Jack Soper, Ian Kelly (Quarries Manager, Burlington Stone Ltd.), Clive Boulter .

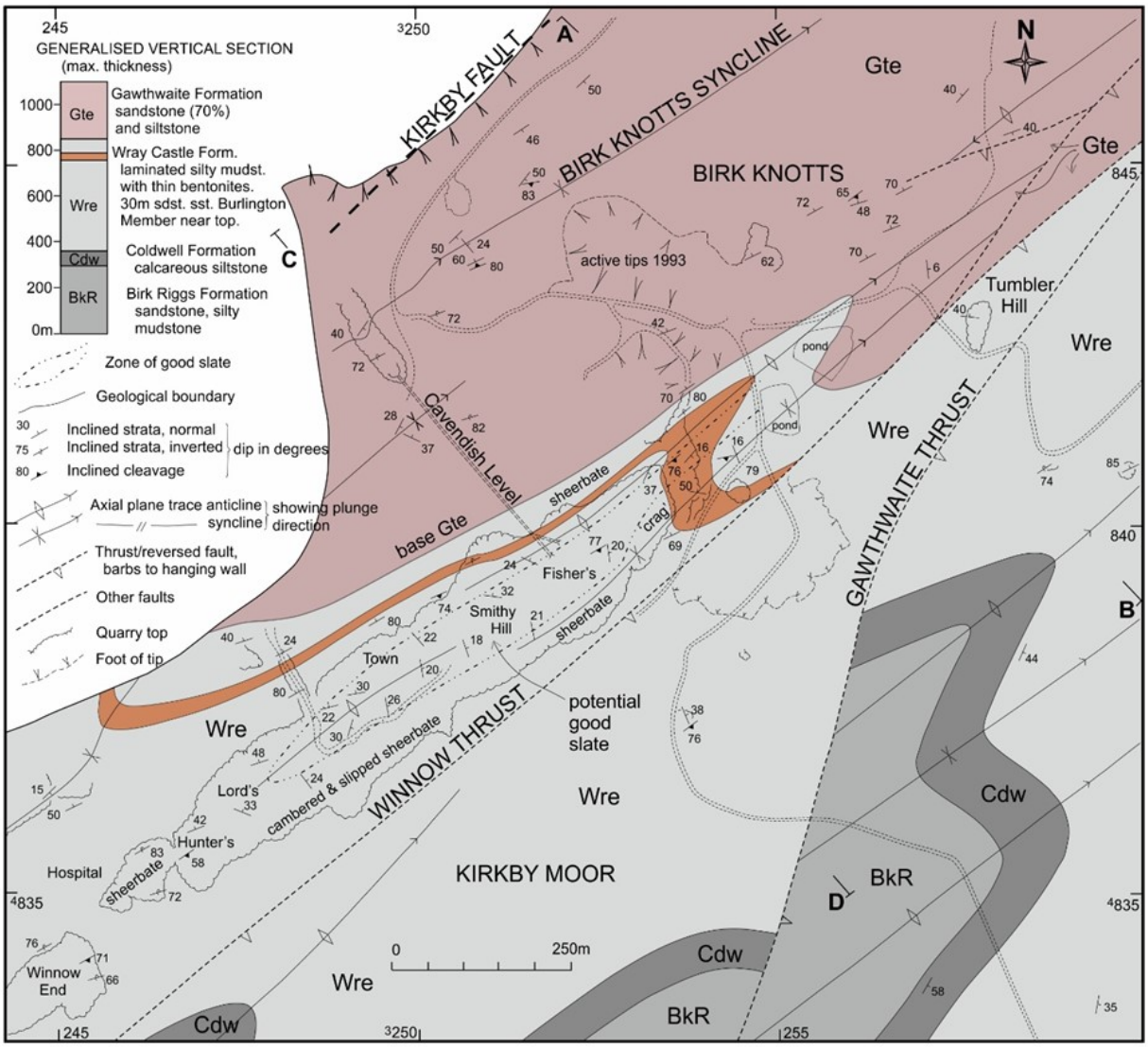


Figure 1 Geological Map of the Kirkby Moor Quarry

Slate has been used since Roman times for roofing and flooring and has long been exploited in the Kirkby Moor district. There are numerous trials and abandoned quarries in the area of map sheet SD28 but the main slate quarries in this district are situated to the north-east of Kirkby-in-Furness. The quarries on Kirkby Moor remain the most productive in England and are worked by Burlington Slate, the first commercially established slate company, founded in 1843. Slates not used locally were shipped out by sea but construction of the railway in 1846 began the major productive period, which lasted until the second world war. Production peaked in 1900 when Burlington Slate produced 8100 tonnes of roofing slate, but thereafter production gradually declined (Stephens Associates, 1988). The declining demand for roofing slate during the 20th century has in part been offset by a more recent growth in demand for monumental and architectural purposes; much of this slate is now exported. There is also a demand for random walling stone which is met by the trimmings from sawn blocks. In 1990, Burlington Slate produced some 5000 tonnes of roofing slate, most of which was the 'blue-grey' type from Kirkby Quarry, and 2000 tonnes of structural and architectural products; the latter were predominantly 'green slates' from the Borrowdale Volcanic Group. Current extraction rates of saleable materials at Kirkby Quarry are typically in the region of 100,000 tonnes per annum and can be categorised as follows:

- Slate sales – 3,300 tonnes per annum
- Stone (tiles) sales – 1,000 tonnes per annum
- Aggregates (combined landscaping and construction) sales – 79,000 tonnes per annum
- Others (walling, paving, off-cuts, lintels and waste) sales – 16,700 tonnes per annum

Large tips testify to the wasteful nature of slate production, although stone for walling, flooring slabs and other construction work were by-products. Only one working quarry remains, Kirkby quarry at SD 25 84 (Fig. 1), owned by the Burlington Slate Co. A history of this quarry and of the local industry is provided by Geddes (1975).

Geological controls of slate formation

The Wray Castle and Brathay formations of the Windermere Supergroup have been quarried for roofing slate around Kirkby-in-Furness since at least the 17th century. Slate was formed during the Early Devonian, Acadian Orogeny, when a slaty cleavage was imposed on the Ordovician and Silurian rocks. The best slate, with the most even and regular cleavage was formed from the lithologically uniform mudstone successions. These slates are locally referred to as 'blue-grey' to distinguish them from the 'green' slate found farther north in the Borrowdale Volcanic Group. The best quality slate on Kirkby Moor occurs where the cleavage is perpendicular to bedding. Because the slaty cleavage is steeply dipping and essentially axial planar to folding, these conditions occur in fold hinge zones and where bedding dips are low. Economic volumes of slate, with cleavage at high angles to bedding, are found in closures of folds with box-like shapes, effectively double hinge folds (Figure 2). A narrow slate band with low bedding dips at Gawthwaite High Quarry (SD262 843), on the crest of the Lowick anticline, was exploited in the past but its width means it cannot be worked economically at the scale of modern operations. Top quality slate is rarely found in the cores of tight angular folds because of the intense brittle fracturing that is usually present there and the limited extent of hinge zones. This variability makes slate production very wasteful and it is generally recognised that up to 95 per cent of quarried rock was discarded in earlier operations. Now that the range of uses for the quarried rocks has expanded, waste has

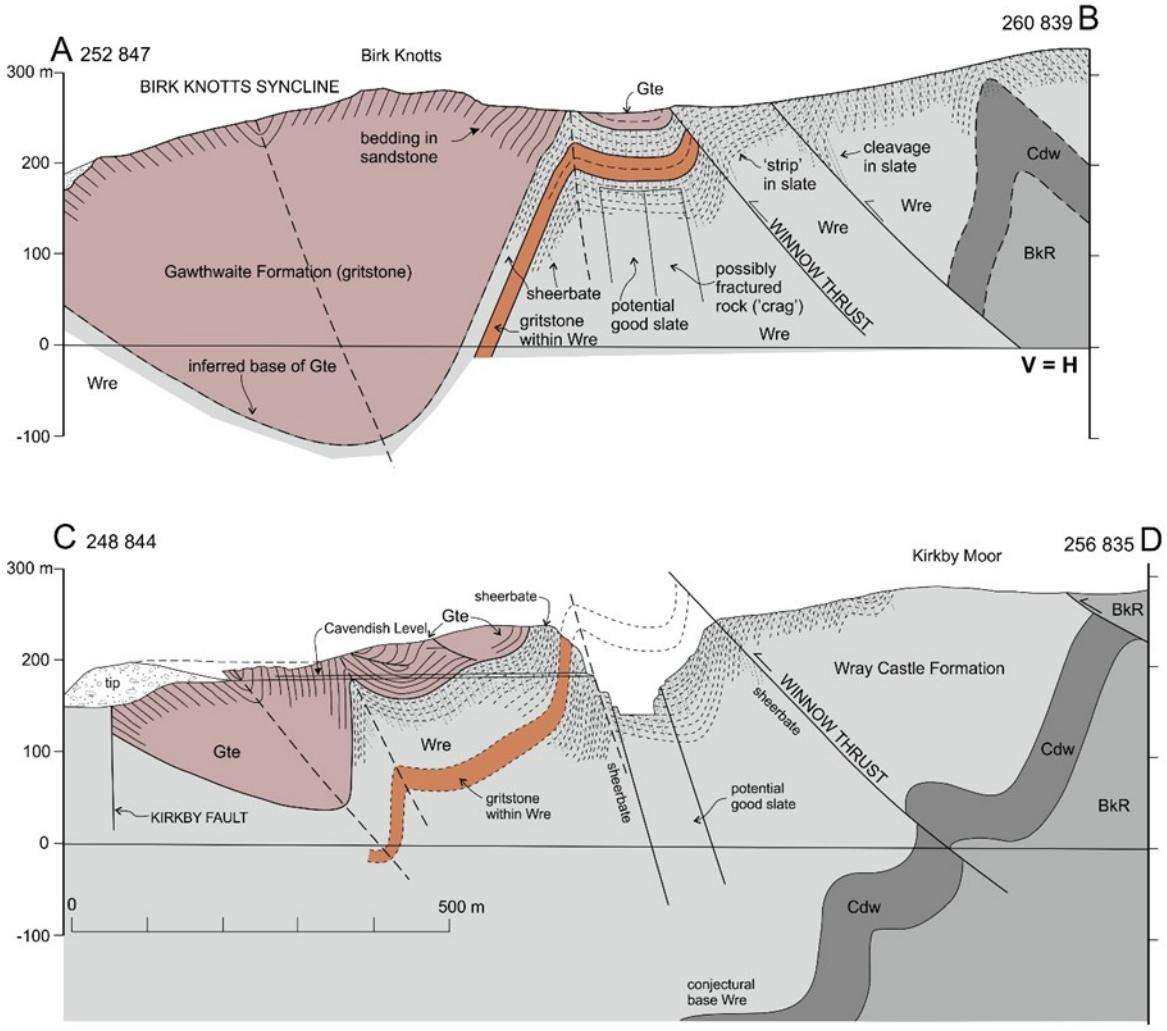


Figure 2 Geological cross-sections along the lines A-B and C-D shown on Fig. 1.

been reduced.

Kirkby Quarry (SD249 840) works slate from the Wray Castle Formation on the north-west flank of the Lowick Anticline (Soper, 1994). There, despite considerable regional structural complexity, a zone of silty mudstone with low dips extends for 750 m along strike and is up to 50 m wide (Figure 2). A uniform, upright planar cleavage passes through the laminated siltstone and thin mudstone interbeds without refraction. The interbeds are spaced uniformly at about 10 cm intervals and give the slates their characteristic banded appearance known as "strip" (a glossary of quarrymen's terms is given below). Siltstone interbeds present a problem as they cannot be "rived" across. The zone of low dips is flanked by steeply dipping strata where cleavage and bedding intersect at a small angle causing the rock to split unevenly along both bedding planes and the cleavage, a feature known as 'sheerbate' by the quarrymen. There are several beds of bentonite (rhyolitic air-fall tuff) up to 0.2 m thick within the sedimentary succession which, being well spaced, provide 'master' bedding planes that formerly aided quarrying.

The cleavage is of 'pressure solution' type, caused by the dissolution of quartz, and other minerals, at grain contacts under stress in the presence of pore fluids. The fabric consists of seams of less soluble material, mainly clay minerals and opaques, that are approximately planar but anastomose on the microscopic scale providing the plane of easy splitting. Slates split best when freshly quarried, due perhaps to stress relaxation.

Extraction methods

Large slate quarries in a hillside location were formerly worked as open pits with near-horizontal access tunnels (levels) that also provided drainage. The present large quarry has developed by the amalgamation of several earlier quarries along the zone of good slate, called Fisher's, Smithy Hill, Town, and Lord's, respectively from NE to SW. Deepening of these led to the progressive abandonment of access tunnels whose entrances can be seen in the NW wall of the quarry. In 1962 Cavendish level was considerably enlarged and used for vehicular access. Subsequently, with the acquisition of dumper trucks and other large plant, a surface access road has been made and Cavendish level abandoned. The quarry bottom is at present 140 m AOD in the former Fisher's and Town's sites and drainage is via Lady Evelyn level at about 150 m AOD. Further deepening to 95 m AOD is underway and this will require pumping.

Before the advent of wire saws natural structural features were utilised in the extraction of blocks of slate. The important features are side-seams (cross joints), slipes (cleavage-parallel joints) and feet (bentonite beds) - see glossary. Blocks weighing many tons were removed using black powder in shot holes drilled along slipes and side-seams, or in the absence of the former, drilled down the cleavage, a convenient foot forming the base of the block. Blocks were reduced to handleable size by further blasting or splitting with hand tools (tully and mell), removed to the processing sheds, sawn to size, split into slates, and trimmed. This method produced a sloping quarry floor, since even the most gently-dipping beds have a dip of about 18° to the NE equal to the fold plunge. This had to be levelled (by 'stumping') before further deepening could be undertaken, a wasteful process. The belt of low dips at Kirkby Quarry appears to be the only example in the area that is large enough for slate production under current economic conditions.

The introduction of endless wire saws (developed in Italy for marble extraction) allows a level quarry bottom to be maintained and minimises the need for blasting. Two intersecting horizontal holes are drilled at right angles, one parallel and one normal to the cleavage, the wire passed through by compressed air, and a horizontal cut made. Blocks are still removed by small blasting charges placed in shot holes along joints. Much of the production is now of sawn slabs for architectural use, though traditional roofing slates are still made. Processing of green slate, from Burlington quarries in the Borrowdale Volcanic Group, is also concentrated at Kirkby Quarry. Reserves of 'Burlington blue-grey' slate are large, since the Wray Castle Formation in the zone of gentle dips probably extends down to near sea level. Prospects of following the slate north-eastwards are less good, as the NE plunge means that increasing overburden has to be removed and the belt of workable slate also appears to narrow in that direction. The glossary that follows contains further information on the geology and working practices.

Glossary of geological terms used in Kirkby slate quarries

BACKWAY See **BATE**.

BAR Seen as bands in every slate. Muddy turbidite layers. Also known as **BLUE BANDS** or **STRIPS**.

BATE Cleavage. The plane of cleavage strikes at about 240^{o} and dips steeply to the SE. Cleavage-parallel rock faces on the NW side of the quarry are thus inclined less than the vertical and this side is known as the **RIGHTWAY**; on the SE side the faces overhang and this is called the **BACKWAY**.

BATE HOLE A hole for blasting drilled along the bate/ slaty cleavage. Nearly all holes were drilled in this direction but those perpendicular to **BATE** are **CROSS HOLES**.

BURSTS – offset rives.

CANT Describes the departure from the vertical of the slaty cleavage. Much easier to work towards the **BACKWAY**.

CLOG A large piece of extracted rock after it has been prepared for transport out of the quarry to the riving shed.

CLOG RIVERS Men who reduced in size large pieces of extracted rock to **CLOGS.**

COMPANY Typically a team of four **ROCKHANDS**, three **RIVERS**, one **DRESSER**, and one apprentice.

CRAG Fractured rock which does not rive cleanly.

CUT WAY See **DOCK**

DEAD HORSE Slate already paid for (alternatively labelled E.B. i.e. bought by the Earl of Burlington's company).

DEAL Weathered rock, where water has got into the bate and caused lots of offset rives (bursts) therefore not allowing a clean rive to be made. The rock can appear crumbly and rotten in extreme cases.

DOCK Verb - to break a piece of rock 'cross-bate', i.e. in any direction that is normal to the cleavage plane. Large pieces were formerly docked with **TULLY** and **MELL** (now sawn), smaller pieces with hammer and chisel. Kirkby slate can be docked cleanly almost in any plane at right angles to the cleavage, by placing the chisel across the cleavage. The exception for Burlington slates is that it cannot be docked along the trace of the bedding on the cleavage plane [the cleavage/bedding intersection lineation]. This suggests that the ellipsoid which describes the cleavage strain at Kirkby Moor is oblate, with its near-circular section in the plane of cleavage. Green slate from the Borrowdale Volcanic Group can be docked cleanly in only one such direction, which is known as the **CUT WAY**. This is probably parallel to the principal extension direction of a non-oblate strain ellipsoid.

DRESSER Worker who trimmed the roofing slates to shape and size. A range of terms was applied to different sizes such as **BEST PEGGIES** which are 10 to 14 inches long.

DRESSING BRAKE Iron bar on which the slate was placed during dressing.

DRIVER Boys in charge of horses and waggons removing waste rock from tunnel-driving operations.

FOOT A 'master' bedding plane, along which the rock breaks. Most feet are bentonite beds, from a few cm to several tens of cm in thickness, and are usually accompanied by vein quartz. Before the introduction of wire saws, the feet were much utilised in the extraction of large blocks. **HUNGER FOOT** A bed of poor slate [bad rock] that could significantly reduce the earnings of a company hence a lack of food.

GARTER Very thin impure bentonite beds, not accompanied by vein quartz, which are not planes of weakness: the rock can be 'rived across' them.

GINNLE/GINGLE The first opening in a solid face usually made by blasting a weakness such as a fault zone [rammle/ramble] or a slipe.

GRAIN [see **DOCK**] The direction in which a slate can be most easily broken at right angles to the bate/slaty cleavage.

JACK Gunpowder.

JUMPERS Lengths of steel drilling rod.

LEVEL A tunnel.

MAIN A barrier in the quarry where levels/tunnels reached the void.

MELL Sledge hammer, a dialect word from the Norse.

METAL Slate that can be riven; "good metal" is the finest splitting rock.

PINNEL Unconsolidated surficial deposit; usually fluvioglacial material or head.

PRICKER & BEATER A pricker was used to push a hole into a pill of dynamite to allow insertion of a detonator; a beater is used to firm the stemming in a shot hole.

RAMMLE Fault breccia; a dialect word meaning 'rubbish'. Also known as **RAMBLE**. Tunnels driven along these zones did not consume good slate. Likewise if they could be followed up a **RISE** once the new quarry had been reached this also saved good metal.

RID A group/company of less-skilled workers who removed broken rock that had no value.

RIGHT WAY See **BATE**.

RIVE Verb, to split; a dialect word from the Norse. Kirkby slate can split in any direction parallel to the cleavage; green slate from the Borrowdale Volcanic Group has a preferential splitting direction in the cleavage plane, the **CUT WAY**, which is parallel to the preferential docking direction.

ROADS The levy applied to monies paid to companies to cover costs involved for example in work done by people such as Driver Boys and Tippers.

ROCKHAND Men working on intact rock at Quarry Bottom.

ROUNDHEAD A roofing slate with the two top corners cut away (Best Round – thinnest; Second Round – thicker; Thirds – variable thickness).

SAW-GATES Vein quartz along a fault (usually in arrays) – renders the rock useless for riving into slates and is not popular in architectural applications.

SEAM A joint or small fault (see **SIDE-SEAM**).

SEAMY FOOT Poor quality slate adjacent to a bentonite bed.

SHEAR LEGS A manual crane.

SHEERBATE On fold limbs where the bedding is steeply inclined, and particularly where it is inverted and dips steeply SE, the angle between bedding and cleavage is small. The rock cannot be riven into slates parallel to the cleavage, but tends to split both along the cleavage and along particular bedding planes, spaced at about 5 cm intervals, which have a polished appearance, hence the term 'sheerbate'. Numerous extensional joints and veins on the fold limbs also make sheerbate rock unsuitable for slates.

'Sheerbate Flags' was a stratigraphic term formerly used for one of the slate bands within the Coniston Grit Group which exhibited these characteristics along much of its outcrop; it is now known as the Latrigg Formation.

SIDE-SEAM A cross-joint. In Kirkby Quarry a prominent joint set strikes roughly normal to the fold traces, but dips steeply to the NE, so that the joints are not normal to the fold axes. Some carry quartz fibres, but show little offset of the bentonite beds.

SILLAR Unconsolidated gravel or shaly material.

SINK Driving of another working into the quarry floor "sinking".

SKULL ROCK A slight bend in the bate/slaty cleavage.

SLIPE A cleavage-parallel joint. Side-seams and slipes are much utilised in the extraction of large blocks of slate rock.

STRIP/BLUE BAND Unlaminated mudstone beds (muddy turbidites), a few cm thick, which occur at intervals of a few tens of cm throughout the laminated silty mudstones of 'Brathay facies' that produce the blue-grey slates in the Kirkby slate belt. The strip does not constitute a plane of weakness; the slate can be 'rived across' it because the slaty cleavage does not change its orientation in the blue band.

STUMPING Refers to the construction of a level floor to the quarry after removing slate on an inclined bed (**FLOOR**). This required blasting and wasted good slate.

THREAD A thin bed of ripple cross-laminated siltstone within the laminated facies, often the lower part of a silt-mud couplet. The slate does not rive well across it, possibly because of cleavage refraction.

TUB and CORRACK Corrack is a hoe like tool used for scraping waste material into the tub which was an open fronted receptacle with handles on either side used to deposit the waste into a rail bogey.

TULLY Long-handled hammer with wedge-shaped head.

WAY ENDWAY describes working the quarry parallel to the strike of the cleavage. The faces cut along the cleavage are the **RIGHTWAY** and **BACKWAY** faces and the **ENDWAY** faces are at right angles to them. In the green quarries where cut-way is at an angle in the rock face you have overhanging endway and sloping away endway, these have been referred to as backway-endway and rightway-endway!

WHITTLE Dressing knife.

WRINKLE A kink-band which affects the cleavage and renders the rock unsuitable for riving into slates.

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