

British Cambrian to Ordovician Stratigraphy

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Chapter 13

*Scotland: Cambrian and Ordovician
of the Grampian Terrane and
Highland Border Sub-terrane*

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INTRODUCTION

Two sites of palaeontological importance fall on the boundary of the Grampian Terrane and the Highland Border Sub-terrane (Figures 1.1, 12.1 and 12.2); they are crucial to the arguments on the geological relationships between the Dalradian Supergroup of the Central Highlands Terrane and the Midland Valley Terrane. A wide variety of rock types of the Highland Border Complex is preserved as a series of narrow slivers along the Highland Border fault zone from Stonehaven in the north-east to Arran in the south-west, and thence into the north-west of Ireland (Bluck *et al.*, 1984, 1992; Curry *et al.*, 1984). Leny Quarry is the source of the only satisfactory Cambrian faunas along the Highland Boundary Fault complex, but it is still debated whether it is on the edge of the Grampian Terrane and forms an upper part of the Dalradian Supergroup or is part of the Highland Border Sub-terrane (or a separate suspect terrane). Limestone from Lime Craig Quarry contains a fauna of Cassinian age (equivalent to mid-Arenig) that is the best-dated fauna from the Highland Border Sub-terrane.

LENY QUARRY (NN 615 098)

Introduction

Leny Quarry is the principal locality for the Leny Limestone, which is the only unit along the Highland Boundary Fault zone that yields identifiable Cambrian fossils. The site is of national significance because the presence of Lower Cambrian fossils there is a crucial factor in the arguments on the age of the Dalradian Supergroup and of the Grampian orogeny. The fauna provides an age constraint on the larger division to which the Leny Limestone belongs, whether it be part of the Upper Dalradian succession or part of the Highland Border Complex, as discussed below.

Harkness (1861, p. 258) described the limestone of Leny Quarry, just north of the Highland Boundary Fault, as occurring near the base of a northwardly ascending succession that passes up into the gneissose rocks (now regarded as part of the Dalradian Supergroup) forming the hills to the north. He was unable to find any fossils. Soon after, Nicol (1863, p. 186) gave a more detailed description of the quarry, including a sketch-section, and introduced the term 'Leny

Limestone'. Clough later mapped the Callander-Aberfoyle area, and although he did not publish his findings in detail, he reported that it did not 'seem possible to draw any line between the grits (that lie immediately north-west of the Leny Limestone) and the Dalradian Rocks farther to the north' (Clough, in Geikie, 1897, p. 28). Later workers who have mapped the area have inverted Harkness' succession, but all have agreed with Clough that the exposed sections through these rocks (for example in Keltie Water) show stratigraphical continuity from the Ben Ledi Grit Formation of the upper Dalradian succession southwards to the Leny Limestone and equivalent strata close to the Highland Boundary Fault (Stone, 1957; Harris, 1969; Tanner, 1995). By contrast, Bluck and Ingham (in Bluck *et al.*, 1997) discussed problems presented by the notion of a stratigraphical connection with the Dalradian and considered the continuity to be apparent only.

Pringle (1939, p. 252) announced the discovery of trilobites in the Leny Limestone (which, following McNair's (1908) use of the name 'Kilmahog Quarry', he referred to as the 'Kilmahog Limestone'). Commonest among them was the predominantly Middle Cambrian genus *Pagetia*. He never published his full results but left manuscript notes, some of which were used to prepare this account. Following the description of the genus *Pagetides* (Rasetti, 1945) from late Lower Cambrian rocks, Stubblefield (1956) revised the identification of the pagetiids and gave the age of the Leny Limestone as late Early Cambrian. These results were taken by some workers to indicate that the upper part of the Dalradian is of early Cambrian age (Tanner, 1995; in Bluck *et al.*, 1997). Other workers prefer to associate the Leny Limestone with the Highland Border Complex (Bluck and Ingham, in Bluck *et al.*, 1997), a collective term for small outcrops of ophiolitic rocks, dark-coloured shales and cherts, with other volcanic and clastic rocks, that crop out within the Highland Boundary Fault zone (Curry *et al.*, 1984). The Highland Border Complex includes the fossiliferous Dounans Limestone of definite Ibexian (= Arenig) age at Lime Craig Quarry (see site report) (Ingham *et al.*, 1986) and some possibly younger rocks that are thought to have had a different metamorphic history from the Dalradian rocks. Bluck *et al.* (1992) concluded that the complex, including the Leny Limestone (Brasier *et al.*, 1992b), is part of a terrane that is

Grampian Terrane and Highland Border Sub-terrane

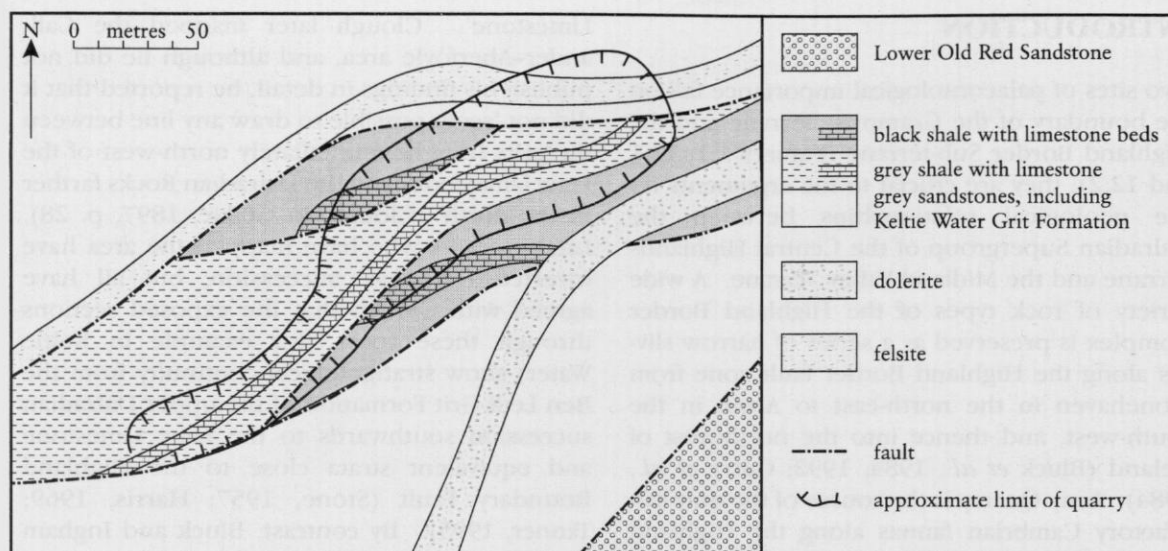


Figure 13.1 Geological map of Leny Quarry, after Pringle (unpublished).

stratigraphically and structurally separate from the Grampian Terrane to the north.

Description

Leny Quarry is a ravine-like excavation extending for about 200 m approximately along strike from south-west to north-east (Figure 13.1). The quarry was opened in about 1745 to work beds of grey limestone interbedded with black slates but was little used after the 1860s. The general dip is 40–60° to the north-west, but there is much folding and faulting and some local evidence that the beds young to the south-east and are overturned. To the north-east of the quarry are grey grits and cleaved sandy slates, part of the Keltie Water Grit Formation of Tanner (1995), locally intruded by a felsite dyke that is exposed in the north-west side of the quarry towards its northern end, where it is in faulted contact with a poorly exposed metabentonite, the identity of which was confirmed by R. J. Merriman (pers. comm., 1994).

On the south-east side of the quarry are further grey grits and slates for some 130 m, before the faulted contact with strata of the lower Old Red Sandstone is reached. A large dolerite dyke intruded on the south of the quarry has in places thermally metamorphosed the Leny Limestone.

The main limestone, a grey sandy rock, weathering brown and shot through with sets of bedding-normal calcite veins that give a distinctive appearance, is mainly quarried away and its out-

crop covered with talus, but part remains supporting the north-west side of the quarry (cf. Nicol, 1863, fig. 4). Harkness (1861) reported the thickness to be 'about eight feet' (2.5 m), though Nicol (1863, p. 186), who observed 15 feet (nearly 5 m) in a part of the quarry then being worked, may have seen a place where there was structural duplication. Clough recorded a bed 5 feet (1.5 m) thick, diminishing to no more than 1 foot (0.3 m). This main bed is practically unfossiliferous, though Pringle observed fragments of phosphatic brachiopod shells.

The south-east side of the quarry exposes a succession a few metres thick of black slate alternating with up to six thin (10 cm scale) beds of dark-grey limestone in a total thickness of 36 cm. These strata are folded and faulted but locally contain very thin layers with small fossils, mainly trilobites and a few brachiopods. Similarly fossiliferous is a small faulted mass of limestone on the north-west side of the quarry, near its mid-length (Figure 13.1); but Pringle recorded in his manuscript that searches along strike, from Leny Glen to Keltie Water, have failed to reveal other localities with identifiable fossils (Pringle, in MS).

The commonest fossils are trilobites (Figure 13.2), many being referable to *Pagetides*, of which more than one species is present. In addition there are small specimens of corynexochids and ptychopariids, together with brachiopods, tubular organisms and sponge spicules. Despite the work of Lamont (1975),

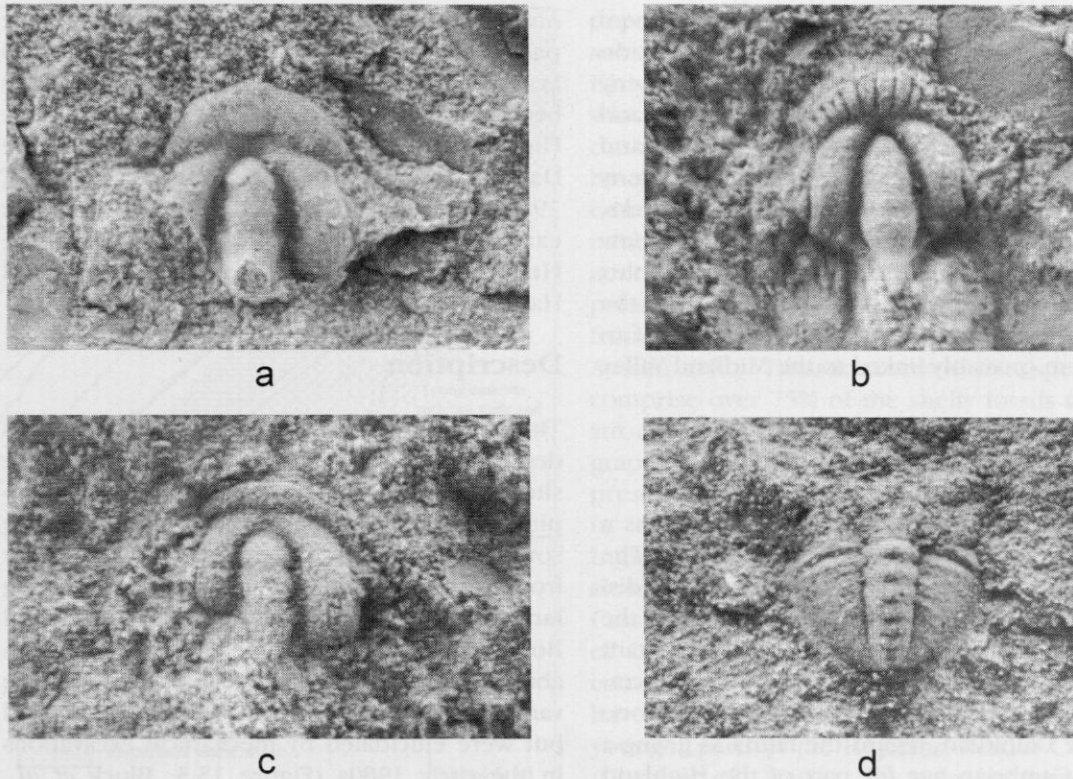


Figure 13.2 Pagetiid trilobites from Leny Limestone, Leny Quarry. Three cephalia, (a) $\times 10$, (b) $\times 12$, (c) $\times 15$, and a pygidium, (d) $\times 15$.

the fauna is still in need of full illustration and detailed assessment.

Interpretation

The trilobites from the Leny Limestone are unquestionably of Laurentian provincial affinity and are (in terms of the Laurentian succession) of late Early Cambrian age. They give evidence of the only undisputed Cambrian rocks along the Highland Border. Lamont's (1975) records of trilobites of Moroccan type (Daguinaspididae, Gigantopygididae?) are not upheld (T.P. Fletcher, pers. comm., 1990). The species present are akin to those that inhabited the outer edge of the Laurentian shelf (Conway Morris and Rushton, 1988, p. 98).

Whichever way the stratigraphical position of the Leny Limestone is interpreted, its late Early Cambrian age has important implications. If the Leny Limestone is part of the Upper Dalradian succession, as appears to all those who have mapped the ground (Tanner, 1995; in Bluck *et al.*, 1997), its fauna provides a minimum age for the deposition of that part of the upper

Dalradian Supergroup and fixes a maximum age for the subsequent deformation event, which, according to radiometric measurements, seems to have been after about 510–520 Ma (Tanner and Leslie, 1994; Tanner, 1995), or approximately equivalent to Branchian (late Lower Cambrian) times (Davidek *et al.*, 1998). This interpretation requires structural separation of the Leny Limestone from outcrops of other rocks of the Highland Border Complex but poses problems concerning deposition of the Leny Limestone on a cooling crustal block (Bluck and Ingham, in Bluck *et al.*, 1997) and is further complicated by Molyneux's (1998) confirmation that the acritarch reported from the upper Dalradian of the Banff Nappe at Macduff, Banff (nearly 200 km to the north-east) is of Tremadoc age or younger.

If, however, the Leny Limestone is regarded as part of the Highland Border Complex (Bluck and Ingham, in Bluck *et al.*, 1997), it is much older than other sedimentary rocks in the complex, outcrops elsewhere having yielded Ordovician ages: a secure Arenig age at Lime Craig Quarry (see site report) and more dubious

records of younger Ordovician rocks elsewhere (Curry *et al.*, 1984). This interpretation demands a structural separation of the Leny Limestone from the Dalradian succession and discounts the appearance of stratigraphical and lithological continuity between the Leny Limestone and the adjoining Dalradian rocks. Tanner (in Bluck *et al.*, 1997) favoured the view that parts of the Highland Border Complex (including the Leny Limestone) belong with the Dalradian, whereas the remainder are parts of an arc system (possibly linked to the Midland Valley Terrane).

Conclusions

The Leny Limestone in Leny Quarry contains a very significant Lower Cambrian fauna. The structural affiliation of the Leny Limestone is disputed. For some, who regard it as part of the Dalradian Supergroup, it gives an important Early Cambrian date for the top of the succession. Others, who separate the Leny Limestone from the Dalradian, regard the fauna as giving a unique Cambrian age for part of the Highland Border Complex.

LIME CRAIG QUARRY (NN 5340 0187)

Introduction

Lime Craig Quarry is critically important for understanding one of the major terrane boundaries in the British Isles, namely the Highland Boundary Fault zone, which marks the junction between the Dalradian and Midland Valley terranes. The rediscovery in 1981 of early Ordovician fossils in the Highland Border Complex here resulted in a major reappraisal of the relationship between this complex and the Dalradian metasedimentary succession to the north.

Although Stubblefield had extracted a silicified fauna by acid etching a piece of the limestone in the early 1940s, his results were never published, and it was 40 years before a similar exercise was undertaken (Curry *et al.*, 1982). This involved the processing of over 7.5 tonnes of limestone, yielding almost 1700 identifiable silicified fossils, three-quarters of which are trilobites (Ingham *et al.*, 1986). These can be matched very closely with faunas of the upper Ibex (or Canadian) Cassinian Stage of North

America. Not only does the fauna indicate the palaeogeographical position of this part of Scotland during the Ordovician, but its age has been used to show that the origins of the Highland Border Complex are not related to the Dalradian (Bluck *et al.*, 1984; Curry *et al.*, 1982, 1984; Ingham *et al.*, 1986), in contrast to some earlier models (Johnson and Harris, 1967; Henderson and Robertson, 1982; Ikin and Harmon, 1984).

Description

The geological setting of Lime Craig Quarry is described by Bluck and Lawson (1992), and the site of the radio mast on the ridge of steeply dipping Old Red Sandstone conglomerate to the south-east provides an excellent vantage point from which to view the markedly contrasting landscapes on each side of the Highland Boundary Fault zone. The quarry has long been abandoned, and the relationships between the various units there are structurally complicated but were elucidated by mechanical excavations in the early 1980s (Figure 13.3; Bluck *et al.*, 1984; Curry, 1986; Ingham *et al.*, 1986). To the immediate north-west of the quarry area are steeply dipping sandstones and shales of the Achray Sandstone of probable Caradoc–Ashgill age, bounded to the north-west and south-east by mid- to late Devonian wrench faults. Much of the intervening ground is covered by quarry spoil but comprises deformed black shales and sandstones of probable Ordovician age, overlain unconformably by the basal sandstones of the lower Old Red Sandstone Arbuthnot Group. These are truncated by a prominent SW–NE dolerite dyke of Carboniferous or younger age intruded along the Gualann Fault, a NW-dipping normal fault that can be traced south-west as far as the west side of Loch Lomond. On the south-east side of the northern end of the dyke, at the edge of the quarry, is an area of dark-coloured serpentinite, whereas along this side of the intrusion to the south-east is a brown-weathering carbonate serpentinite.

The bulk of the quarry is composed of vertical or subvertical grey limestone (the Dounans Limestone), unconformably overlain by, and locally faulted against, steeply dipping sandstones and conglomerates of the Arbuthnot Group, which forms the towering back face of the quarry. The limestones contain clasts, up to gravel size, of serpentinite, gabbro, dolerite,

Lime Craig Quarry

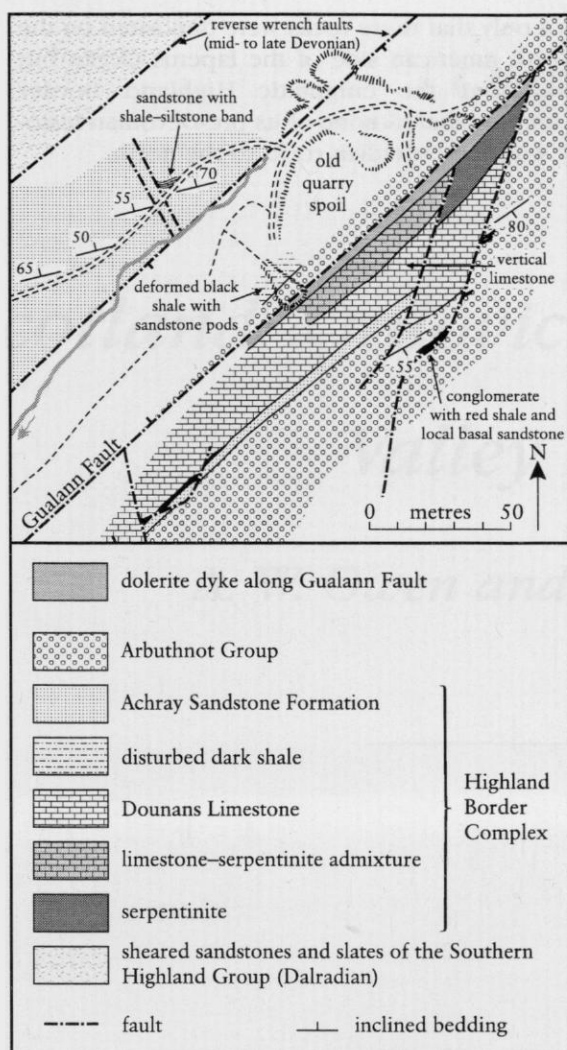


Figure 13.3 Geological map of Lime Craig Quarry showing the faulted Highland Border complex and Lower Old Red Sandstone, from Bluck *et al.* (1984, fig. 7) and Bluck and Lawson (1992, fig. 10.2).

spilite and other basic igneous rocks. The limestones are extensively dolomitized, and only in one small, probably fault-bounded, area in the middle of the quarry were they sufficiently pure for commercial extraction. This area was almost completely quarried out, but in the early 1980s the quarry waste yielded large quantities of the purer limestone for acetic acid dissolution. These provided both the impetus for wider analysis of the Highland Border Complex and the most precise age for any part of it.

Interpretation

The Dounans Limestone is thought to have been

deposited in shallow water above an ophiolitic substrate (Bluck *et al.*, 1984), obducted in the Early Cambrian (Dempster and Bluck, 1991), which provided the serpentinite and other clasts. The limestone yielded silicified trilobites, brachiopods, gastropods, bryozoans, ostracods, crinoids, an orthocone and various undetermined fossil remains (Ingham *et al.*, 1986). A conodont fauna of very low abundance is also present, with only 48 elements being recovered from an estimated 71 kg of rock (Ethington and Austin, 1991). Disarticulated trilobite specimens comprise over 75% of the shelly fossils and are strongly North American in their palaeobiogeographical affinities. Thirteen trilobite species are present, but 80% of the trilobite remains belong in one species, *Ischyrotoma stubblefieldi* Ingham. This species and several others are close to or conspecific with species from the Cassinian Stage of the late Ibexian (mid-Arenig) of Laurentia; a correlation supported by the conodonts. Other, less precise, Ordovician ages have been obtained from microfossils in younger parts of the Highland Border Complex (Curry *et al.*, 1984). The palaeontological evidence indicates that the Highland Border Complex is much younger than the deposition and early episodes of metamorphism and deformation of the Dalradian Supergroup. Nor could the Arenig carbonate platform indicated by the Dounans Limestone and fossiliferous limestone clasts in Ordovician and younger conglomerates in the Midland Valley (Ingham *et al.*, 1986) have been adjacent to an uplifting Dalradian block shedding copious quantities of siliciclastic sediment (Bluck, 1995). The complex probably formed part of the cover sequence of the Midland Valley Terrane (Bevins *et al.*, 1992) and was only brought into juxtaposition with the Dalradian block in the Devonian (Bluck, 1984, 1995). The debate is by no means over, however, as there is still a conflict between the evidence for stratigraphical and structural continuity between parts of the Highland Border Complex and the Dalradian Supergroup at some localities (Tanner, 1995; in Bluck *et al.*, 1997) (see the Leny Quarry site report) and the palaeontological and sedimentological evidence for very different histories until the late Devonian.

Conclusions

Lime Craig Quarry exposes the rocks on the

Grampian Terrane and Highland Border Sub-terrane

Highland Boundary Fault. Fossils from the limestones are closely related to the North American Cassinian division of the Ordovician (approximately mid-Arenig in age). This provides the most precise age yet determined for any part of the Highland Border Complex. The fossils show

not only that these rocks were deposited on the North American side of the Iapetus Ocean but also that the enigmatic Highland Border Complex shared none of its pre-Devonian history with the Dalradian rocks to the north.