local accumulations of detritus doubtless indicate the positions of separate anticlines, for they appear on different lines of strike, and the materials cannot be traced for any distance. The sediments above these black shales consist of grits, greywackes, and shales. Among them one prominent band of conglomerate of special interest has been traced from the county boundary near the Armet Water, by the Clints Farmhouse [NT 44172 53128] and Hartside [NT 46871 53694], to a point about half a mile north of Channelkirk [NT 48133 54528], where it passes into Sheet 33 of the Survey Map. This conglomerate runs parallel with

another still further south, of a slightly different character. The former is regarded as forming part of the Caradoc formation, while the latter is mapped with the Llandovery series. The lithological characters of this-Caradoc conglomerate will be described presently in connection with the exposures of this rock in the quarries at New Channelkirk [NT 48343 55401].

Basin of the Leader Water

Still further to the north-east, in the basin of the Leader Water, evidence occurs of the existence of the *Pleurograptus linearis* zone in certain outcrops of the Moffat Shales, as previously recorded by Professor Lapworth.

About a mile to the north of New Channelkirk (Sheet 33) the Headshaw Burn is joined by the Windycleuch Burn [NT 47766 56462], which, opposite a bend in the road, exposes thin platy black shales including thin worm-piped barren ribs with black shale partings. From the shales the following fossils were obtained:

Dicellograptus sp.

Corynoides curtus (Lapw.)

Corynoides sp.

Climacograptus bicornis (Hall.)

Diplograptus foliaceus (Murch.)

Retiolites sp.

Above this outcrop the fossiliferous black shales graduate upwards into flaggy shales with dark seams, followed by grits and mudstones all much reddened. Below it a blank occurs in the section, till, at a point 70 yards above the culvert, the grey worm-piped ribs with black shale partings are again laid bare and contain *Diplograptus foliaceus*, *Climacograptus bicornis*, and *Corynoides*.

Headshaw Burn (Head of Lauderdale). — [NT 48072 56835] Important evidence is obtained in this stream to show the relation of the Hartfell black shales to the overlying sediments. Above the point of junction with the Windycleuch, a succession of grits, greywackes, flags, and shales, all much reddened and repeated by folding, may be traced up the stream. Between the foot of the Windycleuch and the foot of the second small tributary of the Headshaw from the north, two arches bring up representatives of the Hartfell beds. The one further down the stream only reveals the higher sandy bands with thin leaf-like dark seams, the other, about 500 yards up from the foot of the Windycleuch, near the junction with a second stream from the north, shows alternations of thin hard flinty ribs with black shale partings. The black seams have yielded *Diplograptus foliaceus* and *Climacograptus*. Further up the stream, jointed grits and shales appear, and at a point 700 yards from the foot of Windycleuch [NT 48181 56944], much crushed black shales seen on the north bank contain *Climacograptus*, *Diplograptus foliaceus*, and *Corynoides*. From this point upwards for a distance of 100 yards in an almost continuous section, grey sandy ribs alternate with black shale seams. At a point about 800 yards from the foot of Windycleuch, the beds occurring on the south side of the stream yield *Pleurograptus linearis*, dip to the south, and display certain distinctive characters, for they here consist of alternations of grey sandy siliceous ribs with black shale partings from an eighth to an inch thick. From these partings the following fossils have been obtained:

Pleurograptus linearis (Carr.)

Climacograptus bicornis (Hall.)

Diplograptus foliaceus (Murch.)

Dicellograptus sp.

Retiolites sp.

Corynoides calycularis (Nich.)

Higher in the valley these beds pass outwards into more sandy bands with dark strains, which are succeeded by stained grits and shales. Where the burn takes a bend to the north, and where a stone fence crosses the stream, the Hartfell Shales are repeated along another arch composed of two minor compound folds, the more northerly of which has afforded the following forms:

Pleurograptus linearis (Carr.)

Diplograptus foliaceus (Murch.)

Climacograptus bicornis (Hall.)

Corynoides calycularis (Nich.)

Dicellograptus sp.

Reddened shales intervene between these two folds, while for a further distance of 400 yards up stream an alternation of grits, flags, and shales contains three exposures of the higher bands of the Hartfell black shales, which consist of the sandy bands separated by the dark seams.

In the Headshaw Burn below the foot of Windycleuch, reddened grits and shales dip at high angles and are repeated by folds. At a point about 800 yards down the stream, black shales, much crushed and veined with quartz and carbonate of lime, appear on the west bank, followed on the south side by the grey radiolarian cherts [NT 48006 55875].

On the slope of the hill to the east, black shales with radiolarian cherts in the centre are traceable on the surface by means of debris. Grey shales appear on the south side this exposure, followed by grit. Southwards, beyond, a constant repetition of shales (Lowther type) by folding, the large quarries on the hill slopes E.N.E. of New Channelkirk Farmhouse have been opened along a band of conglomerate and grit. The conglomerate, only a few feet thick; forms a ridge in the quarry, bounded north and south by a coarse grit which has been excavated as building stone for dykes. The conglomerate is what peculiar in character, the matrix being a grit in which small fragments of chert, black shale, grey shale, abundant quartz grains, &c., occur. In fresh fracture the rock has a greenish tint.. Perhaps its most notable feature is the occurrence in it of lenticular masses of grey shale, which are bent and folded with the conglomerate, and, so far, have yielded no fossils. The black shale fragments, however, furnish specimens of *Climacograptus caudatus* in excellent preservation, *Diplograptus foliaceus*, *Corynoides*, *Dicellograptus*. The blocks containing these forms must have been derived from the *Climacograptus caudatus* zone. Another piece of black shale, probably from the Glenkiln horizon, was found to contain *Climacograptus caelatus*, *Diplograptus foliaceus*, *Glossograptus Hincksi*, *Climacograptus Schärenbergi*. Numerous arms of *Dicellograptus* were also found on another slab. Several pebbles have likewise been recorded, one of gabbro and others of fine-grained felsitic rock with porphyritic feldspars, the latter being well rounded, and averaging from three to four inches across. On the north side of the quarry, the junction between the shales and the grit is visible. It is obvious that this conglomerate points to local elevation and erosion of the Arenig. Volcanic rocks, radiolarian chert, black shales, and other sediments. Northwards the beds consist of grey shales or mudstones, containing small flattened nodules of limestone, which differ in character from the limestone of Wrae and Winkston.

Kelphope Burn. — [NT 51330 58379] In this stream, which drains the heights near Lammer Law, grey sandy shales are visible at the shepherd's house of Kelphope, and about half a mile further-south, coarse pebbly grit is well displayed in the bed of the burn and on the hill slope (Sheet 33). This band is the eastern prolongation of the conglomerate at New Channelkirk; though here not so coarse, its included fragments are similar, and it is embedded in shales.

An interesting section of the Glenkiln black shales may be seen in a tributary of the Kelphope Burn which joins the main stream from the west, about half a mile north from Kelphope shepherd's house. About 600 yards up this tributary, [NT 50712 59041] after passing grey shales, the observer encounters a small exposure of flinty black shales on the east

bank, from which the following forms have been collected (2I, (Figure 65)):

Didymograptus superstes (Lapw.)

Caenograptus gracilis (Hall.)

Caenograptus pertenuis (Lapw.)

Dicellograptus sextans (Hall.)

Dicellograptus moffatensis (Carr.)

Glossograptus Hincksi (Hopk.)

Diplograptus foliaceus (Murch.)

Lasiograptus bimucronatus (Nich.)

Climacograptus bicornis (Hall.)

Climacograptus caelatus var. *antiquus* (Lapw.)

Climacograptus Schärenbergi (Lapw.)

Dicranograptus ramosus (Hall.)

Cryptograptus tricornis (Carr.)

The specimens of *D. superstes* are especially abundant and well preserved.

A few yards further up the stream, on the same bank, a small exposure of black shales has furnished specimens of *Climacograptus caudatus* in fine preservation, together with *Diplograptus foliaceus* and *Corynoides* in the same seam, belonging to the Lower Hartfell group (3II, (Figure 65)).

On the opposite bank, the black shales have afforded *Diplograptus foliaceus*, *Corynoides calycularis*, and fragments of *Climacograptus*. Grey barren shales succeed, which are truncated by a fault, followed by much smashed black shales veined with quartz. About ten yards further up some black shales have yielded:

Glossograptus Hincksi (Hopk.)

Climacograptus bicornis (Hall.)

Climacograptus peltifer (Lapw.)

Climacograptus Schärenbergi (Lapw.)

Cryptograptus tricornis (Carr.)

Dicranograptus ramosus (Hall.)

Diplograptus foliaceus (Murch.)

These shales are succeeded by grey shales with dark strains, and after a blank in the section, black shales with the grey cherts occur, while in a side rivulet, which joins the Kelphope Burn from the west, the black shales again appear.

Friar's Nose, Lammer-Law Burn. — [NT 51056 59812] At the Friar's Nose, where the Kelphope Burn bifurcates, its north-east branch, named Lammer-Law Burn, furnishes evidence of the existence of the *Pleurograptus linearis* zone in

the Moffat Shales. Greywackes and shales appear at intervals in the stream as far as a point about 700 yards north from the Friar's Nose (Figure 66), where a fine exposure of black platy shales runs along the banks of the stream for a distance of upwards of 100 yards. On the north-west bank, and within two or three feet of the grey shales, the following assemblage of fossils characteristic of the highest zones of the Hartfell black shales was obtained:

Leptograptus flaccidus (Hall.)

Leptograptus capillaris (Carr.)

Diplograptus foliaceus (Murch.)

Diplograptus quadrimucronatus (Hall.)

Dicellograptus Forchhammeri (Gein.)

Dicellograptus elegans (Carr.)

Dicellograptus pumilus (Lapw.)

Dicellograptus Morrisi (Hopk.)

Neurograptus fibratus (Lapw.)

Pleurograptus linearis (Carr.)

Climacograptus sp.

A peculiar feature of this section is the abundance of *Leptograptidae* in certain seams close to the grey shales.

On the south-east bank, a few yards further up, *Climacograptus*, *Diplograptus foliaceus*, arms of *Dicellograptus* and *Dicranograptus* have been found.

In a small tributary which drains the Red Scar Rig, [NT 51590 60868] black shales appear with grey cherts pierced by a dyke. A few yards above its foot *Climacograptus bicornis* occurs in dark seams in grey shales. Again, the north branch of the Lammer-Law Burn lays bare stained grey flints, and the south branch, black shales and black flints.

Having described the various exposures of the Moffat series which lie to the north of the central Llandoverly and Tarannon area, on the southern slopes of the extreme western end of the Lammermuir Hills, we will now proceed to indicate certain outcrops on the northern declivity of that chain.

Lammermuir Hills

Soutra Hill. — [NT 45941 59086] In the Brothershiels Burn, at the southwest margin of Sheet 33, one-inch, and along the crest of Soutra Hill, two bands of dark or black shales are associated with greywackes and shales. About half a mile to the south of these outcrops the Arenig cherts and black shales are again visible near the sources of the Armet Water [NT 46259 58399], in rivulets upwards of 200 yards E.N.E. of Glisten Peel.

Lammer Law (1733 feet). — [NT 52345 61765] The radiolarian cherts and black shales rise on two anticlinal folds at the head of the East Burn — a tributary of the Birns Water [NT 52101 62274]. In the outcrop on the east side of the coomb-shaped hollow at the head of this tributary the strata are much shattered and veined with quartz. These Moffat Shales are here associated with decomposing brown, sandy shales of the Lowther type, with occasional bands of grit.

Again, on the scar at the head of the western tributary of the Kidlaw Burn, on the north-west slope of the Lammer Law, black shales appear, with a strike to north and south, and in one instance to N.N.W. and S.S.E. These strata form small arches surrounded by brown decomposing shales. They have as yet furnished no fossils. Some of these black shale

outcrops may belong to the same system of folds as those already described in the tributaries of the Kelphope Water, though the beds cannot be traced continuously between the two areas. At least one of the black shale bands on the south slope of the Lammer Law appears to be traceable by means of debris across the moory watershed at the head of the Hope's Water, where the Arenig cherts and black shales appear in a crushed and shattered condition among brown sandy shales, pierced by dykes of acid igneous rock. The chief point of interest in the Hope's Water section is the remarkable system of folding, for although the black shales are exposed at a great height on the slope, they rapidly disappear under brown sandy shales, owing to the pitch of the folds being steeper than the declivity of the ground.

That these sandy shales in all probability represent, in part at least, the Barren Mudstones of the Moffat region is rendered highly probable, if not certain, by the fact that, in the Blinkie Burn — which rises from the north side of Lammer Law [NT 52617 62499]— one of the black shale bands has yielded graptolites which elsewhere are associates of *Pleurograptus linearis*. Here, near the source of the stream, in an exposure of black sandy shales overlain by grits and brown sandy shales, the following among other forms were collected: *Diplograptus quadrimucronatus*, *Diplograptus foliaceus*, *Dicellograptus elegans*, *Corynoides calycularis*. From its lithological characters and included fossils, this band is probably identical with the *Pleurograptus linearis* zone of the Friar's Nose.

Further down the same stream, the Moffat series appears twice about half a mile to the S.S.E. of the Castles [NT 53286 63345]. The dark flinty bands are the lowest beds visible in the upper exposure, while the Arenig cherts are seen in the lower. The black shales associated with the latter contain *Lasiograptus bimucronatus* and *Climacograptus bicornis*. Here the strata are much reddened owing to the proximity of the Upper Old Red Sandstones and conglomerates. The general dip of all the Silurian strata in this portion of the Lammermuir chain is towards the west or W.N.W., and hence the same beds must be constantly repeated by isoclinal folds.

Papana Water. — Further to the north-east, in that portion of the Lammermuirs drained by the streams south of the village of Garvald, evidence is obtainable of the occurrence of the Arenig cherts and Glenkiln black shales. By far the best section of these zones is to be found in Papana Water [NT 58810 67662], about two miles south of the village of Garvald (Figure 67). In this stream, above the point where it is crossed by the fault that brings the Upper Old Red Sandstone in contact with the Silurian rocks, shattered and reddened greywackes and shales extend for a distance of about 100 yards. These are followed by a band of coarse conglomerate which forms a waterfall. This rock contains well-rounded pebbles of greywacke, grey quartzite like that of the Perthshire Highlands, granite, and grey cherts, with fragments of grey and black shale. From the last named, specimens of *Climacograptus* were obtained. Southwards the conglomerate is followed by grey shales, with a band of black shale which contains *Diplograptus foliaceus*. For the next 150 yards there is a constant repetition of black shales, grey shales, and two bands of radiolarian cherts; the beds being much shattered, folded, and traversed by faults. Still further south, grey mudstones succeed, and are followed by black shales with seams of grey shales, visible in the bed of the stream for a distance of 40 yards. At the southern limit of this broad mass of black shales the radiolarian cherts reappear, truncated on the south side by a reversed fault which brings them in contact with greywackes and shales, and followed on the north side apparently in normal order by black shales, enclosing *Didymograptus superstes*, *Diplograptus foliaceus*, and *Climacograptus*. From another point in the same broad mass of black shales the following typical list of Glenkiln fossils was collected:

Didymograptus superstes (Lapw.)

Caenograptus pertenuis (Lapw.)

Caenograptus surcularis (Lapw.)

Caenograptus gracilis (Hall.)

Thamnograptus typus (Hall.)

Thamnograptus scoticus (Lapw.)

Climacograptus caelatus var. *antiquus* (Lapw.)

Climacograptus bicornis (Hall.)

Climacograptus Schärenbergi (Lapw.)

Dicranograptus ramosus (Hall.)

Dicellograptus sextans (Hall.)

Dicellograptus patulosus (Lapw.)

Diplograptus euglyphus (Lapw.)

Diplograptus foliaceus (Murch.)

Lasiograptus bimucronatus (Nich.)

Cryptograptus tricornis (Carr.)

Discina Portlocki (Gein.)

It is probable that the Lower Hartfell black shales are also represented in this section, though too much crushed to yield fossils.

For the next 300 yards, beyond an exposure of shattered grits near the black shales, the strata consist of grey and brown sandy shales repeated by constant folds. At a point where the stream divides, black flinty shales occur, from which no fossils were collected owing to their shattered condition. Grey shales of the Lowther type again succeed, and are traceable southwards for a distance of 500 yards. Here grey grits supervene, which are provisionally regarded as marking the northern base line of the Llandovery Rocks, while the grey and brown shales are viewed as the equivalents of the Barren Mudstones of Moffat.

Proceeding eastwards, the observer finds several folds of the Moffat black shales and Arenig cherts in a tributary of the Papana Water about half a mile to the east. One exposure yielded the following Glenkiln assemblage:

Didymograptus superstes (Lapw.)

Caenograptus gracilis (Hall.)

Lasiograptus bimucronatus (Nich.)

Dicranograptus ramosus (Hall.)

Corynoides curtus (Lapw.)

Climacograptus caelatus var. *antiquus* (Lapw.)

Climacograptus bicornis (Hall.)

Cryptograptus tricornis (Carr.)

Dicellograptus sextans (Hall.)

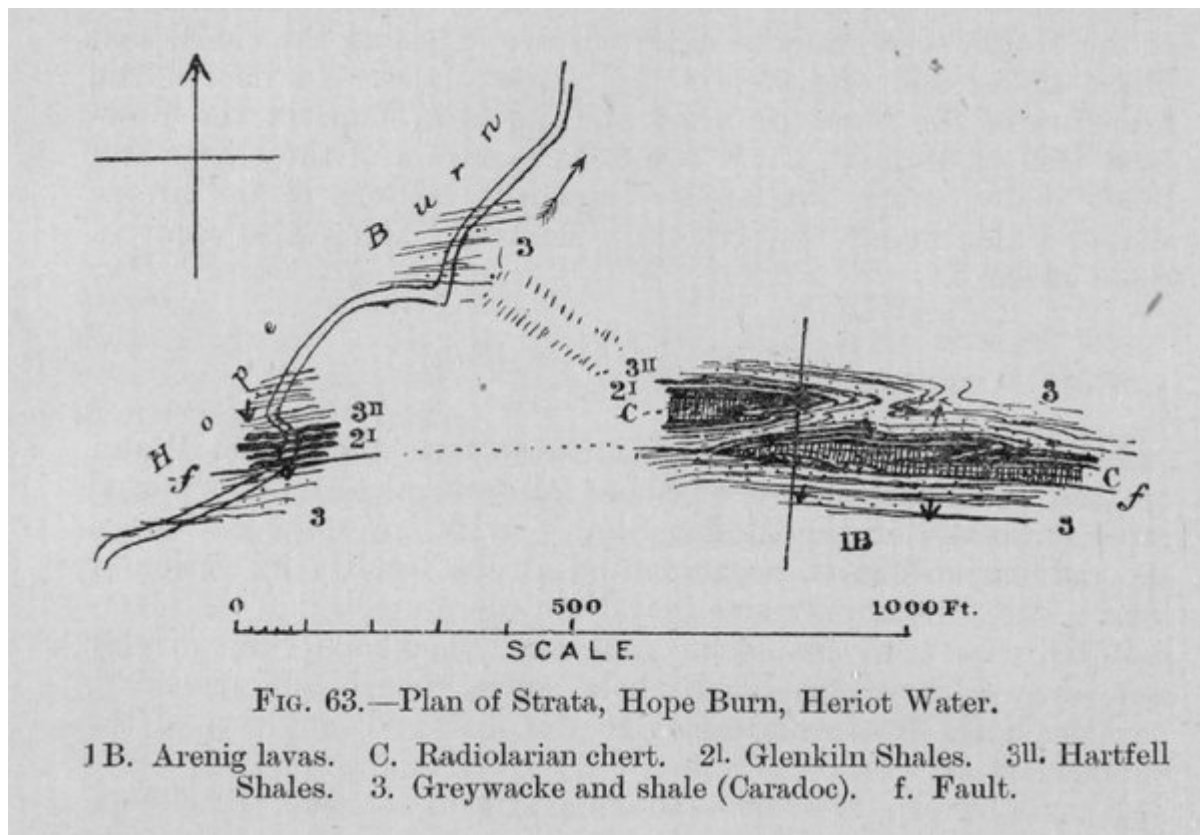
Dicellograptus moffatensis (Carr.)

Discina Portlocki (Gein.)

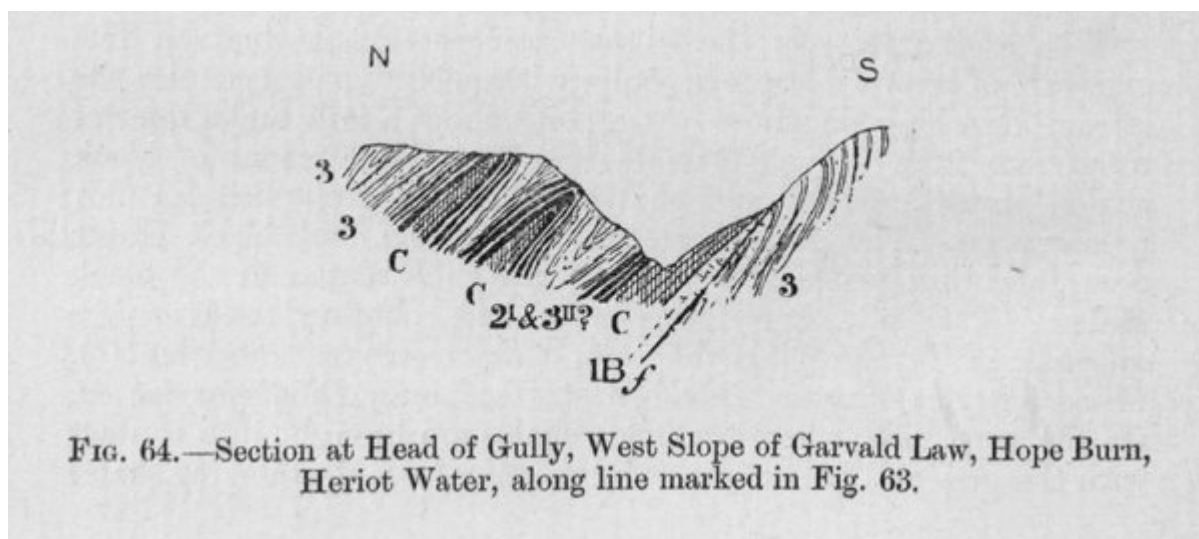
Thorter Burn (near Garvald). — [NT 59882 70425] This stream furnishes evidence of the easterly prolongations of the folds of the Moffat series. For nearly 600 yards south of the fault between the Tipper Old Red Sandstone and the Silurian

region, the rocks exposed in the Thorter Burn consist of crushed dark and grey shales and gritty greywackes; the latter being in places conglomeratic. Just above the point where the burn bends at a right angle, flinty black shales occur, too much shattered to yield fossils; these are followed by jointed grits and shales for a distance of 150 yards, where they are in turn succeeded by crushed black flinty shales affording specimens of *Diplograptus foliaceus*, *Climacograptus bicornis*, *Cryptograptus tricornis*, *Dicellograptus*. Next come grey mudstones with dark seams like the Barren Mudstones of the Moffat region; but soon grits appear which dip to the N.N.W. at 37°, and form a series of cascades. These are followed by a development of black shales that occupy the stream for a distance of fifteen yards, and are traversed by numerous dykes of acid igneous rocks. At one point on the east bank, the following fossils occur in thin black shale partings between the black flinty ribs, the graptolites and shells being in fine preservation: *Lasiograptus bimucronatus*, *D. foliaceus*, *D. euglyphus*, *Dicellograptus*, *Climacograptus bicornis*, *D. perexcavatus*, *Corynoides calyculcuris*, *Discina Portlocki*, *Acrotreta Nicholsoni*. These black shales are immediately followed by greywackes, and then by a broad belt of grey sandy shales of the Lowther type, which are admirably exposed on the banks of the stream. The general dip of the strata in the Thorter Burn is towards the N.N.W., so that the strata must here again be isoclinally folded.

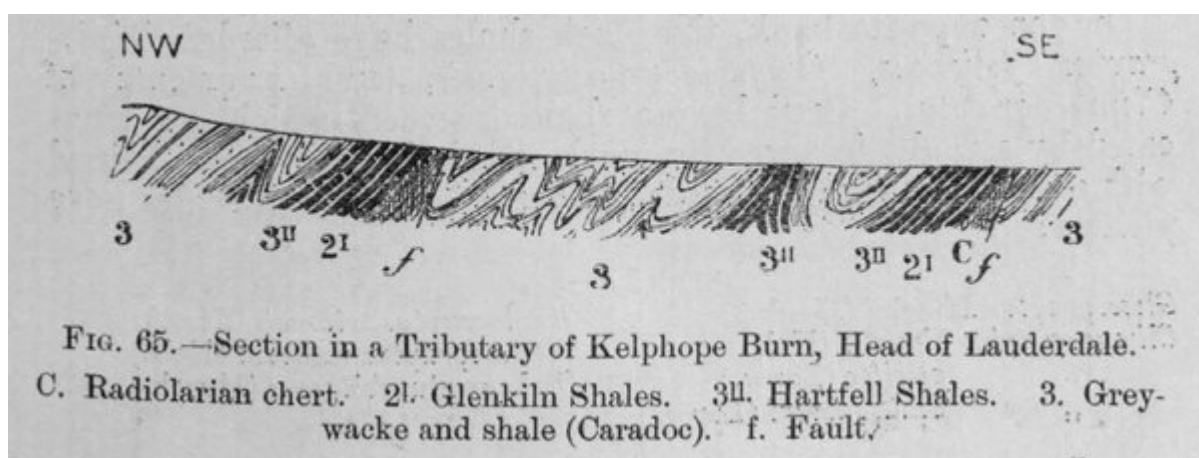
Sauchet Water, South of Stenton. — [NT 61357 72061] The remaining outcrops of the Moffat Shales on the northern slopes of the Lammermuirs are to be found in tributaries of the Sauchet Water, about a mile and a half south of Stenton. Small exposures of black shales with black flinty ribs appear in two tributaries close to the fault which brings the Upper Old Red Sandstone in contact with the Silurian rocks. One of the outcrops in the main tributary north of Stonypath yields *Diplograptus foliaceus* and *Dicellograptus*; but fossils are difficult to obtain owing to the shattered condition of the rocks. The black shales are here succeeded by grits and greywackes, which are followed southwards by a great development of grey sandy shales. In a little tributary of the Sauchet Burn, about a quarter of a mile south of Deuchrie Farmhouse [NT 62251 70962], a thin dark seam in these grey shales afforded *Diplograptus foliaceus* or *truncatus*, *Dicellograptus complanatus*, and *Climacograptus* sp. This evidence is of importance, as it proves beyond doubt that the grey shales, are the equivalents of the Barren Mudstones of Moffat.



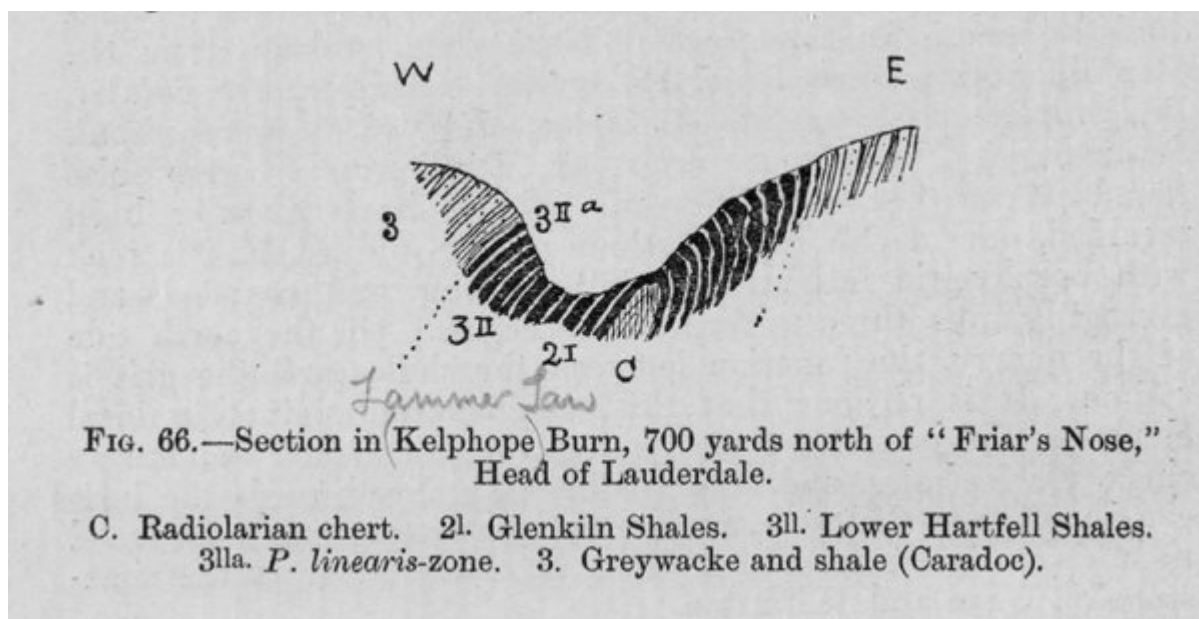
(Figure 63) Plan of Strata, Hope Burn, Heriot Water. B. Arenig lavas. C. Radiolarian chert. 2I. Glenkiln Shales. 3II. Hartfell Shales. 3. Greywacke and shale (Caradoc). f. Fault.



(Figure 64) Section at Head of Gully, West Slope of Garvald Law, Hope Burn, Heriot Water, along line marked in (Figure 63).



(Figure 65) Section in a Tributary of Kelphope Burn, Head of Lauderdale. C. Radiolarian chert. 2I. Glenkiln Shales. 3II. Hartfell Shales. 3. Greywacke and shale (Caradoc). f. Fault.



(Figure 66) Section in Kelphope Burn, 700 yards north of "Friar's Nose", Head of Lauderdale. C. Radiolarian chert. 2I. Glenkiln Shales. 3II. Lower Hartfell Shales. 3IIa. *P. linearis*-zone. 3. Greywacke and shale (Caradoc).

