Dob's Linn

[NT 196 155]–[NT 197 161]

Introduction

Dob's Linn is a site of prime international significance stratigraphically, palaeontologically and historically. It includes the stratotype for the internationally recognized Ordovician–Silurian boundary and includes stratotype sections for the upper Hartfell and Birkhill divisions of the Moffat Shale Group. It shows the most extensive graptolitic sequence in Britain, ranging from low in the Caradoc (Ordovician) to the base of the upper Llandovery (Silurian), and within this span includes essential reference sections for several of the upper Ordovician and lower Silurian graptolite zones. Historically it was the principal section used by Lapworth (1878) to demonstrate the stratigraphy of the Moffat Shale Group, the value of graptolites in correlation, and the elucidation of structural problems in the Southern Uplands of Scotland. It is the type locality for a large number of species, mainly of graptolites. The locality has been studied intensively and, being instructive and easy of access, is visited by large numbers of geologists.

Most of the Southern Uplands of Scotland is made up of greywackes of Ordovician–Silurian age, but there are many inliers of the Moffat Shale Group, of which Dob's Linn ('Dobb's Linn' of many earlier writers) is one. These inliers tend both to lie in NE–SW lines along the line of regional strike and to be elongated in the same direction. This was recognized by Harkness (1851), who considered the Moffat Shale to underlie the greywackes and to be brought up along normal strike-faults, one of which extended through Dob's Linn. The locality was brought to prominence by Lapworth (1878), who, after many year's study of a large area around Moffat, chose Dob's Linn to exemplify his view of the stratigraphy and structure of the area. He gave a detailed description and elegant map of Dob's Linn, and recognized nearly all of his stratigraphical divisions of the Moffat Shale there: the upper part of the Glenkiln Shale and the whole of the Hartfell and Birkhill shales succession. Lapworth considered that the structure was primarily anticlinal, though affected by faulting, particularly by a 'Main Fault' along the axis of the inlier.

Since Lapworth's time Dob's Linn has been the focus of much work. Peach and Horne (1899, pp. 92–100) redescribed it with a map and section similar to Lapworth's and corrected a few details. A more recent description was given by Ingham (1979), whose meticulously detailed map provided a basis for much new work, and there have been ten or more other guides to the site published in the last decade or two, such as recent guides by Williams and Lawson (1992) and Clarkson and Taylor (1993). Accounts by Williams (1988) and Williams and Ingham (1989) pay particular attention to the stratigraphy of the Ordovician–Silurian boundary, and Armstrong and Coe (1997) analysed the sedimentology of the same interval. Webb *et al.* (1993) gave a more general account of the geology of the Moffatdale area, with a 1:25 000 scale map.

Dob's Linn is particularly important for its graptolites. Species described by early workers (Harkness, Nicholson, Carruthers, Lapworth) were redescribed and admirably illustrated by Elles and Wood (1901–1918). Faunas from the Hartfell Shales were further described by Toghill (1970b) and Williams (1982a, b, 1987, 1994) and those from the basal Birkhill Shales by Davies (1929), Toghill (1968) and Williams (1983), the work around the Ordovician–Silurian boundary being well summarized by Williams (1988). Sampling across the Ordovician–Silurian boundary has resulted in parallel studies on the distribution of conodonts (Barnes and Williams, 1988) and organic walled microfossils (Whelan, 1988). The carbon isotope stratigraphy of the Dob's Linn succession was investigated by Underwood *et al.* (1997). In recognition of the monofacial continuity of the succession, the base of the *acuminatus* Zone in the Linn Branch section at Dob's Linn was formally chosen in 1985 as the international strato- type for the boundary between the Ordovician and Silurian Systems (Bassett, 1985).

The metabentonite beds present in the upper Ordovician and abundant in the lower Silurian have been studied by Batchelor and Weir (1988) and by Merriman and Roberts (1990). Zircon crystals from certain of these beds were used to bracket the Ordovician–Silurian boundary with dates of 438.7 ± 2.0 and 445.7 ± 2.4 Ma (Tucker *et al.,* 1990).

The present account concentrates on the Ordovician rocks, the exceedingly important Silurian rocks (essentially the Birkhill Shales) being treated in the companion Geological Conservation Review volume on the Silurian System (Aldridge *et al.,* in press).

Description

Dob's Linn is a ravine on the north side of the A708 Moffat–Selkirk road, near Birkhill Cottage. It is excavated by two tributaries of the Moffat Water (Figure 15.8). One, the Long Burn, flows south and exposes, on its west side, the section known since Lapworth's day as the 'Long Cliff'. The other tributary (the confluence of Maister Grain and High Grain) descends from the west over a high waterfall into an east-west ravine known as the 'Linn Branch' (Figure 15.9); on its north bank is the 'North Cliff', with the 'Corrie' section high above, and on the south bank is the 'South Cliff'. The tributaries unite and flow south, approximately along the line of the 'Main Fault', into the Moffat Water, exposing the 'Main Cliff' on the west bank. The most significant exposures of Ordovician rocks are in the Main Cliff and the North Cliff.

Dob's Linn is a structurally complex locality affected by numerous strike faults. Most of the succession is overturned and dips at a high angle to the north-east. In the Main Cliff, however, the strata are the correct way up and dip at 45° to the west, the correct way up of this section being the result of slump rotation of the cliff during the Pleistocene.

The stratigraphy devised by Lapworth (1878) is applicable, with slight modifications (Table 15.1).

The upper part of the Glenkiln Shale is 'present but poorly exposed at the foot of the Main Cliff, near the confluence of Linn Branch and Long Burn, and on the North Cliff. It consists of grey cherry mudstone with black mudstones that yield graptolites assigned to the '*peltifer*' Zone, as listed by Williams (1994, fig. 2).

The Lower Hartfell Shale is well-exposed in the Main Cliff and North Cliff (Figure 15.10), with a smaller outcrop in the South Cliff. The division consists mainly of black siliceous and pyritous mudstone, but the lower part is grey with thin black laminae, and the top is softer and less siliceous. The lower part, consisting mainly of grey mudstone, is about 2 m thick and is referred to the *wilsoni* Zone; it is characterized by well-preserved *Climacograptus wilsoni* Lapworth (Figure 15.7)d, *Corynoides calicularis* Nicholson, *Dicranograptus nicholsoni* Hopkinson, *Pseudoclimacograptus scharenbergi* (Lapworth) and *Orthograptus calcaratus* (Lapworth) *sensu lato* (*Williams,* 1994).

The succeeding black mudstones of the *dingani* Zone, which are about 8 m thick, are exposed in the Main Cliff and North Cliff (the 'North Cliff Trench' of Williams (1988), and Locality 6 of Clarkson and Taylor, 1993, fig. 42). The faunas from the Main Cliff include representatives of both the *caudatus* Subzone and the *morrisi* Subzone of Zalasiewicz *et al.* (1995). Locality 6 is in the *caudatus* Subzone, which is characterized by *Climacograptus spiniferus* Ruedemann, *Ensigraptus caudatus* (*Lapworth*) *, Dicellograptus flexuosus* Lapworth, *Dicranograptus clingani* Carruthers and species of *Orthograptus.* The North Cliff trench revealed about 5 m of strata with a large fauna of the *morrisi* Subzone, incuding *C. dorotheus* Riva, *Dicellograptus morrisi* Hopkinson (Figure 15.7)b, '*Glyptograptus*' *davisi* Williams, *Neurograptus margaritatus* (Lapworth) and *Orthograptus* spp., the distribution of which is shown by Williams (1982a, fig. 1).

The upper 5 m of the Lower Hartfell division is assigned to the *linearis* Zone. This is present in the Main Cliff (Toghill, 1970b) and the North Cliff trench, where Williams (1982a) logged the faunal distribution in detail. Among the most distinctive species are *Pleurograptus linearis* (Carruthers), with *Climacograptus tubuliferus* Lapworth, *Dicellograptus elegans* Carruthers, *Leptograptus capillaris* (Carruthers) and *Orthograptus* species (Figure 15.7)h.

The Upper Hartfell Shale consists of pale, partly bioturbated, 'barren' mudstone 28 m thick. It includes blocky and nodular, slightly calcareous beds and several thin black graptolitic mudstones. The sedimentology of these beds was analysed by Armstrong and Coe (1997), and the biostratigraphy of the graptolitic beds was described in detail by Williams (1982b, 1987, 1988). The black beds 9 m above the base of the Upper Hartfell Shale, known as the Complanatus Bands, have been traced on the Main Cliff, South Cliff and North Cliff. They contain *Dicellograptus complanatus* Lapworth and *Orthograptus socialis* (Lapworth), with a few other species (Williams, 1987, p. 67), and are referred to the *complanatus* Zone. Williams and Lockley (1983) described the supposedly epi-planktonic brachiopod *Barbatulella* from the upper Complanatus Band.

A group of black beds near the top of the formation, the 'Anceps Bands', have been studied in the Main Cliff and the North Cliff, and also the Long Cliff, where they are strikingly thicker than elsewhere (Williams, 1982b). They are associated with numerous thin beds of metabentonite, one of which yielded zircon crystals that gave the radiometric age of 445.7 ± 2.4 Ma (Tucker *et al.,* 1990). The Anceps Bands contain *Dicellograptus anceps* (Nicholson) (Figure 15.7)e, *Climacograptus supernus* Elles and Wood (Figure 15.7)g, *Orthograptus abbreviatus* and a number of other taxa described by Williams (1982b), who distinguished a lower *complexus* Subzone in the lower bands and an upper *pacificus* Subzone in the top three bands. Barnes and Williams (1988) figured several conodonts from the Anceps Bands, assigning them to the *ordovicicus* conodont zone.

The uppermost 3 m thickness of the Upper Harden Shale is of pale mudstones but includes the very thin Extraordinarius Band of brown graptolitic mudstone. This is the only known representation of the *extraordinarius* Zone in Scotland (Williams, 1983). A bed 0.1 m below the Extraordinarius Band has yielded the blind dalmanitid trilobite *Sonxites* (Lespérance, 1988, p. 365); a similar trilobite was described from the same horizon in County Cavan, Ireland (Siveter *et al.,* 1980).

The basal beds of the Birkhill Shale are recognized where dark mudstones with metabentonites overlie the Upper Hartfell Shale. Toghill (1968) recognized the topmost Ordovician *persculptus* Zone in the Main Cliff, but the best-studied section is at the 'Linn Branch Trench' in the North Cliff ((Figure 15.11); Williams, 1988, figs. 3,4), where the internationally recognized Ordovician–Silurian boundary is now defined. The *persculptus* Zone fauna contains species of *Normalograptus* and *Glyptograptus* (*G.? avitus* Davies, *G.? venustulus* (Legrand) and *G. persculptus* Elles and Wood). The base of the Silurian is taken 1.6 m above the base of the Birkhill Shale, at the base of the overlying *acuminatus* Zone, recognized by the appearance of *Akidograptus ascensus* Davies and *Parakidograptus acuminatus* (Nicholson). The first monograptid, *Atavograptus ceryx* (Rickards and Hutt), appears 0.3 m higher.

(Table 15.1) Stratigraphy devised by Lapworth (1878, slightly modified)

Formation	**Graptolite zone**		
Birkhill Shale (Part	acuminatus perscultus extraordinarius		Silurian (part)
Upper Hartfell Shale (= 'Barren Mudstones')	anceps	pacificus complexus	
Lower Hartfell Shale	complanatus linearis clingani wilsoni	morrisi caudarus	Ordovician
Glenkiln Shales	'peltifer' (gracilis — not seen at Dob's Linn)		

Interpretation

The Moffat Shales exposed at Dob's Linn are interpreted as hemipelagite and distal turbidite deposits (Williams, 1988; Armstrong and Coe, 1997) that accumulated very slowly over a long period in a marine basin, the nature of which is debated (see above). For much of the time deposition was restricted to fine-grained terrigenous matter collecting in poorly oxygenated conditions that favoured the preservation of the remains of planktonic animals but inhibited the development of any benthos. The basin received fine-grained ejectamenta from distant volcanic eruptions (the layers of metabentonite) and occasional incursions of coarse-grained material from turbidity currents (cf. Rushton and Stone, 1991). The pale Upper Hartfell Shale accumulated in less dysaerobic conditions that at times allowed burrowing benthos to disrupt the lamination of the muds. Sedimentological studies by Armstrong and Coe (1997) track oceanographic and climatic changes: they suggest that the alternations of black and pale mudstones in the *anceps* Zone indicate periods of fluctuating climate, the predominantly grey siltstones of the upper *anceps* and *extraordinarius* zones correspond to the

maximum of the end-Ordovician glaciation, and the laminated black mudstones at the base of the *persculptus* Zone reflect the return to global warming.

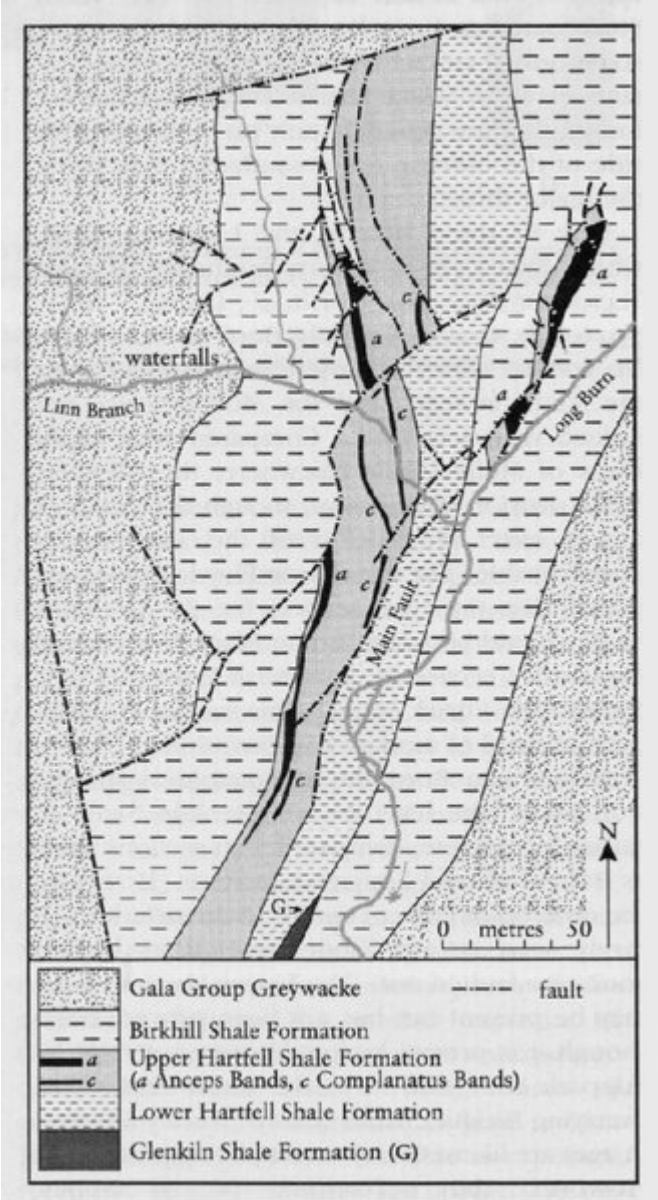
The lithostratigraphy exemplified at Dob's Linn has proved applicable with little modification right across the central belt of the Southern Uplands of Scotland (Peach and Horne, 1899). Many of the graptolites, however, have a much wider distribution, and the zonal succession has been adopted, or adapted, for use in the graptolitic facies in many parts of the world. Apart from the *gracilis* Zone, which is not exposed at Dob's Linn but is seen in Glenkiln Burn (see site report), the whole sequence is visible, and, although it is faulted, superposition can be safely inferred by reference to various sections in Dob's Linn. Graptolite distribution has been logged for the entire succession, with the excep tion of the lower part of the *clingani* Zone, which is better exposed and more fully described at Hartfell Score, 10 km to the WSW (Rushton, 1993; Zalasiewicz *et al.,* 1995). The Ordovician–Silurian boundary was chosen at Dob's Linn because the exposed succession is in continuous graptolitic strata at a level where distinctive, typically 'Silurian', elements evolved. Although the absence of shelly fossils is a hindrance to correlation in some other parts of the world, the carbon isotope stratigraphy reported by Underwood *et al.* (1997) not only tracks the climatic changes during the latest Ordovician but also facilitates correlation between the Dob's Linn sections and contemporaneous deposits of carbonate shelf areas. Their work tends to confirm the continuity of the Dob's Linn succession and demonstrates the appropriateness of a deep-water section for an international stratotype.

Although normal faulting and folding play a part in the structural interpretation of the Dob's Linn Inlier, the main feature is considered to be a thrust fault dipping north-west, whose surface expression may correspond to Lapworth's 'Main Fault'. Such a fault could juxtapose areas of Moffat Shale originally deposited a considerable distance apart, and Williams (1988) invoked this idea to explain differences in the thicknesses of the Anceps Bands to the east of the fault on the Long Cliff and those of the Main Cliff and North Cliff to the west.

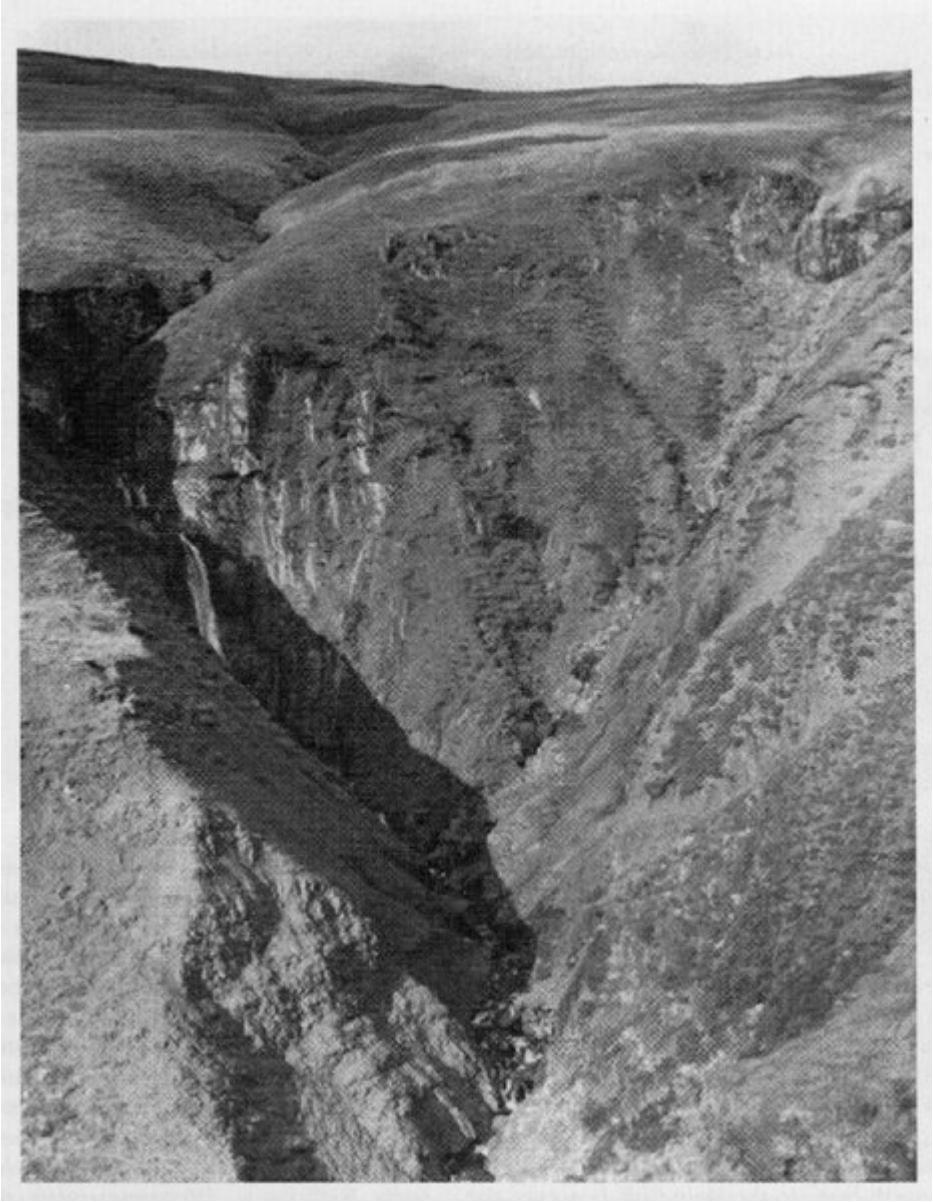
Conclusions

Dob's Linn is of great importance internationally in Ordovician and Silurian stratigraphy. Although it is one of very many exposures of the Moffat Shale Group, it is exceptionally valuable, being an accessible exposure that shows an almost complete succession and displays good stratigraphical contacts at critical levels. It has been thoroughly studied and well documented, such that it is referred to world-wide as a standard, stratigraphically, geochronometrically and for graptolite taxonomy. It is rich in graptolites, many having Dob's Linn as their type locality, and several of these species have been identified in many parts of the world, making the Moffat Shale succession an international standard for correlation. This has led to Dob's Linn being chosen as the standard by which to recognize the base of the Silurian System internationally.

References



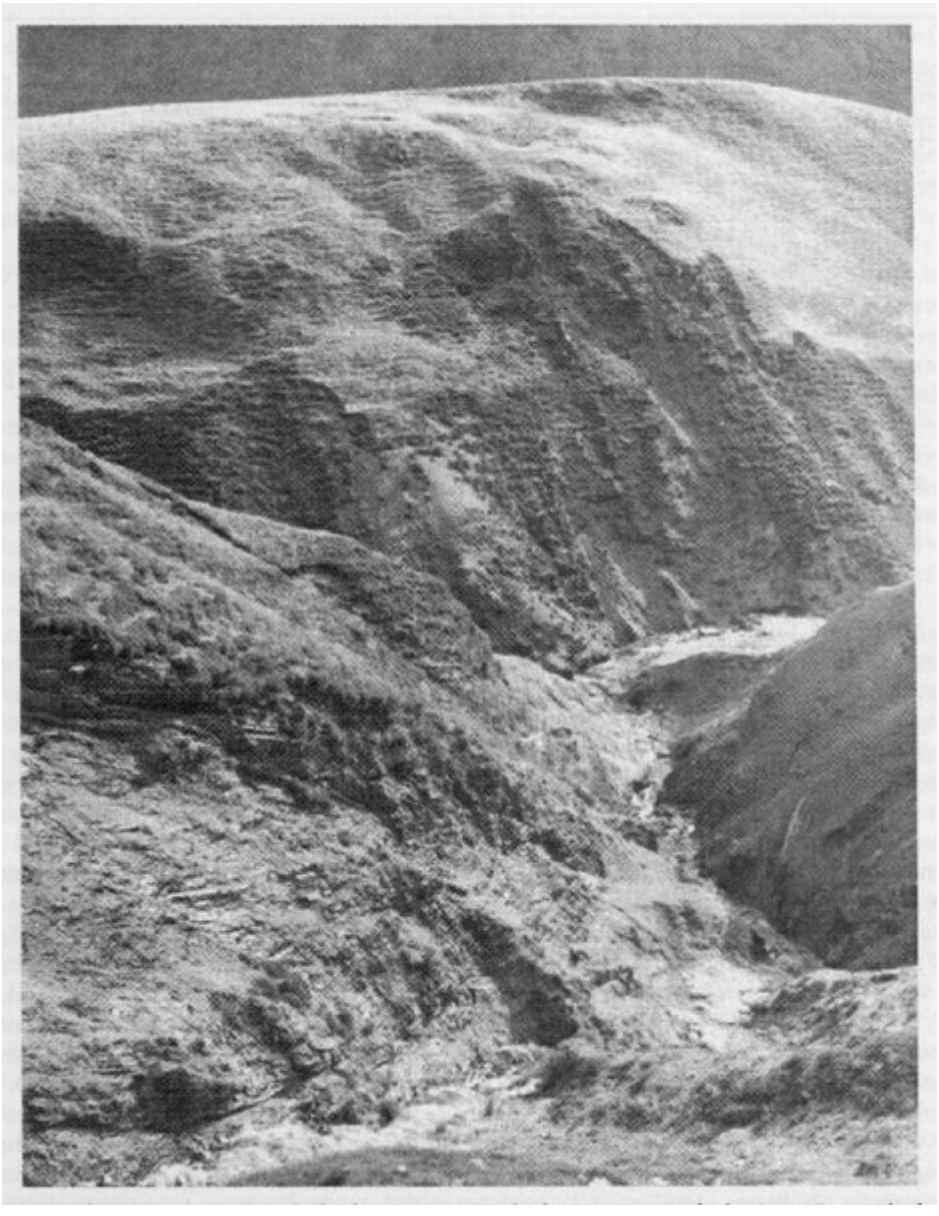
(Figure 15.8) Simplified geological map of Dob's Linn, based on Williams and Ingham (1989, fig. 20).



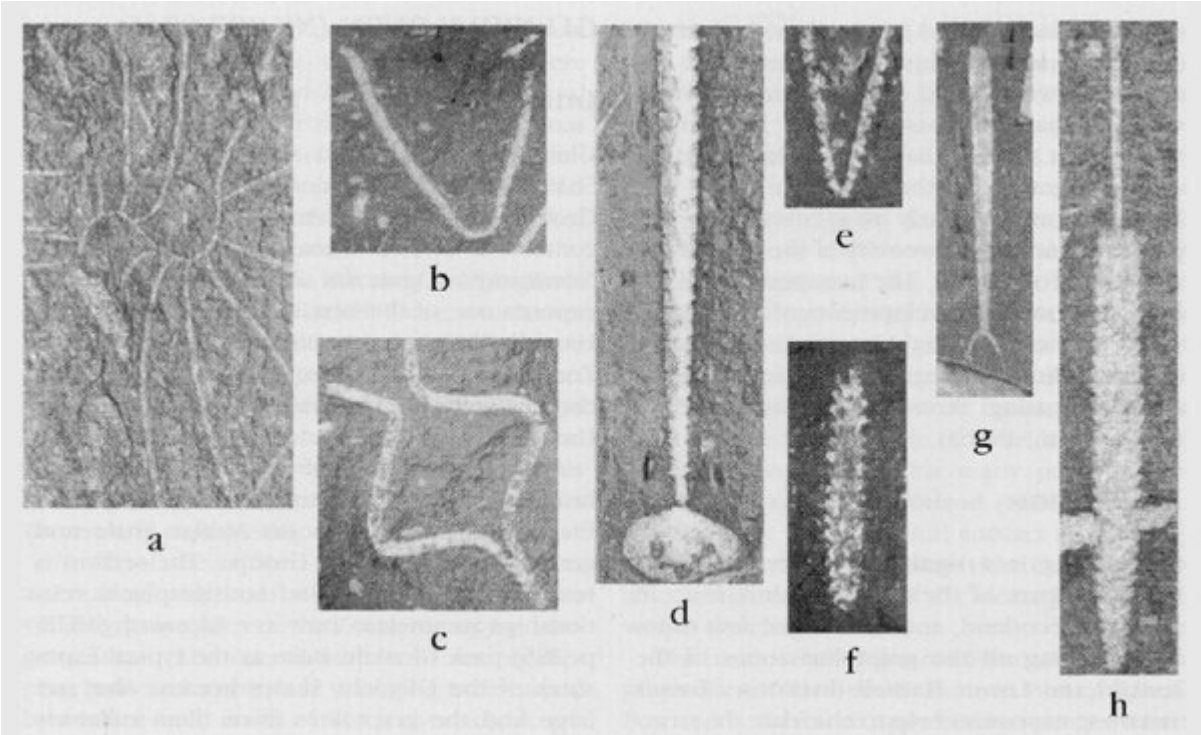
(Figure 15.9) Dob's Linn, Linn Branch, looking west. The stream makes a waterfall over Gala greywackes (Llandovery) and enters a gorge in Birkhill and Hartfell shale formations. The exposure high on the right is in Llandovery shales and the rill extending obliquely down to the Linn Branch approximately follows the strike. The trench across the Ordovician–Silurian boundary was made (after the photograph was taken) on the near side of the rill and to the right of the stream. The Barren Mudstones of the Upper Hartfell Shale (Ashgill) are nearest the viewer. (Photo: British Geological Survey photographic collection, D3559.)

Formation	graptolite zone	
Birkhill Shale (part)	acuminatus	Silurian (part)
	persculptus	
Upper Hartfell Shale (= 'Barren Mudstones')	extraordinarius	Ordovician (part)
	anceps	
	pacificus	
	complexus	
	complanatus	
Lower Hartfell Shale	linearis	
	clingani	
	morrisi	
	caudatus	
	wilsoni	
Glenkiln Shale	'peltifer'	
	(gracilis – not seen at at Dob's Linn)	

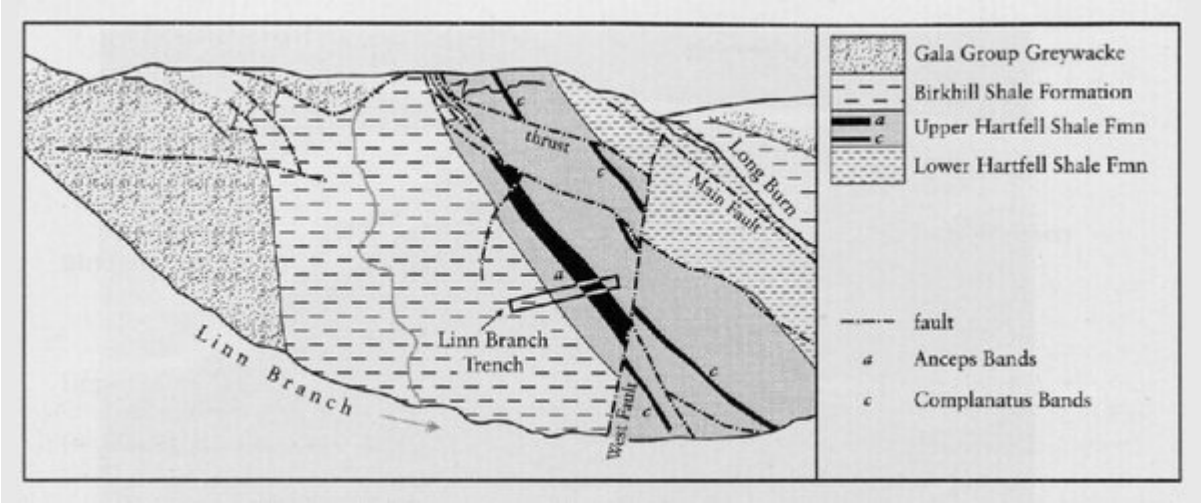
(Table 15.1) Stratigraphy devised by Lapworth (1878), slightly modified.



(Figure 15.10) Dob's Linn, Linn Branch, looking east towards the junction with the Long Burn which flows to the right along the line of the main fault. The beds in the left foreground are inverted Lower Birkhill Shales, mainly lower Llandovery, with the uppermost exposures being close to the Ordovician–Silurian boundary. The Ordovician–Silurian boundary trench was excavated in the bluff of the North Cliff which descends to the Linn Branch. See (Figure 15.11). (Photo: British Geological Survey photographic collection, D3560.)



(Figure 15.7) Graptolites from Glenkiln Burn (a) and Dob's Linn (b-h). All figures x2. (a) Nemagraptus gracilis (Hall), gracilis Zone. (b) Dicellograptus morrisi Hopkinson, clingani–linearis zones. (c) Dicranograptus ziczac Lapworth, peltifer Zone. (d) Climacograptus wilsoni Lapworth, wilsoni Zone. (e) Dicellograptus anceps (Nicholson), anceps Zone. (f) Lasiograptus harknessi (Nicholson), wilsoni Zone. (g) Climacograptus supernus Elles and Wood, anceps Zone. (h) Orthograptus calcaratus (Lapworth) sensu lato clingani–linearis zones.



(Figure 15.11) View of the North Cliff on the north bank of the Linn Branch of Dob's Linn, after Williams and Ingham (1989, fig. 22). The internationally recognized boundary between the Ordovician and Silurian systems is in the Linn Branch Trench.