North Queensferry (A90) Road Cuttings, Fife

[NT 126 807]–[NT 124 835]

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Introduction

One of the most prominent and best-known features of the Carboniferous to Early Permian igneous activity in central Scotland is the Midland Valley Sill-complex. This quartz-dolerite sill-complex may be contemporaneous with the Whin Sill-complex of northern England and represents a brief period in Late Carboniferous times when magmas of tholeiitic affinity were generated (during much of Carboniferous and Permian times, transitional to alkaline volcanism predominated). The spectacular North Queensferry (A90) Road Cuttings GCR site comprises a 2.5 km-long road section along the A90 north of the Forth Road Bridge, together with several quarries to the east of the road (Figure 6.8). There are extensive fresh exposures of quartz-dolerite showing fine examples of chilled upper and lower margins, internal variations in rock-type and petrography, and late-stage segregation veins. No other site in the Midland Valley shows all these features of a quartz-dolerite sill in one continuous section.

The petrography of quartz-dolerite sills in the Edinburgh district has been described by numerous authors including Allport (1874), Geikie (1880), Teall (1888) and Falconer (1906). It was at North Queensferry that Allport described the presence of quartz in the dolerite, although he was of the opinion that it was a secondary mineral, and recognized pseudomorphs after olivine in the chilled margin. Peach *et al.* (1910) produced a thorough account of the petrography and field relationships of sills in the Edinburgh area in their Geological Survey memoir. This was a revision of the first edition (Howell and Geikie, 1861) that described the first published sheet of the Geological Survey of Scotland (Edinburgh, Sheet 32). Further geochemical study of the quartz-dolerites and segregation veins was carried out by Day (1928b). Walker (1935) provided the first comprehensive account of the whole quartz-dolerite suite of the Midland Valley, and subsequent works on the regional and tectonic significance of the sill-complex include Walker (1965) and Francis (1978a). The emplacement mechanism of both the Whin Sill-complex and the Midland Valley Sill-complex was discussed by Francis (1982). The site has been described as a field excursion by Upton (1969).

Description

The quartz-dolerite of the sill exhibits deep spheroidal weathering in most natural outcrops (Figure 6.9) and hence the quarries and road cuttings provide far better illustrations of intrusive and petrographical features. The chilled upper and lower contacts of the quartz-dolerite sill and thermal alteration of the sedimentary country rocks of the Strathclyde Group can be observed at several places within the North Queensferry Road Cuttings GCR site. In a roadside exposure about 300 m north of the Forth Road Bridge [NT 126 811] the base of the sill cuts across an earlier normal fault that juxtaposes mudstones against sandstones. The quartz-dolerite has sagged into the mudstones on one side of the fault, and apophyses of dolerite intrude the locally crumpled and distorted mudstones, but there is no sagging into the more competent sandstone on the other side of the fault.

Coarse pegmatitic rocks characterized by long feathery clusters of augite crystals commonly form much of the top third of the sill at this site and segregation veins can be seen in many exposures. These segregations vary in grain size, texture, orientation and composition, but fine-grained to medium-grained quartzo-feldspathic types predominate. In the disused Ferrytoll Quarry [NT 127 816], by the railway line, there are some excellent examples. Here, the veins are pinkish-yellow and are very distinctive against the dark-blue-grey dolerite. One prominent vein is 12–20 cm wide and extends horizontally across a large part of the quarry walls before slanting upwards slightly. The vein divides at one point then rejoins, enclosing a lenticular mass of dolerite about 2 m long and 30 cm wide. There are also small discontinuous offshoots from the main vein. Other veins have different attitudes and some narrow veins are almost vertical. All veins are cut by the vertical cooling joints.

The petrography and geochemistry of the quartz-dolerite at this site is typical of the Midland Valley Sill-complex in general. It is medium grained to coarse grained and consists of mainly labradorite laths, sub-ophitic augite and Fe-Ti oxides. Intersertal quartz and alkali feldspar are commonly intergrown as micropegmatite. Pseudomorphs after olivine occur in the margins of the sill in the North Queensferry area (Allport, 1874).

The segregation veins typically comprise abundant small plagioclase laths, some orthoclase aligned parallel to the vein margins, and quartz; in addition they are commonly rich in micropegmatite. They contain fewer ferro-magnesian minerals and Fe-Ti oxides than the dolerite, although primary biotite and hornblende are slightly more abundant. Some of the smaller veins have rather diffuse contacts, but larger veins typically have sharp margins although they are not chilled. The dolerite tends to be slightly finer grained near the margins of the segregation veins.

Day (1928b) analysed samples of quartz-dolerite from Prestonhill Quarry, Inverkeithing and Ferrytoll Quarry in this GCR site. Typical dolerites contain 47–49% SiO_2 whereas the most evolved segregation veins have values of 69–71% SiO_2. He also showed that the emplacement of the segregation veins did not affect the chemical composition of adjacent dolerite.

Interpretation

The intrusive nature of the Midland Valley Sill-complex was a subject of much debate and controversy during the 19th century (see 'Introduction' to this chapter) but the road cutting at this GCR site, which was unavailable to the early geologists, shows clearly that the sedimentary rocks overlying the quartz-dolerite are baked.

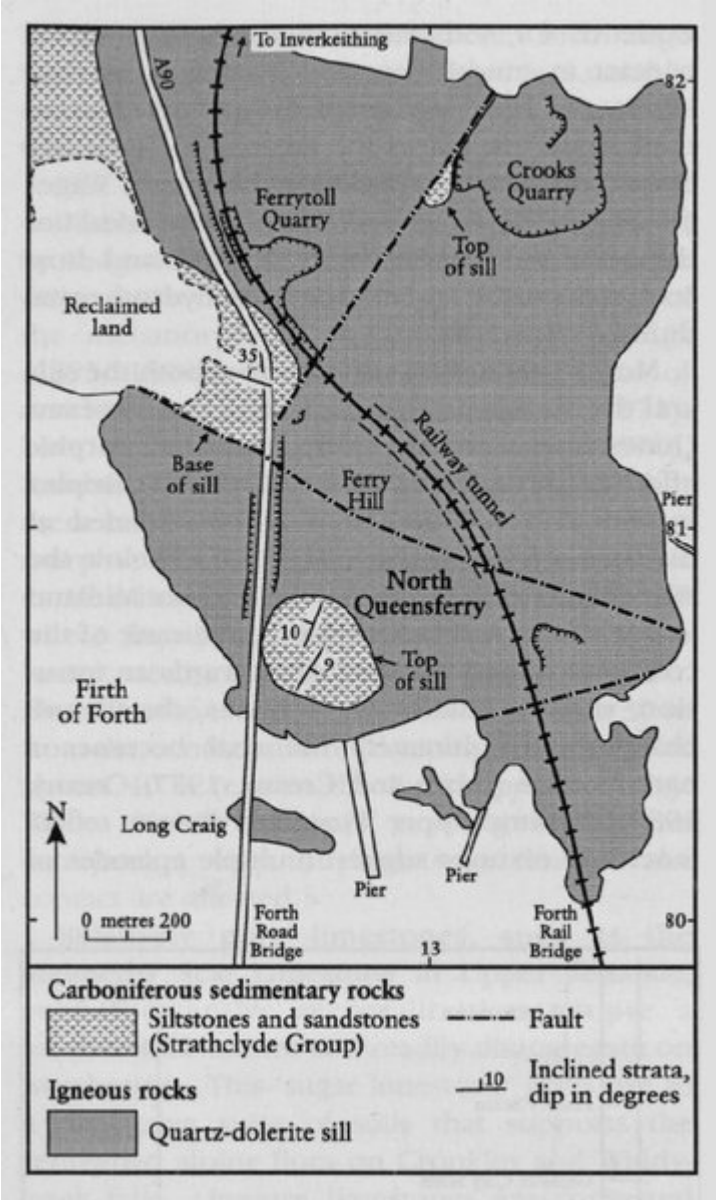
More recent investigations show that the Midland Valley Sill-complex is generally saucer-shaped with much of the intrusion following bedding planes down to the bottoms of basins where the intrusions are thickest (Francis, 1982). Francis proposed that sill emplacement was partly controlled by down-dip gravitational flow on gradients of up to 5°, from feeder dykes that extended to within 0.5 km and 1.0 km of the surface. Prior to this work, most authors (an exception being Robertson in Robertson and Haldane, 1937) had assumed that magma only flowed either upwards or laterally. Francis (1982) described the apophyses of dolerite extending from the sill down into the distorted shales at this GCR site and used this as an example of the downward (gravitational) component to magma movement.

The coarse-grained pegmatitic upper part of the sill that is seen so well at this GCR site is a feature of many large sills worldwide. This common profile shows that the sill is a single cooling unit that was totally molten at the time of emplacement (Francis, 1982). It is clear that the segregation veins, commonly with diffuse contacts, are related to the same parent magma as the dolerite and also that they were intruded while the sill was still cooling (features that were first recognized by Peach *et al.,* 1910).

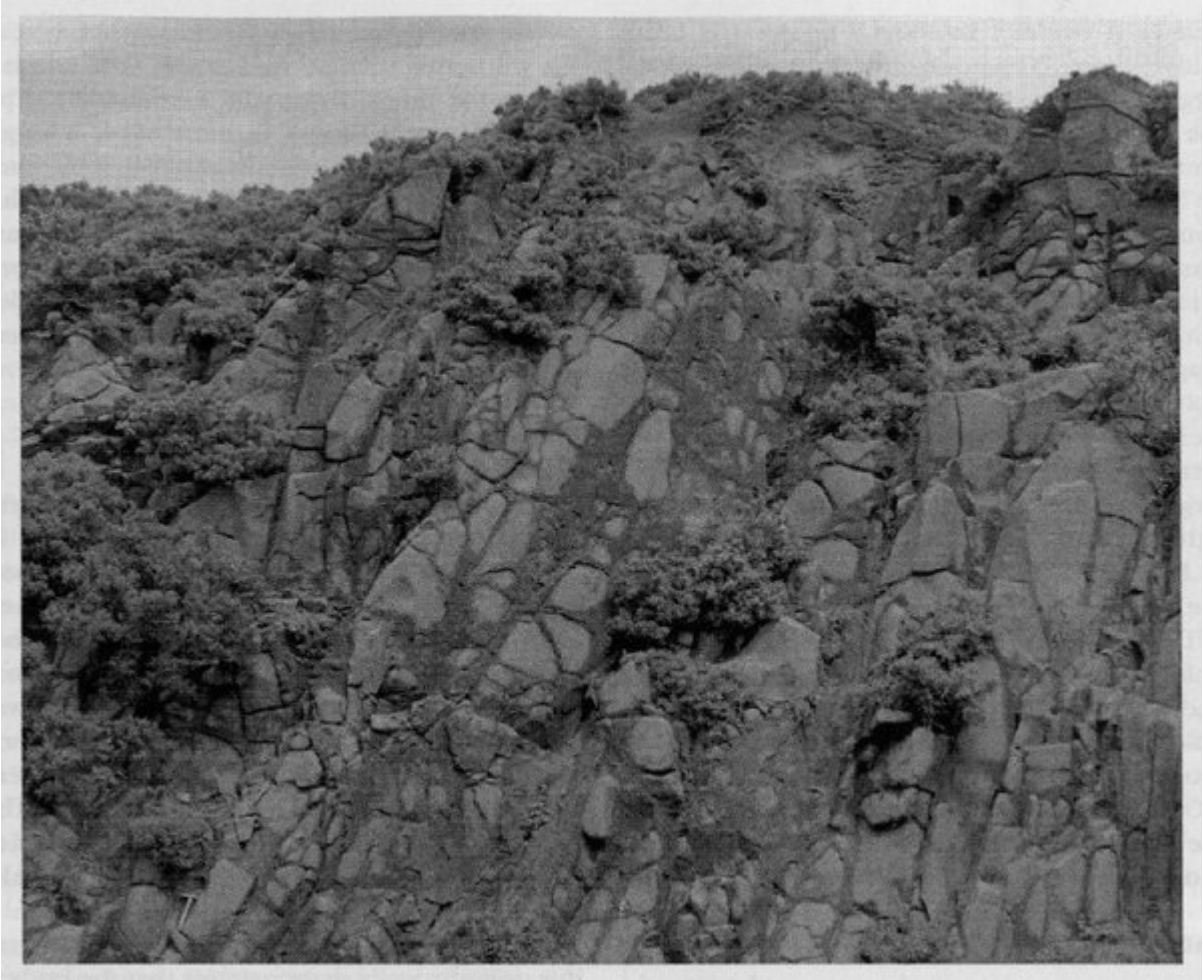
Conclusions

The extensive A90 road cuttings at North Queensferry expose a typical representative of the Midland Valley Sill-complex. The GCR site is significant because of the abundance and easy accessibility of complex features that characterize large sills in general. Much early work on the Midland Valley Sill-complex was carried out in this district but this relatively recently exposed site is the only location where all the critical features may be observed. The upper and lower margins of the sill are chilled to a dark glassy rock and are clearly seen to bake the surrounding sedimentary rock. This is particularly significant at the upper contact as this unequivocally demonstrates that the body is an intrusion and not a lava. Irregular veins of quartz-dolerite can be seen penetrating the underlying sedimentary rocks. Within the sill, grain-size variations are clearly visible, from finer-grained margins to a medium-grained interior, with patches and veins of coarse-grained pegmatitic material in the upper third of the sill. Pale-coloured segregation veins are the most silicic part of the intrusion and form sheet-like bodies within the sill.

References



(Figure 6.8) Map of the area around the North Queensferry Road Cuttings GCR site. Based on Geological Survey 1:10 560 Sheet NT 18 SW (1966).



(Figure 6.9) Quartz-dolerite of the Midland Valley Sill-complex at North Queensferry, showing spheroidal weathering. The hammer shaft (bottom left) is about 35 cm long. (Photo: British Geological Survey, No. D2580, reproduced with the permission of the Director, British Geological Survey, © NERC.)