Whin Sill exposures in Upper Teesdale, County Durham

High Force [NY 880 285]–[NY 885 286], Low Force [NY 903 281]–[NY 912 273], Falcon Clints [NY 815 285]–[NY 829 283], Cauldron Snout [NY 814 286], Cronkley Fell [NY 831 282]–[NY 854 282]

S.C. Loughlin

Introduction

Upper Teesdale contains a number of classic exposures of the Great Whin Sill, which combine textbook examples of features associated with sill intrusion with spectacular landscapes. The abundant features include the presence of baked sedimentary rocks at the upper and lower contacts of the sill, rafts of baked sedimentary rock within the sill, variations in grain size relating to cooling history, and transgressions where the sill changes level within the country-rock succession. Bands of very coarse-grained pegmatitic facies and felsic veins representing the final products of crystallization are well exposed. In places, joint and fracture surfaces are covered with the zeolite pectolite, which crystallized at a late stage in the cooling of the sill. There are also good examples of the bleached and altered sill-rock known as 'white whin', which is caused by the circulation of mineralizing fluids. The alteration of the sill by these fluids suggests that it pre-dates the northern Pennine mineralization. The Great Whin Sill is at its thickest (73 m) and occurs at its lowest stratigraphical level in Upper Teesdale. From here, the sill thins and rises in stratigraphical level in every direction, forming a 'saucer-shaped' intrusion (A.C. Dunham, 1970; Francis, 1982).

Upper Teesdale is a popular area for students and amateur geologists, which is reflected in the number of field guides and popular accounts of the area (e.g. A.C. Dunham, 1970; Johnson and K.C. Dunham in Johnson, 1973; Skipsey, 1992; Senior in Scrutton, 1995).

Description

The Teesdale Fault, which trends northwest–south-east along the upper part of Teesdale, has a downthrow to the north-east. Hence, to the south-west of the fault are the lowest Visean strata exposed in Teesdale, whereas to the north-east are strata that extend up through the Yoredale Series into the Namurian succession. The Great Whin Sill is here intruded into low stratigraphical levels, around the Melmerby Scar Limestone, and hence its outcrop is mostly restricted to the south-west side of the Teesdale Fault, where the valley sides are dominated by long crags of dolerite (Figure 6.21).

The margins of the Great Whin Sill are commonly fine grained and chilled, with a thin black skin that has commonly been described as glassy, although true glass may not be present. Moving away from the margins, the grain size increases to 2 mm (K.C. Dunham, 1948). Grain-size analyses have shown that the percentage of microphenocrysts increases towards the centre of the sill (Strasser-King, 1973; A.C. Dunham and Strasser-King, 1982). The quartz-dolerite of the main part of the sill is composed typically of 48% plagioclase, 29% clinopyroxene, 7% iron-titanium oxides with small amounts of orthopyroxene, pseudomorphs after olivine, chlorite, amphibole, carbonates, sulphides and apatite.

High Force

The spectacular waterfall of High Force [NY 880 284] cuts a classic section through the lower 7.3 m of the Great Whin Sill and the underlying sedimentary rocks. The waterfall lies at the head of a 300 m-long gorge in which the sill and associated sedimentary rocks are well exposed in the walls (Figure 6.22). The sill has strong vertical jointing giving a pseudo-columnar appearance to the rock. At the waterfall a sheet of dolerite is separated from the main sill by a thin raft of baked mudstone. The sill overlies baked sandstone and indurated mudstone and dark recrystallized fossiliferous carbonates of the Tyne Bottom Limestone; a good example of the contact with baked mudstone is exposed along the side of the path leading to the waterfall from the main road at High Force Hotel [NY 884 287]. The section at High Force is as follows (thicknesses based on Clough, 1876):

Dolerite (Great Whin Sill)	7.31 m
Altered mudstone	0.45 m
Dolerite sill	1.82 m
Baked sandstone	3.65 m
Mudstones and limestones (Tyne Bottom Limestone)	9.75 m

High Force Quarry [NY 879 290] (also known as 'Hargreaves Quarry') lies 400 m WNW of the High Force Hotel and provides an excellent section through the central and upper part of the Great Whin Sill. Based on evidence from borings around Ettersgill [NY 882 299], the sill is about 70 m thick at this locality (K.C. Dunham, 1948). The quarry faces reveal considerable variations in grain size and excellent examples of coarsely pegmatitic quartz-dolerite within the 'normal' dark-grey quartz-dolerite. The pegmatitic facies occurs as flat-lying sheets up to 30 cm thick and is characterized by elongate, bladed crystals of black augite up to 50 mm long and smaller laths of plagioclase. Radiometric determinations on grains of baddelyite (ZrO_2) from the pegmatites at this quarry have yielded a weighted mean $^{206}Pb/^{238}U$ age of 297.04 ± 0.4 Ma (M.A. Hamilton and D.G. Pearson, pers. comm., 2002), the most precise date yet obtained from the Whin Sill-complex. Intersertal micropegmatite also occurs with accessory hornblende, biotite and chlorite. Some of the strong vertical joint faces are coated with chlorite, calcite and white radiating crystals of pectolite (a zeolite) up to 5 cm in length.

Low Force

Between Scoherry Bridge [NY 910 273] and Low Force [NY 903 277], the River Tees cuts an excellent section through Carboniferous sedimentary rocks down to the upper contact of the Great Whin Sill. The strata and the sill dip to the east or south-east at an angle just greater than the gradient of the river and hence a traverse upstream, to the north-west, is down the section. The Cockle Shell Limestone overlies sandstone, mudstone and then the Single Post Limestone, which has been baked and recrystallized to a soft, white, crystalline marble. Sandstones and mudstones beneath this limestone are also extensively altered and indurated. The upper contact of the sill is extremely sharp and it is well exposed along the north bank of the river.

Near the south-eastern end of the sill outcrop the dolerite has a bleached appearance where it has been altered to 'white whin' (see 'Introduction' to this chapter). The alteration has occurred around a series of thin anasto-mosing mineral veins, which, though barren within the sill, may be followed up through the succession and into an area of mineralization within the Single Post Limestone. The mineral veins and replacement deposits found here contain sphalerite, siderite and pyrite.

Farther upstream, just below Wynch Bridge [NY 904 279], a 74 m-long 'raft' of baked silt-stone lies within the upper part of the sill, dipping at an angle of *c.* 20°. It is in sharp contact with the surrounding chilled dolerite. Low Force is a series of rapids where the river flows over columnar-jointed dolerite, just upstream from Wynch Bridge.

Cronkley Fell

On the south bank of the River Tees in Upper Teesdale, the Great Whin Sill forms a 3 km-long line of cliffs known as Cronkley Scar [NY 834 280]–[NY 852 285]. At this location the sill is intruded in an irregular manner into the recrystallized Melmerby Scar Limestone near the base of the Carboniferous sequence, and a steeply inclined raft of saccharoidal limestone crops out within the dolerite at Skue Trods [NY 848 289]. The upper contact of the sill is clearly exposed on the hill-top, where it transgresses from the Melmerby Scar Limestone up into the overlying Robinson Limestone, which is also thermally metamorphosed [NY 842 285]. This excellent example of the transgressive nature of the sill contrasts with the very constant level of the sill a short distance to the east at Noon Hill [NY 861 271]. At Noon Hill the sill passes almost unaffected through the Burtreeford Disturbance, an east-facing faulted monocline. Hence, to the east of the monocline it is above the Tynebottom Limestone, whereas to the west it intrudes much lower beds (i.e. the Melmerby Scar Limestone).

Falcon Clints and Cauldron Snout

Cow Green Reservoir covers the site of Cow Green Mine which worked extensive veins of galena and baryte. Small mineral veins occur throughout this area and many were worked until the 1950s. At Cauldron Snout [NY 814 286], just 300 m south-east of the reservoir dam, the River Tees cascades spectacularly down columnar-jointed crags formed from the main body of the Great Whin Sill (Figure 6.23). In addition to typical dolerite, layers of coarse pegmatitic dolerite may be observed and radiating aggregates of pectolite occur as coatings on joint surfaces.

The sill also forms a cliff known as 'Falcon Clints' [NY 816 284]–[NY 827 281], which extends for over 1 km along the north side of the Tees valley, to the east of Cauldron Snout. The basal contact of the sill with the recrystallized (sugary textured) limestone of the Melmerby Scar Limestone and the altered upper part of the Orton Group is clearly exposed close to the foot of the crags. The thermal alteration of the sedimentary rocks is pronounced in this area both above and below the sill and, on weathering, it generates a thin soil that supports the relict arctic alpine flora (e.g. *Gentian verna)* for which the area is well known (Johnson *et al.,* 1971).

Interpretation

The earliest debate about the origins of the Whin Sill focused on the sections in Upper Teesdale, where it was widely believed that the sill is conformable with the surrounding sedimentary rocks (hence the term 'Whin see 'Introduction' to this chapter). Sedgwick (1827) provided very good evidence for the intrusive nature of the sill in Upper Teesdale but, because it appeared to follow almost the same stratigraphical horizon throughout the area, there were those, especially within the mining community, who continued to doubt the evidence (e.g. Hutton, 1838). Phillips (1836) described the sill as a conformable bed, citing the High Force section as an example, but detailed work by the Geological Survey conclusively demonstrated the intrusive nature of the sill in Teesdale (Clough, 1876). Clough presented evidence that the sill is not conformable with underlying sedimentary rocks in the High Force section and also drew attention to the irregular nature of the basal contact, where apophyses of dolerite branch off from the main sill.

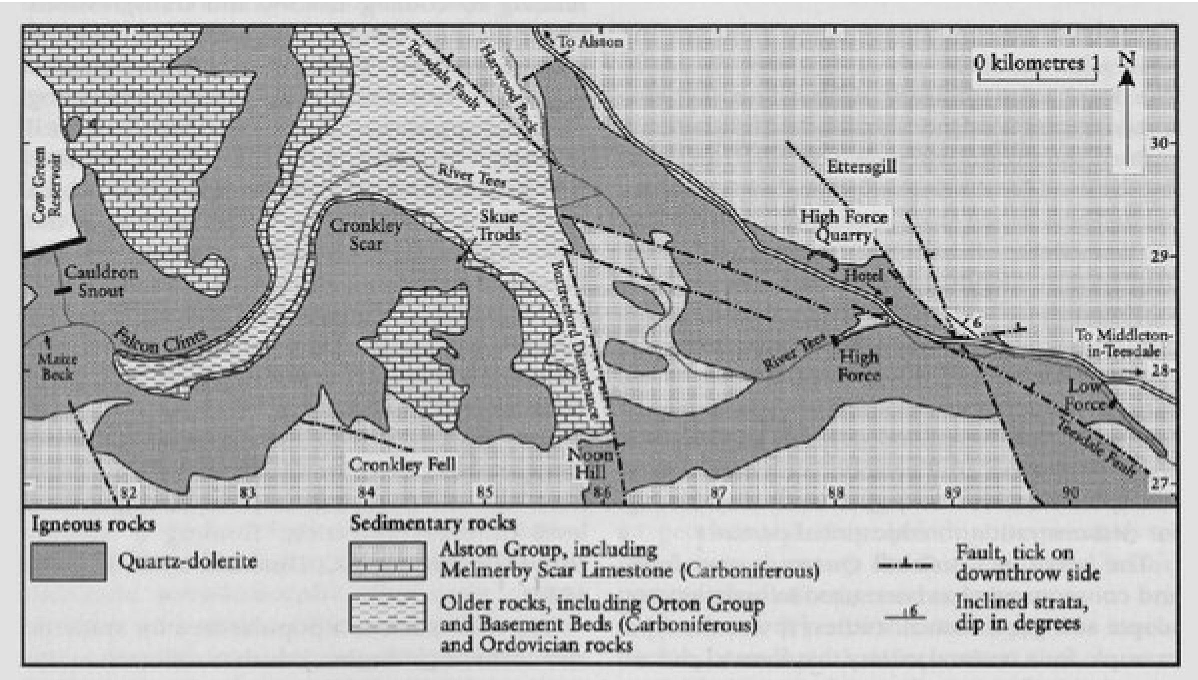
The field relationships revealed at this GCR site are now regarded as type examples of the features required to prove the intrusive character of a sheet of igneous rock. For example, thermally metamorphosed sedimentary rocks at both the lower and upper contacts are clearly demonstrated at High Force, Low Force and at Cronidey Scar. The fine-grained nature of the sill close to both contacts is evidence for rapid chilling of the intruded magma against a cooler host rock (columnar jointing is also an expression of cooling between two surfaces although it also commonly develops in lava flows). At a glance the Great Whin Sill does look conformable with the sedimentary rocks at several places in Upper Teesdale but closer inspection shows that most contacts are in fact transgressive; this is demonstrated extremely well at Cronkley Scar but also on a smaller scale at High Force. Both the upper and lower contacts are transgressive and the occurrence of blocks or rafts of sedimentary rock within the dolerite that have clearly detached from the overlying host rock provide further evidence for intrusion.

The Great Whin Sill attains its greatest known thickness of over 70 m in Upper Teesdale. Hence cooling was slow, possibly having taken about 60 years, according to A.C. Dunham and Kaye (1965). Several features can be attributed to the later stages of this slow cooling, such as the sheets of pegmatitic dolerite and felsic veins that are best seen in this area. The radiating growths of pectolite on joints are also considered to have formed during the late stages of cooling, as hydrothermal fluids circulated through the jointed rock (Wager, 1929a,b; Smythe, 1930a). The mineral veins that cut the sill near Low Force, altering it to 'white whin', are particularly significant because they prove that the sill was emplaced prior to the local mineralization event, which is part of the regional northern Pennine mineralization.

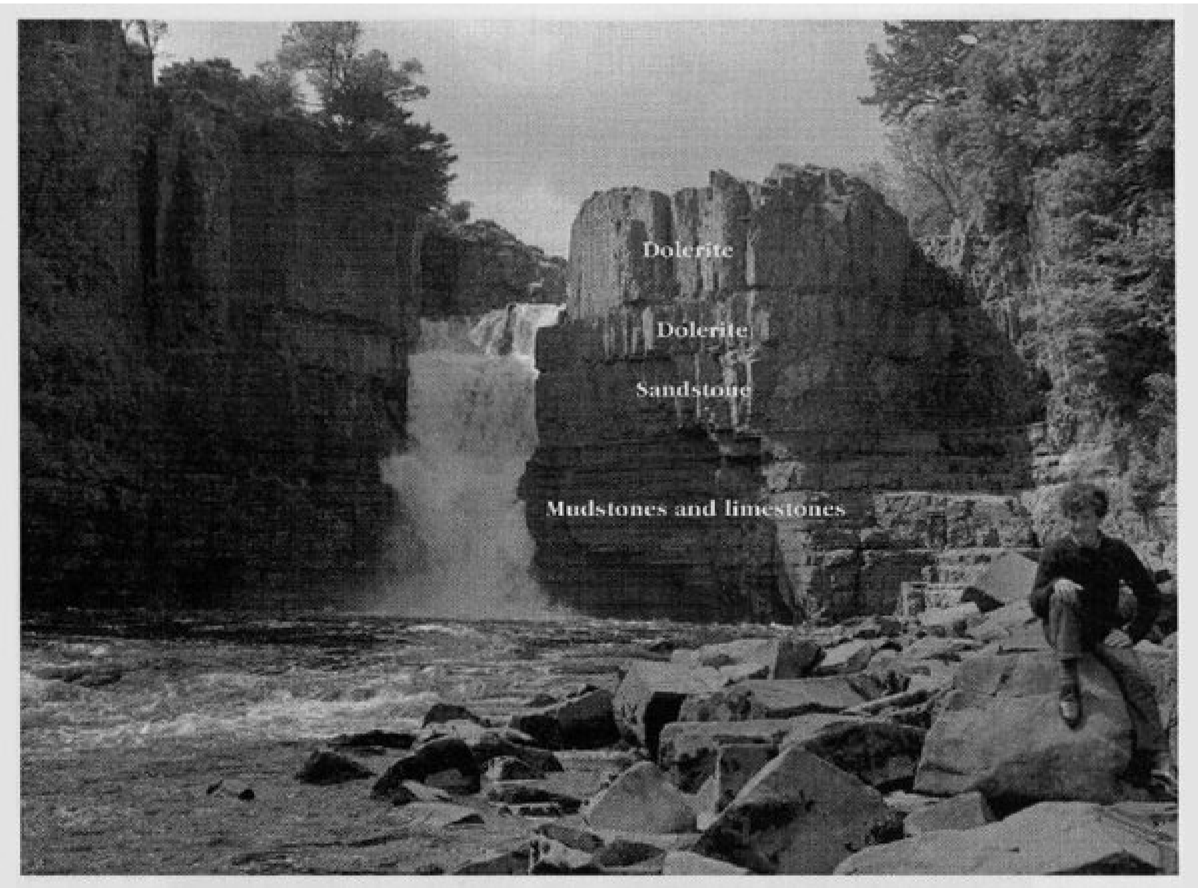
Conclusions

The Upper Teesdale GCR site provides a number of classic and scenic exposures of the Great Whin Sill, which demonstrate clearly most features associated with sill intrusion. The sill represents an extensive magma body intruded between layers of Lower Carboniferous sedimentary rocks. Outcrops reveal superb examples of chilled margins, thermally metamorphosed sedimentary rocks at upper and lower contacts, transgressive upper and lower contacts, rafts of baked roof material incorporated in the sill, and columnar jointing. This is the thickest part of the Great Whin Sill and excellent examples of very coarse-grained pegmatitic dolerite, formed during slow cooling, are exposed. A very precise radiometric date of 297.4 Ma has been obtained from this pegmatitic facies. During the late-stage cooling of the sill, hydrothermal fluids deposited the hydrous zeolite mineral pectolite on joint surfaces, and in places the fluids associated with mineral veins have altered the quartz-dolerite to 'white whin'. The latter relationship suggests that the widespread northern Pennine mineralization post-dated emplacement of the sill, which therefore provides a maximum age for this major ore-field.

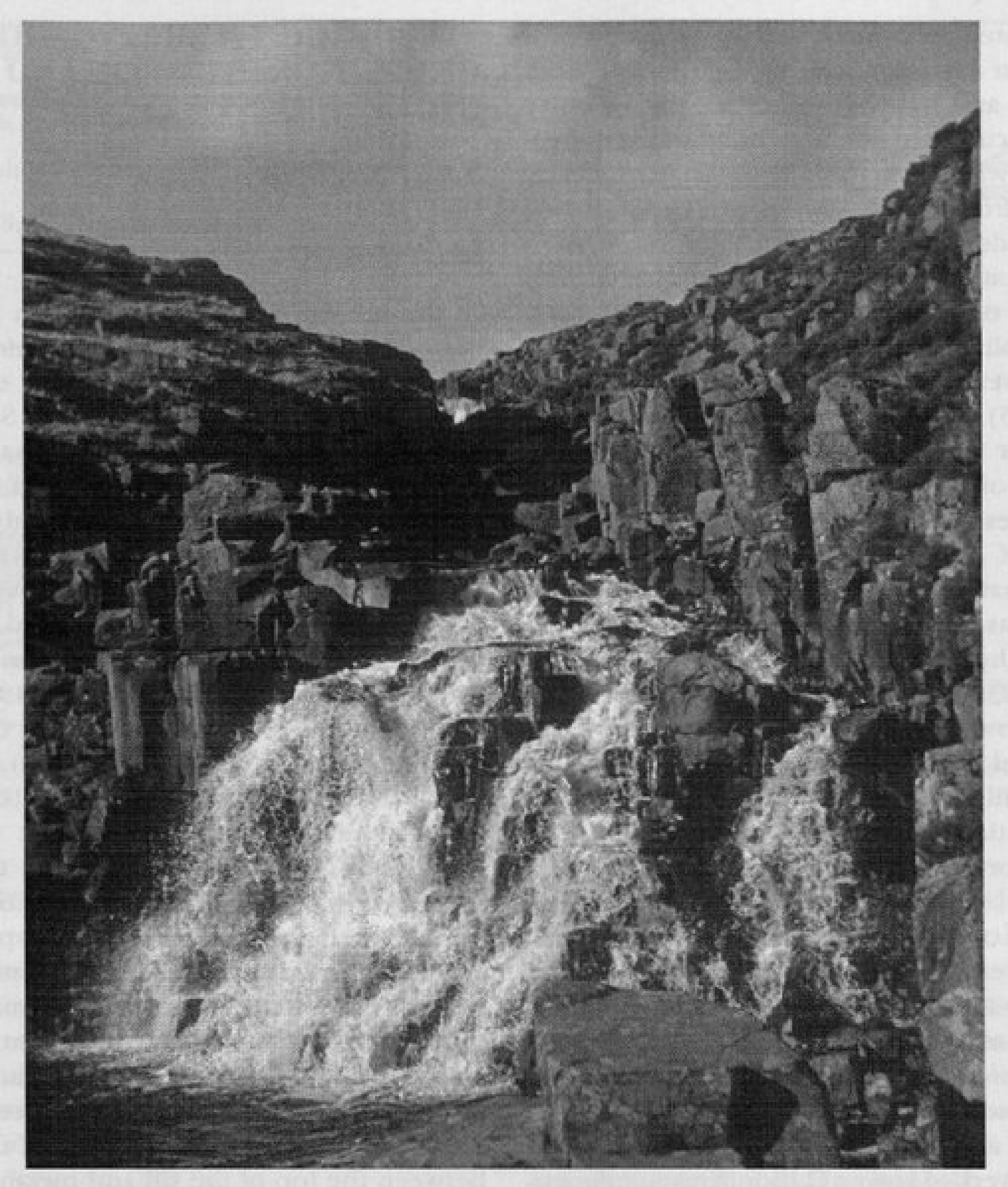
References



(Figure 6.21) Map of the outcrops of the Great Whin Sill in the Upper Teesdale area. Based on Geological Survey 1:50 000 sheets 25, Alston (1965); and 31, Brough-under-Stainmore (1974).



(Figure 6.22) Quartz-dolerite of the Great Whin Sill (upper half of the cliff) at High Force, Upper Teesdale. The two highest layers of massive rock are dolerite, separated by a thin raft of baked sedimentary rock forming a plane of weakness near the top of the waterfall. Beneath is a thick bed of baked sandstone, resting upon well-bedded mudstones and limestones of the Tyne Bottom Limestone in the lower half of the cliff. (Photo: British Geological Survey, No. LFP00382, reproduced with the permission of the Director, British Geological Survey, NERC.)



(Figure 6.23) The Great Whin Sill exhibiting large-scale columnar jointing at Cauldron Snout, Upper Teesdale. (Photo: D. Stephenson.)