Budle Point to Harkess Rocks, Northumberland

[NU 163 361]–[NU 177 355]

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Introduction

Coastal exposures to the west of Bamburgh village, Northumberland show the Great Whin Sill in extremely complicated contact with the host Carboniferous sedimentary rocks. At the Budle Point to Harkess Rocks GCR site, the sill encloses a variety of large rafts and blocks of sedimentary rock that dip in various directions and show varying degrees of contact metamorphism. It seems probable that the sedimentary beds were disrupted, perhaps by faulting, prior to intrusion of the sill. The basal and upper contacts of the sill are irregular and cut up and down the sedimentary succession throughout the site. At Budle Point the upper part of the sill is vesicular, with sinuous flow structures, suggesting that it was intruded at quite a shallow depth. Hydrothermal alteration has occurred close to ENE-trending veins that carry baryte and pyrite, and carbonate-filled fractures may indicate post-emplacement faulting.

This is the most complex of the GCR sites that represent the Whin Sill-complex. The extreme complexity has provoked much interest and many authors have attempted to describe and explain the relationships (e.g. Tate, 1868; Lebour and Fryer, 1877; Lebour, 1886; Carruthers *et al.,* 1927; Smythe, 1930b). Tate (1868) and other early authors described the outcrops but their field sketches were commonly stylized. Short descriptions of the exposures by Randall and Senior can be found in an excusion guide (Scrutton, 1995).

Description

Some 500 m north-west of Bamburgh Castle [NU 184 350] the Great Whin Sill is exposed on the foreshore for about 2 km between Harkess Rocks and Budle Point (Figure 6.30). The sill and the Carboniferous sedimentary rocks into which it is intruded generally dip gently towards the east but there is some minor folding. The sill lies above the Brigantian Oxford Limestone near Bamburgh Castle (outside the GCR site) where it can be seen cutting transgressively through cross-bedded red sandstones, but it lies close to the Budle Limestone at Budle Point [NU 163 361].

The shoreline is devoid of exposures for several hundred metres between Bamburgh Castle and Harkess Rocks, suggesting that the south-eastern margin of the rocks may be fault-controlled. At Harkess Rocks [NU 177 356] the sill is sub-horizontal and the upper chilled surface is exposed on the foreshore, the overlying sedimentary rocks having been completely removed by erosion (Figure 6.31). Close to the chilled surface is a zone of elongate and flattened vesicles, generally up to about 30 cm long by 20 cm wide and little more than 10 mm deep, although some have been recorded that are several metres long. Some are filled with quartz and a little calcite. Scattered about the sub-horizontal surfaces are areas of concentric curving ridges reminiscent of the surface patterns on pahoehoe lavas, but in miniature. These have been termed 'ropy flow structures' (Lebour and Fryer, 1877; Smythe, 1930b) and have been interpreted as having formed on the lower inside surfaces of the flattened vesicles. They have been exposed as the upper parts of the vesicles have been eroded away. Similar flow structures have been observed near to sub-horizontal contacts of the Holy Island intrusion (Randall and Farmer, 1970; see Holy Island GCR site report).

Large inclusions of sedimentary host rock occur within the quartz-dolerite throughout the Harkess Rocks area. Near the south-eastern edge of Harkess Rocks an inclusion of sandstone 11 m long dips steeply to the NNE. Farther to the north at the low-tide mark is a large mass of indurated mudstone, which extends for about 150 m and contains a dyke-like intrusion of quartz-dolerite, 16 m long. This mass of mudstone is surrounded by quartz-dolerite, but farther to the north and west small, thin skins of indurated mudstone lie directly on the fine-grained upper surface of the dolerite. The sill transgresses up through mudstone towards the north and numerous small mudstone inclusions may be observed within the quartz-dolerite along the shoreline.

Two ENE-trending fracture zones, about 25 m apart and with several splays, contain thin veins with baryte and pyrite in places. Between the two fracture zones is a chaotic zone of large blocks of sedimentary rock and irregular intrusions of dolerite. One block of white, rippled, fine-grained sandstone dips south-west at about 10° and just to the east of this, another mass of coarser sandstone dips east at about 60°. These sandstone bodies are clearly enclosed by quartz-dolerite. On the north side of the fracture zones, a thin bed of blue-grey recrystallized limestone dips NNW at about 30° and this is overlain by sandstone that crops out over a distance of about 30 m to the north to where it is overlain by the dolerite sill. The basal contact of the sill is magnificently exposed at the long low cliff extending to the ENE from the lighthouse and known as the Stag Rock [NU 175 359]. The rocks here dip north-west at 10°–15° but curve around to dip just east of north at low-water mark. The contact transgresses the Budle Limestone and the immediately underlying and overlying mudstones and sandstones, cutting both up and down, usually in steps of 1–2 m along vertical joint or fault planes.

Near the lighthouse, the sill contains several rafts of varying size, up to 25 m long and 1 m thick, of blue-grey recrystallized limestone. In the vicinity of the larger rafts, the quartz-dolerite is cut by numerous thin carbonate-filled fractures. Further inclusions occur in the near-continuous exposures of dolerite that extend to the west of the lighthouse for at least 350 m. Most are irregular-shaped bodies of limestone and/or mudstone, with sharp angular outlines and varying in size from several centimetres to several metres. The dips of the bodies vary in direction and degree although there is a tendency towards northerly dips.

Near Budle Point the lower 1.5 m of the sill is amygdaloidal; the amygdales are typically calcite-filled. The sill overlies altered sandy mudstone, and west of Budle Point it terminates sharply against a NW-trending lineament, which is probably the line of a fault. West of this fault, irregular apophyses of dolerite can be seen protruding into almost flat-lying limestone, which extends for a further 200 m along the shoreline.

Some of the beach sands at Budle Bay are pinkish or purple in colour due to a high content of garnet (up to 45%). The garnets are thought to have been derived from Carboniferous age sandstones, where they are present as detrital grains (Hawkes and Smythe, 1931); they have no association with the sill.

Interpretation

The relationship between the sill and the host sedimentary rocks at the Budle Point to Harkess Rocks GCR site is extremely complicated, which is unusual for the Whin Sill-complex. This site and some locations on the Fame Islands are the only places where so many inclusions are observed, although rafts of sedimentary rock are also well exposed at the Longhoughton Quarry GCR site. The inclusions tend to be angular, with distinct, sharp margins, and show evidence of baking and alteration. This implies that they were fully lithified and disrupted before thermal metamorphism took place (e.g. Raymond and Murchison, 1988).

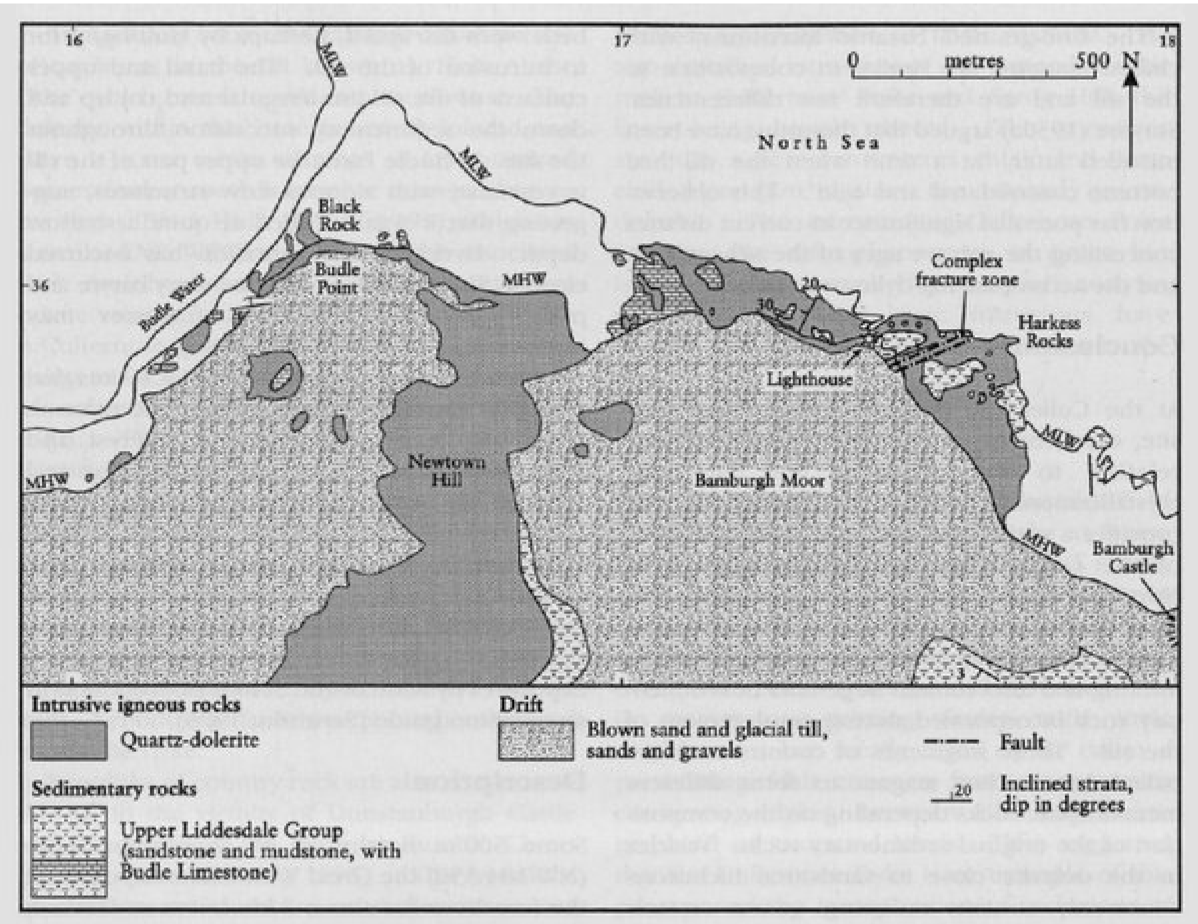
The large blocks of sedimentary rock between the ENE-trending fracture zones are enclosed within and intruded by dolerite, and it seems likely that these were broken up and disrupted by faulting prior to emplacement of the sill. To the immediate south of the fracture zones, the top surface of the exposure seems to be the top surface of the sill, as patches of chilled margin are preserved. However, to the north, a basal contact is exposed. Hence it appears that either the sill changed horizon along the pre-existing fracture zones or there has been a post-emplacement downthrow to the south on the bounding faults to the fracture zones. The total displacement must be of the order of several tens of metres (i.e. the full thickness of the sill) and it is possible that this is due to a combination of both mechanisms. Elsewhere, the sill is known to use pre-existing fault zones as 'risers' along which it transgressed to different stratigraphical levels (e.g. Smythe, 1930b; see Cullernose Point to Castle Point GCR site report) but there is also evidence that some faulting took place after emplacement.

The zones of elongate vesicles are also unusual in the Whin Sill-complex and the internal ropy flow surfaces are highly unusual, if not unique, worldwide. Lebour and Fryer (1877) considered them to be 'shrinkage or cooling marks in the shape of concentric ridges' but Smythe (1930b) suggested that they are 'the result of the slow flow of highly viscous liquid with a free surface'. Smythe considered that these structures are developed at four separate levels within the sill. He almost certainly got this impression as a result of the irregular upper surface of the sill, and Randall and Farmer (1970) pointed out that there is but a single zone, very close to the top. The structures are similar to those observed in short sill-like steps in a dyke at the Holy Island GCR site where Randall and Farmer (1970) suggested that emplacement occurred at shallow levels in the sedimentary pile, where vesicles formed as a result of rapid decompression and exsolution of volatiles from the magma. The vesicles then became flattened parallel to the contact and elongated in the flow direction. The linings of the vesicles began to cool before movement of the magma body had ceased and remained plastic long enough for flow structures to develop in them. Smythe (1930b) measured the elongation direction of the vesicles and the curvature of the ridges and deduced that the final movement of magma in the sill at Budle Point was from east to west, which is the opposite direction to that deduced for final movement in the Holy Island Dyke. Despite the fact that these are only local flow directions at the time of crystallization of the intrusive bodies, Randall and Farmer (1970) suggested that they cast doubt on the idea that the dykes and the Whin Sill were contemporaneous and that the dykes acted as feeders to the sill.

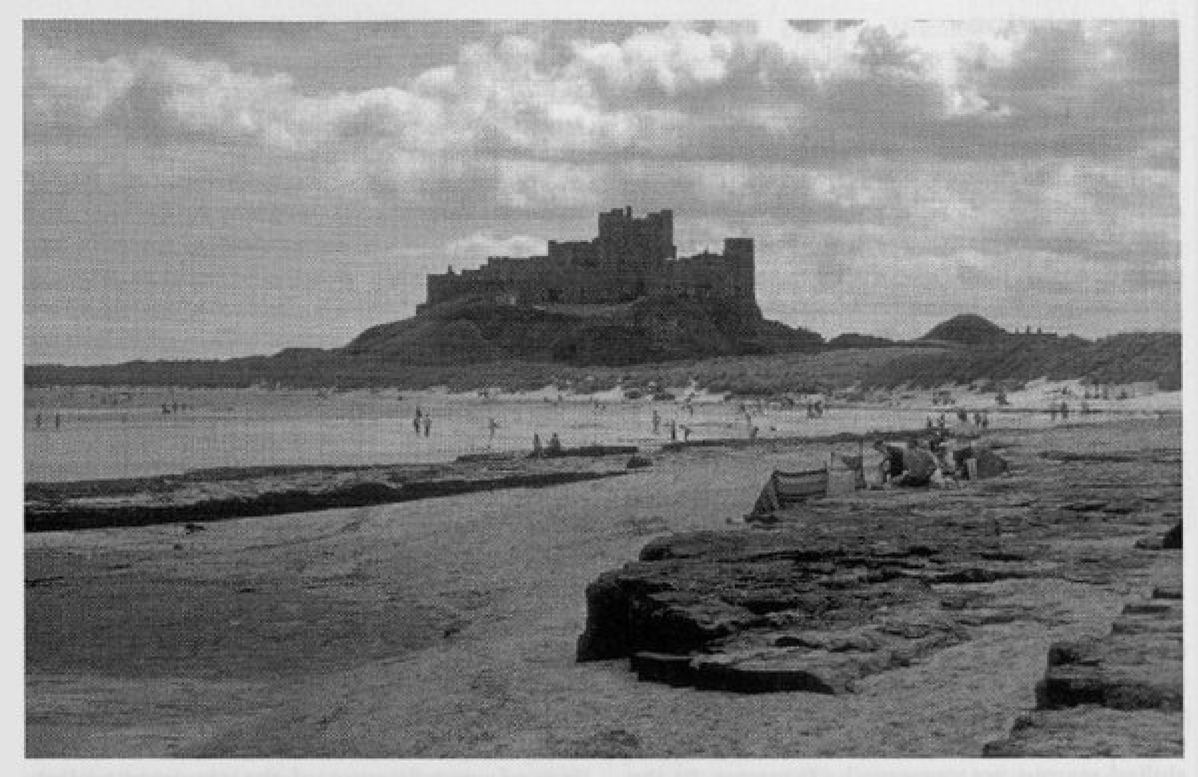
Conclusions

The Budle Point to Harkess Rocks GCR site is unique in the Whin Sill-complex because of the complexity of the relationship between the intrusion and the host sedimentary rocks. The rafts of sedimentary rock found within the intrusion are so numerous and of such diverse shape, size and orientation that it seems likely that the host rock was disrupted prior to intrusion. The angular, sharp margins of the inclusions show that the host rock was lithified prior to sill emplacement. Other features at this site include evidence of transgression of the sill and evidence of faulting after emplacement. Ropy flow surfaces on the inside of large elongate vesicles (gas cavities) near the top of the intrusion are an extremely rare, if not unique, feature worldwide and have been taken to imply emplacement at shallow depths. They suggest a magma flow direction from east to west.

References



(Figure 6.30) Map of the area around the Budle Point to Harkess Rocks GCR site. Based on Geological Survey 1:10 560 Sheet Northumberland, Old Series 16NE (1899).



(Figure 6.31) Bamburgh Castle, sited on a crag of quartz-dolerite of the Great Whin Sill, viewed from Harkess Rocks. The flat rocks in the foreground are close to the top surface of the sill; overlying sedimentary rocks have been removed completely, but the chilled margin of the sill is preserved as a thin skin in places. (Photo: D. Stephenson.)