Keisley Quarry

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Introduction

The area in and around Keisley Quarry contains the only outcrop of the Keisley Limestone, the best example of an Ordovician carbonate mud-bank in England and one of very few such in the British Isles. It has yielded a diverse shelly fauna, including one of the most widely quoted illaenid–cheirurid trilobite faunas typical of pure carbonate environments. The lower parts of the Keisley Limestone may be as old as Cautleyan and the uppermost part includes a *Hirnantia* fauna, characteristic of the lower part of the Hirnantian Stage. Above it is a conformable sequence across the Ordovician–Silurian boundary, containing graptolite faunas that enable the systemic boundary to be identified to within a few centimetres.

The Keisley Limestone was first referred to by Buckland (1817), who considered it part of the Carboniferous Limestone. Harkness and Nicholson (1877), Nicholson and Marr (1891), Marr (1892, 1906, 1913) and Reed (1896, 1897) described the Keisley Limestone its faunas, and its age and possible relationships to other upper Ordovician limestones in the Lake District and Cross Fell. Wright (1985) summarized the more recent arguments on the age and lithological equivalence of the limestone and described the conformable transition into the Silurian Skelgill Formation. He confirmed a Hirnantian age for the uppermost part of the limestone. Both Cautleyan (e.g. Ingham, 1966) and Rawtheyan (e.g. Dean, 1978) ages for the remainder of the Keisley Limestone have been suggested on the basis of the trilobite faunas (Ingham and Wright, in Williams *et al.,* 1972, p. 47), and Orchard (1980) provided conodont evidence for the presence of both stages.

The succession, setting and faunal composition of the Keisley Limestone were outlined by Burgess and Holliday (1979, p. 19) and descriptions of various aspects of the shelly faunas were given by Reed (1896, 1897), Temple (1968, 1969), Dean (1971–1978), Paul (1973–1997), Donovan (1986–1995) and Donovan and Wright (1995). Conodont faunas have been described by Rhodes (1955), Bergström (1971) and Orchard (1980).

Description

The site comprises a western 'New Quarry', and an eastern 'Old Quarry', with Keisley Crags on the hillside to the immediate north (Figure 11.14). These three areas are separated by faults and their stratigraphical interrelationships are not clear. The whole complex is fault-bounded to the north and the relationships with the Dufton Shale Formation are not seen. To the south of the New Quarry, however, there is certainly a conformable passage up into Silurian shales of the Skelgill Formation. Within the Old Quarry, dark-grey siltstones with thin impure limestones are exposed in the core of a west–east striking anticline and are thought to be the oldest part of the Keisley Limestone (locality K16 of Burgess and Holliday, 1979, pp. 13, 20). They are probably fault-bounded and abut strongly jointed massive grey limestones. The north wall of the quarry contains a siltstone that clearly shows the northward dip of the beds on the northern limb of the anticline. Keisley Crags expose some 12 m of south-dipping bedded grey bioclastic limestones, some crinoidal, overlain by about 3 m of white to pink fine-grained limestone with abundant large shelly fossils.

The most continuous section is in the New Quarry, where about 30 m of limestone dips south (Figure 11.15). The lowest beds, at the back of the quarry, are dark-coloured nodular limestones with siltstone partings (informally termed the 'lower Keisley Limestone' by Orchard, 1980). These are overlain by paler, more massive limestones that are locally dolomitized (the upper Keisley Limestone of Orchard, 1980). A temporary trench section in the track to the New Quarry was documented in detail by Wright (1985) and revealed that the limestones and calcareous siltstones of the uppermost part of the Keisley Limestone are capped by a thin (7 cm) synsedimentary breccia overlain by 24 cm of siltstone, succeeded in turn by black shales with bentonites.

Interpretation

The detailed sedimentology and environmental interpretation of the Keisley Limestone have yet to be described. Many authors have considered it to be some kind of reef or reef-mound, and most recently Wright (1985) applied the term 'carbonate mudmound'. The limestone is locally richly fossiliferous, although structural complexity and the poorly localized nature of much of the early sampling means that the internal stratigraphy and the range of species is not fully clear. Burgess and Holliday (1979, p. 20) noted that a substantial part of the shelly fauna is from the middle of the succession and that its composition varies markedly from sample to sample. Moreover, the shelly fauna is very much a 'facies fauna', which further hinders precise correlation with the standard Ashgill biozonation. Thus, Dean (1978) demonstrated statistically the long-recognized generic similarity of the trilobite fauna to those of the Chair of Kildare Limestone (probably Rawtheyan) in eastern Ireland and the Boda Limestone (upper Pusgillian to Rawtheyan) of Dalarne, Sweden. All are examples of the illaenid-cheirurid trilobite biofacies that occupied pure carbonate environments from the Arenig to the Devonian (Owen *et al.,* 1991, p. 816, and references therein). Some of the arguments on the age of the shelly faunas have hinged on the possible equivalence of the Keisley Limestone to the Swindale Limestone developed elsewhere in the Cross Fell Inlier (see the Swindale Beck and Melmerby Road site reports). Reconstructions have shown the Swindale Limestone as a tongue-like extension of some part of the Keisley Limestone (Ingham and McNamara, 1978, p. 129, fig. 43; Burgess and Holiday 1979, fig. 12). The Swindale Limestone is now thought to represent a level at about the Cautleyan–Rawtheyan boundary (Price, 1981).

The limestones at the top of the Keisley Limestone, exposed in Wright's (1985, 1988) trench section, contain the calcareous alga *Girvanella* and a *Hirnantia* brachiopod fauna (see the Cwm Hirnant site report), the latter typical of the lower part of the latest Ordovician

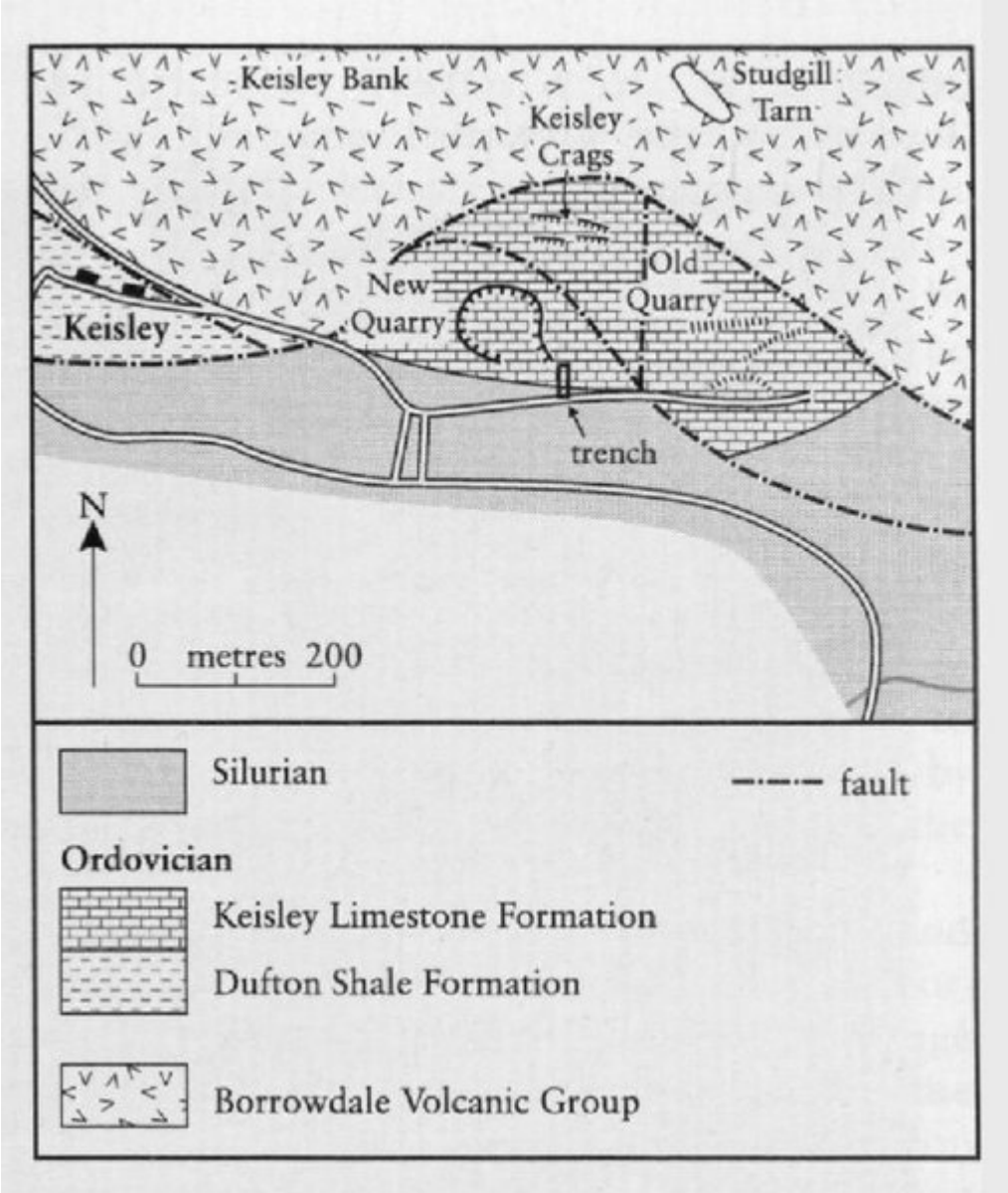
Hirnantian Stage. The *Hirnantia* fauna described by Temple (1968, 1969) from exposures nearby also belongs in this stage, not the lower Llandovery as thought by Temple (Ingham and Wright, in Williams *et al*., 1972; Wright, 1985). The upper half of the siltstone immediately above the Keisley Limestone is graptolitic and contains a fauna indicative of the *Glyptograptus persculptus* Zone, succeeded by *Parakidograptus acuminatus* Zone faunas. The boundary between the two zones marks the base of the Silurian, which can be located to within a few centimetres. The overlying black shales contain graptolites of the *Atavograptus atavus* Zone. The sedimentological implications of the lithological changes in the trench section were discussed by Brenchley (1988) and conform to the global pattern of regression followed by abrupt transgression near the end of the Hirnantian.

If the conodont data of Orchard (1980) and some of the trilobite-based correlations are correct, the Keisley Limestone may range in age from a level within the Cautleyan to well into the Hirnantian. The Ashgill Shale Formation exposed in Swindale Beck (see site report) must be a lateral equivalent of the uppermost part of the Keisley Limestone and the Swindale Limestone an equivalent of its lower parts.

Conclusions

The Keisley Limestone is the sole example of a carbonate mudmound in the Ordovician of Britain. Its diverse shelly faunas include a prime example of an illaenid-cheirurid trilobite fauna — an ecological assemblage typical of pure carbonate environments. The top of the Keisley Limestone contains shelly fossils of the lower Hirnantian *Hirnantia* fauna, and it is succeeded by graptolitic rocks, within which the Ordovician–Silurian boundary can be recognized precisely.

References



(Figure 11.14) Geological map of the Keisley area, after Burgess and Holliday (1979, fig.13). The Ordovician–Silurian boundary section in the trench across the track to the New Quarry was described by Wright (1985).

(Figure 11.15) Keisley New Quarry, the north part, showing several metres of southward-dipping limestone. The lower beds to the left are nodular with siltstone partings. The more massive overlying beds are disturbed by faulting. (Photo: British Geological Survey photographic collection, L1057.)