Excursion 10 Aberfoyle District

Key details

Authors	B.J.Bluck and James D. Lawson
Themes	The relationships between the Dalradian block and the Midland Valley; some details of the structure and stratigraphy of the Highland Border Complex; recumbent folding in Upper Dalradian rocks.
Features	Serpentinite, serpentinite breccias, fossiliferous limestones, unconformity, conglomerates; Aberfoyle Grits and Slates, grading, bedding–cleavage relationships, recumbent fold.
Maps	O.S. 1: 50 000 Sheet 57 Stirling O.S. 1: 25 000 Sheet NN 40/50 The Trossachs B.G.S. 1: 63 360 Sheet 38 Loch Lomond
Distance and Time	10 km in total, including 3 km walking: 8 hours.
Access	Unrestricted, but stay on the forestry paths as much as possible and leave vehicles at the car parks provided. Do not drive vehicles through the forests.
Short itinerary	Localities 3 a, b, c, d, 4, 5, 6 and 8.

In the vicinity of Aberfoyle there are fine sections through the Dalradian where details of its structure may be simply seen and sections through the Highland Border Complex where fossiliferous carbonates, critical in determining its age and association, are well exposed.

The age and affinities of the Highland Border Complex have been debated for a long time. Some workers (e.g. Henderson and Robertson 1982) maintain that these beds were folded together with the Dalradian and are therefore either part of the Dalradian sequence, or lay on top of the Dalradian at the time of folding. Others (e.g. Longman et al 1979) took the view that the Highland Border Complex was younger than the rocks of the Dalradian and represented an entirely different rock assemblage formed in a totally different tectonic setting.

Two important discoveries resolved this difference:

1. The age of the Dalradian sedimentary rocks and their folding. There are a number of granites which cut the folded Dalradian rocks, and are therefore younger than both the Dalradian rock sequence and the episodes of folding which occurred prior to their intrusion. One of these granites (Ben Vuirich) has cut through Dalradian rocks which at the time of intrusion had already undergone two initial phases of folding. This granite yielded an age of 590 Ma (Late Precambrian; Rogers et al 1989), indicating that the sedimentation of the Dalradian and the two phases of folding which affected it are older than this date.

2. The age of the Highland Border Complex. This and the association of the Highland Border Complex were both solved with the rediscovery of a fauna in Lime Craig Quarry (Locality 3). A lens of limestone exposed in this quarry yielded a fauna of trilobites, brachiopods and other fossils to Curry et al (1982) and Ingham et al (1986) which demonstrated their lower Ordovician age. With the sedimentation and two phases of folding already completed in the Dalradian Block by Late Precambrian times this part of the Highland Border Complex could not have been associated with the Dalradian block as had been previously suggested.

In the Upper Dalradian grits and slates adjacent to the Highland Border Series, sedimentary structures led Shackleton (1957) to conclude that the Aberfoyle Slates occupy the core of a major fold of which grits form the limbs. Shackleton (1957) has also shown that the axial planar slaty cleavage of the Aberfoyle 'Anticline' has a downward-facing relationship to bedding (ie. the axial plane of folds on all scales encounters successively younger rocks when traced downwards).

Consequently, he concluded that the Aberfoyle 'Anticline' is a synform–the downbeat nose of a major gravity nappe, the Tay Nappe, which has its roots far to the north across the Cowal Anticline.

From the west end of Aberfoyle take the small road south over the Forth, and head SSW to a car park at Balleich (c.lkm from Aberfoyle). Follow the forestry road west from the car park to the locality where this road crosses Bofrishlie Burn

Locality 1. Bofrishlie Burn [NS 5003 9901]: Black shales and cherts (Figure 10.1)

In both the stream section and along the forest road are good exposures of folded and sheared black shales and cherts. These rocks have yielded brachiopods, bivalves and radiolaria to Jehu and Campbell (1917) and chitinozoa to Downie et al (1971). On the basis of chitinozoa these beds are probably Llanvirn–Llandeilo in age, and beds with these characteristics have been recorded in Stonehaven, where they are also assigned to that age-span.

On the NW and SE side of the Burn there are exposures of grey sandstone with interbedded siltstones and black shales. These beds make up most of the ridge lying parallel with the road on the NW side. The contact between these sandstones and the black shales is faulted, although Jehu and Campbell (1917) record an unconformable relationship between them. Some grey sandstones have black mudstone and shale clasts in them which may support the view that they rest unconformably on the shale-chert sequence.

Locality 2. [NX 4954 9861]: Unconformity between Highland Border Complex and Old Red Sandstone (Figure 10.1)

FromLocality 1, continue SW along the forestry track. Take the left fork at the first road junction and the right fork at the second junction. Walk 90 m on the road over a small hill to the low lying outcrops 20 m from the road. The unconformable contact between the Old Red Sandstone and the underlying Highland Border Complex is seen in these bare rock exposures (Figure 10.1). The basal Old Red Sandstone is a breccia with clasts of shale and sandstone and forms the base to a sequence of coarse, quartzite bearing conglomerates, sandstones and a thin andesitic lava which partly forms the high ridge to the south.

Locality 3. Lime Craig Quarry [NN 533 018]

Fossiliferous limestones and section through the Highland Boundary Fault (Figure 10.2). This locality is on Forestry Commission land, and is best approached from the David Marshall Lodge where there is parking, refreshments and (at the time of writing) a simple introduction to the rocks at Lime Craig Quarry. From the David Marshall Lodge the trail to the quarry is clearly marked and is about 1 kin long.

(a). Before reaching the quarry, there are exposures in steeply dipping sandstones and shales on the north side of the track. These sandstones belong to the Achray Sandstones and the interbedded shales have yielded pale yellow (unheated) chitinozoa of middle Ordovician age (Burton and Curry 1984). The same shale has also yielded black chitinozoa of lower Ordovician age which have probably been derived from an older formation which experienced elevated temperatures after deposition.

Lime Craig Quarry lies c100 in south of the Highland Boundary Fault (Figure 10.1) and (Figure 10.2) and east of the high quarry spoil. It exposes Lower Old Red Sandstone conglomerates, Ordovician limestones, serpentinite-limestone mixtures, serpentinite and the trace of the Gualann Fault along which there is now a Carboniferous dyke (cf. Balmaha excursion). Mechanical excavation here has exposed the rocks and clarified their relationships (Figure 10.3).

(b). A vertical dark rock surface exposes the dolerite dyke, to the north of which is the serpentinite and to the south a thin sliver of Old Red Sandstone conglomerate. Conglomerates are also visible in the very high east face of the quarry, so the thin outcrop at (b) is a downfaulted part of this thicker conglomerate sequence to the NE. The fault responsible for this displacement is the Gualann Fault which can be traced as far as the west side of Loch Lomond.

On the east side of the dyke lies an outcrop of soft dark serpentinite. This rock differs in colour and texture from the brown weathering carbonate-serpentinite which is associated with the limestone: this latter rock is probably a sheared breccia and conglomerate made up of serpentinite clasts.

(c). The high ground to the SW of the quarry is partly formed of brown weathering, pale grey limestone from which an abundant fauna has been collected (Curry et al 1982; Ingham et al 1986). The limestone contains sand-gravel sized clasts of serpentinite, gabbro, dolerite, spilite and other clasts of basic igneous rock. It was probably deposited in shallow water and was partly sourced in a pre-existing mass of oceanic crust (Bluck et al 1984). The discovery hi the Isle of Bute of a metamorphic sequence which resembles one produced beneath obducted ocean crust provided further evidence for the existence of an ophiolite along the Highland Border. Furthermore, the age of 540 Ma for the cooling of this metamorphic assemblage indicated that the ophiolite was older than the limestone found at this locality and could therefore be the source of the ophiolitic detritus found within it.

Although a large fauna has been obtained from this limestone, the fossils are small and difficult to see without the aid of a hand lens. The faunas include the trilobites: *Distazeris*, *Punka*, *Ischyrotoma*, *Illaenus*; brachiopods: *Archaeorthis*, *Orthiclium*, *Orthambonites* and gastropods, bryozoans and crinoids. These and many others are figured in Ingham et al (1986) and indicate a Lower Arenig age.

(d). Steeply dipping Lower Old Red Sandstone conglomerate with clasts up to cobble and small boulder size interstratified with thin red sandstones. The cobbles are mainly quartzite and andesite and both are very well rounded. The brittle quartzite clasts are often fractured and the significance of these fractures has been recognised by Ramsay (1964) as indicating shear, as well as reverse movement along the Highland Boundary and related faults.

(e). This locality, and to a lesser extent (f) are difficult to find, particularly in the summer when there is much vegetation. (e) is also fairly inaccessible so only the agile and enthusiastic should attempt this part of the excursion. Follow the cliff made by the limestone along the path for c. 100 metres, then scramble and climb to the limestone-Old Red Sandstone boundary. Here the Old Red Sandstone is seen to rest on the limestones of the Highland Border Complex. The contact is an unconformable one but with some minor movement along the plane of the unconformity. The formerly held view that this is the Highland Boundary Fault is now discarded.

(f). Conglomerates with abundant quartzite and psammitic clasts up to small boulder size. This is a conglomerate which is considered by Bluck et al 1984 to be part of the Highland Border Complex and probably younger than the Lower Arenig Dounans Limestone. Some of the psammitic clasts have yielded ages of 1800 Ma (Dempster and Bluck 1988) suggesting a source in a metamorphic terrane far older than the Moine and Dalradian.

Locality 4. Quarry [NN 5205 0225]: Graded grits (Figure 10.1)

Return to David Marshall Lodge and take the A821 northwards to traverse the Dukes Pass. Along this road there are numerous exposures of the Aberfoyle Grits and Slates belonging to the Southern Highland Group of the Upper Dalradian. It is possible to determine the way up of the strata and recognise the presence of a major recumbent fold with a downturned nose.

Along the winding part of the road there are many roches moutonnées in the grits, some with glacial striations, but parking here is difficult. As the road straightens out before the quarry, the stream on the right displays good water worn surfaces of a graded grit with load casts indicating that the beds are inverted, as they dip north-eastwards but young to the SW. However , the best exposure is not easy to find and there is not room for a group of people. It is normally preferable to carry on a short distance and park the car or bus at a lay-by on the right, close to a small quarry.

Cross the small (unless in flood) stream to enter the quarry, the floor of which is usually very wet. It should be possible to appreciate from the lay-by that the grits are dipping steeply to the left (i.e. roughly northwards). These so-called 'grits' are really greywacke type sandstones deposited by turbidity currents in deep sea fans. At the entrance to the quarry two graded units can be recognised (often with difficulty) at and below eye level. The basal layers are coarse and pebbly, containing subangular fragments of quartz, feldspar and rock e.g. shale. The bottom of the graded unit is often irregular and rests sharply on finer sediment. The grading is not very convincing in these exposures but the top layers are distinctly finer and may show lamination. On the north (far) side of the quarry there is an interbedded purple slate and an impressive grit with large feldspars: some visitors are more convinced by the graded bedding here. The conclusion that should be reached is that the grits in the quarry are younging approximately southwards although the dip is roughly to the north. In other words the grits are inverted (Figure 10.4).

Locality 5. Forestry track [NN 5210 0228]

Bedding-cleavage relationships in slates. About 30 m north of Locality 4 is a forestry road with a cutting through the Aberfoyle Slates. The grits of the quarry dip steeply below these slates but as the strata are inverted, the slates must be older that the grits. Careful examination along this section will reveal folded bedding, often picked out by colour changes (maroon and green) in the slates, cut by a constant cleavage. It is possible for a qualified geologist to determine from the relative dips of bedding and cleavage that the major structure is closing downwards (Figure 10.4).

Locality 6. Hill Cottage crags [NN 5158 0290]

Graded grit on slates. Drive about one km northwards over more slates and grits which are involved in faulting (Figure 10.1). Park on the left-hand (west) side opposite some prominent crags and before reaching the cottage where the road branches off westwards into the slate quarries. The roadside crag shows grits dipping at about 80 degrees to the north and resting on slates which are at road level. The base of the grit is very coarse and obviously grades upwards: the under-surface displays large elongate lumps which are considered to be sole markings known as load-casts and are characteristic of the base of turbidite sediments. This evidence indicates that the grits here are younging to the NNE in the same direction as the dip and are therefore not inverted. The cleavage dips more steeply than the bedding. Between Localities 3 and 5, therefore, we have crossed the axis of a fold: the slates in the middle are older than the grits and the fold can be shown (from bedding-cleavage relationships) to close downwards. Although the structure is synformal the presence of older rocks in the centre indicates that it is an inverted anticline (Figure 10.4).

The crags behind this exposure and those near the little waterfall opposite also show graded bedding which confirms the northward younging. Just to the south there are roadside exposures of purple and green slates in which bedding can be recognised as well as cleavage.

Locality 7. Aberfoyle Slate quarries

Seven main bands of slate can be distinguished with occasional thin bands of grit and limestone. The rocks in the quarry are intersected by at least six north-easterly trending faults in a distance of approximately 370 m. They are presumably sinistral tear (strike-slip) faults trending sub-parallel to the larger fracture indicated on the map (Figure 10.1). Faint laminae and cross-laminae representing original bedding occur in several places, intersected by the slaty cleavage planes. These indicate that cleavage is oblique to bedding at least in the hinges of the minor folds and that the cleavage in the slates faces downwards.

Locality 8. Creag Noran (Loch Achray) [NN 5041 0658]

Flat-lying grits. Continue northwards along the road for about 4 kin, skirting the southern shore of Loch Achray. Immediately after a sharp right turn at the Loch Achray Hotel there is a cliff on the left with limited parking space opposite.En route one passes exposures of grits and slates although these finer sediments are now altered to the shinier phyllites, with larger white mica crystals due to the higher degree of metamorphism.

The roadside cliff exposes mainly flat-lying grits but they have obviously suffered a greater degree of deformation than the grits on the Duke's Pass with a wavy cleavage developed. The distinct graded bedding indicates that these almost horizontal beds are upside down. The finer sediments have been altered beyond phyllite grade to chlorite schist. We are here on the inverted lower limb of the flat part of the large recumbent fold shown in (Figure 10.4).This is the Flat Belt of the Tay Nappe which affects most of the southern Highlands.

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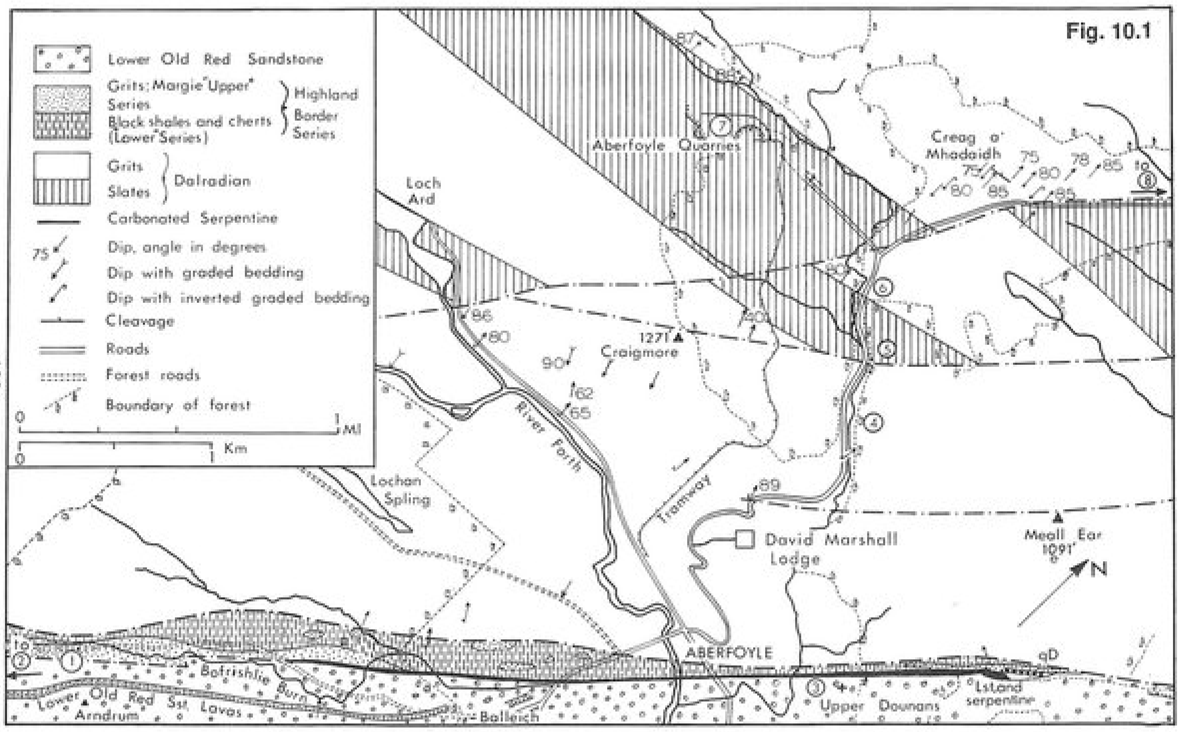
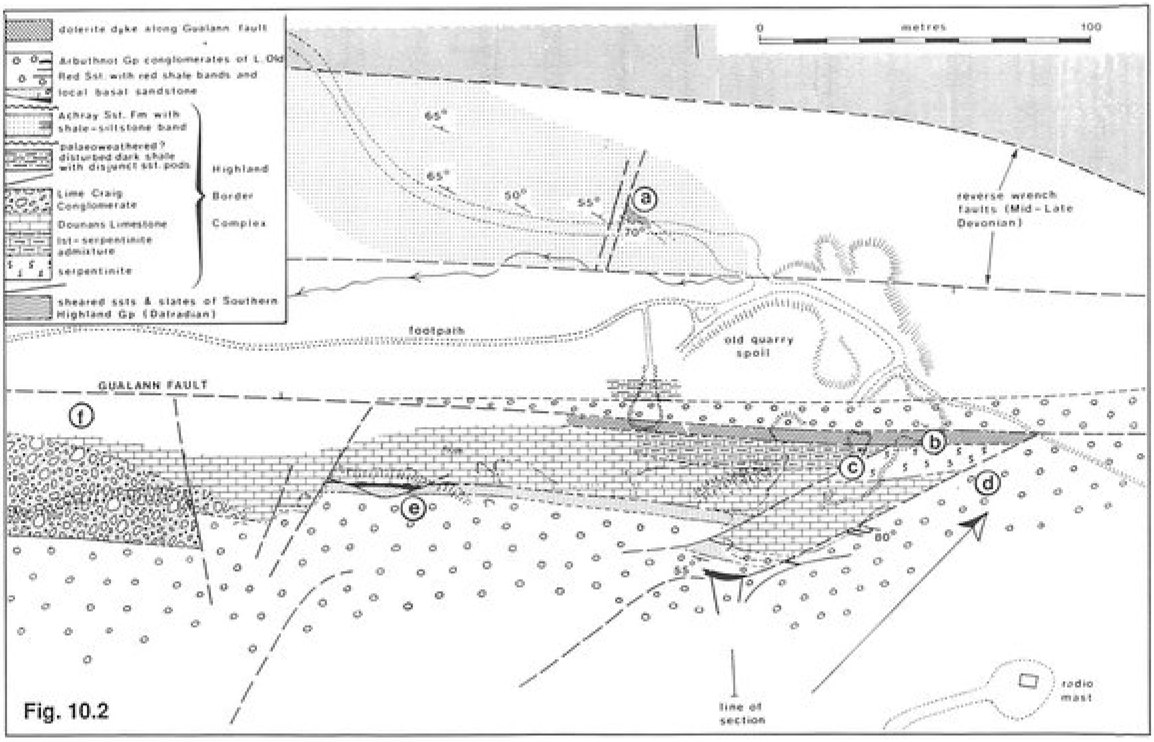
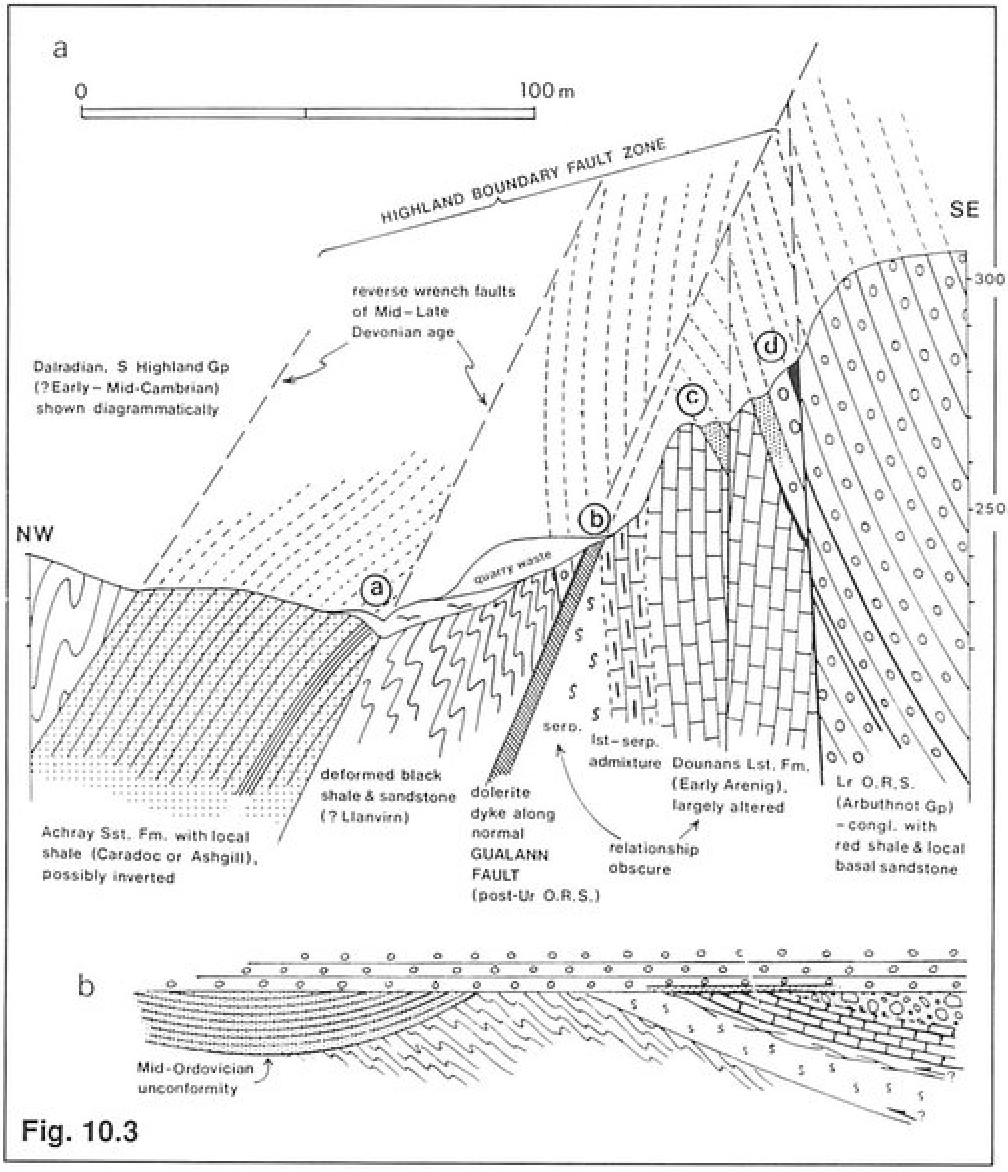


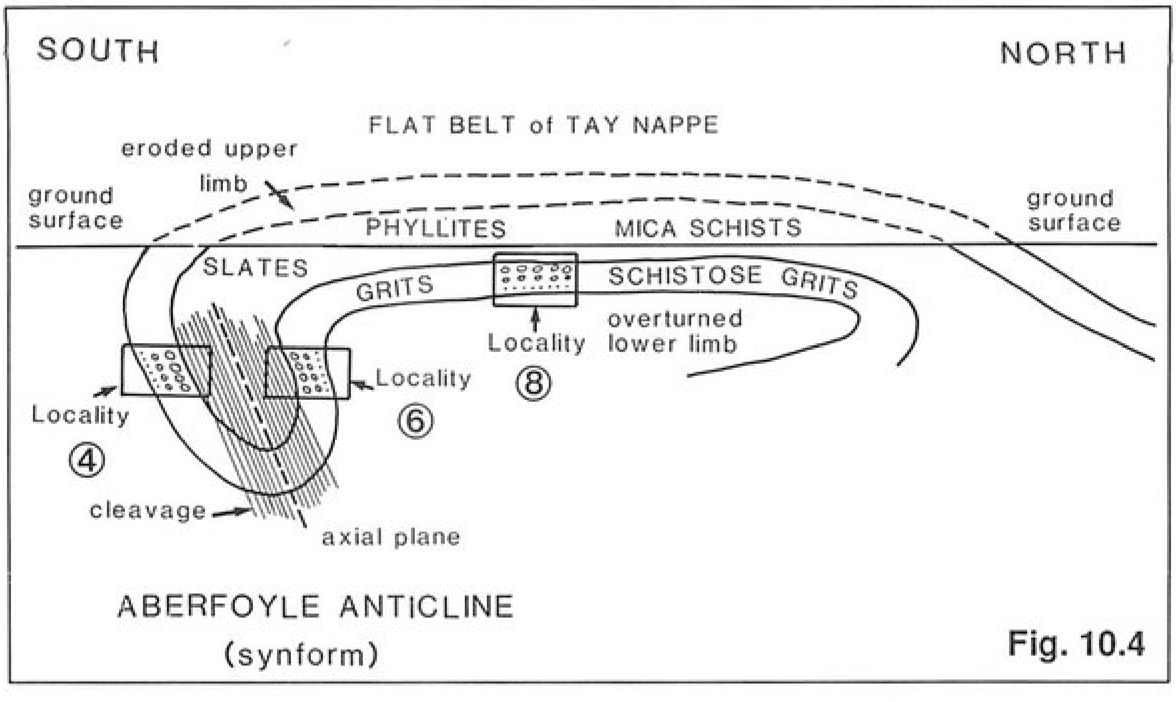
(Figure 10.1) Geological map of the Aberfoyle district with locality numbers.



(Figure 10.2) Geological map of Limecraig Quarry and environs, with locality numbers (From Bluck et al 1984).



(Figure 10.3) (a) Geological cross section (as indicated on (Figure 10.2)); (b), the attitude of the Highland Border Complex at the time of Lower Old Red Sandstone deposition. (from Bluck et al 1984).



(Figure 10.4) Diagrammatic section from south to north along the excursion route to show how the folding can be interpreted from the exposures visited.