
Chapter 22 The Girvan district — continued. Upper Silurian

The sedimentary and igneous rocks which have been discussed in the three preceding chapters belong to the Lower Silurian division of the geological scale. But they do not exhaust the varied geological history of the Girvan region during Silurian time. This interesting area includes also representatives of the Upper Silurian rocks, which, though palaeontologically identifiable with the Upper Silurian formations of the rest of Scotland, nevertheless present many points of difference, which serve to indicate that the local peculiarities of sedimentation which characterised the older part of the Silurian period in the south of Ayrshire, were prolonged also into the later part.

Llandoverly

The series of rocks now to be described occurs in certain isolated areas to the north and south of the Girvan valley, (1) in the Craighead inlier, (2) in a narrow belt on the south side of the Girvan valley extending along the northern margin of the Silurian plateau from Saugh Hill by Camregan to the slopes of Hadyard Hill, (3) on the shore at CraigsKelly and Woodland south of Girvan. These strata are the stratigraphical equivalents of the Birkhill Shales of the Moffat region, which are here represented by conglomerates, Shelly sandstones, limestones, and shales, in which some of the Birkhill graptolite zones occur. The following sub-divisions, in descending order, have been established by Professor Lapworth in what he has termed the Newlands series of Girvan.

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| | c. Camregan Group | <i>Rastrites maximus</i> shales. 2. Camregan limestone. 1. <i>Rhynchonella</i> grits. 3. <i>Monograptus spinigerus</i> shales. 2. Saugh Hill sandstones and grits. 1. Woodland Beds, comprising; On the south side of the Girvan valley — |
| Newlands Series | b. Saugh Hill Group | c. <i>Diplograptus modestus</i> and <i>Monograptus gregarius</i> shales. b. Woodland limestone. a. CraigsKelly conglomerate. In the Craighead inlier — b. <i>Monograptus gregarius</i> shales (Glen-shalloch). a. <i>Pentamerus</i> grits (Newlands). 3. Glenwells shales. 2. Mulloch Hill sandstone. 1. Mulloch Hill conglomerate. |
| | a. Mulloch Hill Group | |

Craighead Inlier

Mulloch Hill Conglomerate. — Of the lowest subdivision of the Llandoverly series, the various members of the Mulloch Hill group are typically developed in the Craighead inlier, where the order of succession is admirably clear. At the base comes a coarse conglomerate with well-rounded pebbles composed of Arenig volcanic and plutonic rocks, radiolarian chert, quartzite, quartz, and other materials. The lithological characters of the pebbles closely resemble those of the blocks in the Benan Conglomerate. The matrix, however, is sandy and of a dull purple colour, differing in these particulars from the characteristic matrix of the Benan Conglomerate. The north limb of the anticline on Quarrel Hill dips northwards at an angle of 15°, but, round the eastern and southern slopes of that eminence, the outcrop of the conglomerate is shifted by faults and is inclined to the south-east at high angles. From Quarrel Hill [NS 25666 03550] it can be followed westwards along the northern margin of the underlying trilobite mudstones to Drummuck [NS 23655 03206] and the stream near Kipperry [NS 22732 02617]. As already indicated, various exposures of conglomerate are

visible near Trochraigue [NS 21150 00343], but from the presence of certain graptolites in shales embedded in it, that special deposit would seem to be partly if not wholly of Caradoc age. The fossils obtained by Professor Lapworth from the basal Llandovery conglomerate on Quarrel Hill [NS 25998 03427] "are principally Brachiopoda of the genera *Rhynchonella*, *Orthis*, *Leptaena*, and *Strophomena*, identical in species with those we shall find to be characteristic of the overlying Mulloch Hill sandstones, and generally distinct, considered as a group, from those that mark the immediately subjacent Drummuck mudstones. Indeed the distinction in physical features and in fossils between the soft Drummuck mudstones, with their abundant examples of *Trinucleus*, *Asaphus*, *Dionide*, *Ampyx*, and hosts of *Bellerophon*, &c., and these overlying brachiopod-sandstones is most striking, and we find here the grandest palontological break in the entire Girvan succession. None of the genera enumerated above as characteristic of the Ardmillan group have ever yet been certainly met with above the base of this conglomerate; while the most characteristic species and genera of Trilobita, Brachiopoda, and Graptolithina of the overlying beds are equally absent from the Ardmillan series" (Quart. Jour. Geol. Soc., vol. XXXVIII, p. 622).

Mulloch Hill Sandstones. — Overlying the basal conglomerate an interesting sequence of highly fossiliferous sandstones, typically developed on Kirk or Mulloch Hill [NS 26623 04327], is exposed in a series of old quarries by the side of the road that leads from North Threave [NS 24556 04158] to High Newlands [NS 27104 04800]. These strata dip towards the north or north-east at angles varying from 20° to 25°. They present distinctive lithological characters; they are soft and have a green tint, which on weathered surfaces becomes purple or brown, and they likewise break up into flaggy masses like tilestones. They pass upwards into yellow sandstones, followed by yellow-tinted mudstones which are seen in a small burn about 400 yards south of the farmhouse of High Newlands and yield a few brachiopods and species of *Ptilograptus*.

The fossils given in the subjoined list have been collected by the Geological Survey from the various quarries on Kirk or Mulloch Hill [NS 26631 04320]:

Nidulites favus (Salt.)

Favosites mullochensis (Nich. & Eth.)

Heliolites interstinctus (Wahl.)

Heliolites tubulatus (Lonsd.)

Petraia subduplicata (M'Coy.)

Petraia elongata (Phil.)

Pinacopora Grayi (Nich. & Eth.)

Streptelasma (Petraia) aequisulcatum (M'Coy.)

Fenestella sp.

Ptilodictya sp.

Calymene Blumenbachi (Brong.)

Encrinurus punctatus (Brun.)

Iliaenus (Bumastus) Bowmani (Salt.)

Iliaenus (Bumastus) Maccallumi (Salt.)

Iliaenus (Dysplanus)

Thomsoni (Salt.)

Phacops Stokesi (M. Edw.)

Phacops sp.

Atrypa (Leptocaelia) hemispherica (Sow.)

Atrypa reticularis (Linn.)

Leptaena (Christiania) tenuicincta (M'Coy.)

Meristella angustifrons (M'Coy.)

Orthis calligramma (Dalm.)

Orthis confinis (Salt.)

Orthis (Dalmanella) elegantula (Dalm.)

Orthis mullockiensis (Dav.)

Orthis rustica (Salt.)

Orthis sagittifera (M'Coy.)

Pentamerus undatus (Sow.)

Rhynchonella cuneata (Dalm.)

Rhynchonella llaudoveriana (Dalm.)

Strophomena applanata (Salt.)

Strophomena compressa (Sow.)

Strophomena (Rafinesquina) expansa (Sow.)

Strophomena pecten (Linn.)

Strophomena (Leptaena) rhomboidalis (Wilck.)

Strophomena sp.

Ctenodonta sp.

Bellerophon fastigiatus (Lindat.)

Holopella obsoleta (Sow.)

Holopella tenuicincta (M'Coy.)

Conularia Sowerbyi (Defr.)

Orthoceras sp.

Mrs. Gray has obtained the following additional species from the quarries by the roadside on Mulloch Hill:

Diplograptus sp.

Halysites catenularia (Linn.)

Heliolites parasitica (Nich. & Eth.)

Glyptocrinus sp.

Ptilodictya costellata (M'Coy.)

Retepora sp.

Acidaspis sp.

Encrinurus punctatus var. *arenaceus* (Salt.)

Lichas ambigua (Barr.)

Lichas palmata (Barr.)

Phacops (Acaste) Downingae (Murch.)

Proetus sp.

Staurocephalus unicus (Portl.)

Atrypa scotica (M'Coy.)

Crania siluriana (Dav.)

Dinobolus Davidsoni (Salt.)

Leptaena sericea (Sow.)

Rhynchonella decemplicata (Sow.)

Strophomena antiquata (Sow.)

Ambonychia orbicularis (Conr.)

Ctenodonta sp.

Orthonota semiscalata (Sow.)

Orthonota undata (Sow.)

Palaearca modiolaris (Salt.)

Palaearca quadrata (Salt.)

Pleurorhynchus pristis (Salt.)

Acroculia (Platyceras) sp.

Bellerophon dilatatus (Sow.)

Bellerophon expansus (Sow.)

Bellerophon squamosus (Lindat.)

Bellerophon subdecussatus (M'Coy.)

Bellerophon wenlockensis (Sow.)

Euomphalus granulatus (Portl.)

Euomphalus sp.

Murchisonia cancellata (M'Coy.)

Oriostoma (Euomphalus) angalatum (Lindst.)

Pleurotomaria claustrata (Lindat.)

Trochonema sp.

Trochus Moorei (M'Coy.)

Conularia bilineata (Lindst.)

Hyalithes (Theca) sp.

Cyrtoceras annulatum (Hall.)

Oncoceras sp.

Orthoceras angulatum (Wahl.)

Orthoceras imbricatum (Wahl.)

Orthoceras tenuicinctum (Portl.)

Phragmoceras arcuatum (Sow.)

Trocholites (Lituites) cornu-arietis (Sow.)

The shelly sandstones of Mulloch Hill are likewise well displayed in an old quarry in a wood about 150 yards west of the farmhouse of Rough Neuk [NS 27004 03986], and 400 yards north-east of High Mains Farmhouse, where they dip to the east at an angle of 40°, and fold round the anticline of Quarrel Hill. They have here furnished to the Geological Survey the fossils given in the annexed list:

Nidulites favus (Salt.)

Dictyonema sociale (Salt.)

Aulocophyllum mitratum (His.)

Favosites asper (D'Orb.)

Favosites gothlandicus (Fongt.)

Favosites sp.

Heliolites interstinctus (Wahl.)

Heliolites tubulatus (Lonsd.)

Palaeocyclus sp.

Petraia bina (Lonsd.)

Petraia elongata (Phil.)

Ptilodictya costellata (M'Coy.)

Ptilodictya sp.

Glyptocrinus basalis (M'Coy.)

Catymene Blumenbachi (Brong.)

Atrypa reticularis (Linn.)

Leptaena (Christiania) tenuicincta (M'Coy.)

Leptocaelia (Atrypa) hemispherica (Sow.)

Meristella angustifrons (M'Coy.)

Orthis calligramma (Dalm.)

Orthis reversa (Salt.)

Rhynchonella Ilandoveriana (Dav.)

Orthonota simplex (Portl.)

Pterinea hyans (M'Coy.)

Bellerophon dilatatus (Sow.)

Macrocheilus elongatus (Portl.)

Murchisonia cancellata (Sow.)

Murchisonia elongata (Portl.)

Gomphoceras sp.

The following additional species have been obtained by Mrs. Gray from the Rough Neuk Quarry.

Heliolites parasitica (Nich. & Eth.)

Pinacopora Grayi (Nich. & Eth.)

Streptelasma (Petraia) aequisulcatum (M'Coy.)

Tentaculites anglicus (Salt.)

Fenestella sp.

Retepora sp.

Encrinurus punctatus var. *arenaceus* (Salt.)

Illaeenus (Dysplanus) Thomsoni (Salt.)

Lichas ambigua (Barr.)

Lichas palmata (Barr.)

Phacops (Acaste) Downingae (Murch.)

Staurocephalus unicus (Portl.)

Crania siluriana (Dav.)

Dinobolus Davidsoni (Salt.)

Leptaena sericea (Sow.)

Lingula ovata (M'Coy.)

Orbiculoidea Forbesi (Dav.)

Orthis (Dalmanella) elegantula (Dalm.)

Orthis mullockiensis (Dav.)

Orthis rustica (Sow.)

Orthis sagittifera (M'Coy.)

Rhynchonella cuneata (Salt.)

Strophomena antiquata (Sow.)

Strophomena (Rafinesquina) expansa (Sow.)

Strophomena (Leptaena) rhomboidalis (Wikk.)

Ambonychia orbicularis (Conr.)

Ctenodonta sp.

Orthonota semisulcata (Sow.)

Orthonota undata (Sow.)

Palaearca modiolaris (Salt.)

Palaearca quadrata (Salt.)

Pleurorkynchus pristis (Salt.)

Bellerophon dilatatus (Sow.)

Bellerophon subdeoussatus (M'Coy.)

Bellerophonwenlockensis (Sow.)

Euomphalus granulatus (Portl.)

Holopella obsoleta (Sow.)

Holopella tenuicincta (M'Coy.)

Murchisonia cancellata (M'Coy.)

Oriostoma angulatum (Lindst.)

Pleurotomaria claustrata (Lindst.)

Trochonema sp.

Trochus Moorei (M'Coy.)

Conularia bilineata (Lindst.)

Hyalithes sp.

Cyrtoceras annulatum

Orthoceras imbricatum (Wahl.)

Orthoceras tenuicinctum (Portl.)

Phragmoceras arcuatum (Sow.)

Trocholites (Lituites) cornu-arietis (Sow.)

From Rough Neuk the shelly sandstones can be traced westwards along the south limb of the arch in the direction of Auldthorns, where they yield in abundance the fossils of this horizon.

Glenwells Shales. — [NS 27408 04029] The strata following next in order — the Glenwells Shales — are seen to advantage in the Glenwells Burn, which, rising on the east slope of Kirk or Mulloch Hill, enters the Carboniferous basin at the cottage of Glenwells, half a mile east of High Mains Farmhouse. Owing to the covering of superficial deposits the section in this stream is not continuous, but there can be no doubt of the super-position of these shales to the Rough Neuk Sandstones, for near the head of the burn Shelly sandstones belonging to the latter horizon are visible, and can be traced more or less continuously round the slope towards Rough Neuk Quarry. Further down the stream, below a blank in the section, green and blue mudstones, which dip towards the E.S.E. at an angle of 40°, are exposed in the bed of the burn for some distance. They have a distinct concretionary or nodular structure, and break with a conchoidal fracture. Fossils are not readily found in them, but certain striped shales in them yield a few graptolites, which are valuable in defining the horizon relatively to the Moffat sequence. Professor Lapworth here obtained *Diplograptus acuminatus*, *Climacograptus scalaris*, and *Monograptus tenuis* (?), while the following forms were collected by the Geological Survey: *Climacograptus normalis*, *Diplograptus*, *Avicula Danbyi*, and *Orthoceras*.

Saugh Hill Group (Craighead Inlier). — The relations of the graptolitic mudstones last mentioned to the succeeding strata are not visible, owing to a concealed space of nearly fifty yards, beyond which, above the cottage of Glenwells, a group of strata appears, on the horizon of the *Pentamerus*-grits of Newlands.

In the extreme north-east corner of the Craighead inlier, where the Llandovery strata disappear under the covering of Lower Old Red Sandstone to the north, and where they are truncated by the powerful fault at the margin of the Carboniferous rocks of the Girvan valley, two subdivisions are developed, viz.: the *Pentamerus*-grits of Newlands [NS 27556 04370] and the graptolite shales of Glenshalloch [NS 28596 04440]. These shales belong to the horizon of the *Monograptus gregarius* zone of the Birkhill Shales of the Moffat region. Unfortunately, no continuous section shows their

relations to the Mulloch Rill Sandstones and Glenwells Shales, but though their relative position can only be determined by means of isolated exposures, it is clear that they form the outermost and highest zones of the Llandovery series in the Craighead inlier.

Pentamerus-Grits of Newlands. — The lowest visible beds are met with in the Glenwells Burn a few yards above the cottage [NS 27500 03953], where they consist of pale yellow sandstones and flags with bands of conglomerate. The sandstones are more or less calcareous, and alternate with pebbly or conglomeratic beds. Northwards from this locality, along the strike, these strata appear close to the farmhouse of Newlands, where grey grit is seen in the burn west of the house, and yellow sandstones further down the stream. The best exposure of fossiliferous bands, however, is to be found in the streamlet in a narrow belt of plantation about 250 yards north-east of Newlands [NS 27720 04550], where pale yellow sandstones and calcareous flags appear immediately to the east of an old quarry. Here fossils occur in considerable abundance, and the following forms have been collected by the Geological Survey:

Calymene Blumenbachi (Brong.)

Cheirurus bimucronatus (Murch.)

Orthis (Dinorthis) flabellulum (Sow.)

Pentamerus oblongus (Sow.)

Pentamerus undatus (Sow.)

Rhynchonella borealis ? (Schl.)

Stricklandinia lens (Sow.)

Holopea concinna (M'Coy.)

In addition to the foregoing forms, Mrs. Gray has obtained from the *Pentamerus* beds at Newlands the fossils enumerated in the annexed list:

Ischadites sp.

Halysites catenularia (Linn.)

Pinacopora Grayi (Nich. & Eth.)

Glyptocrinus sp.

Fenestella sp.

Turrilepas sp.

Cythere sp.

Acidaspis sp.

Bronteus Andersoni (Nich. & Eth.)

Encrinurus punctatus var. *arenaceus* (Salt.)

Lichas ambigua (Barr.)

Phacops Stokesi (M. Edw.)

Staurocephalus globiceps (Wyv.-Thom.)

Orthis sowerbyana (Dav.)

Crania llandoveriana (Dav.)

Crania (Pholidops) implicata (Sow.)

Rhynchonella sp.

Strophomena applanata (Salt.)

Strophomena corrugatella (Dav.)

Strophomena pecten (Linn.)

(Leptaena) rhomboidalis (Wilck.)

Orthonota undata (Sow.)

Bellerophon sp.

Cyrtotites euryomphalus (Lindst.)

Pleurotomaria (Euomphalus) qualteriata (Bahl.)

Metoptoma sp.

Platyceras cornutum (His.)

Pterotheca sp.

Oncoceras sp.

Orthoceras angulatum (Wahl.)

Glenshalloch Shales. — In the streams to the southeast of Newlands Farmhouse, near the old ruins of Glenshalloch [NS 28582 04477], the highest Llandovery strata of the Craighead inlier have yielded an assemblage of graptolites characteristic of the *Monograptus gregarius* zone. Perhaps the best section is that exposed in the west branch of the Baldrennan Burn [NS 28558 04075], that enters the Carboniferous basin near Pathhead, where the rocks occupy the stream course for a space of 150 yards. The lowest visible beds consist of flagstones which pass upwards into flaggy grey shales, while at the lower or east end of the section black and grey striped shales appear. The strata dip at a high angle to the south-east, but are sometimes vertical and highly folded. The black seams yield graptolites sparingly; the forms given in the following list have been collected from this locality by the Geological Survey:

Climacograptus normalis (Lapw.)

Diplograptus tamariscus (Nich.)

Petalograptus folium (His.)

Monograptus attenuatus (Hopk.)

Monograptus gregarius (Lapw.)

Monograptus tenuis (Portl.)

Rastrites peregrinus (Barr.)

Retiolites sp.

Pterinea tenuistriata (M'Coy.)

Orthoceras politum (M'Coy.)

From these striped shales Professor Lapworth obtained the following additional graptolites: *Monograptus argutus*, *M. crenularis*, *M. fiambriatus*, and *M. leptotheca*.

The evidence adduced in the foregoing paragraphs regarding the sequence of Llandovery strata in the Craighead inlier may thus be tabulated in descending order:

Saugh Hill Group

2. Striped shales of Baldrennan and Glenshalloch (*Monograptus gregarius* zone).

1. *Pentamerus* grits and sandstones of Newlands.

Mulloch Hill Group

3. Glenwells mudstones and shales (*Diplograptus acuminatus* zone).

2. Shelly sandstones of Mulloch Hill and Rough Neuk.

1 Mulloch Hill conglomerate

District of Penwhapple Glen, Saugh Hill, and Cannregan

The sequence and physical relations of the Llandovery strata on the south side of the Girvan valley present serious difficulties to the investigator, owing to the prevalence of inverted folding and the existence of strike faults. Indeed the persistent isoclinal folding of the Llandovery grits and shales on Saugh Hill and in Penwhapple Glen, whereby these beds appear to dip beneath the Barren Flagstones and Ardwell beds lying to the south, led Murchison and subsequent investigators to the erroneous belief that the Saugh Hill grits belong to a lower geological horizon than the graptolite-bearing flags (Caradoc) of the Ardmillan series. The palaeontological difficulties involved in this reading of the section were ultimately solved by Professor Lapworth when he identified in Penwhapple Glen three prominent graptolite zones of the Birkhill division of the Moffat sequence, viz.: (1) *Monograptus gregarius*, (2) *M. spinigerus*, (3) *Rastrites maximus*, which here occur in inverted order among the coarse grits, shales, and limestones with which they are associated. He further proved that the belt of Llandovery strata, extending from the Saugh Hill, by Penwhapple Glen, to the slopes of Hadyard Hill, are separated by a strike fault from the Barren Flagstones of Caradoc age to the south. At first one might be apt to suppose that this fault must be of considerable magnitude owing to the absence of the Mulloch Hill group in the Llandovery areas south of the Girvan valley, but the same observer has adduced evidence, which will be referred to presently, from the shore at Shalloch Forge, south of Girvan, pointing to an unconformability between the Craigs Kelly conglomerate (the local base of the Saugh Hill group) and the underlying Barren Flagstones of Caradoc age. If this unconformability be granted, the strike fault, though it disturbs the natural sequence, will be seen to be of no great amount for the lowest well-defined zone of Llandovery age in Penwhapple Glen is that of the *Diplograptus modestus* shales (*Monograptus gregarius*), which are not separated by any great thickness of strata from the Craigs Kelly Conglomerate (Figure 112), (Figure 114).

***Diplograptus confertus (modestus)*-Shales.** *Diplograptus modestus* (Lapw.) = *Diplograptus (Dimorphograptus) confertus* (Nich.) — Immediately to the north of the strike-fault that forms the southern boundary of the Llandovery series [NX 23344 97738], some green and grey calcareous flags and shales in Penwhapple Glen have yielded to Professor Lapworth *Pentamerus* sp. These strata are succeeded northwards by black mudstones and shales charged with graptolites, of which the following forms have been collected by the Geological Survey, viz.: *Monograptus gregarius*,

M. crenularis, *Diplograptus confertus (modestus)*, *D. tamwiscus*, *D. Hughesi*, *Petalograptus folium*, and *Dimorphograptus Swasstoni*. In addition to these species, Professor Lapworth records *Monograptus leptotheca*, and *Climacograptus normalis*. These graptolitic mudstones pass upwards into the thick mass of grey shales which form the dominant lithological feature of the zone; some of the dark seams interleaved in them yield similar graptolites, together with orthoceratites. Like the Barren Flagstones to the south, the beds of this zone have a persistent inverted dip to the south-east.

Saugh Hill Grits. — [NX 23066 98028] Northwards, from the shales last mentioned, massive grey grits in inverted order contain small quartz pebbles, weather with a yellow tint, and are remarkably destitute of fossils. They are associated with flagstones, and at the point where a small tributary joins the Penwhapple Burn from the west, shattery grey shales appear in the heart of the grit series.

***Monograptus Sedgwicki* — Mudstones (*M. spinigerus*-Zone).** — These pebbly grits are followed northwards by a prominent zone of grey and black mudstones and shales, which is well displayed at a bend in the Penwhapple Glen, about 400 yards south of the foot of Penkill Burn [NX 23088 98122]. The lower or southern half of this band is formed of greyish-green shales, yielding no fossils, while the northern portion furnishes a characteristic assemblage of graptolites. The graptolitic part is thus described by Professor Lapworth<ref>Quart. Jour. Geol. Soc., vol. xxxviii., p. 633.</ref>: "It consists essentially of soft shaly mudstones, containing a large proportion of carbonaceous matter, and impregnated with sulphate of iron. The entire group is stained of a deep iron-shot colour, and is so excessively crushed and contorted that the bedding can only be made out with the utmost difficulty. Calcareous matter is occasionally present in notable quantity, and large nodular concretions are abundant in the steep cliffs of the rock which overhang the right bank of the stream. Graptolites are abundant, but are most difficult of extraction in consequence of the crushing to which these beds have been subjected, while fragments of crustacea and orthoceratites are occasionally seen". These fossiliferous mudstones and shales yielded the following forms to the Geological Survey: *Monograptus Sedgwicki*, *M. spinigerus*, *Petalograptus ovatus*, *Rastrites peregrinus*, and *Lingula brevis*.

Professor Lapworth obtained the additional forms given in the annexed list:

Monograptus tenuis (Pord.)

Monograptus attenuatus (Hopk.)

Monograptus Hisingeri (Carr.)

Monograptus intermedius (Carr.)

Monograptus spiralis (His.)

Diplograptus Hughesi (Nich.)

Diplograptus tamariscus (Nich.)

Climacograptus normalis (Lapw.)

Petalograptus folium (His.)

Petalograptus palmaeus (Barr.)

Camregan Grits and Limestone. — [NX 22998 98439] The black fossiliferous mudstones and shales just described are succeeded northwards by an important group of strata, comprising grits, impure limestone, shales, and mudstones, which have yielded a large series of organic remains of an undoubted Llandovery facies. These strata are well seen below Camregan Plantation on the east bank of the rocky gorge formed by the Penwhapple Burn, where they are nearly vertical or inclined at high angles to the south-east. The beds in contact with the crushed mudstones of the *Monograptus Sedgwicki* zone consist of massive grits and flags (*Rhynchanelle*-grits), which extend for several yards down stream. They resemble the Saugh Hill grits in Ethological characters, and, like them, are comparatively barren, except near the

base, where Professor Lapworth found in them "casts of *Rhynchonella*, associated with rarer examples of *Orthis* and *Strophomena*". Next come in inverted order nodular calcareous flagstones, which merge into impure highly fossiliferous limestones (Camregan Limestone) that dip to the S.S.E. at an angle of about 70°. These are followed by blue calcareous shales and mudstones, which are likewise fossiliferous, many of the organisms occurring in a fine state of preservation. The species given in the annexed list were obtained from these strata by the Geological Survey:

Ischadites antiquus (Salt.)

Calostylis Lindströmi (Nich. & Eth.)

Halysites catenularia (Linn.)

Petrada sp.

Ptilodictya dichotoma (Portl.)

Bronteus Andersoni (Eth. & Nich.)

Catymene Blumenbachi (Brong.)

Cheirurus trispinosus (Young.)

Encrinurus punctatus (Brunn.)

Iliaenus (Dysplanus) aemulus (Salt.)

Iliaenus (Dysplanus) Thomsoni (Salt.)

Iliaenus (Bumastus) Bowmani (Brong.)

Iliaenus nexilis (Salt.)

Iliaenus sp

Phacops Stokesi (M. Edw.)

Atrypa reticularis (Linn.)

Glassia (Athyris) obovata (Sow.)

Leptaena (Plectambonites) transversalis (Dalm.)

Lingula Symondsi (Salt.)

Orthis calligramma (Dalm.)

Orthis (Dalmanella) elegantula (Dalm.)

Orthis polygramma (Dav.)

Pentamerus globosus (Sow.)

Pentamerus oblongus (Sow.)

Pentamerus rotundus (Sow.)

Pentamerus undatus (Sow.)

Crania (Pholidops) implicata (Dav.)

Spirifera plicatella (Linn.)

Strophomena antiquata (Sow.)

Strophomena applanata (Salt.)

Strophomena (Rafinesquina) expansa (Sow.)

Triplesia incerta (Dav.)

Bellerophon bilobatus (Sow.)

The following additional forms are recorded by Mrs. Gray from the same fossiliferous horizon:

Chondrites sp.

Monograptus galaensis (Lapw.)

Monograptus Hisingeri (Carr.)

Monograptus spiralis (Geinitz.)

Dictyonema (Fenestella) assimile (Lonsd.)

Acidaspis bispinosus (M'Coy.)

Encrinurus punctatus var. *arenaceus* (Salt.)

Iliaenus Murchisoni (Salt.)

Iliaenus Rosenbergi (Eichw.)

Atrypa imbricata (Sow.)

Crania sp.

Cyrtia exporrecta (Wahl.)

Leptaena sericea (Sow.)

Orthis polygramma var. *pentlandica* (Dav.)

Pentamerus galeatus (Sow.)

Strophomena Walmstedti (Lindst.)

Ambonychia, bellistriata (Hall.)

Avicula sp.

Cardiola striata (Sow.)

Goniophora cymbaeformis (Sow.)

Mytilus mytilimeris (Corr.)

Mytilus semirugatus (Portl.)

Orthonota sp.

Bellerophon expansus (Sow.)

Bellerophon sp.

Cyclonema sp.

Euomphalus sp.

Pleurotomaria sp.

Hyalithes sp.

Pterotheca sp.

Cyrtoceras compressum (Sow.)

Gomphoceras sp.

Orthoceras angulatum (Wahl.)

Orthoceras bacchus (Barr.)

Orthoceras fusiforme (Hall.)

Orthoceras imbricatum (Wahl.)

Orthoceras multinctum (Hall.)

Orthoceras primaeven (Forbes.)

Poterioceras sp.

Rastrites maximus-Shales. — [NX 22634 98615] *The Pentamerus* limestone and shales of Camregan are immediately followed by purple and green mudstones, which, with the exception of annelid tracks are remarkably destitute of fossils. They contain, however, a thin seam of silky carbonaceous shale, which is well seen in the bed of the Penwhapple Burn and in the streamlet on the west side of a gorge, where Professor Lapworth obtained the following characteristic suite of graptolites, together with occasional examples of phyllopodous erustacea:

Rastrites maximus (Carr.)

Monograptus turrieulatus (Barr.)

Monograptus erassus (Lapw.)

Monograptus Hisingeri (Carr.)

Monograptus runcinatus (Lapw.)

Petalograptus palaeceus (Carr.)

Peltocaris aptychoides (Salt.)

The observations of the same geologist further show that the purple mudstones containing the seam of carbonaceous shale, with *Rastrites maximus* and some of its associates, are succeeded northwards by massive grits, which are regarded by him as the highest sub-division of the Camregan group.

Sections east of Penwhapple Glen

Besides the typical section in Penwhapple Glen of Llandovery strata, ranging from the *Diplograptus confertus (modestus)* shales to the *Rastrites maximus* zone, the prolongations of the same beds are to be seen both to the east and to the west of that line of section.

The Geological Map (Sheet 8) shows that the fault which forms the southern boundary of the Llandovery strata in Penwhapple Glen, and separates them from the Barren Flagstones of Caradoc age to the south, can be traced eastwards to the slope of Hadyard Hill and westwards along the south flank of Saugh Hill. Though, in Penwhapple Glen this dislocation is probably of no great magnitude, yet eastwards to the slope of Hadyard Hill it evidently increases in amount, for in that direction the members of the Camregan group are brought into contact with the Caradoc Rocks to the south. In other words, the strata associated with the *Diplograptus confertus* shales and the Saugh Hill grits have there been thrown out by this east and west fault.

Owing partly to this dislocation and partly to the covering of superficial deposits, the Llandovery beds underlying the Camvegan group are almost wholly concealed from view in the area east of Penwhapple Glen. Several good sections, of the Camregan beds in that region, however, have supplied large and characteristic suites of organic remains. The first of these is met with near the head of the southern branch of the Penkill Burn [NX 23999 98111] — a tributary which joins the Penwhapple Burn from the east. This exposure is merely the easterly prolongation of the outcrop in Penwhapple Glen, though only a portion of the sequence is visible, which here consists of calcareous bands and yellow grits. Situated close to the road leading to the village of Barr from Girvan, the fossiliferous zones are easy of access, and the various brachiopods, trilobites, and other organisms characteristic of the *Pentamerus* limestone of Camregan may be readily obtained.

About a mile still further east, at the head of Bargany Pond Burn, which rises on the western slope of Hadyard Hill, near Littlelane [NX 25834 98212], another good outcrop is to be seen of the Camregan Group, composed here of grey clayey shales or mudstones with calcareous ribs and bands of grit, which dip towards the south at high angles. On the weathered surfaces of the limestone, crinoids and other organic remains appear, while the grey clayey shales yield well-preserved trilobites belonging to the genera *Encrinurus*, *Phacops*, &c. A careful search at this locality furnished the following forms to the Geological Survey:

Glyptocrinus sp.

Crinoid stems.

Myrianites sp.

Beyrichia Kloedeni (M'Coy.)

Acidaspis sp.

Cheirurus bimucronatus (Murch.)

Encrinurus punctatus var. *arenaceus* (Salt.)

Iliaenus (Bumastus) barriensis (Murch.)

Iliaenus Bowmani (Salt.)

Phacops Stokesi (M. Mw.)

Proetus girvanensis (Eth. & Nich.)

Cyrtia exporrecta (W)

Discina perrugata (M'Coy.)

Discina rugata (Sow.)

Leptaena sericea (Sow.)

Leptaena (Plectambonites) transversalis (Wahl.)

Orthis balcletchiensis (Dav.)

Orthis (Bilobites) biloba (Linn.)

Orthis (Dalmanella) elegantula (Dalín.)

Pentamerus globosus (Sow.)

Pentamerus rotundus (Sow.)

Pentamerus undatus (Sow.)

Crania (Pholidops) implicata (Dav.)

Spirifera crispa (His.)

Spirifera plicatella var. *radiata* (Sow.)

Strictlandinia lens (Sow.)

Strophomena antiquata (Sow.)

Strophomena applanata (Salt.)

Strophomena (Rafinesquina) deltoidea (Corr.)

Strophomena (Leptaena) rhomboidalis (Wick.)

Strophomena undata (M'Coy.)

Whitfieldia (Meristella) tumida (Dalm.)

Bellerophon squamosus (Lindst.)

Pleurotomaria (Euomphalus) qualteriata (Schl.)

Orthoceras fimbriatum (Sow.)

Orthoceras Grayi (Blake.)

Orthoceras sp.

Mrs. Gray has collected from the same locality the additional forms given in the annexed list:

Ptilodictya dichotoma (Portl.)

Beyrichia Kloedeni var. *scotica* (Jones & Holl)

Utrichia Grayae (Jones.)

Bronteus Andersoni (N. & E.)

Harpes sp.

Iliaenus nexilis (Salt.)

Staurocephalus sp.

Atrypa imbricata (Sow.)

Lingula Symondsi (Salt.)

Nucleospira pisum (Sow.)

Orthis sowerbyana (Dav.)

Triplesia incerta (Dav.)

Mytilus semirugatus (Portl.)

Pleurotomaria sp.

Orthoceras Bacchus (Barr.)

About thirty yards down the stream to the north of this outcrop of limestone and shales, grey and purple mudstones with dark carbonaceous seams appear, from which Professor Lapworth obtained well-preserved specimens of

Rastrites maximus (Carr.)

Monograptus crassus (Lapw.)

Monograptus turriculatus (Barr.)

Monograptus Hisingeri (Barr.)

Diplograptus palmaeus (Barr.)

Peltocaris aptychoides (Salt.)

It thus appears that the *Rastrites maximus*-mudstones have here the same relative stratigraphical position with reference to the Camregan Limestone as in the typical section in Penwhapple Glen. But owing to the covering of drift deposits the relations of these sub-divisions of the Camregan group to the underlying and overlying strata are not apparent. Nevertheless it is possible to fix approximately the position of the fault that forms the southern boundary of the Llandovery Rocks [NX 25328 98452], for in a quarry about 300 yards to the south of the outcrops just referred to in Bargany Burn, dark grit and greenish greywacke furnish specimens of *Diplograptus truncatus* and other Upper Hartfell forms (Upper Caradoc).

Sections west of Penwhapple Glen

Proceeding now to deal with the westerly prolongations of the Llandovery (Birkhill) strata visible in Penwhapple Glen, we may note that various excellent exposures of the different subdivisions occur on Saugh Hill, likewise near Camregan Wood and in the adjoining streams. The shales associated with the *Diplograptus confertus* (*modestus*) band are visible

near the foot of the streamlet that flows eastwards between Tralorg and Camregan Hills, but westwards they are truncated and cut out by the Saugh Hill fault as far as the south-west slope of that eminence. From dark seams at this latter locality Professor Lapworth records the following characteristic graptolites

Diplograptus tamariscus (Nich.)

Diplograptus modestus (Lapw.)

Climacograptus normalis (Lapw.)

Monograptus cyphus (Lapw.)

Monograptus gregarius (Lapw.)

Monograptus tenuis (Portl.)

The coarse yellow grits (Saugh Hill Grits) occupying an intermediate position between the *Diplograptus confertus* (*modestus*)-shales and the *Monograptus Sedgwicki*-mudstones form a conspicuous feature on the plateau to the west of Penwhapple Glen, for they may be traced almost continuously from that stream along the ridge of Camregan Hill [NX 21933 97688] to the crest of Saugh Hill [NX 20898 97188], where they form a belt nearly 200 yards in width. From the Geological Map (Sheet 8) it will be seen that the prominent development of this zone on Saugh Hill is due to folding. The strata, which may there be studied in many quarries and natural exposures, have generally an inverted dip to the S.S.E., and consist of flaggy and massive yellow grits with bands of conglomerate and breccia, containing angular fragments of grits, shales, and other materials.

The overlying *Monograptus Sedgwicki*-mudstones cannot be traced for any distance, owing to the covering of drift, but they do appear on the northern slopes of Saugh Hill. At a locality not far to the west of the fence which forms the boundary between the estates of Bargany and Killochan [NX 21237 97340]?, these mudstones supplied Professor Lapworth with the following forms:

Rastrites hybridus (Lapw.)

Monograptus Sedgwicki (Portl.)

Monograptus spiralis (Gein.)

Monograptus lobiferus (M'Coy.)

Diplograptus palmaeus (Barr.)

Diplograptus tamariscus (Nich.)

Climacograptus normalis (Lapw.)

In like manner, the fossiliferous grits of the Camregan group that overlie the *Monograptus Sedgwicki* mudstones can be traced westwards to the south-east corner of Camregan Wood [NX 21903 97926]?, where they appear in a quarry, charged with many of the characteristic fossils of that sub-division. Regarding these beds, Professor Lapworth remarks that "they are crowded with casts of brachiopoda, which are so abundant in certain seams as irresistibly to recall to mind the wonderfully prolific Shelly sandstones of Mulloch Hill, on the north of the Girvan valley. The beds, too, have the same coarse sandy texture, calcareous and gritty composition, and more or less flaggy fracture". From the sandstones and grits in this quarry the following fossils have been obtained]:

Cheirurus sp.

Encrinurus punctatus (Brun.)

Phacops Stokesi (M. Edw.)

Leptocoelia (Atrypa)

Leptocoelia hemispherica (Sow.)

Pentamerus oblongus (Sow.)

Rhynchonella llandoveriana (Dav.)

Pterinea sp.

Platyceras cornutum (His.)

The Camregan group is likewise seen in a burn at the west end of Camregan Wood, where it has supplied some of its characteristic fossils, and still further west at the head of Cuddystone Burn, from which locality Mrs. Gray records the species given in the annexed list:

Calymene Blumenbachi (Brong.)

Leptaena segmentum (Ang.)

Orthis rustica (Sow.)

Pentamerus oblongus (Sow.)

Pentamerus undatus (Sow.)

Straphomena applanata (Salt.)

Straphomena Walmstedti (Lindst.)

Straphomena Waltoni (Dav.)

Orthonota sp.

Cyclonema sp.

Euomphalus sp.

Orthoceras imbricatum (Wahl.)

Shalloch and Woodland, South of Girvan

The only remaining patches of Llandoverly strata (Birkhill or Newlands series, Lapworth) south of the Girvan valley which have yet to be described are to be found on the shore immediately to the south of Girvan, where they form a series of reefs near high-water level. Though disconnected and available for study only when the tide is favourable, the strata are nevertheless of considerable interest, both on lithological and palaeontological grounds. At these localities, coarse conglomerates, which Professor Lapworth believes to rest unconformably on the underlying Caradoc Rocks, are associated with grits, shales, and coralline limestones, which, in virtue of their fossil contents, can be referred to the lower portion of the Saugh Hill group. The physical relations of the beds forming these rocky islets have been studied by Professor Lapworth, from whose descriptions the following details are taken.<ref>Quart. Jour. Geol. Soc., vol. xxxviii., p. 638, et seq.</ref>

The first of these exposures occurs on the beach at Shalloch [NX 17906 96145], about half a mile south of Girvan, where the strata strike inland from the shore and dip towards the north and N.N.E. The prominent feature in this section is the

ridge of conglomerate named the Horse Rock. It measures about fifty feet in thickness, and rests with a slight unconformability on green flagstones and shales to the south, which can be seen only at low tide. While destitute of organic remains, these flagstones and shales resemble lithologically the Barren Flagstones of the Ardmillan series (Caradoc), and in all likelihood belong to that sub-division of the Silurian system. The overlying conglomerate, which is interbedded with bands of green granular grit, has a green matrix containing well-rounded blocks of diabase-lava, acid and basic intrusive rocks, chert, shale, greywacke, quartzite, mica-schist, and other materials. Indeed, except for its highly indurated character and the presence of the quartzite pebbles, the rock is similar to the characteristic conglomerate of Benan. A few yards to the north the sandy beach lays open some limited outcrops of calcareous flagstone or impure limestone, from which Professor Lapworth obtained specimens of *Alveolites Labechei*, *Favosites gothlandicus*, and other corals, together with numerous casts of *Pentamerus oblongus* and other brachiopods. Next in order come dark blue and grey flaggy shales with thin carbonaceous seams, traceable across the beach, and yielding graptolites of the following species: *Diplograptus (confertus) modestus*, *Climacograptus normalis*, *Monograptus tenuis*, and *M. cyphus*, together with forms of *Dictyonema* and *Orthoceras* — an assemblage similar to that found in the *Diplograptus confertus (modestus)* shales in the typical section of Penwhapple Glen.

Above these graptolite-bearing shales come conglomeratic sandstones with numerous white quartz-pebbles, the lowest beds of which contain angular fragments of the underlying shales, as if the junction between the sandstones and shales had originally been an unconformable one, though this relationship is now masked to some extent by an intervening fault. The phenomena presented by these rocks at their line of contact are thus described by Professor Lapworth: "The lowest visible zone of the sandstone conglomerate is filled with pieces of the same striped shales, which are surrounded and buried up by the coarser pebbly rock, as if they had projected from the sea-floor at the time of the formation of the sandstone, and had been enveloped and buried by the latter, being deposited around and above them. Thus it is highly probable that the conglomeratic sandstones, which now dip generally with the underlying beds, were originally somewhat discordant with them, and that their present steep dip is owing to the intercalary fault we have referred to. This fault, however, while it has permitted these overlying beds to be crushed into a general correspondence in inclination with the underlying strata, has not actually allowed of their removal far from their original position, the angular fragments included in the sandstones being previously derived from the striped shales with which they are still in contact".

From these details it may be inferred that some of the zones near Shalloch are the equivalents of part of the lower portion of the Saugh Hill group; for example, the graptolite-bearing shales are evidently the counterpart of the *Diplograptus confertus (modestus)* shales of Penwhapple Glen, and the overlying quartz-conglomerate and sandstones correspond to similar strata at the base of the Saugh Hill Grits, while the coarser conglomerate of the Horse Rock apparently occupies a lower geological horizon than any of the Llandoverly beds exposed in the Penwhapple Glen or Saugh Hill sections.

Craigskelly. — [NX 17745 96021] Not far to the south-west of the Horse Rock, coarse conglomerate reappears, with a north-east and south-west strike, in a rocky islet named Craigskelly, where it is associated with grits, weathering with a yellow tint and yielding fragments of *Strophomena grandis*, *Atrypa reticularis*, *A. hemispherica*, and *Dictyonema*.

Woodland Point. — [NX 16914 95312] About three-quarters of a mile along the shore to the south of Craigskelly, these Lower Llandoverly Grits are again visible in certain reefs, named the Scart Rocks, in Woodland Bay, and also at Woodland Point. At this latter locality they are associated with calcareous bands, which have yielded a large number of organic remains that clearly define the geological horizon of the beds. The rocky headland is formed of massive grits, weathering with a yellow tint and nearly vertical, and having a north-east strike in the direction of the Scart Rocks and Craigskelly; indeed, there can be little doubt that the grits visible at these various exposures are merely the prolongations of the same band.

These pebbly grits and conglomerates are succeeded along their south-east margin by highly fossiliferous strata, which protrude through the sandy beach, and are available for study only at low tide. First a few feet of green flaggy shales with thin carbonaceous and calcareous seams, are probably faulted against the conglomeratic sandstones their geological horizon, however, is placed beyond doubt by the graptolites which have been obtained from them, viz.: *Diplograptus confertus (modestus)*, *Climacograptus normalis*, *Monograptus tenuis*, *M. gregarius*, and *M. leptotheca*. These strata are succeeded by soft green shales containing specimens of *Strophomena grandis*, *Atrypa reticularis*, *A. imbricata*, *Orthis elegantula*, &c., and then by about thirty feet of calcareous flagstones or limestones, crowded with organic remains,

including *Pentamerus oblongus* and *Stricklandinia lens*. The following fossils have been collected from this horizon by the Geological Survey:

Favosites mullochensis (Nich. & Eth.)

Pinacopora Andersoni (Nich. & Eth.)

Fenestella sp.

Bronteus Andersoni (Eth. & Nich.)

Cheirurus bimucronatus (March.)

Encrinurus punctatus (Beim)

Iliaenus sp.

Phacops (Acaste) Downingae (Murch.)

Staurocephalus unicus (Wyv.-Thom.)

Atrypa imbricata (Sow.)

Atrypa reticularis (Linn.)

Crania siluriana (Dav.)

Leptaena (Plectambonites) quinquecostata (M'Coy.)

Leptaena segmentum (Ang.)

Leptaena (Plectambonites) transversalis (Wahl.)

Leptaena (Plectambonites) transversalis var. *Lingula Symondsi* (Salt.)

Orbiculoidea Forbesi (Dav.)

Orthis (Bilobites) biloba (Linn.)

Orthis calligramma var. *plicata* (Sow.)

Orthis (Dalmanella) elegantula (Dalm.)

Orthis rustica var. *rigida* (Dav.)

Pentamerus undatus (Sow.)

Pholidops (Crania) implicata (Dav.)

Skenidium woodlandiensis (Dav.)

Stricklandinia lens (Sow.)

Stricklandinia lirata (Sow.)

Strophomena antiquata (Sow.)

Strophomena corrugatella (Dav.)

Strophomena pecten (Linn.)

Strophomena (Leptaena) rhomboidalis (Wilck.)

Mrs. Gray has obtained the following additional species from the same strata at Woodland Point:

Ischadites antiquus (Salt.)

Monograptus gregarius (Lapw.)

Monograptus leptotheca (Lapw.)

Monograptus tenuis (Portl.)

Diplograptus confertus (modestus) (Nich.)

Clathrodictyon vesiculosum (N. and Murie.)

Halysites catenularia (Linn.)

Halysites sp.

Heliolites foliaceus (Nich. & Eth.)

Heliolites interstinctus (Linn.)

Plasmapora girvanensis (Nich. & Eth.)

Glyptocrinus sp.

Fenestella assimilis (Lonsd.)

Fenestella Milleri (Lonsd.)

Fenestella patula (M'Coy.)

Fenestella subantiqua (D'Orb.)

Glaucanome disticha (Goldf.)

Gorgonia regularis (Portl.)

Hippothoa inflata (Nich.)

Ptilodictya dichotoma (Portl.)

Ptilodictya lanceolata (Goldf.)

Rhinopora verrucosa (Hall.)

Acidaspis Brighti (Murch.)

Calymene Blumenbachi (Brong.)

Encrinurus punctatus var. *arenaceus* (Salt.)

Encrinurus punctatus var. *calcareus* (Salt.)

Iliaenus (Bumastus) barriensis (Much.)

Iliaenus (Dysplanus)

Iliaenus Thomsoni (Salt.)

Lichas sp.

Dinobolus Davidsoni (Salt.)

Leptaena scissa.

Orthis pentlandica (Dav.)

Orthis sowerbyana (Dav.)

Strophomena cemula (Salt.)

Strophomena (Rafinesquina) deltoidea (Conr.)

Triplesta monilifera (M'Coy.)

Ambonychia amygdalina (Hall.)

Ambonychia orbicularis (Conr.)

Avicula elliptica (Hall.)

Cardiola sp.

Goniophora cymbaeformis (Sow.)

Mytilus mytilimeris (Conr.)

Bellerophon dilatatus (Sow.)

Bellerophon expansus (Lindst.)

Bellerophon sphaera (Lindst.)

Bellerophon sp.

Ecculiomphalus sp.

Fusispira elongata (Hall.)

Holopella sp.

Murchisonia sp.

Oriostoma discors (Sow.)

Pleurotomaria alata (Wahl.)

Pleurotomaria scutulata (Lindst.)

Conularia aspera (Lindst.)

Conularia subtilis (Salt.)

Cyrtoceras arcuatum (Hall.)

Gomphoceras crater (Blake.)

Oncoceras sp.

Orthoceras angulatum (Wahl.)

Orthoceras distans (Sow.)

Orthoceras imbricatum, (Wahl.)

Orthoceras mocktreense (Sow.)

Orthoceras tracheale (Sow.)

Phragmoceras sp.

Trochoceras aspersum (Barr.)

A comparison of the sections at Woodland Point and Shalloch seems to favour the view suggested by Professor Lapworth (1) that the Scart Grits at Woodland Point and in Woodland Bay are the equivalents of the conglomeratic sandstones and quartz-conglomerate of Shalloch; (2) that the Scart Grits, which seem to overlie the *Diplograptus confertus* (*modestus*) shales are the counterpart of the Saugh Hill Grits; (3) that the *Pentamerus* limestone at Woodland Point corresponds to the coralline band at Shalloch. These conclusions regarding the order of succession of the Llandovery Rocks on the shore south of Girvan may be tabulated as follows, in descending order:

Saugh Hill Sandstones

2. Scart grits and conglomeratic sandstones.

1. Quartz-conglomerate.

Woodland Beds

3. Green and black graptolitic shales and mudstones, *Diplograptus confertus* (*modestus*) shales.

2. *Pentamerus* limestone and shales (Woodland).

1. Craigs Kelly conglomerate (Horse Rock).

In the foregoing paragraphs relating to the Llandovery Rocks at Woodland Point reference has been made to the fact that some of the zones are only accessible at low tide, and that even under these conditions the section is partly obscured by the sandy beach. For this reason their relation to the underlying Barren Flagstones of the Ardmillan series is not quite clear, but it is probable that they are brought into conjunction with that series by a strike fault which runs more or less parallel to the shore.

Tarannon (part of Dally Series, Lapworth.)

The series of strata within the Girvan area which may be regarded as the equivalent of the Tarannon Rocks of Wales extends as a narrow belt along the northern margin of the Silurian plateau from Penkill near Penwhapple Glen to the northern slope of Hadyard Hill, where it is abruptly truncated by the fault which brings it in contact with the Old Red

Sandstone and Carboniferous rocks on the south side of the Girvan valley. But even beyond these limits, the irregular strip of Upper Silurian strata which stretches along the northern flank of the uplands from the northern slope of Hadyard Hill by Blair to Straiton, includes a group, named the Drumyork Flagstones, which, on account of their unfossiliferous character and their resemblance to the "Hawick Rocks" of the Southern Uplands, we are inclined to regard as belonging to this division of the Silurian system. This correlation is strengthened by the fact that the Drumyork Flagstones, like the "Hawick Rocks", seem to pass upwards into beds at Blair and Knockgardner which yield a facies of fossils akin to that of Wenlock age. In the case of the beds near Penkill and Bargany they yield an assemblage of fossils sufficiently conclusive for the purpose of correlation. The various sub-divisions of the Tarannon Rocks, which, according to the classification here adopted, include the zones of the Penkill and Bargany groups, established by Professor Lapworth, together with the Drumyork Flagstones, may thus be tabulated in descending order:

Tarannon Series

c. Drumyork Group

Green flags and shales, unfossiliferous.

b. Bargany

2. Yellow, blue, and grey flagstones with zones of shales (Blackwood beds).

1. Pale blue thick-bedded flagstones and shales (Glenfoot beds).

a. Penkill Group

4. *Cyrtograptus Grayi* mudstones and shales.

3. *Protovirgularia* grits.

2. Penkill flags and shales.

1. Purple shales and mudstones with *Crossopodia*, *Nemertites*, &c,

a. Penkill Group

Penwhapple Glen Section. — [NX 22742 98689] The lower portion of this stream, between the outcrop of the Camregan beds and the great fault that brings the Old Red Sandstone into conjunction with the Silurian rocks, affords an excellent section of the various sub-divisions of the Penkill group, ranging from the *Crossopodia* shales to the *Cyrtograptus Grayi* mudstones.

(1) Crossopodia Shales. — Immediately to the north of the Camregan beds, above described (p. 535), a great development of finely laminated shale appears, usually of a purple colour, but with occasional green or grey seams, and are either vertical or inclined at high angles to the south-east. Some of the bands are covered with those peculiar markings resembling the tracks of annelids which are so characteristic of the red and purple shales of Tarannon age in the Central Belt of the Southern Uplands. Indeed, lithologically and palaeontologically they resemble the purple slates of Thornylee, in the valley of the Tweed. The various forms of markings obtained from these beds are:

Crossopodia scotica (M'Coy.)

Nemertites tenuis (M'Coy.)

Nereites Sedgwicki (M'Coy.)

Nereites cambrensis (M'Coy.)

The palaeontological evidence is strengthened by the occurrence of graptolites in some thin carbonaceous seams interleaved in the purple and green shales, which present a well-marked Tarannon facies. The following species have been collected by Professor Lapworth from these layers:

Monograptus exiguus (Nich.)

Monograptus Becki (Barr.)

Monograptus galaensis (Lapw.)

Rastrites distans (Lapw.)

Diplograptus sp.

Retiolites obesus (Lapw.)

(2 and 3) Flagstones and Grits with *Protovirgularia*. — In the Penwhapple section a gradual passage may be traced from the purple mudstones with *Crossopodia* into an alternating series of flaggy bands with green and purple shales, which are succeeded in turn by greywackes and grits, well seen near the foot of Penkill Burn [NX 22984 98490]. Northwards from that locality flaggy greywackes supervene and continue as far as the *Cyrtograptus Grayi* beds. This zone of grits and flaggy greywackes, which cannot exceed a few hundred feet in thickness, is believed to be the attenuated representative of the coarse sediments that are so prominently developed in the Llandovery area of the Central Belt. Although fossils are scarce, some of the species of graptolites characteristic of the underlying *Crossopodia* shales have been collected from these beds.

(4) *Cyrtograptus-Grayi* Mudstones. —The grits and flaggy greywackes are followed by finer sediments of considerable interest, from the abundance and excellent preservation of their organic remains. These strata consist of green and purple mudstones, which contain seams of graptolite shale, resembling lithologically the Wenlock graptolite shales of Riccarton and Kirkcudbright, but the palaeontological evidence leaves no room for doubt that they are still a sub-division of the Tarannon series. They are well seen at a prominent bend of the Penwhapple Glen, about 300 yards north of the foot of Penkill Burn [NX 22803 98656], where, on the bank of the stream, they are readily accessible. From this horizon Mrs. Gray has collected the following fossils:

Cyrtograptus Grayi (Lapw.)

Monograptus colonus (Barr.)

Monograptus concinnus (Lapw.)

Monograptus exiguus (Nich.)

Monograptus galaensis (Lapw.)

Monograptus Hisingeri (Carr.)

Monograptus priodon (Bron.)

Monograptus Sedgwicki (McCoy.)

Rastrites distans (Lapw.)

Retiolites geinitzianus (Barr.)

Cheirurus bimucronatus (Murch.)

Atrypa reticularis (Linn.)

Discina crassa (Hall.)

Orthis calligramma (Dalm.)

Orthis reversa (Salt.)

Orthis rustica (Sow.)

Orthis rustica var. *rigida* (Dav.)

Orthis turgida (M'Coy.)

Pentamerus rotundas (Sow.)

Strophomena (Leptaena) rhomboidalis (Wilck.)

Cardiola fibrosa (Sow.)

Lunulicardium elegans (Salt.)

Orthoceras annulatum (Sow.)

Orthoceras Bacchus (Barr.)

Orthoceras fusiforme (Hall.)

Orthoceras Grinrodi (Blake.)

The strata which follow the *Cyrtograptus Grayi* mudstones in the Penwhapple Glen, northwards to the fault, consist of grey flagstones and shales with hard greywacke bands, which are unfossiliferous, and in general are either vertical or inclined at a high angle to the south-east.

b. Bargany Group

The members of this division appear in the streams to the south of Bargany in the Girvan valley, and still further east on the northern slope of Hadyard Hill. Of these sections, perhaps the most interesting is that laid open in Bargany Burn. In its higher portion, thick-bedded grey and green flagstones and shales are met with (Glenfoot beds) resembling those in Penwhapple Glen to the north of the *Cyrtograptus* mudstones. From the point where the stream enters the plantation at Blackwood Head [NX 24449 99262]? northwards to the fault that bounds the Silurian plateau, a fine exposure of grey, finely laminated flaggy shales may be seen with occasional harder ribs, which, near the waterfall, show excellent examples of overfolding. A few thin seams of carbonaceous matter associated with these strata have yielded specimens of *Monograptus acus* and *Monograptus priodon*. At the eastern limit of the Blackwood Head plantation, where several small burns drain the north-west slope of Hadyard Hill, an interesting fossiliferous horizon appears among the beds of this group. At the foot of one of these rivulets, and about 100 yard south of the fault that brings the Carboniferous rocks in contact with the Silurian strata [NX 25137 99449]?, blue, grey, and green fissile shales with limestone ribs crop out and are well seen on a cliff beside the waterfall, where the following fossils have been collected from them by the Geological Survey:

Land plants.

Heliolites interstinctus (Linn.)

Palaeocyclus sp.

Discinocaris gigas (Woodw.)

Encrinurus sp.

Orthis calligramma (Dalm.)

Orthis polygramma (Sow.)

Pentamerus oblongus (Sow.)

Pentamerus sp.

Oriostoma (Euomphalus) discors (Sow.)

c. Drummyork Flagstones

The final sub-division of the Tarannon series appears along the southern margin of the narrow belt of Upper Silurian strata which, between Blair and Straiton, on the south side of the Girvan valley (Sheet 14), are faulted against the Lower Old Red Sandstone and associated igneous rocks. Perhaps among the best exposures are those visible in the Lady Burn near the fault to the south of Drummyork Farmhouse, and near the head of Glenmartin Burn [NS 32310 01898] to the south and south-east of Blair. The strata consist of green and grey shales, occasionally weathering brown, with flagstones and greywacke bands, which are destitute of fossils. Their prevalent dip is to the south-east at high angles, so that merely from superposition they might be inferred to be stratigraphically the highest members of the Blair and Straiton (Wenlock) series, but in reality they appear to be inverted like the strata along the northern margin of the tableland of Penwhapple Glen, and they are followed towards the north by beds yielding fossils of Wenlock age.

In illustration of the general structure of the ground in which the Caradoc and Llandovery formations, described in the preceding pages, are developed, a section is here given (Figure 116) drawn from the Old Red Sandstone district southwards by Drummuck across the Craighead inlier, the valley of the Girvan, and Saugh Hill, to the valley of the Stinchar near the railway-station of Pinwherry.

Wenlock (Blair, Knoelegardner, and Straiton Beds)

The representatives of this division of the Upper Silurian rocks are traceable for a distance of four miles from the neighbourhood of the farm of Blair to the village of Straiton — a tract which is much covered with superficial deposits, but is traversed by several small streams that expose the strata.

The beds which, in the neighbourhood of Blair, immediately succeed the Drummyork Flagstones consist of greenish shales which weather occasionally with a yellowish tint, are associated with bands of greenish greywacke and contain thin seams of carbonaceous shale charged with graptolites. Some good exposures are met with in the Glenmartin Burn — a tributary of the Shiel Burn — about 500 yards east of Blair Farmhouse, where, on the banks of the stream not far to the south of Glenmartin Cottage [NS 32875 02490], green and carbonaceous shales with flagstones from two to three inches thick, yield graptolites and orthoceratites. Still further west, a quarry on the south side of the road, about 150 yards east of Blair Farmhouse [NS 32628 02448], is the best locality for graptolites in the Blair and Straiton region. Here the beds dip to the S.S.E. at 60°, and consist of alternations of green and grey shales, flagstones, and greywacke bands. The shales are variable, some being fissile, others carbonaceous and decomposing with a yellowish tint, while some are calcareous and have a rough irregular fracture. One highly fossiliferous seam, about eight inches thick, yields specimens of *Monograptus vomerinus* in abundance, together with forms many of which occur in the Wenlock rocks of Riccarton and Kirkcudbright. The fossils given in the annexed list have been collected from this quarry by the Geological Survey:

Monograptus galaensis (Lapw.)

Monograptus priodon (Bronn.)

Monograptus riccartonensis (Lapw.)

Monograptus vomerinus (Nich.)

Monograptus sp.

Retiolites geinitzianus (Barr.)

Favosites sp.

Beyrichia Kloedeni (M'Coy.)

Beyrichia impendens (Jones.)

Entomis globulosa (Jones.)

Eurypterus sp.

Lingula Symondsi (Salt.)

Lingula sp.

Orthis sp.

Siphonotreta anglica (Morris.)

Cardiola fibrosa (Sow.)

Bellerophon sp.

Orthoceras subundulatum (Portl.)

Professor Lapworth has also recorded *Cyrtograptus* sp. and *Bellerophon wenlockensis* from the same band.

Again, in the Lady Burn, between Brownford Bridge [NS 33326 02646] and the southern margin of the unconformable Upper Old Red Sandstone, several outcrops of strata belonging to this horizon, consist of flagstones, blue and grey shales, and occasional greywackes. From these beds Professor Lapworth obtained *Monograptus Flemingi*, *M. vomerinus*, *Cyrtograptus* sp., and *Orthoceras subundulatum*.

To the north-east, in the neighbourhood of Knockgardner, the prolongations of these strata are met with in certain artificial exposures, where they yield organic remains. For instance, in a quarry about half a mile west of Knockgardner Farmhouse, and a few yards north of the road [NS 34471 03635], green shales, flagstones, and grit bands, dipping S.S.E. at 83°, furnish specimens of:

Beyrichia Kloedeni (M'Coy.)

Primitia sp.

Ctenodonta sp.

Grammysia sp.

Modiolopsis sp.

Orthonota truncata (M'Coy.)

Orthonota sp.

Pterinea pleuroptera (Corr.)

Again, in another opening in a field about a quarter of a mile east of Knockgardner, and to the south of the road [NS 35477 03595], fossils occur in great abundance in some of the grit bands. Here the strata consist of yellow-weathering shales, with sandy and gritty flagstones from two to nine inches thick, and dip E.S.E. at high angles; the gritty flagstones, where not decomposed, have a grey or cream colour, but, when exposed to the action of the weather, have a brown tint. Among the weathered debris of these gritty flagstones at the base of the cliff, casts of fossils may be readily obtained. The following species have been here collected by the Geological Survey:

Favosites sp.

Ptilodictya lanceolata (Goldf.)

Cornulites sp.

Beyrichia Kloedeni (M'Coy.)

Acidaspis sp.

Calymene Blumenbachi (Brong.)

Encrinurus punctatus (Brun.)

Encrinurus punctatus var. *arenaceus* (Salt.)

Phacops (Acaste) Downingae (Murch.)

Phacops Stokesi (M. Edw.)

Proetus Stokesi (Murch.)

Atrypa reticularis (Linn.)

Leptaena (Plectambonites) transversalis (Wahl.)

Orthis (Platystrophia) biforata (Schl.)

Orthis Bouchardi (Dav.)

Orthis (Dalmanella) elegantula (Dann.)

Orthis (Dinorthis) flabellulum (Sow.)

Orthis rustica (Sow.)

Retzia Barrandei (Dav.)

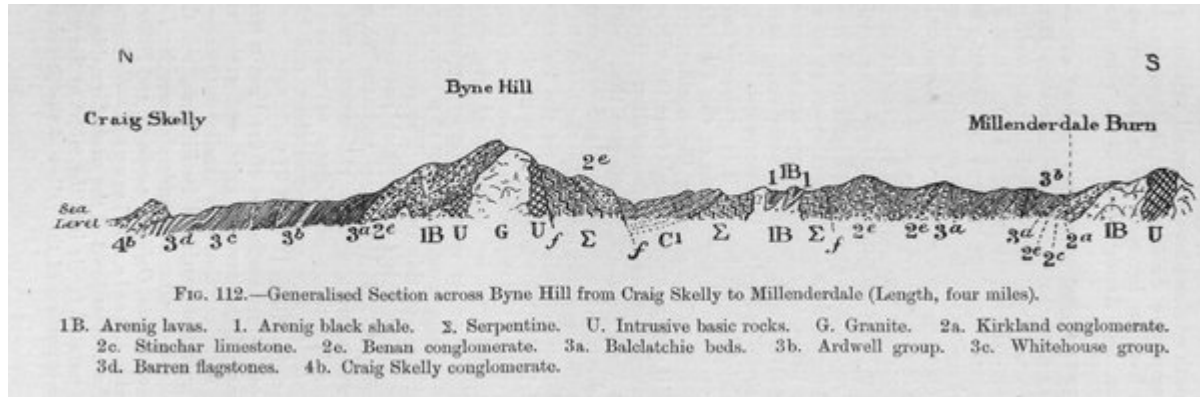
Spirifera sulcata (His.)

Orthoceras sp.

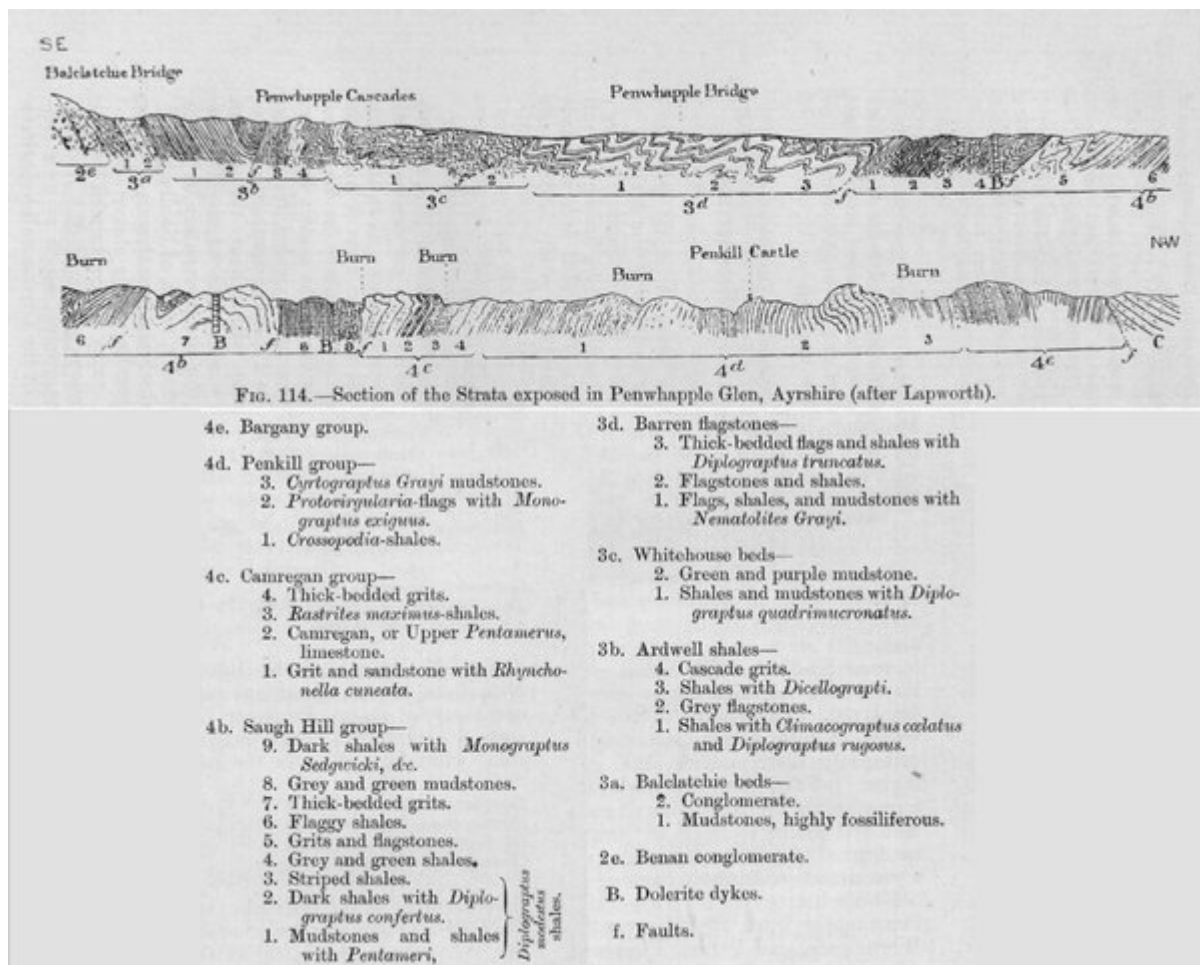
About half a mile still further east, green shales and thin gritty flags, visible in a streamlet running south from Dyke Farmhouse to the Cawin Burn [NS 36260 03739], have yielded specimens of *Ptilodictya*, *Orthoceras MacLareni*, *O. angulatum*, and encrinite stems. Similar strata are observable in the Cawin Burn, which flows eastwards from the Green Hill of Knockgardner to the Girvan Water at Straiton, but no fossils have been recorded from these exposures.

The remaining sub-division of the Wenlock rocks of the Blair and Straiton area differs to some extent in lithological character from the strata just described, inasmuch as it contains prominent bands of conglomerate or conglomeric

sandstone. Owing to the sinuous nature of the boundary-line of the unconformable Upper Old Red Sandstone as it passes transgressively across successive zones of the Upper Silurian Rocks, it is not possible to trace continuously the conglomeratic series. But the beds are visible in a wood and in a streamlet north of Cawin Burn, north of the road leading to Knockgardner, and about three-quarters of a mile west of the village of Straiton, where they consist of purple and grey conglomerates and flags, associated with green shales and mudstones. They are either vertical or highly inclined to the south-east, thus presenting an inverted dip in common with the Upper Silurian rocks of the rest of the surrounding district. About two miles further to the southwest, midway between Knockgardner and Kirkbride, the prolongations of this sub-zone reappear at the margin of the Upper Old Red Sandstone, as massive conglomerate and grit in a quarry now abandoned.

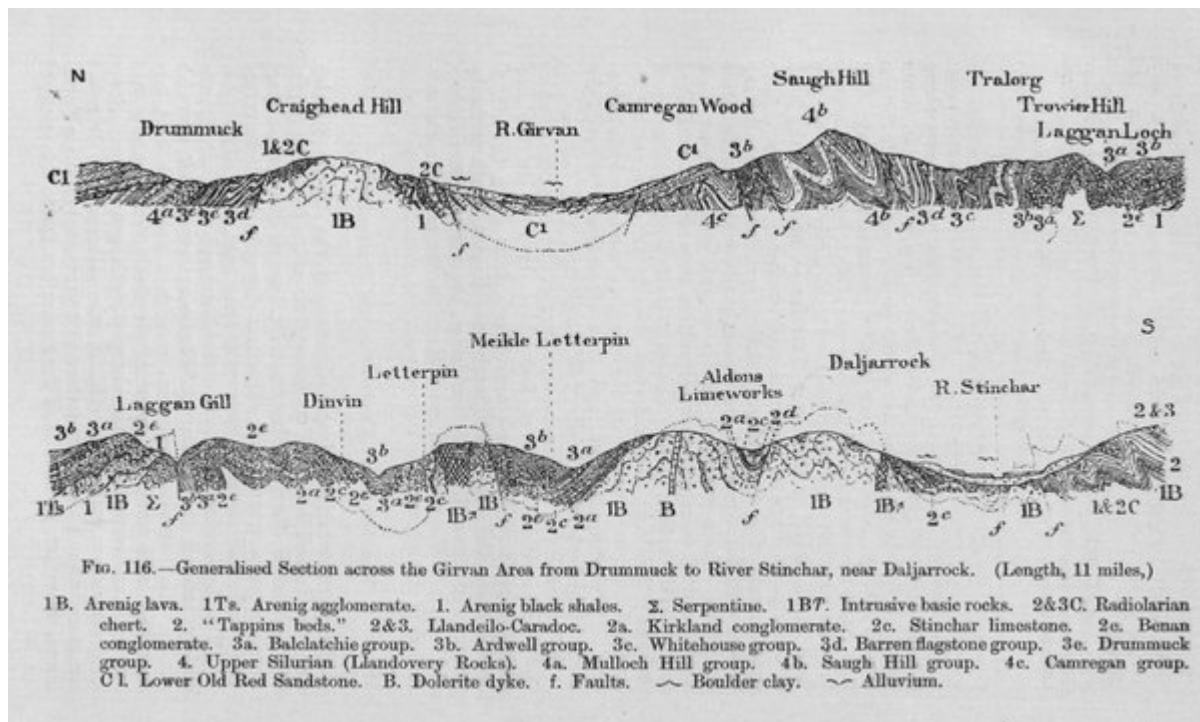


(Figure 112) Generalised Section across Byne Hill from Craig Skelly to Millenderdale (Length, four miles). 1B. Arenig lavas. 1. Arenig black shale. Σ. Serpentine. U. Intrusive basic rocks. G. Granite. 2a. Kirkland conglomerate. 2c. Stinchar limestone. 2e. Benan conglomerate. 3a. Balclatchie beds. 3b. Ardwell group. 3c. Whitehouse group. 3d. Barren flagstones. 4b. Craig Skelly conglomerate.



(Figure 114) Section of the Strata exposed in Penwhapple Glen, Ayrshire (after Lapworth). 4e. Bargany group. 4d. Penkill group: 3. *Cyrtograptus Grayi* mudstones. 2. *Protovirgularia*-flags with *Monograptus exiguus*. 1. *Crossopodia*-shales. 4c.

Camregan group: 4. Thick-bedded grits. 3. *Bastrites maximus*-shales. 2. Camregan, or Upper *Pentamerus*, limestone. 1. Grit and sandstone with *Rhynchonella cuneata*. 4b. Saugh Hill group: 9. Dark shales with *Monograptus Sedgwicki*, cf. c. 8. Grey and green mudstones. 7. Thick-bedded grits. 6. Flaggy shales. 5. Grits and flagstones. 4. Grey and green shales. 3. Striped shales. 2. Dark shales with *Diplograptus confertus*. 1. Mudstones and shales with *Pentameri* 1, 2, 3 previous *Diplograptus modestus* shales 3d. Barren flagstones: 3. Thick-bedded flags and shales with *Diplograptus truncatus*. 2. Flagstones and shales. 1. Flags, shales, and mudstones with *Nematolites Grayi*. 3c. Whitehouse beds: 2. Green and purple mudstone. 1. Shales and mudstones with *Diplograptus guatrimucronatus*. 3b. Ardwell shales: 4. Cascade grits. 3. Shales with *Dicellograpti*. 2. Grey flagstones. Shales with *Climacograptus coelatus* and *Diplograptus rugosus*. 3a. Balclatchie beds: 2. Conglomerate. 1. Mudstones, highly fossiliferous. 2e. Benan conglomerate. B. Dolerite dykes. f. Faults.



(Figure 116) Generalised section across the Girvan area from Drummuck to River Stinchar, near Daljarrock. (Length, 11 miles,) 1B. Arenig lava. 1T. Arenig agglomerate. 1. Arenig black shales. Σ. Serpentine. 1B[arrow]. Intrusive basic rocks. 2 & 3 C. Radiolarian chert. 2. "Tappins beds". 2&3. Llandello-Caradoc. 2a. Kirkland conglomerate. 2c. Stinchar limestone. 2e. Benan conglomerate. 3a. Balclatchie group. 3b. Ardwell group. 3c. Whitehouse group. 3d. Barren flagstone group. 3e. Drummuck group. 4. Upper Silurian (Llandoverly Rocks). 4a. Mulloch Hill group. 4b. Saugh Hill group. 4c. Camregan group. C1. Lower Old Red Sandstone. B. Dolerite dyke. f. Faults. [symbol] Boulder clay. [symbol] Alluvium.