
Chapter 25 Upper Silurian rocks north of The Tableland — continued. The Pentland Hills

Within the range of the Pentland Hills and completely surrounded by various sub-divisions of the Old Red Sandstone and some of the associated igneous rocks, four isolated patches of Upper Silurian strata have, at various localities, furnished a large and definite assemblage of organic remains. Though far removed from the Upper Silurian inliers near Lesmahagow they nevertheless have certain features in common, for here, as in Lanarkshire, an ascending series can be traced from the Upper Ludlow rocks into the Downtonian passage-beds, while some of the palaeontological zones may be correlated in the two regions. But apart from these characteristics, considerable differences in the respective types of sedimentation were recognised by Salter in his Appendix to the Geological Survey Memoir on the Geology of the neighbourhood of Edinburgh.

In order to understand the complicated relations of the various patches of Upper Silurian strata to the younger Palaeozoic rocks of the Pentland Hills, it is necessary to bear in mind that we have here three great divisions, which for some time have been regarded by the Geological Survey as belonging to the Old Red Sandstone. First, there is the series of passage beds (Downtonian) which rest conformably on the Upper Ludlow rocks and are composed of red and yellow sandstones, alternating with green and red mudstones and sandy greywackes, well displayed in the sections of the river Esk and the Lyne Water. Second, there is the volcanic series of the Lower Old Red Sandstone, which includes a great succession of lavas and tuffs underlain by red sandstones, shales, and conglomerates, the basal bed being a coarse conglomerate composed mainly of greywacke pebbles derived from the ancient Silurian Tableland. While in Lanarkshire no unconformability has been traced between the Upper Silurian and Old Red Sandstone groups (p. 568), yet in the Pentland Hills this greywacke-conglomerate rests on the upturned edges of the Wenlock, Ludlow, and Downtonian or passage beds into the Lower Old Red Sandstone. This prominent discordance is well seen along the southern and part of the northern margins of the Silurian inlier between the Lyne Water and the river Esk. Third, there are the representatives of the Upper Old Red Sandstone, which are separated by a marked unconformability from all older rocks indeed, this discordance is so conspicuous on the northern slopes of the range that at Bavelaw Castle the red sandstones of this upper division repose immediately on the highly inclined Silurian series.

A study of the physical relations and distribution of the strata in the various Upper Silurian inliers in the Pentland Hills reveals the important fact that some of the graptolite zones which occur close to the North Esk reservoir reappear several miles to the north at Habbie's Howe and Bavelaw Castle. It is therefore apparent that during the interval represented by the unconformability between the Downtonian beds and the greywacke-conglomerate the Upper Silurian and Downtonian groups must together have been reduplicated by folds and subjected to prolonged denudation.

The various areas of Upper Silurian rocks in the Pentland Hills may be grouped as follows: (1) The tract on the south side of the watershed extending from the Lyne Water by the North Esk River to Green Law, a distance of three and a half miles; (2) the patch at Loganlee reservoir; (3) the Hare Hill and Bavelaw Castle inlier; (4) the patch in Bavelaw Burn near Craigenterrie, situated to the north-east of the Black Hill.

i. Inlier extending from the Lyne Water by the North Esk to Green Law

This patch of Upper Silurian strata, which occupies between two and three square miles of the hilly ground at the head of the North Esk and Lyne Water, is the largest and most important of the series; indeed, it is the only one in the Pentland Hills that shows the Downtonian passage beds in addition to the Wenlock and Ludlow rocks. The two main sections are those exposed in the North Esk and Lyne Water, the former showing a complete transverse section of the Wenlock, Ludlow, and portion of the Downtonian strata, while the latter traverses mainly the passage beds overlying the Ludlow rocks.

Wenlock and Ludlow Series

In the chapter devoted to the History of Research among the Silurian rocks of the Pentland Hills reference has been made to the gradual development of our knowledge regarding the geological structure and palaeontological sub-divisions of the district. It may be sufficient to recall the fact that the general order of succession in the North Esk as given by Sir A. Geikie in the Memoir on the Geology of the neighbourhood of Edinburgh has been confirmed by subsequent investigators. He showed that by traversing the Esk from Carlops northwards to the watershed, the observer crosses the series nearly at right angles to its strike, and that with the exception of certain minor folds an ascending succession is traceable from the green, grey, and reddish shales at the reservoir to the Downtonian or passage beds near the watershed. The researches of various local observers, notably of Messrs. John Henderson and D. J. Brown, have proved the existence of certain palaeontological zones, some of which yield a large assemblage of organic remains. Messrs. Henderson and Brown further showed that the Downtonian or passage beds at the head of the North Esk section are traceable across the hills in a south-west direction to the Lyne Water, suggesting at the same time, from the presence of marine fossils in the conformable red sandstone series, that the latter might belong to the Silurian instead of the Lower Old Red Sandstone system. <ref>Trans. Edin. Geol. Soc. Vol. i., p. 272,</ref>

Since the North Esk section was first mapped by the present Director-General of the Survey, the various palaeontological zones, as indicated by Messrs. Henderson and Brown in their papers on the Silurian Rocks of the Pentland Hills (Trans. Edin. Geol. Soc., vol. i., pp. 23–33, pp. 266–272), have been examined by the Geological Survey, and a large suite of fossils has been gathered, which, together with some of the lists published by Messrs. Henderson, Brown, and others, are incorporated in the following descriptions (Figure 120).

At the southern limit of the section, below the reservoir, the river and the adjoining rivulets have laid bare numerous exposures of green, grey, and reddish shales with occasional bands of grit, which dip sometimes towards the north-west and sometimes towards the south-east at angles varying from 50° to 75°. From certain seams below the reservoir the Geological Survey obtained specimens of *Monograptus*, *Nucleospira pisum*, *Cucullella* sp., while Messrs. Henderson and Brown have recorded the following additional forms: *Monograptus priodon*, *Retiolites geinitzianus*, *Glassia (Athyris) compressa*, and *Theca* sp. from a knob near the cottage at the reservoir (Band A) [NT 15399 57836]. Northwards towards the northern side of the reservoir, strata of the same general type as those just described are well seen on the shore of the lake above the mouth of Gutterford Burn. Here occur zones of green and red lumpy shales, with occasional grit bands, containing abundant remains of *Dictyocaris Ramsayi?*, (Salt.), which are either vertical or inclined to the north-west at high angles. Similar strata appear in the North Esk as far as the quarries below the mouth of the second rivulet above the reservoir. On the right bank of the river, near the head of the reservoir, certain flaggy bands of sandy grit, east of an old quarry, yielded to the Geological Survey crinoid stems, *Dictyocaris Ramsayi*, *Orthonota*, and *Pterinea*; and to Messrs. Henderson and Brown *Glassia (Athyris) compressa* and *Bellerophon dilatatus*.

The Gutterford Burn — [NT 15813 58836] an important tributary of the Esk from the north-east — displays an admirable section of this series of shales, which has become widely known within recent years from the discovery by Mr. Henderson of certain seams, yielding new forms of eurypterids, described by Mr. Malcolm Laurie.

These organic remains are associated with a few species of graptolites of characteristic Wenlock types, which leave no doubt as to the stratigraphical horizon of the beds. Of further interest is the occurrence of a thin band of coralline and encrinital limestone and certain beds containing well preserved remains of starfishes. The strata in the Gutterford Burn consist generally of green and grey shales with bands of micaceous flaggy greywacke and red and purple shale, which, from the constant change of dip, are apparently repeated by sharp folds indeed, throughout some parts of the section the dip is so persistently to the south-east that many of the outcrops may be inverted. Near the head of the stream, which is about a mile in length, green and buff-coloured mudstones alternate with green micaceous sandy flags and greywackes. At a point about twenty-five yards north from the ruin of Gutterford shepherd's house [NT 15986 59392], on the east bank, the fossiliferous beds yield well-preserved specimens of starfishes. From the green and buff-coloured mudstones and shales the following specimens have been obtained: <ref>We beg to express our obligations to Dr. Traquair, F.R.S., for permission to examine the Hardie collection of fossils from the Upper Silurian Rocks of the Pentland Hills, now placed in the Museum of Science and Art, Edinburgh. This collection was made by the late Mr. Hardie, of Bavelaw, who, for many years, searched the Silurian Rocks of the Pentland Hills for eurypterids and starfishes.</ref>

Monograptus vomerinus (Nich.)

Palaeaster sp.

Cheirurus bimucronatus (Murch.)

Phacops Stokesi (M. Edw.)

Glassia (Athyris) obovata (Sow.)

Orthis sp.

The starfishes, however, occur in greater abundance in one of the green sandy bands, varying in thickness from a few inches to a foot and a half, which are associated with the mudstones. These have yielded specimens of *Ptilodictya*, *Monograptus vomerinus*, *Palaeaster*, *Palasterina*, *Protaster*, and *Periechocrinus*.

About a quarter of a mile below the ruin of the shepherd's house [NT 15845 59009] the beds crop out which have yielded the new forms of eurypterids. The locality is about half a mile up the burn from the North Esk reservoir, where on the east bank the strata consist of flaggy micaceous greywackes, breaking with an irregular fracture and dipping towards the south-east at an angle of 80°. A characteristic feature of this eurypterid bed is the abundance on the divisional planes of that enigmatical fossil, *Dictyocaris Ramsayi*, forming, indeed, large black patches about an inch and a half across. Graptolites, though numbering few species, are not of infrequent occurrence, and considering the sandy nature of the material, are in fairly good preservation. The following list of organisms from this band is based partly on the researches of Mr. Malcolm Laurie, and partly on an examination of specimens in the Hardie collection determined by Mr. B. N. Peach:

Amphispongia sp.

Nidulites favus (Salt.)

Dictyonema venustum (Lapw.)

Dictyonema (Chondrites) verisimile (Salt.)

Oyrtograptus Murchisoni? (Carr.)

Monograptus priodon (Bronn.)

Monograptus vomerinus (Nich.)

Favosites sp.

Tentaculites tenuis (Sow.)

Palasterina sp.

Crinoid fragments.

Phacops sp.

Ceratiocaris sp.

Bembycosoma pomphicus (Laurie.)

Drepanopterus pentlandicus (Laurie.)

Drepanopterus bembycoides (Laurie.)

Drepanopterus lobatus (Laurie.)

Eurypterus conicus (Laurie.)

Eurypterus minor (Laurie.)

Eurypterus scoticus (Laurie.)

Eurypterus cyclophthalmus (Laurie.)

Eurypterus sp. undetermined.

Stylonurus elegans (Laurie.)

Stylonurus macrophthalmus (Laurie.)

Stylonurus ornatus (Laurie.)

Slimonia dubia (Laurie.)

Dictyocaris Ramsayi (Salt.)

Palaeophonus loudonensis (Laurie.)

Lingula Lewisi (Sow.)

Lingula Symondsi (Salt.)

Strophomena Walmstedti (Lindst.)

Euomphalus rugosus (Sow.)

Conularia monile (Lindst.)

Conularia Sowerbyi (Def.)

Conularia sp.

Ortheceras angulatum (Wahl.)

Gomphoceras ellipticum? (M'Coy.)

Mr. Malcolm Laurie, who has described the *Arthropoda* from the locality just referred to in the Gutterford Burn, has kindly furnished the following note, giving the results of his researches:

"The zoological interest of the *Arthropoda* found in this deposit is very great. Notwithstanding the small exposure of the fossiliferous band, four genera, embracing ten species of *Eurypteridae* have been collected. Two of the genera are peculiar to this horizon. The great variety of forms together with the high development of two of the species (*Stylonurus ornatus* and *Eurypterus scoticus*), occurring in this band — as yet the oldest from which specific forms have been obtained — shows that their first appearance must date further back than Wenlock time. While, however, certain forms are highly developed, the general facies of the remains as a whole is of an opposite character. *Slimonia dubia*, *Stylonurus macrophthalmus*, and *S. elegans* are all forms in which the generic characters are somewhat slightly developed. This is most marked in the limbs in the two species of *Stylonurus* and in the form of the body in *Slimonia*.

"The generalised aspect of this fauna is still better exemplified in the genus *Brepanopterus*, in which the most marked generic character is the absence of specialisation of the limbs. This is best seen in *D. bembycoides*, in which there is a

gradual increase in the length of these, organs from before backwards, but an entire absence of the differentiation of the posterior pair either into flattened swimming 'feet' as in *Eurypterus*, *Pterygotus*, and *Slimonia*, or into elongated crawling legs as in *Stylonurus*. Along with the absence of specialisation in the limbs, there is a conical form of body without any marked distinction between the mesosomatic and metasomatic regions. This unspecialised type of eurypterid is of great interest, especially as it is found in such a low stratigraphical horizon where it might naturally be expected to occur.

"The somewhat problematical form which I have described as *Bembycosoma pomphicus* may possibly be related to *Hemiaspis* rather than to the *Eurypteridae*. If this be so, it is markedly less highly developed as regards the form of the body than the typical *Hemiaspis*. In the latter there is a marked narrowing at the metasomatic region, whereas in *Bembycosoma* the body is conical.

"Perhaps the most interesting species from this deposit, however, is a Scorpion — *Palaeophonus loudonensis*— described from one specimen which is in a bad state of preservation but shows the forward position of the eyes and the proportionately large *chelicerae* characteristic of the genus. The point of the greatest morphological importance in this specimen is an indication of what may have been plate-like appendages on the mesosomatic segments. Should this interpretation of the obscure markings on these segments be correct it would imply either that this form was aquatic and furnished with gills, or, if terrestrial, that the original gill bearing appendages had not become completely fused with the abdomen to form an air chamber as in the recent forms.

"Looking at the fauna of this bed as a whole it may safely be said to have yielded more information of importance and interest concerning these fossil *arthropoda* than any other single deposit. This makes it the more to be regretted that it is now almost impossible to get further material from it.

"The species described from it are:

†*Palaeophonus loudonensis* (Laurie.)

†*Slimonia dubia* (Laurie.)

**Stylonurus macrophthalmus* (Laurie.)

**Stylonurus ornatus* (Laurie.)

†*Stylonurus elegans* (Laurie.)

†*Drepanopterus tobatus* (Laurie.)

**Drepanopterus pentlandicus* (Laurie.)

†*Drepanopterus benbycoides* (Laurie.)

†*Eurypterus scoticus* (Laurie.)

†*Eurypterus minor* (Laurie.)

**Eurypterus conicus* (Laurie.)

**Eurypterus cyclophthalmus* (Laurie.)

†*Bembycosoma pomphicus* (Laurie.)

Ceratiocaris sp".

* Trans. Roy. Soc. Edin., vol. xxxvii., p. 151. † Trans. Roy. Soc. Edin., vol. xxxix,

About fifteen yards down stream from the eurypterid band a seam of limestone about ten inches thick lies embedded in mudstones, shales, and greywackes. Weathering with a rich brown colour, this rock in fresh fracture is found to be made up in large part of crinoid stems, while containing also remains of corals, brachiopods, and several other calcareous organisms. The species given in the annexed list have been determined from specimens in the Hardie collection obtained from this locality, together with specimens collected by the Geological Survey:

Nidulites famus (Salt.)

Dictyonema (Chondrites) verisimile (Salt.)

Monograptus priodon (Bronn.)

Monograptus vomerinus (Nieh.)

Cyrtograptus sp.

Ceriopora granulosa (Goldf.)

Pitlodictya sp.

Favosites gothlandicus (Foug.)

Favosites multiporus (Lonsd.)

Favosites asper (D'Orb.)

Heliolites sp.

Cyathophyllum.

Ptychophyllum patellatum (M. Edw.)

Strontbodes plicatus (Lonsd.)

Streptelasma (Petraia) elongatum (Phil.)

Leptaena (Plectambonites) transversalis (Wahl.)

Orthis (Dalmanella) elegantula (Dalm.)

Atrypa reticularis (Linn.)

Strophontena (Leptaena) rhomboidalis (Wilck.)

Cyrtoceras sp.

Returning now to the North Esk section, the observer finds in certain quarries near the second rivulet [NT 15201 58388]?, about a third of a mile above the reservoir, a group of vertical strata, about 200 feet thick, which differ considerably in character from the great shaly division just described. They consist of hard sandstones and quartzose grits, which contain fossils, easily discernible on weathered surfaces, and in the centre of the quarry a shaly band yields specimens of *Orthonota amygdalina*. From these beds the following forms have been collected at various dates by the Geological Survey (Band B of A. Geikie, C of Henderson and Brown):

Crinoid stems.

Periechocrinus sp.

Glassia (Athyris) compressa (Sow.)

Atrypa reticularis (Linn.)

Orthonota (Ctenodonta) thracioides (Salt.)

Orthonota amygdalina (Sow.)

Platyschisma simulans (Salt.)

Mytilus mytilimeris (Conrad.)

Pterinea sp.

Holopella obsoleta (Sow.)

About half a mile to the south-west of this locality these arenaceous beds reappear near the head of Deerhope Burn [NT 14276 58027], where they present similar characters and yield a similar assemblage of organic remains.

In the North Esk section the fossiliferous grits of the quarry above mentioned are succeeded by greenish-grey shales and sandy bands, which are highly fossiliferous. It was the large assemblage of organic remains from this horizon (Band D) which led Messrs. Henderson and Brown to the conclusion<ref>Trans. of the Geol. Soc. Edin. Vol. i., p. 268.</ref> that the rocks of Wenlock age occur in the Pentland Hills — an opinion which has been confirmed by Mr. Davidson in his memoir, "On the Upper Silurian Brachiopoda of the Pentland Hills". The forms given in the annexed list are taken from the papers published by Messrs. Henderson and Brown (Trans. Geol. Soc. Edin., pp. 31–33, p. 268, Band D):

Chaetetes Fletcheri (M. Edw.)

Petraia subduplicata (M'Coy.)

Petraia sp.

Stenopora fibrosa (Goldf.)

Ceriopora granulosa (Goldf.)

Ptilodictya fucoides (M'Coy.)

Atrypa reticularis (Linn.)

Chonetes striatella (Dalm.)

Leptaena transversalis (Wahl.)

Lingula Lewisi (Sow.)

Meristella tumida (Dalm.)

Nucleospira pisum (Sow.)

Orbiculoidea Forbesi (Dav.)

Orthis biloba (Linn.)

Orthis elegautula (Dalm.)

Orthis Lewisi (Dav.)

Orthis polygramma (Sow.)

Orthis sp.

Strophomena antiquata (Sow.)

Strophomena applanata (Salt.)

Strophomena compressa (Sow.)

Strophomena Hendersoni (Dav.)

Strophomena pecten (Linn.)

Strophomena rhomboidalis (Wilck.)

Strophomena Walmstedti (Lindst.)

Anodontopsis bulla (M'Coy)

Ctenodonta 2 sp.

Cucullella antiqua (Sow.)

Goniophora cymbaeformis (Sow.)

Mytilus mytilimeris (Conrad.)

Orthonota amygdalina (Sow.)

Orthonota bulla (Salt.)

Orthonota impressa (Sow.)

Orthonota rigida (Sow.)

Orthonota rotundata (Sow.)

Orthonota truncata (M 'Coy.)

Pterinea asperula (M'Coy.)

Pterinea tenuistriata (M'Coy.)

Pterinea sp.

Bellerophon dilatatus (Sow.)

Bellerophon sp.

Cyclonema sp.

Euomphalus alatus (His.)

Euomphalus funatus (Sow.)

Euomphalus rugosus (Sow.)

Euomphalus sculptus (Sow.)

Euomphalus sp.

Holopella obsoleta (Sow.)

Loxonema elegans (M'Coy.)

Platyschisma simulans (Salt.)

Pleurotomaria sp.

Lituities sp.

Orthoceras excentricum (Sow.)

Orthoceras angulatum (Sow.)

Orthoceras 3 sp.

Phragmoceras compressum, (Sow.)

Beyrichia Kloedeni (M'Coy.)

Entomis impendens (Jones.)

Entomis tuberosa (Jones.)

Aciciaspis Wrighti (Murch.)

Calymene Blumenbachi (Brong.)

Encrinurus sp.

Phacops Stokesi (M. Edw.)

Not far to the south-west of this outcrop of fossiliferous shales (Band D of Henderson and Brown) in the North Esk, an exposure of similar beds may be seen alongside of a footpath high up on the south slope of the tributary valley of Netherlaw Linn, whence the following fossils have been collected by the Geological Survey:

Plant.

Amphispongia oblonga (Salt.)

Coral.

Alveolites repens (Fougts.)

Alveolites sp.

Favosites sp.

Petraia sp.

Heliolites sp.

Diastopora sp.

Ptilodictya sp.

Crinoid stems.

Turrilepas Wrighti (Woodw.)

Beyrichia impendens (Jones.)

Calymene Blumenbachi (Brong.)

Encrinurus punctatus (Brünn.)

Encrinurus sp.

Phacops Stokesi (M. Edw.)

Phacops sp.

Atrypa reticularis (Linn.)

Chonetes striatella (Dalm.)

Leptaena (Plectambonites) transversalis (Wahl.)

Meristella MacLareni (Hasw.)

Nucleospira pisum (Sow.)

Orbiculoidea Forbesi (Dav.)

Orthis (Bilobites) biloba (Linn.)

Orthis (Dalmanella) elegantula (Dalm.)

Orthis Lewisi (Dav.)

Orthis polygramma (Sow.)

Crania (Pholidops) implicata (Sow.)

Rhynchonella nucula (Sow.)

Rhynchonella pentlandica (Hasw.)

Rhynchonella Wilsoni (Sow.)

Spirifera exporrecta (Wahl.)

Strophomena antiquata (Sow.)

Strophomena applanata (Salt.)

Strophomena Hendersoni (Dav.)

Strophomena pecten (Linn.)

Strophomena (Leptaena) rhomboidalis (Wilck.)

Strophomena sp.

Whitfieldia (Meristella) tumida.

Anodontopsis bulla (M'Coy.)

Anodontopsis lucina (Salt.)

Modiolopsis allied to *Chemnitzia*.

Modiolopsis sp.

Orthonota Salteri (Eth. jun.)

Orthonota sp.

Cardiola sp.

Ctenodonta sp.

Pterinea sp.

Bellerophon sp.

Cyclonema sp.

Euomphalus sculptus (Sow.)

Holopella obsoleta (Sow.)

Comularia sp.

Theca sp.

Orthoceras sp.

Still further towards the south-west the same band reappears near the head of the Deerhope Burn [NT 14097 57933], where it has likewise furnished to the Geological Survey a large number of characteristic fossils.

In the Esk section, the beds of the succeeding zone (Band E of Henderson and Brown) are exposed at the mouth of the Wetherlaw Linn — a small tributary stream on the west side of the valley [NT 14832 58686] — and also on the west bank of the Esk, a few yards to the north of that tributary. They consist of mudstones, shales, and sandy bands of a greenish-grey tint, and weather with a marked concretionary structure. In certain layers, they are crowded with casts of fossils, a characteristic form of one of the seams being *Leptaena transversalis*. From the scar on the west bank of the Esk, a few yards north of the Wetherlaw Linn Burn, the fossils given in the subjoined list were obtained by the Geological Survey:

Amphispongia oblonga (Salt.)

Sponge spicules.

Monograptus sp.

Favosites gothlandica (Fougt.)

Coral.

Ceriopora granulosa (Goldf.)

Diastopora sp.

Ptilodictya sp.

Turrilepas Wrighti (Woodw.)

Beyrichia (Entomis) impendens (Jones.)

Beyrichia Kloedeni (M'Coy.)

Beyrichia (Entomis) tuberosa (Jones.)

Calymene Blumenbachi (Brong.)

Encrinurus punctatus (Brun.)

Encrinurus sp.

Phacops Stokesi (M. Edw.)

Atrypa reticularis (Linn.)

Chonetes.

Leptaena (Plectambonites) transversalis (Wahl.)

Lunulicardium elegens (Salt.)

Orthis (Dalmanella) elegantula (Dalm)

Orthis Lewisi (Dav.)

Orthis minuta (young of *S. pecten*.)

Rhynchonella pentlandica (Hasw.)

Strophomena antiquata (Sow.)

Strophomena applanata (Salt.)

Strophomena pecten (Linn.)

Strophomena (Leptaena) rhomboidalis (Wilck.)

Strophomena Walmstedti (Lindst.)

Anodontopsis lucina (Salt.)

Anodontopsis Salteri (Eth.)

Ctenodonta obesa (Salt.)

Pterinea.

Bellerophon carinatus (Sow.)

Euomphalus funatus (Sow.)

Euomphalus sp.

Holopella obsoleta (Sow.)

Cyclonema.

Platyceras (Acroculia) antiquatum (Salt.)

Platyceras Gibbsi (Eth. jun.)

Conularia Sowerbyi (Def.)

Theca sp.

Lituites sp.

Orthoceras sp.

The concretionary sandy mudstones just described preserve their highly fossiliferous character in the lower portion of the Wetherlaw Linn Burn; they likewise pass south-westwards across the head of Deerhope Burn, and are eventually overlapped by the greywacke-conglomerates and sandstones at the base of the volcanic zone of the Lower Old Red Sandstone.

Next in order in the Esk section, at a point about 150 yards north of Wetherlaw Linn [NT 14817 58843], come concretionary greenish-brown sandstone and shales (Band F of Henderson and Brown), which furnish numerous and well-preserved specimens of *Orthoceras MacLareni*. In addition to this form, the Geological Survey has collected from it *Dictyonema (Chondrites) verisimile*, *Rhynchonella micula*, *Platyceras (Acroculia) antiquatum*, *Entomis tuberosa*, with a fragment of a crustacean; while Messrs. Henderson and Brown have obtained also *Crania (Pholidops) implicata*, *Spirifera* sp., *Pterinea retroflexa*, and *Conularia Sowerbyi*.

A little further north the Esk is joined from the west by the Henshaw Burn, in which, a few yards from its foot, yellowish brown sandy concretionary sparingly fossiliferous bands appear. These are rapidly succeeded by dark brown sandy shales yielding a large assemblage of organic remains (Band H of Henderson and Brown); those given in the subjoined list have been here collected by the Geological Survey:

Dictyonema (Chondrites).

Athyris sp.

Meristella MacLareni (Haswell.)

Nucleospira pisum, (Sow.)

Rhynchonella pentlandica (Hasw.)

Anodontopsis bulla (M'Coy.)

Cucullella antiqua (Jones.)

Nucula sp.

Holopella obsoleta (Sow.)

Platyceras (Acroculia) antiquatum (Salt.)

Platyceras Gibbsi (Eth. jun.)?

Conularia Sowerbyi (De Franc.)

Orthoceras subundulatum (Portl.)

Encrinurus sp.

Pterygotus bilobus (Salt.)

Slintonia acuminata (Salt.)

Entomis tuberosa (Jones.)

Dictyocaris Bantsayi (Salt.)

The following additional forms have been recorded from this zone by Messrs. Henderson and Brown, viz.:

Antifopsis sp.

Beyrichia impendens (Jones.)

Cythere umbilicata (Jones.)

Leperdita umbonata.

Lingula lata (Sow.)

Cyrtia exporrecta (Wahl.)

Pterinea retroflexa (Wahl.)

Platyschisma simulans (Salt.)

Bellerophon expansus (Sow.)

Orthoceras gregarium (Sow.)

Among the noteworthy palaeontological features of the zone are: (1) the great abundance of a new species of *Rhynchonella* discovered by the late Mr. Haswell and named by him *R. pentlandica*, and (2) the common occurrence of *Platyschisma simulans*. Indeed, in the North Esk section the members of this zone (Band H) lie not far beneath the Downtonian or passage beds, for they graduate upwards through some green sandy shales and soft red shales into a band of red conglomerate which here marks the base of the Conformable red sandstone series. In the first edition of the Geological Survey Map of the Edinburgh region (Sheet 32), these soft-red shales and conglomerates were correctly taken as indicating the base of the conformable red sandstone series, but in the sequel we shall show that Messrs. Henderson and Brown were likewise right in their contention that these red beds and the underlying Ludlow rocks are prolonged south-westwards to the Lyne Water, where they appear to the south of Hareshaw.

Downtonian Series

The exposures of this overlying conformable series both in the North Esk and Renshaw Burn are by no means satisfactory, as the sections are not continuous, but taken in connection with the evidence furnished by the Lyne Water, the strata may be correlated in a general way with their probable equivalents in the Lesmahagow region. In the North Esk they consist of red and yellow sandstones, grits, and shales, which are exposed only at intervals in the stream northwards for a distance of about 300 yards. At their northern limit they are abruptly truncated by a fault which brings

down against them the Upper Old Red Sandstone. In like manner, in the Renshaw Burn, similar red sandstones appear at intervals, and at one point near their northern limit a band of conglomerate with a few quartzite pebbles, recalls the quartzite-conglomerate that overlies the fish-bed in the Lesmahagow region. In these sections we fail to find the green shales and mudstones associated with the conformable red sandstones at Lesmahagow and in the Lyne Water. There are, however, numerous gaps where no strata are visible, so that these rocks might quite well occur in the North Esk section though not at present exposed there. The discovery by Messrs. Henderson and Brown of *Entomis tuberosa*, *Platyschisma helicitis*, and fragments of an *Orthoceras* in certain yellow and red beds on the Deerhope Rig, at a point about 600 yards west from the foot of the Henshaw Burn, may be of importance, if these fossils really occur within the Red Sandstone series.

The section in the Lyne Water (Figure 121) at the south-west limit of the Upper Silurian inlier of the Pentland Hills, lays open an important development of Upper Ludlow rocks. A small tributary which joins the Lyne from the east, at a point about 300 yards south of Hareshaw shepherd's house [NT 12993 56143] flows nearly parallel to the general strike of the Silurian strata, which here consist of green shales and mudstones, resembling the Upper Ludlow rocks of the North Esk. Along their southern limit they are faulted against the greywacke-conglomerate which forms the base of the sedimentary strata underlying the volcanic division of the Lower Old Red Sandstone. This dislocation is of no great amount, for the beds of conglomerate and sandstone are nearly flat or dip at a gentle angle to the south-east — that is, away from the Upper Silurian axis. But such as it is, the fault is seen in the Lyne Water below the foot of this tributary stream [NT 13785 53629?], and likewise in the south branch of that tributary. Towards the close of 1896 a careful search for fossils was made in the green shales and mudstones exposed in this burn, with the result that some of the characteristic forms of the Upper Ludlow rocks in the North Esk were obtained in considerable numbers, which, with others, are given in the accompanying list:

Turrilepas sp.

Beyrichia impendens (Jones.)

Beyrichia Kloedeni (M'Coy.)

Ceratiocaris Murchisoni (M'Coy.)

Rhynchonella pentlandica (Hasw.)

Grammysia rotundata (Sow.)

Mytilus mytilimeris (Conr.)

Bellerophon sp.

Chelodes sp.

Platyceras (Acroculia) cornutum (His.)

Platyceras antiquatum (Salt.)

Platyschisma simulans (Salt.)

Orthoceras MacLareni (Salt.)

In the Lyne Water at the junction of the two streams a small exposure of conglomerate may be seen, the relations of which are uncertain, but which is probably faulted against the Silurian rocks, for there is here evidence of much disturbance. Immediately to the north of this conglomerate the green shales and mudstones of Upper Ludlow age reappear, and have yielded the following forms:

Periechocrinus moniliformis (Mill.)

Crinoid stems.

Entomis sp.

Turrilepas Wrighti (Woodw.)

Ceratiocaris leptodactylus (M'Coy.)

Ceratiocaris Murchisoni (M'Coy.)

Orthonota solenoides.

Platyceras (Acroculia) antiquatum (Salt.)

Platyschisma simulans (Salt.)

Pleurotomaria helicina (Lindst.)

Tremanotus longitudinalis (Lindst.)

Orthoceras MacLareni (Salt.)

Northwards, at a prominent bend in the Lyne Water to the west, and about 270 yards south of Hareshaw shepherd's house [NT 12911 56190], coarse conglomerate is met with, dipping towards the north-west at high angles. It contains large pebbles of porphyry and other rocks, but these are hardly distinctive enough to determine the precise geological horizon of this band. At the point where the Lyne leaves its east and west course and resumes its normal trend, this coarse conglomerate is bounded on the west side by a north and south fault, having a downthrow to the east, which brings it in contact with fine conglomerate and red sandstones, well seen on the west bank of the Lyne about 260 yards south of Hareshaw, where they are inclined to the north-west at high angles. These pebbly and sandy sediments are evidently the basement beds of the conformable red sandstone series (Downtonian). They are exposed at intervals in the bed of the Lyne Water northwards as far as the shepherd's house of Hareshaw, and are either vertical or inclined at high angles to the northwest.

Further up the same watercourse these conformable red sandstones are succeeded by green and blue shales and mudstones with bands of flaggy greywacke, which, at a bend in the stream one-third of a mile north of Hareshaw, have yielded fragments of *Dictyocaris*. From their lithological characters they are evidently the counterpart of the green and grey slaty shales which, in the Lanarkshire area, overlie the first zone of red sandstones and underlie the conglomerate so abundantly charged with quartzite pebbles. A careful search has here been made for the fish-band which is such a persistent horizon in the Lesmahagow region. During 1898, Mr. Tait detected a brown sandy shale, on both sides of the Lyne Water north of Hareshaw which yielded the fossils characteristic of the *Glanconome* zone in the Downtonian rocks of Lanarkshire. On the east bank of this stream, twenty yards north of the sheepfold, about one-third of a mile north of Hareshaw, this band yielded a sponge, *Glaucanome*, *Spirorbis*, together with a fragment of *Ateleaspis tessellata*. Moreover, along the line of strike, about three-quarters of a mile north-east of the locality just referred to, the *Glanconome* band was noted in the Lynslie Burn [NT 13328 57535].

Northwards, in the Lyne Water these green mudstones and shales are followed by red pebbly sandstones and shales with sun-cracks, which extend up stream for a distance of a quarter of a mile, and can be followed along the strike to the north-east, for about half a mile to the Lynslie Burn. To the north of this narrow belt of red sandstones, green and red mudstones and shales again appear which are visible in the Lyne Water and in a tributary from the east, up to its junction with the Lynslie Burn. In the Lyne Water below the fork [NT 12439 57574], these mudstones have yielded detached fragments of fishes, and near the foot of Lynslie Burn, close to the red sandstones, they furnished to Mr. Tait, a sponge (?), crinoid stems, *Spirorbis*, together with minute fragments, chiefly scutes, of the Downtonian fishes; *Birkenia elegans*, *Ateleaspis tessellata*, and *Lasanius problematicus*. The stratigraphical horizon of the more northerly belt of red sandstones is not quite clear; in the accompanying section (Figure 121) it is represented as a repetition by folding of the

sandstone belt south of Hareshaw.

The green mudstones and shales north of the second belt of red sandstones in the Lyne Water, in turn, are followed by red sandstones with red and green shaly partings and thin bands of conglomerate, that are covered unconformably by the greywacke-conglomerate and sandstones which form the base of the great volcanic series of Lower Old Red Sandstone age. It is of importance to note that in the Lyne section the quartzite-conglomerate which overlies the fish-band in Lanarkshire has not hitherto been observed.

From the evidence now advanced regarding the main Upper Silurian inlier of the Pentland Hills, we may draw the following conclusions:

1. In the lower portion of the North Esk section, to the south and north of the reservoir, and especially in the Gutterford Burn, an important development of Wenlock rocks can be separated on palaeontological grounds from younger strata.
2. In the higher part of the North Esk, to the north of Wetherlaw Linn Burn, representatives of Ludlow rocks contain some of the characteristic fossils of the Upper Ludlow rocks of Lanarkshire.
3. In the Esk section, and again in the Lyne Water, green shales and mudstones (Upper Ludlow) pass upwards into a conformable series of strata (Downtonian) composed of conglomerates with red sandstones and green and grey shales and greywackes, the latter yielding some organic remains found in the Wenlock and Ludlow rocks.
4. Between the Wenlock, Ludlow, and Downtonian strata on the one hand, and the volcanic series of the Lower Old Red Sandstone on the other, there is here a complete discordance, for the conglomerates with greywacke pebbles, derived from the Silurian Tableland and forming the base of the volcanic series, rest on the upturned edges alike of Wenlock, Ludlow, and Downtonian strata.

Habbie's Howe Inlier

The second tract of Upper Silurian strata, exposed at Habbie's Howe, near Loganlee reservoir [NT 19224 62894], in the heart of the Pentland Hills, is of considerable interest from the occurrence in it of certain graptolites that help to define the geological horizon of the beds. The area is very limited, since it forms only a narrow lenticle, about three-quarters of a mile in length and a quarter of a mile in breadth. It is bounded on the south by a fault that brings the Upper Silurian strata in contact with the contemporaneous igneous rocks of Lower Old Red Sandstone age, while on the north side it is bounded by a mass of felsite belonging to the same period of volcanic activity.

Westwards from the Loganlee reservoir, the Silurian strata are exposed by the road-side, at a point about 250 yards from the lake [NT 18756 61921], immediately to the west of a band of tuff, and they likewise appear at intervals for a distance of 200 yards up the valley. As a rule they are vertical or nearly so, and on the north-west side are faulted against the mass of acid intrusive rock just referred to. Towards the north-east they are visible on the hill slope, and likewise in a streamlet that empties into the reservoir. Their general inclination is towards the southeast at high angles. There is little variety in the character of the strata, as they consist mainly of grey slaty shales. Mr. Henderson found in them several species of graptolites, regarding which Professor Lapworth has made the following observations: <ref>Trans. Geol. Soc., Edin. Vol. II., p. 377</ref>

"On the whole it may be asserted with safety that the researches of Mr. Henderson have furnished us with six distinct species of graptolites from the shales of Habbie's Howe viz.: *Monograptus colonus*, *M. priodon*, *M. scoticus*, *M. Flemingi*, *Retiolites geinitzianus*, and *Dictyonema assimile*. The general facies of this group shows at a glance that the containing beds are of Upper Silurian age. The absence of *Monograptus Sedgwicki*, *M. Nilssoni*, and other peculiar Llandovery forms forbids us to place the beds in that formation, while the certain presence of *Monograptus priodon* and *Cyrtograptus scoticus*, which are unknown in the Ludlow, equally forbids us to assign them to that formation. They must, therefore, be considered as of Wenlock age. This result is in perfect harmony with that deducible from their stratigraphical position and from the fact of their great lithological resemblance to the neighbouring beds of the Esk reservoir, which are certainly of Wenlock age".

Bavelaw Castle Inlier

On the northern slope of the Pentland Hills, another Upper Silurian inlier is of triangular shape, and extends from the quarries at Bavelaw Castle [NT 16790 62584] to the western slope of Black Hill [NT 17959 63395], including a portion of Hare Hill [NT 17296 62273]. In this small patch numerous rock-exposures are to be seen along its southern margin between Bavelaw Castle and the northern slope of Hare Hill. The strata present very uniform lithological characters consisting of zones of grey slaty shales, with sandy bands or flaggy greywackes and occasional grits. They resemble lithologically those in the lower part of the North Esk — a correlation which is supported by their palaeontological evidence.

In the quarries at Bavelaw Castle, where the beds dip in different directions, sometimes to the south-east at 75° and sometimes to the north-west, the following fossils have been collected by the Geological Survey:

Glassia (Athyris) compressa (Sow.)

Lingula lata (Sow.)

Lingula Lewisi (Sow.)

Phacops sp.

Ctenodontasp.

Euomphalus sp.

Pleurotomaria sp.

Theca sp.

Orthoceras sp.

Dictyocaris sp.

The slope of the range along the northern declivity of Hare Hill [NT 17296 62273], exposes in many places grey slaty shales, sandy bands, and occasional grits, which are evidently repeated by folding, though their general dip is to the west or W.N.W. at angles varying from 40° to 65°. Two small ravines have laid open fossiliferous strata; the west ravine has furnished specimens of *Acidaspis*, *Glassia (Athyris) compressa*, *Meristella MacLafreni*, *Cucullella* sp., *Theca*, *Orthoceras*; and the east ravine, *Monograptus*, *Retiolites geinitzianus*, *Dictyocaris*, *Lingula Lewisi*, and *Orthoceras*.

This palaeontological evidence, while supporting the conclusion that the graptolite-bearing bands found near the north Esk reservoir, appear not only at Habbie's Howe but at Hare Hill on the northern slope of the Pentlands, serves to show that the Wenlock, Ludlow, and Downtonian rocks must together have been folded and extensively denuded before the advent of the volcanic period of the Lower Old Red Sandstone.

Special interest attaches to this inlier, from the fact that along its north-west and southern margins the Silurian strata are overlain unconformably by the red sandstones and breccia of Upper Old Red Sandstone age.

Craigenterrie Inlier

At the base of the northern slope of the Black Hill, and about a mile to the east of Threepmuir Quarry [NT 19640 64304], the fourth Upper Silurian inlier may be seen. It forms a small triangular patch, which, on the west side, is covered unconformably by the Upper Old Red Sandstone, on the east side is faulted against the Lower Old Red Sandstone volcanic series, and on the south side is pierced by a mass of intrusive acid igneous rock. The slaty shales appear at the base of the northern declivity of Black Hill and at the source of a small burn that flows eastwards into Threepmuir

reservoir, but so far as known to us, no fossils have yet been obtained from them.

In connection with the Upper Silurian rocks of the Pentland Hills, reference ought to be made to the occurrence of numerous blocks of limestone in the greywacke conglomerate of Lower Old Red Sandstone age in the Logan Burn, about half a mile west of the Loganlee reservoir [NT 18239 62065]?, which contain corals and other organisms, a large number of which are Upper Silurian forms. In all likelihood these blocks were obtained from bands of limestone similar to that in the Gutterford Burn, and occurring within the Silurian area of the Pentland Hills. The following list of fossils procured from these limestone-blocks includes forms collected by the Geological Survey, together with those in the Hardie collection:

Girvanella sp.

Crinoid stems.

Tetradium Peachi (Nich.)

Favosites gothlanctica (Fougt.)

Favosites Hisingeri (Milne Edw.)

Favosites sp.

Plasmapora sp.

Halysites sp.

Heliolites sp.

Alveolites sp.

Ptilodictya sp.

Entomostraca.

Harpes ungula (?) (Barr.)

Calymene sp.

Phacops sp.

Lingula sp.

Cyrtia exporrecta (Wahl.)

Chonetes striatella (Palm.)

Chonetes sp.

Leptaena (Plectambonites) transversalis (Wahl.)

Leptaena sericea (Sow.)

Leptaena sp.

Orthis calligramma (Palm.)

Orthis (Dalmanella) elegantula (Dalm.)

Orthis rustica (Sow.)

Orthis sp.

Atrypa reticularis (Linn.)

Strophomena imbrex (Pand.)

Strophomena pecten (Linn.)

Strophomena (Leptaena) rhomboidalis (Wilck.)

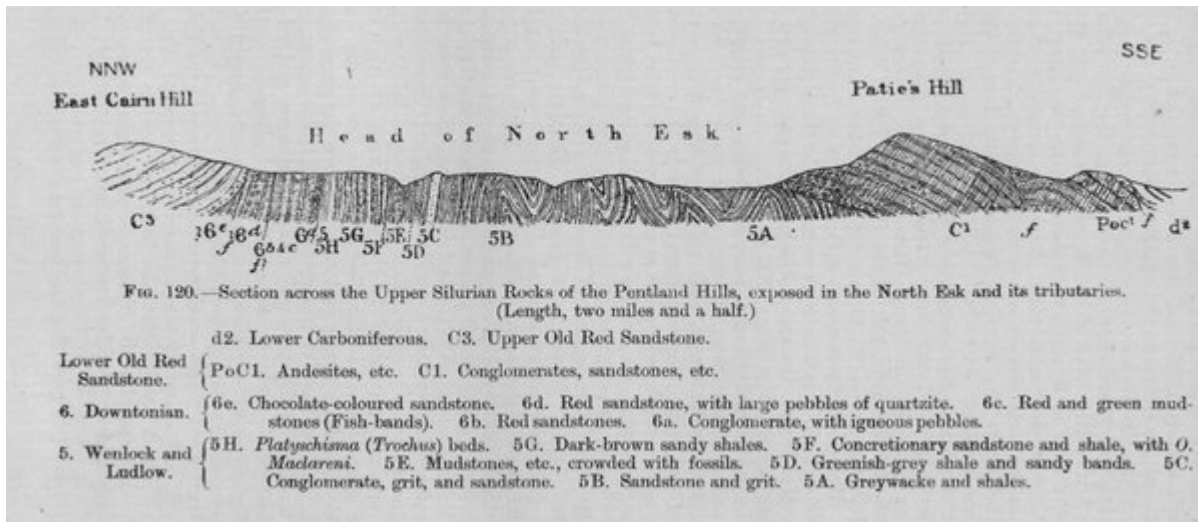
Rhynchonella Wilsoni (Sow.)

Rhynchonella sp.

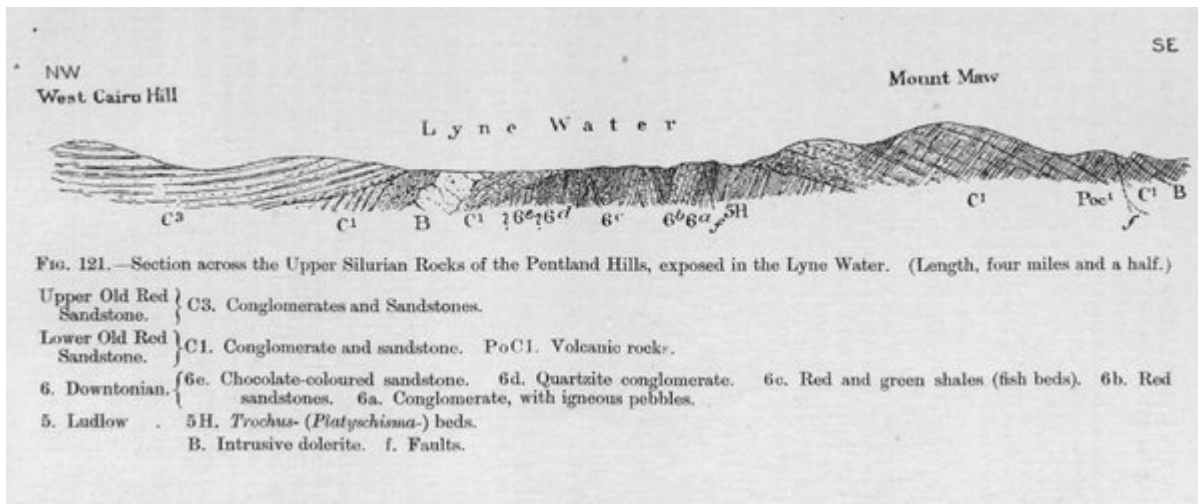
Sprifera elevata ? (Palm.)

Cyclonema sp.

Orthoceras candiculatum (Sow.)



(Figure 120) Section across the Upper Silurian Rocks of the Pentland Hills, exposed in the North Esk and its tributaries. (Length, two miles and a half.) d2. Lower Carboniferous. C3. Upper Old Red Sandstone. Lower Old Red Sandstone. PoC 1. Andesites, etc. C1. Conglomerates, sandstones, etc 6. Downtonian: 6e. Chocolate-coloured sandstone. 6d. Red sandstone, with large pebbles of quartzite. 6c. Red and green mudstones (Fish-bands). 6b. Red sandstones. 6a. Conglomerate, with igneous pebbles. 5. Wenlock and Ludlow: 5H *Platyschisma (Trochus)* beds. 5G. Dark-brown sandy shales. 5F. Concretionary sandstone and shale, with *O. Maclareni*. 5E. Mudstones, etc., crowded with fossils. 5D. Greenish-grey shale and sandy bands. 5C. Conglomerate, grit, and sandstone. 5B. Sandstone and grit. 5A. Greywacke and shales.



(Figure 121) Section across the Upper Silurian Rocks of the Pentland Hills, exposed in the Lyne Water. (Length, four miles and a half.) Upper Old Red Sandstone: C3. Conglomerates and Sandstones. Lower Old Red Sandstone. : C1. Conglomerate and sandstone. PoC1. Volcanic rocks. 6. Downtonian. : 6e. Chocolate-coloured sandstone. 6d. Quartzite conglomerate. 6c. Red and green shales (fish beds). 6b. Red sandstones. 6a. Conglomerate, with igneous pebbles. 5. Ludlow. :5 H. *Trochus-* (*Platyschisma-*) beds. B. Intrusive dolerite. f. Faults.