# Dob's Linn

[NT 196 158]

## Introduction

Dob's Linn (written 'Dobb's Linn' by several authors) is a site of major international importance as it incorporates the stratotype section for the base of the Silurian System. It is located 6 km north-east of Moffat in the Central Belt of the Southern Uplands of Scotland, where the Ordovician and Silurian strata comprise alternations of greywackes and graptolitic shales. Harkness (1851) produced an early interpretation of the relationship between the strata, considering the Moffat shales to underlie the greywackes, between which they were brought up along NE–SW strike faults. It was with the detailed work of Lapworth (1878), however, that the locality at Dob's Linn attained classic importance. Lapworth published a description and map of the site, determined the stratigraphical divisions, and interpreted the structure, which he considered to be primarily anticlinal, but cut by a number of faults including a 'Main Fault' along the axis of the shale inlier. There is a considerable subsequent literature referring directly or indirectly to Dob's Linn; Peach and Horne (1899) and Ingham (1979), in particular, have provided revised maps and redescriptions. The major exposures at the GCR site occur at two points: on the Main Cliff on the western side of Long Burn, and on the steep banks on both the north and south sides (the 'North Cliff' and the 'South Cliff') of the Linn Branch (Figure 3.62).

Dob's Linn has long been known as a major graptolite locality, exhibiting the most extensive late Ordovician to early Silurian graptolite sequence in Britain, and it was the principal section employed by Lapworth (1878) in demonstrating the biostratigraphical value of these fossils. Species described from the site by Lapworth and by other early workers were incorporated and revised by Elles and Wood (1901–18) in their major monograph, and further studies have been published by Davies (1929), Packham (1962), Toghill (1968, 1970), and Williams (1982a, b, 1983, 1987, 1995). A summary of the graptolite distribution across the Ordovician–Silurian boundary was provided by Williams (1988) and by Williams and Ingham (1989).

The graptolitic rocks of Dob's Linn were assigned by Lapworth (1878) to the 'Moffat Series', subsequently termed the Moffat Shale Group (Ingham, 1979). The Moffat Shale Group is divided into the Glenkiln Shale, Lower Hartfell Shale, Upper Hartfell Shale and Birkhill Shale formations (Figure 3.63). The Birkhill Shale Formation is overlain by greywackes of the Gala Group. The base of the Silurian System is defined at the base of the *acuminatus* Biozone, 1.6 m above the bottom of the Birkhill Shale Formation in the Linn Branch (Bassett, 1985; Cocks, 1985; Williams, 1988; Holland, 1989; Williams and Ingham, 1989) (Figure 3.64).

Few fossils other than graptolites have been found in the rocks of Dob's Linn, and this has led to some criticisms of its selection as the basal Silurian stratotype (e.g. Berry, 1987; Lesperance *et al.,* 1987). Barnes and Williams (1988) reported and illustrated a small number of conodont specimens from shale surfaces within the Silurian part of the Birkhill Shale Formation; these are dominantly blackened coniform elements, but one broken specimen identified as *Oulodus? kentuckyensis* was recorded from 1.75 m above the base of the formation. Conodont specimens are a little more numerous in the Hartfell Shale formations; and the lowermost Birkhill Shale Formation, below the base of the Silurian, has yielded the Ordovician genera *Amorphognathus* and *Scabbardella* (Barnes and Williams, 1988). Whelan (1988) also recovered blackened chitinozoans and acritarchs from Ordovician shales of the *anceps, extraordinarius,* and *persculptus* biozones, and a few chitinozoans and sphaeromorph acritarchs from the *acuminatus* Biozone. The graptolites, however, are indubitably the prime fossils at Dob's Linn, and the site is the type locality for numerous graptolite taxa, including the Silurian species *Glyptograptus elegans* Packham, 1962, *Glyptograptus avitus* Davies, 1929, *Torquigraptus involutus* (Lapworth, 1876a), *Climacograptus normalis* Lapworth, 1877, *Climacograptus innotatus* Nicholson, 1869, *Orthograptus insectiformis* (Nicholson, 1869), *Orthograptus mutabilis* Elles and Wood, 1907, *Petalolithus minor* Elles, 1897, *Dimorphograptus elongatus* Lapworth, 1876a, *Dimorphograptus decussatus decussatus* Elles and Wood, 1908, *Dimorphograptus erectus erectus* Elles and Wood, 1908, *Rhaphidograptus toernquisti* (Elles and Wood, 1906), *Akidograptus ascensus* Davies, 1929, *Monoclimacis? crenularis* (Lapworth, 1880c), *Atavograptus strachani* (Hutt and Rickards in Rickards, 1970a), *Campograptus communis communis* (Lapworth, 1876a), *Coronograptus cyphus cyphus*

(Lapworth, 1876a), *Coronograptus gregarius* (Lapworth, 1876a), *Pribylograptus argutus* (Lapworth, 1876a) and *Rastrites hybridus hybridus* Lapworth, 1876a.

In an attempt to supplement the biostratigraphical data with another correlative tool, Underwood *et al.* (1997) have undertaken a study of carbon isotope patterns in kerogen samples across the Ordovician–Silurian boundary. They found a marked positive $\delta^{13}C$ excursion in the uppermost Ordovician strata, and used the architecture of the isotope curve to correlate with coeval successions in carbonate shelf environments that lack graptolites. These data clearly enhance the global utility of the Dob's Linn section as a boundary stratotype.

Metabentonites are common in the Moffat Shale Group; a detailed study by Merriman and Roberts (1990) recorded 135 horizons of Ashgill and Llandovery age, representing a total accumulation of about 6 m of volcanic ash. These metabentonites have yielded zircon crystals from which radiometric U-Pb dates have been determined by Tucker *et al.* (1990). Dates of 438.7 ± 2.0 and 445 ± 2.4 Ma were found to bracket the Ordovician–Silurian boundary.

This GCR site is important for both its Ordovician and Silurian strata. The account given here deals only with the uppermost Ordovican shales and with the Silurian rocks. The Ordovician rocks, assigned to the Glenkiln Shale, Lower Hartfell Shale, Upper Hartfell Shale and lowermost Birkhill Shale formations, are described in the companian GCR volume on British Cambrian to Ordovician stratigraphy (Rushton *et al.,* 1999).

## Description

Much of the succession at Dob's Linn is overturned with a high angle of dip to the north-east. However, the Main Cliff has become rotated through slumping during the Pleistocene, and the beds here are the right way up, dipping at 45° to the west. The Lower and Upper Hartfell Shale formations are well exposed on the Main Cliff and the North Cliff. The Upper Hartfell Shale comprises 28 m of grey mudstone and shale, in which three graptolitic bands have been identified. The uppermost of these is a very thin dark-brown mudstone with *Climacograptus? extraordinarius* and other graptolites (the *Extraordinarius* Band) (Ingham, 1979; Williams, 1983). The base of the Birkhill Shale Formation is recognized 1.17 m above the *Extraordinarius* Band by a lithological change to dark mudstones and shales with metabentonites (Williams, 1983). The formation is 43 m thick (Toghill, 1968); at the base is 0.15 m of black shale, above which 1.45 m of graptolitic shales represent the *persculptus* Biozone.

The base of the *acuminatus* Biozone is marked by the appearance of *Akidograptus ascensus* and *Parakidograptus acuminatus sensu lato* at 1.6 m above the base of the Birkhill Shale Formation. This level has been adopted as the global standard for the Ordovician–Silurian boundary, marked by the first occurrence of *A. ascensus.* The first monograptid, *Atavograptus ceryx,* appears 0.3 m higher, and *Climacograptus trifilis* first occurs 0.6 m above the bottom of the *acuminatus* Biozone (Williams, 1983). Typical examples of *P. acuminatus* appear higher in the biozone. The stratotype section for the base of the Silurian System is in a trench (the Linn Branch Trench) dug on the North Cliff of the Linn Branch gorge (Figure 3.64), (Figure 3.65).

The Birkhill Shale Formation comprises massive black graptolitic mudstones interbedded with grey mudstones that lack graptolites; there are numerous soft, pale metabentonites, several of which contain bands of calcareous nodules (Figure 3.66). The lower part of the unit is dominated by the black mudstones, with the paler mudstones becoming thicker and more frequent in the upper half. Two greywacke horizons were reported from within the *cyphus* Biozone along the western side of Long Burn by Rushton and Stone (1991). The graptolite faunas through the formation were documented by Toghill (1968), who recognized the presence of the *persculptus, acuminatus, vesiculosus* (= *atavus*)*, cyphus, gregarius, convolutus, sedgwickii* and *turriculatus* biozones. *Atavograptus atavus* is present from the base of the *vesiculosus* Biozone to the lowest beds of the *gregarius* Biozone. *Lagarograptus acinaces* occurs in beds referred by Toghill (1968) to the upper *vesiculosus* and basal *cyphus* biozones, allowing separation of the *acinaces* Biozone (Webb *et al.,* 1993). The *gregarius* Biozone has been divided into three sub-biozones, identifiable at Dob's Linn (Webb *et al.,* 1993): (1) the *triangulatus* Sub-biozone, marked by the appearance of *Monograptus triangulatus* with *Petalograptus,* (2) the *magnus* Sub-biozone characterized by *Diplograptus magnus* and *Monograptus triangulatus fimbriatus* and (3) the *leptotheca* Sub-biozone, defined by the appearance of *Pribylograptus leptotheca* and *Monograptus argenteus.* The highest graptolitic band, referable to the *turriculatus* Biozone (*maximus* Sub-biozone), is about 4 m below the top of the

Birkhill Shale Formation. The graptolites indicate that the Birkhill Shale Formation spans a chronostratigraphical range from the uppermost Ordovician (Hirnantian) to the lower Telychian; key biostratigraphical taxa are illustrated in (Figure 3.67).

In the upper Linn Branch, the lithological change to greywackes of the Gala Group results in the development of a waterfall. The first of these greywackes appears below the waterfall and is taken as the base of the Gala Group (Lapworth, 1878; Toghill, 1968); above this, 4.5 m of massive grey mudstones, thin greywackes and metabentonites are exposed below the massive greywackes at the base of the waterfall.

## Interpretation

Throughout the Southern Uplands the strata strike at approximately 060° and are mostly steeply inclined. At individual outcrops the younging direction is dominantly towards the north-west, but the oldest rocks of the Southern Uplands are found in the north-west of the region and the youngest in the south-east. This apparent paradox is the result of multiple strike faults, which create a series of blocks within each of which the youngest rocks are in the northwest. Progressing from the south-east, however, each block has older strata at the base, resulting in an overall increase in age north-westwards (see (Figure 1.6)). This structural and stratigraphical pattern has been elegantly explained by accumulation of the deposits on an accretionary prism at the northern margin of the subducting Iapetus Ocean (Leggett *et al.,* 1979a; Leggett, 1987). In this model, the black graptolitic shales were deposited on oceanic crust that became the site of greywacke distribution as it reached the deep ocean trench bordering the active northern continental margin of the ocean ((Figure 3.68)a). As the oceanic plate became subducted, the sedimentary cover was scraped off and added to the accretionary stack by underthrusting. Each slice that was accumulated in this way comprised black shales at the base with greywackes above, and the age of each successive slice was younger at the base and at the top than its predecessor. During final collision as the ocean closed during the later Silurian the entire stack was rotated to the vertical.

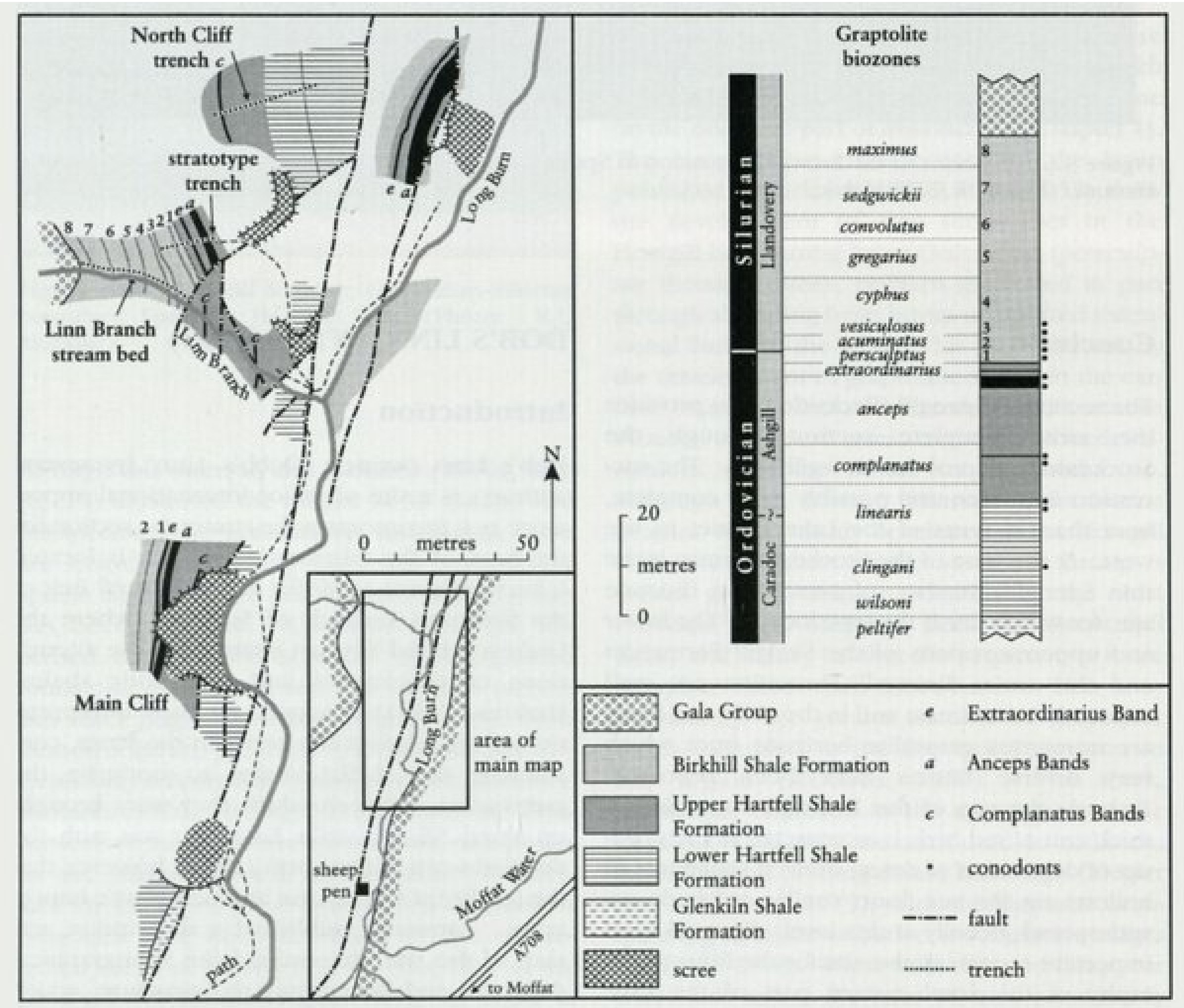
An alternative interpretation, presented by Stone *et al.* (1987), views the strata of the Southern Uplands as having been deposited in a back-arc basin, with a continental landmass to the north and a rifted continental fragment containing an active volcanic arc to the south ((Figure 3.68)b). In this model, collision of the opposing continental margins during the Llandovery was accompanied by underthrusting of the southern margin, initiating a south-eastward propagating thrust stack that may have ramped over the eroded remnants of the volcanic arc. The lithological, petrological and geochemical characteristics of the metabentonites were considered by Merriman and Roberts (1990) to be inconsistent with an exclusively pelagic origin for the Moffat Shale Group, and thus lend support to this hypothesis. In addition, the occurrence of greywacke beds within the Birkhill Shale Formation is indicative of the influence of a continental margin (Rushton and Stone, 1991).

However this debate is resolved, the shales of the Moffat Shale Group appear to have been deposited as a fine rain of hemipelagic material that accumulated very slowly. The proximity of a volcanic arc is indicated by the metabentonite horizons, and their high frequency in the Birkhill Shale Formation may reflect increased volcanic activity or a closer source region. Oxygenation on the sea floor was generally poor, especially in the lower part of the formation (Armstrong and Coe, 1997), with the increasing dominance of paler beds from the upper *sedgwickii* Biozone upwards attesting to a relative increase in sea-bed oxygen. This may reflect climatic changes, with more vigorous oceanic circulation introducing more richly oxygenated waters into a previously salinity-stratified stagnant basin (Jeppsson, 1990; Aldridge *et al.,* 1993a). The onset of the Gala Group marks the introduction of a major phase of turbidity currents discharging into the region. At Dob's Linn this influx of sediment began in the early Telychian.

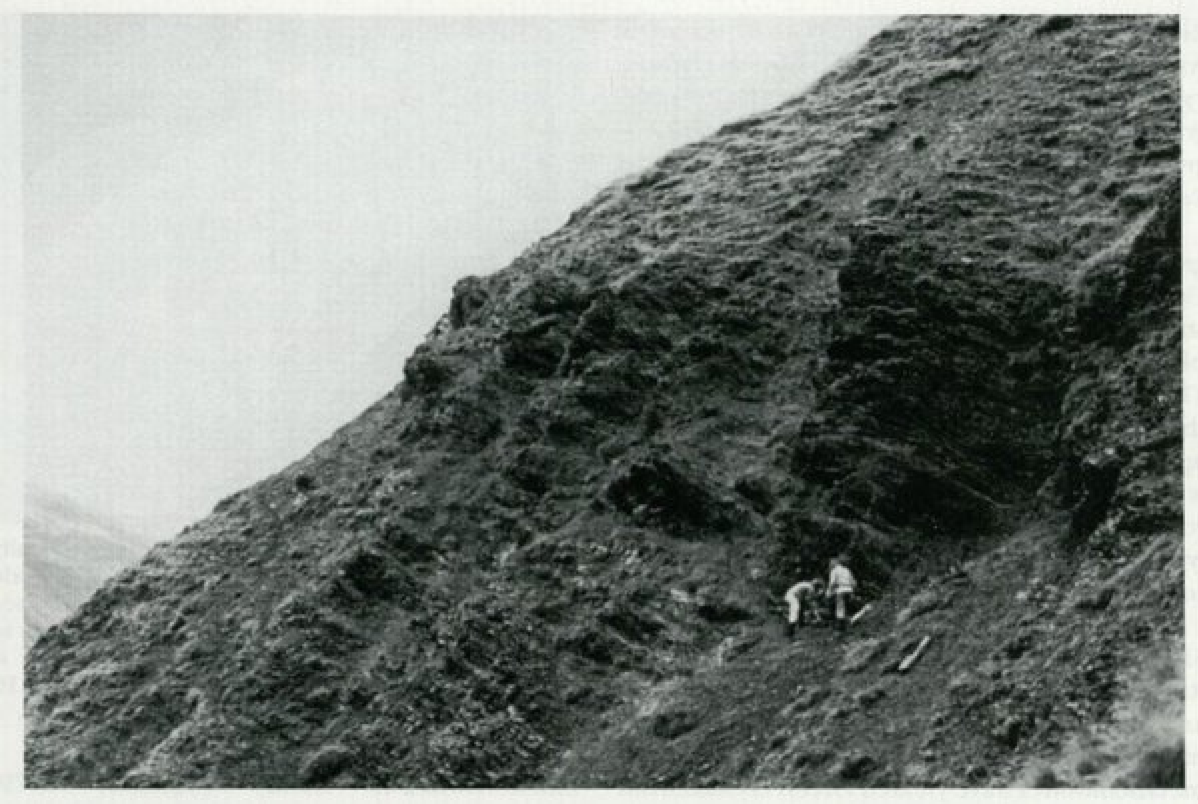
## Conclusions

Dob's Linn is a site of primary international importance. It incorporates the internationally recognized stratotype section for the definition of the base of the Silurian System, and is thereby also the locality at which the bases of the Llandovery Series and the Rhuddanian Stage are defined. It is also historically and biostratigraphically important for the relatively complete graptolitic sequence it displays through strata representing the upper part of the Ordovician System and the lower part of the Silurian System. Several major papers on graptolite faunas have been fully or largely based on the Dob's Linn sequence, and the site is the type locality for numerous species. In addition, it provides a representative section through the Moffat Shale Group of the Southern Uplands, and displays the nature of the contact between these shales and the greywackes of the overlying Gala Group. Along with other exposures in the area, it has contributed towards an understanding of the complex environmental history, stratigraphy and structure of the Southern Uplands.

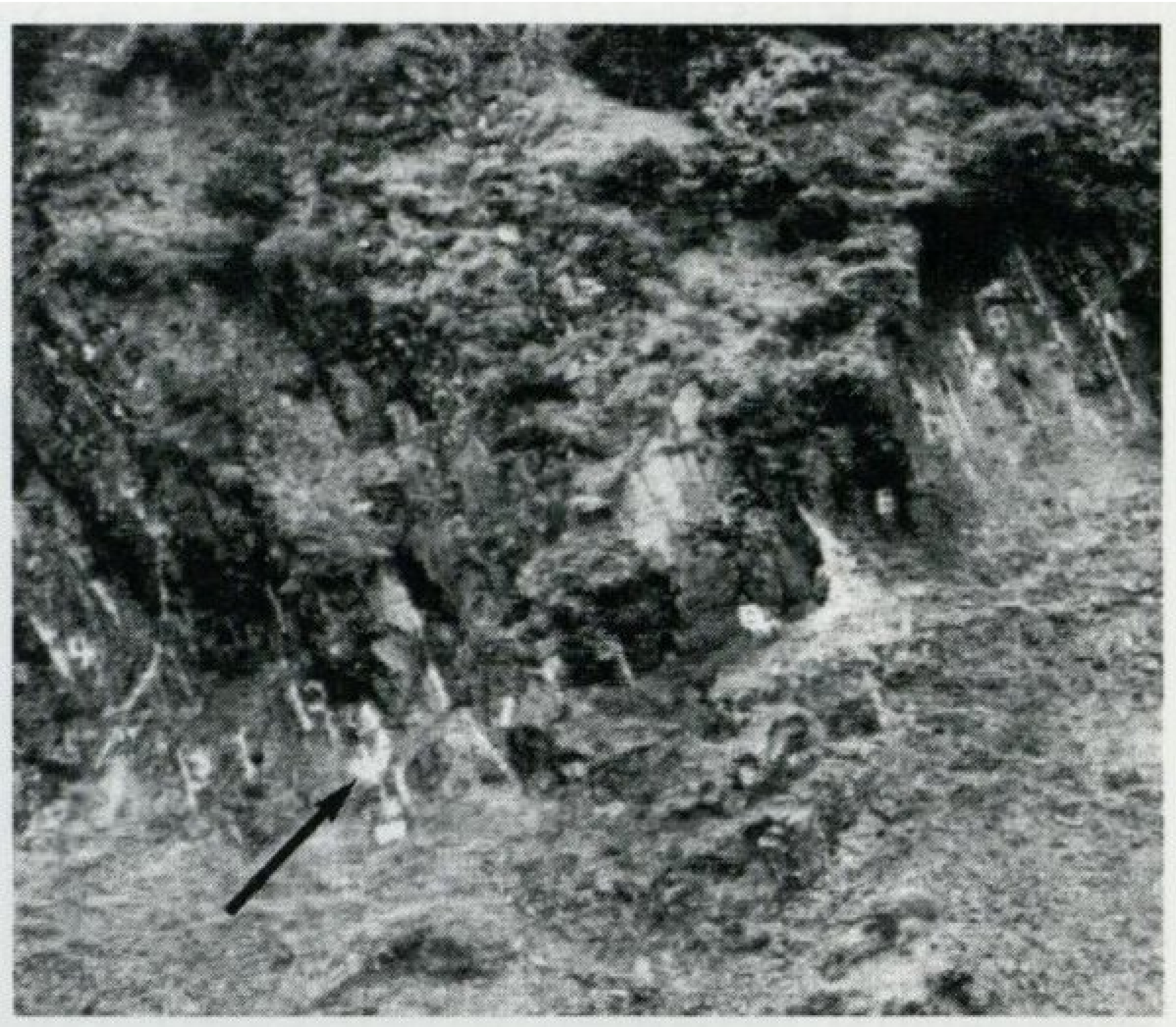
**References**



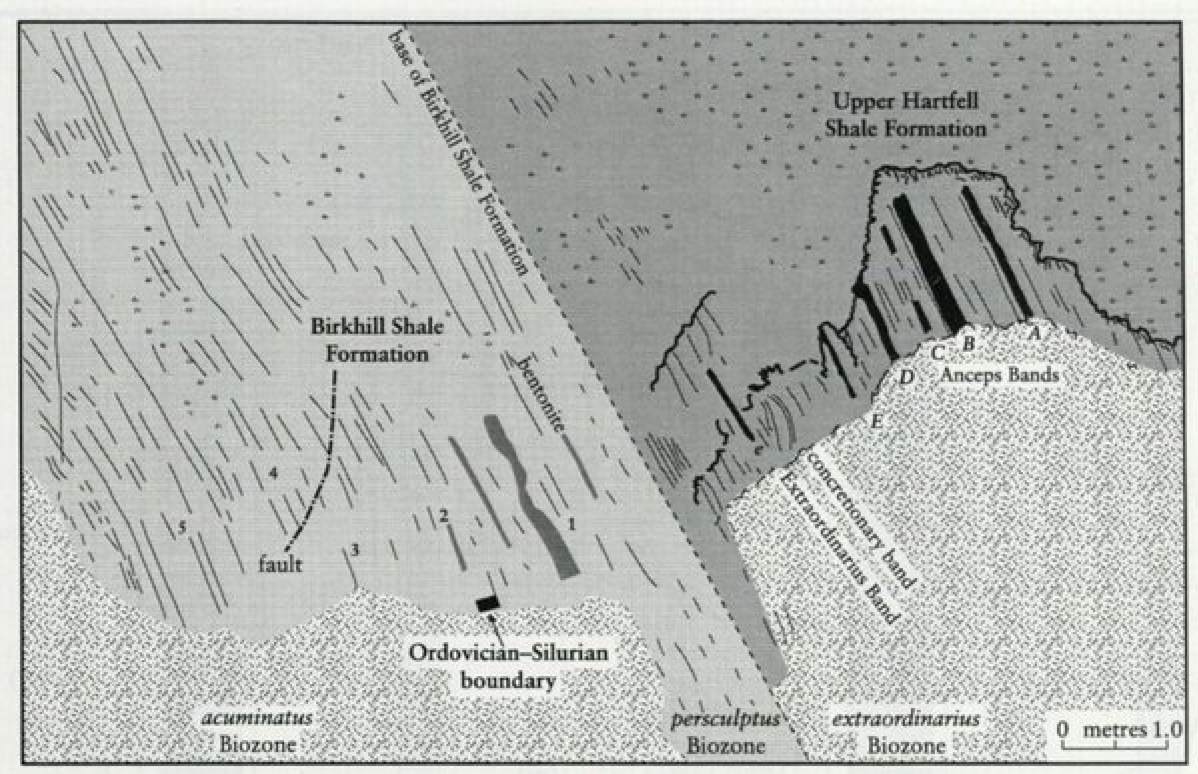

*(Figure 3.62) Simplified geological map of Dob's Linn, with a stratigraphical section; inset shows location relative to the A708 (after Williams, 1980).*



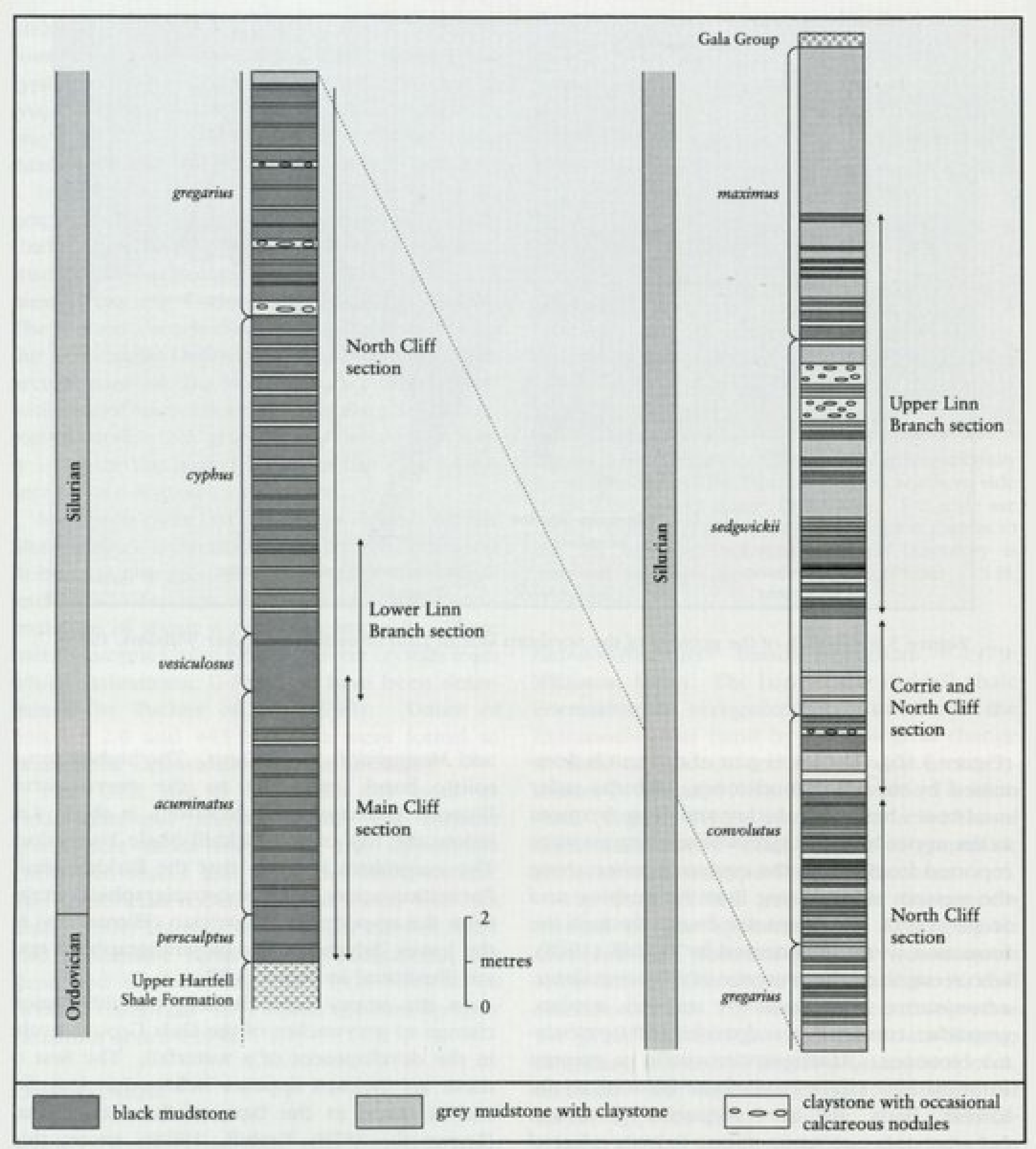
*(Figure 3.63) Section on the Main Cliff at Dob's Linn, showing the Upper Hartfell Shale Formation and the Birkhill Shale Formation. The two geologists are standing approximately at the position of the Ordovician-Silurian boundary (Photo: David J. Siveter.)*



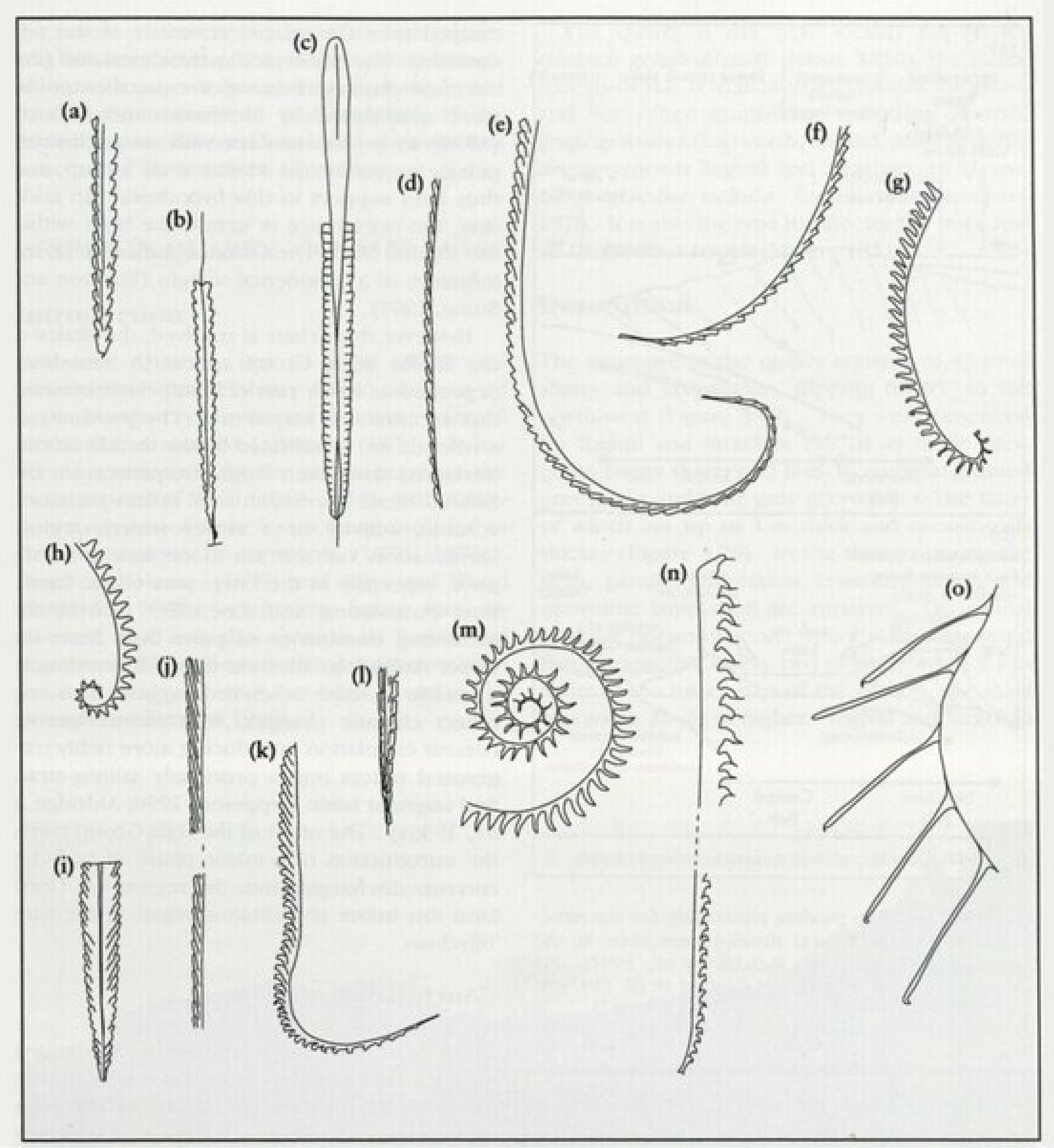
(Figure 3.64) Strata incorporating the internationally recognized base of the Silurian System, northern side of the Linn Branch gorge, Dob's Linn. For scale see sketch opposite Figure 3.65. The section youngs to the left and the Ordovician–Silurian boundary is arrowed between beds 1 and 2. (Photo: S.H. Williams.)



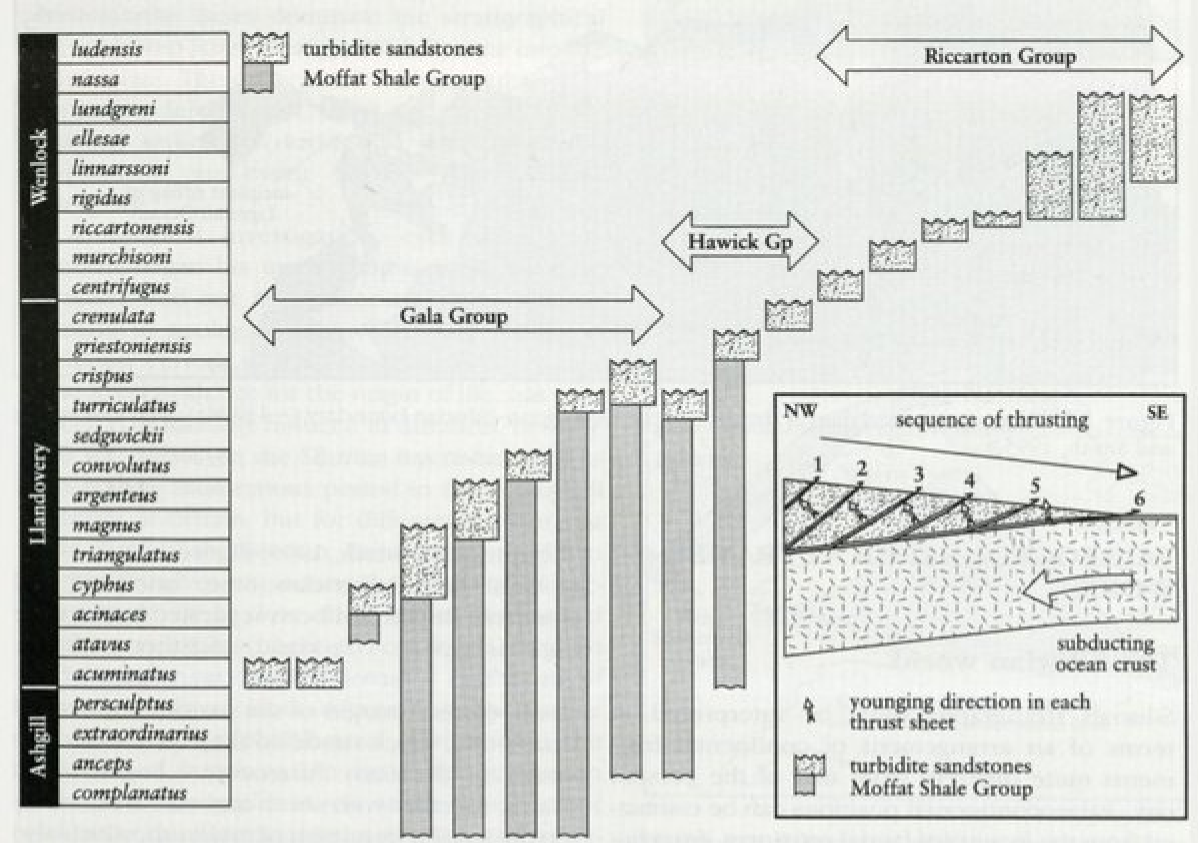

(Figure 3.65) Sketch of the geology of the northern side of Linn Branch gorge (after Williams, 1988).



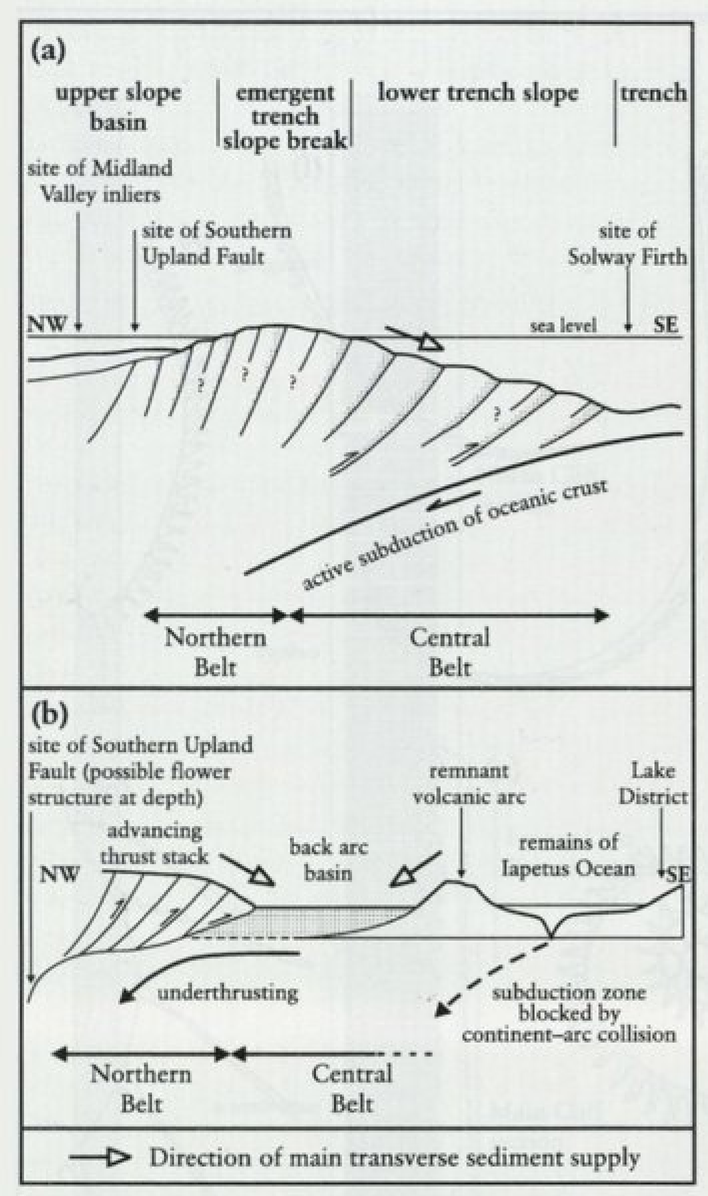

*(Figure 3.66) Section through the Birkhill Shale Formation at Dob's Linn, showing the graptolite biozonation (after Toghill, 1968). The base of the Silurian System is at the base of the P. acuminatus Biozone.*




*(Figure 3.67) Some biostratigraphically important graptolite taxa from the Birkhill Shale 'Formation of Dob's Linn (after Webb et al., 1993). (a) Glyptograptus persculptus; (b) Parakidograptus acuminatus; (c)Cystograptus vesiculosus; (d) Atavograptus atavus; (e) Coronograptus cyphus cyphus; (f) Coronograptus gregarius; (g) Monograptus triangulatus triangulatus; (h) Monograptus triangulatus fimbriatus; (i) Diplograptus magnus; (j) Pribylograptus leptotheca; (k) Monograptus argenteus; (l) Rhaphidograptus toernquisti; (m) Monograptus convolutus; (n) Monograptus sedgwickii; (o) Rastrites maximus. Figure (c) x 1.3, all other figures approximately x 2.*




*(Figure 1.6) The stratigraphical columns of successive tectonic slices across the south-west end of the Southern Uplands of Scotland (after Rushton et al., 1996). Inset shows the geometry of an accreting sedimentary prism.*




(Figure 3.68) Two models accounting for the structural and stratigraphical development seen in the Southern Uplands (from McAdam et al., 1992). (a) accretionary prism model of Leggett et al. (1979a); (b) back-arc basin model of Stone et al. (1987).