Chapter 11 The Central Belt — continued, Tarannon rocks

The belt of territory, upwards of twenty-five miles in width, which stretches from the northern limit of the Llandovery strata on the slopes of the Moorfoot Hills and the Lowther range, to the boundary of the Wenlock and Ludlow Rocks along the southern margin of the Silurian Tableland, is occupied by strata mainly of Tarannon age. In the foregoing chapters we have described the various boat-shaped inliers of the Moffat series which, within this region, rise from underneath the younger Tarannon Rocks. We have indicated that throughout these numerous inliers the lowest zone of the Birkhill Shales, viz.: that of *Diplograptus acuminatus,* is regarded as the base of the Upper Silurian sediments of the Central Belt; for, as Professor Lapworth has shown, a great palaeontological break intervenes between the Birkhill Shales and the underlying divisions of the Moffat series. The assemblage of graptolites found in the various sub-divisions of the Birkhill Shales proves that the beds containing them are of Llandovery age. In order, therefore, to complete the description of the rocks that enter into the structure of the Central Belt, we now propose to deal with those coarse-grained sediments which, though remarkably barren, nevertheless yield, at a few localities, fossils characteristic of the Tarannon Rocks of other regions.

Northern Base-line of Llandovery Rocks of the Central Belt. — In referring to the geological map of the Silurian Tableland, it will be seen that the Llandovery Rocks of the Central Belt are bounded by two great structural lines. The one on the south marks the upper limit of the Tarannon beds, where the latter pass conformably upwards into the Wenlock formation, while that on the north indicates the northern base-line of the Llandovery sediments, where they rise to the surface and are followed northwards by the representatives of the Bala, Arenig, and Llandeilo formations. The northern baseline extends along the tableland from the crest of the Lammermuirs in the far north-east to a point on the Wigtbwnshire coast about five miles south of Portpatrick. It is also observable that this boundary line along its outcrop follows a series of loop-like curves — a feature which might naturally be expected from the highly convoluted character of the rocks of the Silurian Tableland. For example, from the crest of the Lammermuirs the boundary has been drawn across the head of Lauderdale by the southern declivity of the Moorfoot Hills, where the curvatures are very marked, to a point north of Peebles. Thence it sweeps up the valley of the Tweed, and by the Kingledores Burn to Elvanfoot, on the river Clyde, and from the latter point it has been traced along the southern slopes of the Lowther Hills, where the rapid flexures are again prominent, to Enterkinefoot, in Nithsdale. Westwards it follows a devious course by Dalry, in Glen Ken, and across the Wigtownshire moors to Glenluce, whence after passing underneath the sands of Luce Bay it crosses the south-western peninsula by Stoneykirk to a point south of Portayew Bay, on the shores of the Irish Channel.

It must be admitted that the tracing of this northern base-line has been a matter of considerable difficulty, and, in some parts, its delineation on the map cannot be regarded with complete satisfaction, for over much of the area we have failed to obtain conclusive palaeontological evidence for fixing the precise position of the line. In the detailed descriptions of the various inhere of the Moffat series within the Central Belt, ample evidence has been given to show how the different sub-divisions of the Birkhill Shales gradually disappear or undergo important modifications, as they are followed north-westwards from the Moffat region. Where thin seams of dark shales, containing recognisable Lower Birkhill graptolites, are still traceable along the north-west margin of the Central Belt, the northern limit of the Llandovery Rocks may be fixed with approximate certainty. Where, on the other hand, only fragments of undoubted *Monograptidae* and other forms are obtainable in thin films intercalated in coarse sediments, or where even these forms disappear, the boundary line laid down on the map can be regarded only as a provisional one which may be modified by future research. Referring for details to the evidence above adduced in proof of the gradual modification of the Birkhill Shales towards the north-west, we may here indicate generally the nature of the data for fixing the northern limit of the Llandovery Rocks.

Over the north-eastern portion of the Central Belt, in the basin of the Gala Water, and especially in the Lugate and Heriot Waters and their tributaries, representatives of the *Monograptus spinigerus, Monograptus gregarius,* and *Diplograptus acuminatus* zones are separated from each other by grits, conglomerates, greywackes, and shales along the northern margin of the Llandovery area. In some cases, as, for instance, in the Ladyside Burn in the basin of the Heriot Water, thin leaf-like seams interleaved in massive grits contain specimens of *Monograptus attenuatus, M. tenuis,* and *Climacograptus normalis,* which usually present themselves as dwarfed representatives of the forms so characteristic of

the central Moffat region. The boundary line has here been drawn with approximate certainty along the northern margin of these sediments, which still yield recognisable Llandovery graptolites. South-westwards in the basin of the Leithen Water similar evidence is obtained, for there stunted specimens of *Monograptus tenuis, Dimorphograptus, Diplograptus,* and *Climacograptus* may be gathered from dark seams in shales associated with greywackes, near the northern margin of the Central Belt.

Again, in the valley of the Tweed at Stobo, the boundary line has been drawn between the Stobo slates on the north, which are regarded as Caradoc, and certain massive grits to the south, believed to be of Llandovery age. Further up the river at Tweedsmuir, in certain dark blue shales associated with grits which are exposed at the foot of the Fruid Water, *Diplograptus vesiculosus, D. acuminatus, Climacograptus normalis,* and *siculae* of graptolites have been obtained; while still further north the zonal Birkhill forms disappear, and attenuated representatives of *Diplograptus* and *Climacograptus* survive.

Between the Clyde and the Nith certain flaggy shales or slates with dark carbonaceous films, containing a large *Diplograptus,* an attenuated form of *Climacograptus* of *C. normalis* type, and *siculae* of graptolites, which are exposed in various quarries and natural sections on both sides of the road leading from Elvanfoot to the Dalveen Pass, have been regarded as there forming the base of the Llandovery formation, since they are followed towards the north by the Lowther Shales (Caradoc).

Still further to the west, in that section of the tableland stretching from Nithsdale to the valley of the Ken, no characteristic Birkhill graptolite has been obtained from strata near the Llandovery boundary-line. The position of this line has there been fixed by the outcrop, towards the north, of grey mudstones and shales that represent the Barren Mudstones, and blue-black shales containing some of the characteristic forms of the *Pleurograptus linearis* zone. In the tract of metamorphosed rocks between New Galloway and Newton Stewart, with its two large granite masses, no palaeontological evidence is available; but on the southern side of the Wigtownshire moors about Glenluce, similar phenomena to those already described are obtained. On the shore to the south of this town certain thin dark carbonaceous seams, embedded in greywackes and shales, yield dwarfed specimens of *Diplograptus acuminatus, Climacograptus normalis,* another stunted form of *Climacograptus* of common occurrence on this horizon, *siculae* of graptolites, and specimens of the young stages of *Dimorphograptus.*

From these data it appears that along the northern limit of the Llandovery Rocks of the Central Belt, where the Moffat type of the Birkhill Shales has entirely disappeared, and where thin seams of carbonaceous shales, interleaved in greywackes and shales, contain a few dwarfed representatives of the prolific Birkhill fauna, the original physical conditions of deposit in Silurian time must have been unfavourable for the development of that group of organisms. The forms apparently indicate arrested stages of progress. If such be the true explanation, it may account for the difficulty in fixing the precise position of the northern base-line of the Llandovery Rocks. In the absence of palaeontological evidence, this line has been drawn between the series of massive grits, greywackes, and shales, which are the dominant feature of the Tarannon Rocks of the Central Belt, and the group of shales to the north (Lowther Scales, Stobo Slates, &c.), which are associated with the Hartfell black shales of the Northern Belt.

The broad extent of territory occupied by rocks, mainly of Tarannon age, in the Central Belt, is due solely to the extraordinary plication whereby the same strata are brought repeatedly to the surface. The numerous anticlines of the Moffat series afford conclusive proof of the reduplication of the strata by lateral compression, but even where the Moffat Shales do not appear at the surface, there can be little doubt that the overlying Tarannon Rocks have been similarly affected. For the observer has only to traverse any of the striking coast sections at either termination of the Central Belt to assure himself of this phenomenon. Since the time of Sir James Hall, the remarkable flexures of the strata between Cockburnspath and St. Abbs Head, in Berwickshire, have been classic features in Scottish geology, for there the system of normal and isoclinal folds may be studied in detail.

The phase of sedimentation represented by the Tarannon Rocks of the Central Belt differs widely from that of the underlying Birkhill Shales. Its dominant type is that of massive grits and greywackes (Queensberry Grits), which locally merge into conglomerates. This type is specially characteristic of the central and northern portions of the Central Belt. But towards the southern margin of the belt a remarkable change is observable, for there the highest Tarannon Rocks, which

pass conformably upwards into the Wenlock formation, consist of brown-crusted flags, with grey, green, or red shales, and bands of brown or yellow greywacke from one to two feet thick (Hawick Rocks).

Though the Tarannon Rocks of the Central Belt are in general remarkably barren, there is one area in the tract, extending from Selkirk and Innerleithen to Melrose and Lauder, where fossils have been obtained from a large number of localities. The assemblage of organisms, as shown by Professor Lapworth, differs widely from that of the underlying Birkhill Shales, for it includes some graptolites which are survivors from these shales, some which pass up into the Wenlock strata, and others which are restricted to the Tarannon group. From the constant association of graptolite-bearing shales with grits and greywackes, and the rapid reduplication of the strata, it is difficult to establish a zonal sequence of the Tarannon graptolites. Further detailed investigation, however, may throw considerable light on this question.

North-eastern district

Beginning with that portion of the Central Belt which has proved the most fossiliferous, from Melrose and Selkirk in the south to Innerleithen and Lauder in the north, we find that the Upper Birkhill Shales at Coldshiels Loch, south-west of Melrose, are immediately followed by mudstones, shales, and flagstones with *Monograptus turriculatus,* which is regarded as one of the zonal forms of the basal beds of Tarannon age. These strata pass upwards into brown flagstones and shales (Abbotsford flags), surmounted by massive grits and shales (Buckholm grits), which usually in the finer bands contain graptolites, with *Crossopodia, Myrianites,* and other tracks. Reference may first: be made to the more important fossiliferous localities which have been detected in the region to the north of the arch of Moffat Shales in the Rhymer's Glen, and next to those on the south side of that anticline.

Packman's Burn. — [NT 57212 36307] In this stream, which joins the Leader Water about a mile to the north of Leaderfoot, a section of flagstones and shales with greywacke bands is exposed for about half a mile west from the railway bridge. The strata usually dip towards the north-west. At a point on the north bank, about 100 yards west from the railway bridge, the following fossils were obtained from a baud of gritty greywacke, viz.: *Monograptus turriculatus, M. exiguus, Monograptus priodon, Dictyonema,* crustacean fragments, &c. About a quarter of a mile to the west of the same bridge certain beds yielded *Monograptus turriculatus, M. exiguus, M. priodon, M. galaensis;* while near the western termination of the rock-section thin grey shales furnished specimens of *Monograptus priodon, M. galaensis, M. vomerinus, Cyrtograptus (?).*

River Tweed near Melrose. — [NT 53335 34983] Along the strike of the strata seen in Packman's Burn certain sandy shales which appear in the Tweed at a cottage south-east of Pavilion and a mile and a quarter north-east of Melrose, have yielded specimens of *Monograptus exiguus.* Still further to the south-west, along the same line of strike, a similar assemblage of organisms may be observed in an old quarry, a few yards to the north of Cascade Farmhouse [NT 48969 32992], on the north bank of the Tweed, and about a mile and a half west of Abbotsford. Here hard grey grit is associated with greenish grey shales, which contain *Monograptus turriculatus* in great abundance, together with *M. exiguus, M. galaensis,* &c.

Long Phillip Burn. — In this stream, which joins the River Ettrick opposite the town of Selkirk [NT 46297 28722], about three and a half miles to the south-west of the last mentioned locality, certain blue-black shales at Corbie Burn have yielded *Monograptus exiguus, M. priodon,* &c., while at the foot of a small tributary rivulet the same forms occur with M. *crispus* [NT 44800 29542].

Allan Water. — [NT 52084 37096] About a mile further north, across the strike of the strata, important fossiliferous bands are visible in this stream, which joins the Tweed about a mile and a half north-west of Melrose. Nearly opposite the Avenel Plantation (Geological Survey Map, Sheet 25) the following forms have been obtained from shales associated with greywackes in the Allan Water: *Monograptus exiguus, M. vomerinus, Diplograptus tamariscus,* &c. Again, about one-third of a mile further down, where a stone fence crosses the water, a thin band of dark-blue shales, interleaved in greywackes and flags, has furnished the following assemblage of fossils:

Monograptus exiguus (Nich.)

Monograptus galaensis (Lapw.)

Monograptus priodon (Bronn.)

Monograptus attenuatus (Hopk.)

Monograptus spiralis (Gemitz.)

To the south-west of Avenel Plantation, on Westa Hill [sic "Wester"][NT 50764 36028], at a point about a mile east of Galashiels, hard flaky grit and flaggy red shales, dipping to the north-west at angles from 65°–70°, have yielded specimens of *Monograptus turriculatus, M. crispus, Myrianites, Crossopodia,* &c.

Buckholm Hill. — [NT 49022 37547] The series of massive grits and greywackes which overlie the Abbotsford flags, greywackes, and shales are well seen on the Buckholm Hill, north of Galashiels, where they form rocky ridges, traceable south-westwards by the Meigle and Blakehope Hills to Cadonfoot, south of Clovenfords. In this region the shales associated with the massive grits yield a characteristic Tarannon fauna. A quarry at the road-side west of Buckholm Hill, about half a mile W.N.W. of Galashiels, has laid open an interesting section of massive grits and shales, the latter yielding specimens of *Monograptus exiguus, M. convolutus, M. proteus, Dexolites gracilis, Myrianites,* and branching tracks. In a quarry now abandoned at Buckholmside, Galashiels [NT 48181 37308], and not far to the north of the locality just referred to, red and grey shale partings in massive greywackes have yielded *Monograptus crispus, Retiolites Geinitzianus, Myrianites,* and other tracks. Nearly in the strike of the beds at Buckholmside, fossiliferous bands appear in the Ladhope Burn [NT 49677 37174]?, at the old bridge about a mile above Buckholmside, where greyish blue shales have furnished the following, among other forms, viz.: *Monograptus exiguus, M. Sedgwicki, M. convolutus,* var. communis*, M. proteus, Petalograptus folium, Climacograptus normalis.*

The grits, flags, and shales of Buckholm [NT 48136 38662], when followed southwestwards to Clovenfords and Cadonfoot, have been found to yield a characteristic Tarannon fauna.

Clovenfords and Cadonfoot. — [NT 44678 36304], [NT 44834 34995] Keeping to the road southwards from Clovenfords Station, in the direction of Cadonfoot, the observer comes upon a large quarry close to the railway viaduct at the bend near Cadonlee. Here the strata consist of alternations of flags, shales, and greywackes, which dip towards the N.N.W. at 75°. Some of the greywacke bands at the south side of the excavation are seven feet thick, while zones of shaly mudstones occur, one about two feet thick, in which the material breaks up into thin flaky particles. The fossiliferous bands vary in character; one type which decomposes into a light grey rock, stained with iron-pyrites, crumbles as a rule under a slight pressure, and is crowded with graptolites. Where fresh parts of this rock can be obtained, the fossils are well preserved. Another type consists of grey platy shales, weathering brown, in which the graptolites, though not very abundant, are in excellent preservation. The fossils given in the subjoined list were here obtained:

Monograptus turriculatus (Barr.)

Monograptus exiguus (Nich.)

Monograptus crispus (Lapw.)

Monograptus galaensis (Lapw.)

Monograptus priodon (Bronn.) abundant.

Monograptus attenuatus (Hopk.)

Dictyonema sp.

Southwards from this quarry, the greywackes and grits become more massive towards Cadonfoot, their general dip being to the N.N.W., at angles varying from 60° to 70°. At Cadonfoot, on the banks of the Tweed, in an old quarry now partly built over, a few yards to the south-east of the schoolhouse, red shales, interleaved in grey and blue shales, have been

found to enclose *Crossopodia, Myrianites,* &c.

Cadonlee. — [NT 44013 35706] About half a mile to the north-west of Cadonfoot, and about a quarter of a mile north-west of Cadonlee Farmhouse, shales seen on the north side of the road leading to Galashiels dip to the north-west at angles varying from 45° to 50°. From certain thin dark seams, interleaved in these blue and grey fissile shales, the following graptolites were obtained:

Monograptus crispus (Lapw.)

Monograptus exiguus (Nich.)

Monograptus galaensis (Lapw.)

Monograptus Sedgwicki (Portl.)

Monograptus priodon (Bronn.)

Monograptus convolutus (His.)

Monograptus runcinatus (Lapw.)

Diplograptus Hughesi (Nich.)

Diplograptus tamariscus (Nich.)

Cyrtograptus sp.

Aptychopsis glabra (Woodw.)

Dictyonema sp.

Plant remains.

Much in the same line of strike, and about half a mile northeast of Clovenfords, in a quarry on the south side of the road near Meigle Farmhouse, where massive greywackes and flags with red and grey shales have been exposed, the red shales contain remarkably fine examples of *Protovirgularia*and *Myrianites,* while the grey shales furnish *Monograptus priodon* and *Monograptus galaensis.*

Hillend. — [NT 44886 36887] About half a mile due north of Clovenfords, from a quarry at the wayside, near Hillend, a well marked suite of Tarannon fossils was obtained in blue shales and mudstones, with micaceous greywackes in bands and ribs. Some of the blue shales contain dark seams, which have yielded:

Monograptus turriculatus (Barr.)

Monograptus exiguus (Nich.)

Monograptus priodon (Bronn.)

Monograptus communis (Lapw.)

Petalograptus folium (Ms.)

Retiolites sp.

Diplograptus sp.

Peltocaris aptychoides (Salt.)

Aptychopsis glabra (Woodw.)

Ceratocarus sp.

Thornylee. — [NT 41260 36288] Still further towards the north-west, across the strike of folded strata of Tarannon age, an excellent section has been laid bare at Thornylee, in the valley of the Tweed, on the north bank of the river (Sheet 25 of Geological Survey Map). At the western limit of the rock-exposures, where greenish grey and red flaggy shales, alternating with bands of grit, dip to the north-west at an angle of 70°, the shales are crowded with *Crossopodia.* South-eastwards, along the road towards the quarry, the beds roll over to the south-east, and in the quarry itself greenish grey and purple Baggy shales are seen to be charged with *Crossopodia* and *Myrianites,* together with *Monograptus exiguus, M. priodon, M. galaensis,* &c.

Basin of the Cadon Water. — [NT 40211 40897] As the observer continues north-westwards, across the strike of the Tarannon Rocks, he meets with these fossiliferous zones at intervals, with their characteristic organisms. For instance, on the east side of the valley, near Newhall [NT 42402 37677], certain red and sandy shales, interleaved in thick-bedded greywackes and grits, which dip in a north-east direction at angles varying from 55° to 60°, have yielded *Myrianites, Crossopodia,* and other tracks. Again, on the east bank of the stream, near the farmhouse of Cadonhead, about four miles north-west of Clovenfords, certain greywacke bands, weathering spheroidally, and grey shales have furnished specimens of *Monograptus exiguus, M. spinigerus, Petalograptus folium.*

Similar evidence is found near the head-waters of the Cadon, immediately to the south of the moory watershed named the Deaf Heights [NT 38752 44410], at the western margin of 25, one inch. Here the stream flows nearly east for about a mile, and at a point almost due south of the Deaf Heights, a scar on the north bank of the burn shows drab-coloured shales, with dark or blue-black seams, containing *Monograptus exiguus* in abundance, and *Monograptus pandus* [NT 38787 43998]. Not far to the west of this locality, where a crescent-shaped cliff bounds the northern margin of the alluvium, a fine exposure of grey and yellow shales has supplied graptolites in fine preservation, including specimens of *Monograptus turriculatus, M. exiguus, M. pandus, M. spiraris,* together with *Myrianites* and *Crossopodia.* Further west, near where the Cadon Burn enters Sheet 25 of the Map, the following forms have been obtained from grey sandy shales, viz.: *Monograptus exiguus, M. convolutus, M. communis.*

Innerleithen district

On the other side of the watershed between the sources of the Cadon and certain tributaries of the Tweed, near Innerleithen [NT 33301 36611], confirmatory evidence is obtained of the presence of Tarannon graptolites in strata which are evidently the south-west prolongations of those in the higher part of the Cadon Water. About two miles east of Innerleithen the Walker Burn, about a mile up from its junction with the Tweed, divides into two branches, that drain the slopes of the Glede Knowe (1915 feet) and the surrounding heights. About 200 yards up the east branch [NT 36148 40005], flaggy dark blue shales appear, which contain thin leaf-like dark seams, yielding *Monograptus exiguus,* beautifully preserved in the solid form, *M. Sedgwicki, Rastrites maximus, Petalograptus folium,* and *Climacograptus normalis.* In the west branch similar evidence is obtained not far below the level of the 1250 feet contour line [NT 35454 40571], where slaty shales appear in the stream and dip to the north-west at 75°. About 50 yards above that level, in a fine exposure of platy and flaggy shales with dark seams, inclined in a similar direction, one of the carbonaceous layers contains *Monograptus turriculatus* in great abundance and in excellent preservation, together with other forms. Further up the burn other shales appear, in which one of the graptolites resembles *Monograptus spinigerus.* These strata continue in the section for some distance upwards. Near the source of the burn, dark shales with decomposing clays are the last visible strata in this tributary of Walker Burn.

Grieston Quarry. — [NT 31359 36185] The strata in this quarry have been familiar to geologists since Professor Nicol first recorded graptolites from them. They consist of blue and grey slaty shales, with occasional thin seams of limestone or calcareous ribs, from ¼ to an ½ inch thick, and are inclined to the north-west at high angles. The following fossils were obtained from this quarry by the Geological Survey: *Monograptus priodon, M. convolutus, M. vomerinus, M. Sedgwicki, Retiolites geinitzianus, Myrianites* sp. From the same locality have been recorded the following additional forms: by Professor Lapworth, *Monograptus colonus* and *Diplograptus;* by Mr. R. Mathieson, a *Discinocaris;* and by the Innerleithen

Alpine Club, *Monograptus tenuis.*

Lauder district

Turning now north-eastwards along the strike of the strata, from Innerleithen, across the Cadon and Gala Waters to the neighbourhood of Lauder [NT 53112 47560], we find at various localities characteristic assemblages of graptolites of Tarannon age. To the south-west of the village of Lauder, red and purple flaggy shales and grits are visible in the Lauder Burn, and also in certain quarries, with a general dip to the south-east at high angles. In one of the quarries, about a mile south-west of Lauder, certain red shales contain *Monograptus priodon, M. Sedgwicki, M. leptotheca, M. convolutus, M. spiralis, Climacograptus.* Again, about two miles to the north-west of the village of Lauder, in the Harry Burn, nearly opposite Old Whiplaw, specimens of *Monograptus priodon, M. galaensis,* &c., have been obtained from shales.

Bruntaburn. — [NT 59648 49735] To the north-east of the Upper Old Red Sandstone of Lauderdale a triangular tract of strata mainly of Tarannon age has likewise yielded characteristic fossils. In the area between the arch of the Moffat series in Earnscleuch, and the margin of the Upper Old Red Sandstone at Spottiswoode, several exposures of fossiliferous bands furnish Tarannon graptolites. Near the mill at Bruntaburn [NT 59648 49735], west of Spottiswoode, red flags, with a dip to the N.N.W., furnish specimens of *Protovirgularia dichotoma, Myrianites, Crossopodia,* and other tracks. This is one of the few localities in the Tarannon area of the Central Belt where *Protovirgularia* occurs in great abundance. Above Bruntaburn Wood [NT 59555 51238] thick-bedded shales have yielded *Crossopodia, Grossochorda, Myrianites,* and other tracks. Again, in the higher part of this stream, where it receives the name of Pondreigh Burn [NT 59575 52262], grey shales with grit bands appear close to the footpath leading to Flass, where they have furnished an interesting suite of fossils, viz.:

Monograptus exiguus (Nich.)

Monograptus priodon (Bronn.)

Rastrites maximus (Carr.)

Petalograptus cream (Barr.)

Petalograptus palmaeas (Barr.)

Wedderlie Burn. — [NT 64124 52026] About three miles to the north-east of the exposures in Bruntaburn, fossiliferous bands reappear in the Wedderlie Burn, near Wedderburn Farmhouse, where some red and grey mudstones have furnished specimens of *Protovirgularia, Grossopodia, Myrianites, &c.,* and sandy shales have yielded *Monograptus exiguus, M. convolutus, M. spiralis,* and *Retiolites.*

Blythe Burn. — [NT 57729 48702] Similar evidence is obtained in the Blythe Burn and its tributaries, for at the bend in the stream north from Heugh Farmhouse, reddish-green shales have yielded specimens of *Monograptus exiguus, M. priodon,* and tracks. Again, in the slate quarries on the east side of the burn [NT 57434 49836], near the farmhouse of Blythe, the following forms have been obtained from blue shales: *Protovirgularia dichotoma, Crossopodia scotica, Myrianites,* and radiating worm-burrows. In a streamlet near the same locality examples of *Monograptus exiguus, M. priodon,* &c., were collected. Further up the Blythe Burn, at a sheep-fold about half a mile below Howebog [NT 57563 51873], certain sandy shales have furnished specimens of *Protovirgularia, Myrianites, &c.,* and near Broadshawrig [NT 58058 52818], *Monograptus exiguus* and M. *galaensis.* At the last-named locality the Blythe Burn is joined by the Easter Burn, in which a fossiliferous conglomerate, about 150 yards up from the junction of the two streams [NT 58110 52938], contains the following organisms in an imperfect state of preservation, viz.: *Orthis* or *Strophomena, Palaeocyclus, Petraia bina,* coral, crinoid stem, *Ptilodictya.* A similar pebbly grit or fine conglomerate reappears in the Wheel Burn, south-west of Wheelburn Law.

Whelplaw Burn. — Near the northern margin of Sheet 25 of the Survey Map, and to the north of the anticline of the Moffat Shales in the Earnscleuch, Tarannon fossils are likewise found in the Whelplaw Burn — a tributary of the Leader

Water — at a point about 400 yards up stream from Longcroft Farmhouse [NT 53168 53839], where brown mudstones, weathering spheroidally, furnish specimens of *Monograptus crispus, M. exiguus, M. attenuatus.* and are associated with grey flaggy shales and greywackes.

District south of Melrose

In the district south of Melrose, comparatively few fossiliferous localities have been met with in the Tarannon Rocks. On the banks of the wooded glen at Faldonsidemoor [NT 50595 31705] a good section may be seen of thin-bedded brown greywackes and flagstones, with grey and blue shales; the latter yielding *Monograptus vomerinus, M. priodon, M. galaensis.* In the Bowden Burn, which flows E.N.E. along the strike of the Silurian rocks and joins the Tweed near Dryburgh, fossils have been found in the strata belonging to the typical Hawick Rocks. South of the village of Bowden, between Bowden Mill and Maxpoffle [NT 55653 30325], grey-blue calmy shales and flagstones appear, followed further down stream by purple and grey shales with hard ribs or grey earthy decomposing greywacke. The former series, near Maxpoffle, has furnished a telson of *Eurypterus,* fragments of *Dictyocaris,* and crinoid stems.

In the neighbourhood of Selkirk, as for example on Selkirk Common, where the strata lie well to the north of the anticlines of the Moffat Shales at Melrose and Ettrickbridge-end, some of the beds consist of grits from 8 to 10 feet thick, which may possibly represent some of the thick bands of the Buckholm Grits. The strata, as seen in the quarry on Selkirk Common [NT 47789 27573], are normally folded, while along the same line of strike to the south-west of Ettrickbridge-end, they are repeated by isoclinal folds which have a persistent dip to the north-west. Although no graptolites have been obtained from these rocks in the neighbourhood of Selkirk, some of the shales are crowded with *Crossopodia, Myrianites,* and other tracks so common at Thornylee and Grieston. Mr. Pringle of Selkirk has obtained specimens from a quarry at the roadside near Merrycourt Park, about a mile north of Greenhill [NT 48340 24800], which show that the two sets of tracks figured by Salter in his Appendix to the memoir on the Geology of East Lothian (pp. 70, 71) must have been produced by the same animal.

District between Ashkirk and Hawick

South of the district around Ettrickbridge-end and Selkirk, the most typical development of the so-called "Hawick Rocks" is to be seen. They consist of greenish-grey shales with thin bands of greywacke, which are singularly destitute of fossils. Innumerable exposures throughout the belt show that the rocks are intensely plicated; the axes of the folds being for the most part vertical.

Though no graptolites have as yet been collected from the strata in the neighbourhood of Hawick, yet *Protovirgularia, Crossopodia, Nemertites, Nereites,* and other tracks are abundant in some of the shales; all of which are to be found in Stirches Quarry [NT 49762 16867] near that town. From the same locality a specimen showing the body segments of a species of *Ceratiocaris* was obtained by Mr. Andrew Waugh, Hawick, and presented to the Geological Survey. For a distance of three miles to the north of Hawick this sub-division of the Tarannon Rocks preserves its normal characteristics. The strata show constant reduplication by folding, the axial planes of the folds being there generally inclined to the south-east.

Cockburnspath and St. Abbe District

The coast line from Cockburnspath [NT 77337 71037] to St. Abbs Head [NT 91165 69406], and thence to Burnmouth, north of Berwick, displays a magnificent section of rocks of Tarannon age, where both types of sedimentation are represented, first the massive grits and greywackes (Queensberry Grits) and the brown weathering flagstones, greywackes and calmy shales (Hawick Rocks). The various convolutions of the strata exposed in this remarkable section are described and illustrated by Sir A. Geikie in the Survey Memoir on the Geology of Eastern Berwickshire, from which the following extract is taken:;

"Standing on the western verge of the precipices of St. Abbe Head, the observer sees before him one of the wildest cliff-lines on the East of Scotland. The Silurian strata are there thrown into vast folds, which in oft-changing curves jut out,

headland after headland, here worn into dim twilight creeks, there standing up as tangle-covered reefs and skerries, or grey sea-stacks, round which the gull and the auk and the solan goose are wheeling above, while the surge is ever breaking into foam below. His eye can trace the stratification of the cliffs as the sunlight falls on each successive promotory, now on an arch that has been half removed by the ocean, now on a trough that descends deep into the precipice, until these details are lost in the blue distance, as the coast-line bends away by the rocks of Fast Castle".

Along that part of the coast-line extending from Cockburnspath to St. Abbs Head, there are constant repetitions of massive greywackes, grits, flagstones, and shales (Queensberry Grits), while the peculiar lithological type representing the "Hawick Rocks" is found near Eyemonth. Near the Siccar Point [NT 81268 70967], Sir A. Geikie, together with Ramsay and Salter, obtained a specimen of *Monograptus priodon* in the course of the survey of that district, which was figured by Salter in the Appendix to the Memoir on the Geology of East Lothian. In the course of the re-examination of this region by the Geological Survey, a characteristic suite of Tarannon graptolites was recently obtained from an old slate quarry about half a mile south-west of Siccar Point; possibly the same locality which long ago yielded *Monograpius priodon.* The excavation is situated about 250 yards to the north-east of the farmhouse of Old Cambus, in an old dry water-course [NT 80694 70535]. Here grey and red fissile shales and grey flaggy shales, weathering brown, dip in a S.S.E. direction at an angle of 30°, and contain fossils in considerable numbers in certain seams. The following list comprises the forms obtained by the Geological Survey:

Monograptus priodon (Bronn.)

Monograptus pandus (Lapw.)

Monograptus galaensis (Lapw.)

Monograptus Hisingeri (Carr.)

Monograptus convolutus (His.)

Monograptus exiguus (Nich.)

Monograptus crispus (Lapw.)

Monograptus Barrandei (Tullb.)

Monograptus turriculatus (Barr.)

Monograptus leptotheca (Lapw.)

Diplograptus sinuatus (Nich.)

In addition to these graptolites the same strata yield *Crossopodia. Myrianites,* and other tracks.

Moffat district

In the Moffat [NT 08530 05298] region, the Tarannon Rocks may be grouped as follows:; (1) Purple and grey flags and shales; (2) greywackes and shales with massive grits and bands of conglomerate (Queensberry Grits); (3) grey, green, and red shales with rusty brown flags and greywacke bands (Hawick Rocks, Ardwell Group). The lithological characters of these various groups closely resemble those already described as occurring in the north-east portion of the Central Belt.

The green and grey shales of the first sub-division are well seen at the waterfall in the lateral gorge at Dobb's Linn [NT 08530 05298], where, with an inverted dip, they rise from underneath the *Rastrites maximus* zone of the Upper Birkhill beds. In many of the anticlines to the north of Dobb's Linn, where the Birkhill zones partly or wholly disappear, this zone

of green, grey, or purple shales is conspicuous. It is not improbable that this group of shales may in part represent the Birkhill beds. To the north and east of Dobb's Linn the phase of sedimentation indicated by the Abbotsford flags intervenes between the Birkhill division and the massive grits, which are there represented by grey or purple shales and flags with thin greywacke bands.

Next in order come the massive grits, greywackes, and shales of the second sub-division, the bands of grit varying in thickness from two to twenty feet. The thin partings of shales in this arenaceous series in one or two instances yield fossils; as, for instance, on Hunterheck Hill [NT 11013 05518], two miles north-east of Moffat, where *Dexolites gracilis, Crossopodia scotica,* and *Myrianites tenuis* have been obtained. Occasionally the pebbly grits merge into bands of coarse conglomerate. One of these in the neighbourhood of Moffat is locally known as the "Bannock Rock". The various outcrops, evidently repeated by folds, are indicated on the Map (Sheet 16) between Moffat and Harden. Again, towards the northern margin of the Llandovery area, a prominent band of conglomerate has been traced from the basin of the Clyde to the valley of the Tweed. One locality where it is typically developed is in the Pinstane Hill [NT 01691 16739], about a mile and a half to the E.N.E of Little Clyde (Sneet 16). Here the rock possesses a greywacke matrix, in which are embedded rounded pebbles of quartz, red chert with radiolaria, Arenig volcanic rocks, with boulders of granite and quartzite from 8 to 10 inches in diameter. Some small pieces of mica-schist have also been observed. The fragments of quartzite and mica-schist resemble rocks of those types' in the Eastern Highlands; there can be little doubt that they were derived from that region, Their occurrence, therefore, in the Llandovery conglomerate at Pinstane suggests that some at least of the crystalline schists of the Eastern Highlands had been elevated and denuded prior to Llandovery time. Towards the northern limit of the Llandovery area, the massive grits seem to pass laterally into greywackes with zones of shale (Dalveen Group).

From certain microscopic sections of the Llandovery greywackes and grits from this region, examined by Mr. Teall, it appears that some of the bands contain quartz, orthoclase, microcline, plagioclase, mica, and fragments of various volcanic rocks belonging to the andesitic and felsitic groups. It is clear, therefore, that both volcanic and plutonic rocks have contributed to their formation. The fragments are angular or sub-angular. Well-rounded grains are rare. There is, further, a very great variability in the sizes of the constituent grains; indeed, the material does not appear to have been well sorted by aqueous action.

For a distance of nine miles to the north of Moffat the Tarannon Rocks (Queensberry Grits), as has been shown in the foregoing chapters, are constantly repeated by a series of inverted folds, the prevalent dip being towards the north-west. An interesting feature connected with this plication of the strata in the northern region is the development of slight schistosity in the grits, greywackes, and shales. This alteration is specially noticeable in a belt of ground, three miles in width, between Nether Howecleuch [NT 02943 12645] in the Eyan Water and the Little Clyde [NS 99378 16051], excellent sections being visible in the railway cuttings. Under the microscope Mr. Teall has observed that "these schistose greywackes have a well-marked micro-flaser structure, and that the fine material of the matrix sweeps round the larger constituents in fluxion curves. These constituents occasionally *give* undulose extinction, indicative of strain, but they have not been much broken, and are as a rule sharply separated from the matrix. Peripheral granulation, so common in the gneissose grits of the Southern Highlands, is entirely absent". The shales are converted into slates approaching phyllites, "the main mass being a fine-grained aggregate very difficult to resolve under the microscope into distinct individuals. It consists apparently of quartz and sericite, with minute grains and crystals of rutile and a small quantity of brown or black granular matter, which gives a dirty aspect to the microscopic section. The sericite occurs in the form of very minute scales".

The normal type of the Queensberry Grits of the Central Moffat area extends as far south as Ettrick Pen. A line drawn north-east and south-west along the south side of the watershed on that hill roughly indicates the southern limit of this type of sediment, for to the south and east of that line the rocks lose their massive character. For some distance to the south of this line, the strata consist of flagstones" shales, and greywackes, repeated by sharp isoclinal folds whose axial planes dip to the north-west at low angles. The greywackes are traversed by a series of joints coated with quartz and calcite, and break into sub-angular blocks or fragments. The shales are rudely cleaved, though the cleavage is by no means persistent.

Reference may now be made to certain shales yielding graptolites which occur in the Tima Water, Rankle Burn, and at Deloraine, in the basin of the Lower Ettrick. Some of these bands yield *Monograptus exiguus,* and it is therefore probable that they belong to a higher horizon than the *Rastrites maximus* zone of the Birkhill Shales, and may be of Tarannon age.

Tima Water. — [NT 28006 12935] In the Lower Ettrick Valley the Tima Water, about a mile above its junction with the Ettrick, exposes thin black seams which dip steadily to the north-west at angles from 30° to 60°. At the northern margin of their outcrop a few graptolites have been obtained, where the shales are succeeded by alternations of black grits and shales with thin bands of black shale. The beds seen furthest up stream consist of grey and green mudstones. The strata in the Tima Water and on the Law Kneis Hill [NT 29303 13101] to the east are repeated by isoclinal folds and are accompanied by reversed faults.

Rough Sike, Gamescleuch. — [NT 29096 14361] Two thin bands of dark shale in this section yield imperfectly-preserved graptolites. In the Annelshope Burn, about 600 yards above Annelshope [NT 30100 15617], similar seams contain *Monograptidae.*

Rankle Burn and its Tributaries. — [NT 30721 17035] At the roadside at Cacrabank, on the Rankle Burn, a thin, dark, rusty band, interleaved in blue shales and flaggy greywackes, supplied *Monograptus exiguus, M. crispus,* and *M. priodon,* forms which are characteristic of the Tarannon shales north of Melrose. Near the head of the March Sike [NT 32457 16483], joining the Rankle Burn from the east, grits of the Queensberry type come to the surface, stained red with haematite. For a distance of about 50 yards below this point red greywackes and shales, with silky bands yielding *Rastrites maximus* (Carr.) and other forms, dip towards the north-west at angles from 40° to 50°. They are succeeded by black grits, among which two thin seams of black shale yielding *Diplograpti* are associated with dark grey greywackes and shales, followed by a band of black shales from four to five inches thick yielding *Monograptus exiguus.*

Not far to the south, greywackes and shales are thrown into an isoclinal fold, and rise again with an apparent normal dip to the north-west. These strata rest on calcareous grits with galls of black shale, succeeded by rusty grits and greywackes underlain by decomposing rusty mudstones, which, by means of a reversed fault, are made to overlie thick-bedded greywackes. Below this point the stream cuts through boulder clay. But from the evidence now adduced it is probable that there is here the remnant of a fold, the southern limb of which has been removed by a reversed fault.

Again, on the right bank of the Deloraine Burn, about 350 yards below the shepherd's cottage [NT 33943 19065], dark shales with *Rastrites maximus* dip to the north-west at 25°. Another anticline occurs on the left bank south of the cottage.

On the slope of Mossbrae height, south of the river Ettrick, grey grits dip at from 15° to 30°. The north-east face of the hill presents an overhanging cliff, the upper portion of which is composed of grits, the lower of grey shales with dark bands yielding *Rastrites maximus, Monograptus crispus, M. Sedgwicki.* In the hollow that curves round the hill fragments of mudstones and black shales were observed.

To the south-east of the watershed of Ettrick Pen [NT 19957 07640] representatives of the "Hawick Rocks" occupy the valleys of the Teviot, the Borthwick Water, the Dryfe Water, and some of the tributaries near Eskdalemuir. They consist of rusty greywackes, pale argillaceous shales, and flagstones with zones of red shale. Like the prolongations of this series in the far north-east of the Central Belt, these beds are remarkably barren. Professor Harkness, however, obtained *Protovirgularia Harknessi* from a band in this series in the railway cutting near Lockerbie.

From the apparent order of superposition, as indicated by the inclination of the strata, one might infer that the "Hawick Rocks" are here arranged in the form of an anticline, the axis of which appears to run from Eskdalemuir by Lochmaben to Dumfries. This structure is, however, entirely deceptive. The strata, as a result of intense lateral compression, have been thrown into folds, of which the axial planes dip outwards from a central line; that is, towards north-west and south-east from a line running along Eskdalemuir.

District between the Nith and the Cree

In the region between the Nith and the Cree, the Tarannon Rocks may be arranged in three divisions, similar to those already described, viz.: (1) Flags and shales with greywacke bands yielding forms characteristic of the *Monograptus turriculatus* zone, (2) massive (Queensberry) grits and greywackes, (3) Hawick Rocks or Ardwell Beds.

The members of the first two groups stretch from Castle-Douglas to Dalry and New Galloway, where they lie in synclinal folds, frequently inverted between the successive arches of the Birkhill Shales. On the south side of the Moffat black shale band, exposed in Trowdale Glen (p. 164), beds belonging to the *Monograptus turriculatus* zone make their appearance in a small quarry on the north side of Mountskip Plantation, and about 500 yards south of Trowdale Glen. A dark band, interleaved in shales and greywackes, has there yielded the following forms:

Monograptus turriculatus (Barr.)

Monograptus exiguus (Nich.)

Monograptus tenuis (Portl)

Monograptus attenuatus (Hopk.)

Diplograptus palmaeus (Barr.)

Aptychopsis minor (Barr.)

The Tarannon age of the flagstones and shales above the Birkhill division of the Moffat series is defined by the occurrence of *Monograptus exiguus in a* dark seam in green shales south-west of the Coal Heugh, on the south slope of the Culcaigrie Hill, and also near the Benjarg Wood, between Kirkcudbright and Gatehouse.

To the north of the Moffat Shales, at the village of Lawrieston [NX 68323 64796], reddish grey flags and shales follow in regular sequence and dip underneath the coarse purple grits of the Livingstone and Dornell Hills [NX 70004 66686]. By means of folding, the grits are spread northwards to the slope of Ulloch Hill. From Drumglass north to the Hensol Band of the Moffat Shales there are several rapid plications of the flaggy series (Division No. 1). The features of this series may be studied in the Parton Slate Quarries, where it has a reddish tint like the grits associated with it.

From Parton Station [NX 69118 70137] northwards to Moniaive (Sheet 9 of the Survey Map) massive (Queensberry) grits forming the dominant feature of the Tarannon Rocks, vary from two to ten feet in thickness and sometimes merge into bands of conglomerate. An excellent example of the latter rock is to be found on Craigenputtock Hill, where the pebbles consist of greywacke, grey shale, black shale, quartzite, quartz-schist, felsite, vein-quartz, &c. The most common ingredient is greywacke, the pieces measuring from eight to ten inches across. Next to the greywacke pebbles the fragments of quartzite and quartz-schist are the most numerous. In the presence of materials probably derived from the Highland region, the Craigenputtock conglomerate resembles that at Pinstane (p. 210). The pieces of black shale in this conglomerate contain fragments of *Dicellograptus* and *Diplograptus.*

In the northern portion of the Tarannon area between Loch Ken and Thornhill in Dumfriesshire, no zonal graptolites have been obtained from the few lenticular exposures of black shales in the midst of the coarse sediments. Neither have any determinable forms been procured from the sediments of younger date than the Moffat Shales. From certain dark films in the slates of the Marnhoul Quarries [NX 71824 78022] fragments of graptolites, which may probably belong to one or other of the Birkhill horizons, have been procured.

From Castle-Douglas southwards to Kirkcudbright Bay, and onwards to Gatehouse-of-Fleet, the massive (Queensberry) grits give place to a different series of strata (Hawick Rocks, Ardwell Beds), which consist of brown-crusted flags from three to six inches thick, with grey, green, and, in some instances, red shales. These are associated with brown, yellow, or ochreous greywackes from one to two feet thick. Frequently the shales are very fissile, splitting into thin laminae. They often occur in zones from twelve to twenty feet in breadth. Though the dominant type of the series is flaggy, yet in certain areas bands of greywacke and grit can be traced for considerable distances. These usually break up into angular blocks. From the oxidation of their iron, the rocks weather with a brown crust to the depth of about half an inch, but on the fresh

fracture they are grey or blue. Veins of quartz frequently traverse them, and their joints are often coated with carbonate of lime. Many of the flags and greywacke bands effervesce with acids.

The zones of shale throughout the area are more or less cleaved. On the west side of Kirkcudbright Bay, north of Bar Point, the direction of the strike is N. 35° E., while that of the cleavage is E. 23° N. Again, in the Borness cliffs, in the parish of Borgue, the direction of the strike is N. 36° E., and that of the cleavage about E. 30° N. The prevalent trend of the cleavage-planes throughout the area is about E.N.E. and W.S.W.

The best section of the Hawick Rocks (Ardwell group) occurs on the shore between the mouth of the Fleet [NX 55671 51427] and the Meikle Ross [NX 65310 43336], on the west side of Kirkcudbright Bay, where the innumerable plications of the strata may be seen to advantage, especially between Knockbrex [NX 58305 49582] and Kirkandrews Bays [NX 59795 47950]. So rapid are the folds that upwards of sixty anticlines and synclines have been mapped between Corseyard Point and Knockbrex, a distance of one mile and a quarter. Many of the folds are inverted. The presence of isoclinal folds in strata of such uniform lithological character shows how natural it is to exaggerate the thickness of these sediments by trusting merely to apparent superposition. Indeed, it frequently happens that, owing to the inclination of the axes of the folds in one general direction, the strata may seem to dip in unbroken sequence towards the same quarter for a considerable distance, while along the same line of strike at no great distance the anticlines and synclines may assume a normal character and show themselves by their divergent and convergent dip. For example, on the shore section on the west side of the estuary of the Dee, between the Doon and the base of the Wenlock Rocks, the strata are generally inclined to the southwest. But along the same line of strike round the shores of Falbogue and Brighouse Bays, onwards to the Borness cliffs, they rarely have a persistent dip in one direction. Yet there can be little doubt that they are as much folded in the one case as in the other.

Here, as elsewhere, the group of Hawick Rocks is singularly destitute of fossils. At Castle-Douglas Station, in the railway cutting at Halketleaths Mill [NX 79819 63377], and on the east shore of Kirkcudbright Bay, about 300 yards north of Torr Point, *Protovirgularia Harknessi* has been obtained.

District west of the Cree

The various sub-divisions of the Tarannon series can be traced across the "Rhinns" and "The Machars" of Wigtownshire. At one or two localities in this region fossils characteristic of the *Monograptus exiguus* zone have been collected. Thus, in the railway cutting to the north of Whaup Hill Station, where the strata approach the type of the Abbotsford flags, brown-crusted flags and shales dip north-west at high angles. They are surmounted by flags, shales, and greywacke bands, with occasional dark seams, from which the following graptolites have been obtained:

Monograptus exiguus (Nich.)

Monograptus Sedgwicki (Portl.)

Monograptus Clingani (Carr.)

Petulograptus palmaeus (Barr.)

Petulograptus folium (His.)

Discinocaris or *Peltocaris*

These fossils are in an imperfect state of preservation, more than half of the specimens collected being undeterminable.

Again, in the railway cutting near Baldoon [NX 42610 53628], on the south side of the Bladenoch, a thin band of shale interleaved in greywackes contains *Monograptus exiguus* and *M. convolutus.* In addition to these graptolites, specimens of *Protovirgularia,* were procured from the beds on the north side of Garliestown Bay.

To the west of Luce Bay, the Tarannon Rocks may be traced across "The Rhinns" from Stoneykirk to the Mull of Galloway. In this area the lithological characters and relative distribution of the various sub-divisions of the Tarannon Rocks closely resemble those of the regions already described. Fortunately in one of the zones of shale which overlie the Moffat series, about two miles north of Drummore, graptolites were obtained indicating the horizon of the *M. exiguus* or *M. crispus* zone. These strata occur at Grennan [NX 12593 39342], on the east coast, about sixteen miles to the south of Stranraer, where, on the slope adjoining the road leading to Drummore, a fine development of grey and blue shales has been quarried for slates. On the south face of the largest of the artificial openings, which has been excavated for some distance along the strike, the strata dip to the N.W. at angles varying from 65° to 70°. Here a seam, about an eighth of an inch thick, dark on a fresh fracture and bleaching white when exposed to weathering, is interleaved among the slates, and encloses in considerable abundance well-preserved specimens of *Monograptus exiguus* and *M. pandus.* At the roadside leading into this quarry, a form resembling *Monograptus crispus* was found among the debris. At the top of the rocky dip-slope, half way along the quarry, fine specimens of *Monograptus pandus* were collected in a thin dark film bleaching white, one of which measured 11½ inches in length.

On the rocky headland at the Mull of Galloway [NX 15728 30313], and on the cliffs near St. Medans Cell [NX 1437 3159], typical representatives of the Hawick Rocks occur. They consist of zones of fine grey and green mudstones and calmy shales, alternating with greywackes, which usually weather with a grey crust. Specimens of *Protovirgularia* have been found north of St. Medans.