South Queensferry to Hound Point, City Of Edinburgh

[NT 137 784]–[NT 159 794]

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Introduction

Major basic sills of both alkaline and tholeiitic affinity are prominent within many parts of the Midland Valley of Scotland. The southern shore of the Firth of Forth, to the east of the famous railway bridge, provides a unique opportunity to examine both types of sill in close proximity, where they intrude mudstones and sandstones of the Gullane Formation (Strathclyde Group). The superb exposures and great diversity of features make this a valuable site for educational purposes and it is a favoured field excursion venue (e.g. MacGregor, 1973; McAdam in McAdam and Clarkson, 1986).

The site has been a source of interest and debate since the 19th century. Some of the more important early studies include Howell and Geikie (1861), Geikie (1880, 1897), Stecher (1888), Flett (in Peach *et al.,* 1910) and Walker (1923). The alkaline Mons Hill Sill, formerly classed as a 'teschenite', exhibits considerable petrographical variation but mainly comprises analcime-dolerite. It shows many features characteristic of other alkali dolerite sills in the eastern Midland Valley (e.g. Flett, 1930, 1931a,b, 1932; Campbell *et al.,* 1932, 1934; Higazy, 1952), but also has slight petrographical differences that are of academic interest. The tholei-itic Hound Point Sill comprises mainly quartz-dolerite and is a component of the Midland Valley Sill-complex (see Chapter 6). It is petrographically and geochemically similar to other quartz-dolerite sills in the eastern Midland Valley (e.g. Falconer, 1906; Tyrrell, 1909b; Bailey in Clough *et al.,* 1911) and shows typical features such as the development of a coarse-grained and slightly evolved facies just above mid-height, and segregation veins. Near the railway bridge smaller doleritic sills, intruded into a sequence of carbonaceous mudstones and oil-shales, have been altered to a distinctive rock-type known as 'white trap' (Day, 1930a). 'White trap' is relatively common in the Edinburgh district but this is a particularly well-exposed example.

There is no precise field evidence for the age of the sills within the South Queensferry to Hound Point GCR site, or for their age relative to each other. Alkaline basic sills were emplaced during various magmatic episodes from Visean to Early Permian times. In Fife and the Lothians many olivine-dolerites may be Visean or Namurian, as they are petrographically and geochemically similar to neighbouring extrusive rocks of that age (e.g. the Bathgate Hills Volcanic Formation). Some radiometric dates confirm this correlation (De Souza, 1979, 1982). The distinctive 'teschenitic' sills (analcime-dolerites) were thought to be younger, possibly Namurian to Westphalian in age, as appeared to be confirmed by a K-Ar whole-rock date of 308 ± 7 Ma on the Mons Hill Sill (De Souza, 1979, recalculated by Wallis, 1989). However, a re-determination of this sample by Ar-Ar dating has yielded a latest Visean age of 329.3 ± 1.3 Ma (A.A. Monaghan and M.S. Pringle, pers. comm., 2002). Radiometric dates on the tholeiitic Midland Valley Sill-complex elsewhere suggest a Stephanian age on current timescales (see Chapter 6).

Description

Walker (1923) mapped this site in some detail (Figure 5.6), slightly modifying the linework of the 1910 edition of the Geological Survey one-inch Sheet 32 on which some quartz-dolerite outcrops had been mapped as 'teschenite'. He recognized that the quartz-dolerite commonly shows spheroidal weathering and crude columnar jointing whereas the analcime-dolerite does not have such distinctive weathering but does have well-developed, sharp-edged columnar joints. In addition, analcime-dolerite is more leucocratic in appearance than quartz-dolerite and ferro-magnesian minerals are usually fresher. Analcime-dolerite commonly contains irregularly shaped cavities (druses) into which euhedral crystals of the rock project.

The section is described from east to west, up the succession.

The Hound Point Sill (tholeiitic)

Hound Point, at the eastern extremity of the site [NT 158 796], and rocks on the shore to the north, are composed of a gently westward-dipping (*c.* 15°) quartz-dolerite sill. Here the sill is 20–30 m thick, but it thickens inland. Crude columnar jointing is developed and pale-grey, curviplanar segregation veins are well displayed locally as a result of differential weathering. The sill intrudes sandstones and black mudstones belonging to the Gullane Formation (formerly part of the 'Queensferry Beds').

The base of the sill is exposed on the east side of Hound Point, where it lies on indurated mudstones and sandstones. The more arenaceous beds are baked to quartzite, whereas black carbonaceous mudstone has been altered to a cordierite-bearing hornfels. The cordierite is commonly pseudomorphed by calcite or altered to micaceous material and gives the altered mudstones a spotted appearance (Flett in Peach *et al.,* 1910; Day, 1928b). Two thin sheets of quartz-dolerite with chilled margins occur below the main body of the sill (MacGregor, 1973). These are probably apophyses from the main sill. The sill becomes finer grained towards its base and has a chilled margin. At one place the base of the main sill has wedged into the bedded sediments producing a transgressive contact (Figure 5.7) that resembles Hutton's famous locality at Salisbury Craigs (see Arthur's Seat Volcano GCR site report). Above this contact a thin sheet-like body of quartzite within the sill, which superficially resembles a quartzo-feldspathic segregation vein, has chilled basalt on each side.

Basalt exposed in reefs close to the low-water mark north-west of Hound Point is presumed to represent the chilled margin at the top of the sill.

The Mons Hill Sill (alkaline)

Just above the horizon of the Hound Point Sill the Gullane Formation is intruded by another major basic sill known as the 'Mons Hill Sill' (e.g. Flett in Peach *et al.,* 1910; Walker, 1923; MacGregor, 1973). Virtually the whole thickness of the sill is seen in well-exposed sections from the west side of Peatdraught Bay [NT 154 794] to Whitehouse Point [NT 147 789]. Inland, the sill forms the upstanding ridge of Mons Hill, from which it takes its name, and it is seen in several, now disused, quarries. Jointing in the sill suggests a dip of about 11° to the west, more-or-less conformable with the country-rock strata, which here dip westwards at 13°–19°. Original estimates of the thickness were 150–155 m, but undulations in the dip, suggested by the jointing, mean that it may be thinner (McAdam and Clarkson, 1986).

The basal contact of the sill is obscured by sand and the upper contact is accessible only during exceptionally low tides. The upper few metres of the sill are vesicular and well jointed. Contact-altered spotted mudstones and indurated sandstones of the Gullane Formation are exposed close to the supposed locations of both contacts and a good section through these beds is exposed intermittently for 25–35 m along the top of the beach on the east side of Whitehouse Bay (MacGregor, 1973).

This 'teschenitic' sill is composed mainly of analcime-dolerite and analcime-gabbro, with some nepheline-dolerite. In common with other alkaline sills of the Midland Valley, internal contacts separate a number of distinct sheets showing variations in texture, petrography and chemical composition. The description of the coastal section (see below), is based largely on Walker (1923), who distinguished what he termed 'modifications', but apparently was unable to give precise thicknesses.

Top

1. **Nepheline-dolerite**, dark, medium grained with idiomorphic kaersutite needles, black and pink segregation veins and a vesicular top; angular jointing

Contact fairly sharp but not chilled

2. **Analcime-dolerite**, compact, medium grained, sub-ophitic, fresh with mottled appearance and no segregation veins

Sharp contact seen at Whitehouse Point

3. **Analcime-gabbro**, coarse grained and very coarse-grained, mottled; large ophitic titaniferous augite crystals, plagioclase partly altered to analcime, much chlorite; pink segregation veins; calcite-filled cavities and conspicuous zeolitic drusy cavities; rounded jointing. Forms the bulk of the sill, between a point 300 m west of Peatdraught Bay and Whitehouse Point

Sharp contact

4. **Analcime-dolerite**, dark, medium grained, sub-ophitic; angular jointing

Uncertain contact

5. **Nepheline-dolerite**, pale, medium grained, with small kaersutite needles

Merging contact

6. **Kaersutite analcime-gabbro**, coarser grained than the nepheline- and analcime-dolerites above. Seen just east of a small sea-stack *Sharp contact, not chilled*

7. **Analcime-dolerite**, dark, medium grained, idiomorphic titaniferous augite; angular jointing

Base

The analcime-gabbro that comprises the main part of the sill (layer 3 above) contains distinctive ophitic titaniferous augites measuring up to 2 cm x 15 cm and enclosing strongly zoned plagioclase that is partially replaced by analcime. Chlorite is also prominent and there are rare pseudomorphs after olivine. Alkali feldspar, analcime, natrolite and large skeletal ilmenite occur as prominent accessories along with some biotite and apatite. The kaersutite analcime-gabbro towards the base of the sill (layer 6 above) contains sub-ophitic titaniferous augite and variably sized kaersutite prisms. There is much chloritization and no nepheline.

The analcime-dolerite (layers 2 and 4 above) contains sub-ophitic titaniferous augite and plagioclase, most of which is altered to analcime. Pseudomorphs after olivine are common, as is biotite but there is no kaersutite. A variety of analcime-dolerite with idiomorphic rather than ophitic titaniferous augite comprises layer 7.

The nepheline-dolerite (layers 1 and 5 above) is dominated by idiomorphic kaersutite and green-rimmed (presumably slightly sodic) titaniferous augite. In layer 5 the kaersutite forms prominent needles. The groundmass comprises zoned plagioclase (lahradorite to oligoclase), alkali feldspar, analcime, nepheline (mostly altered), titaniferous magnetite and pyrite with accessory apatite and biotite. There are also rare pseudomorphs after olivine.

Distinctive pink segregation veins occur in layers 1 and 3. They are medium grained, non-porphyritic and contain biotite, alkali feldspar, analcime and rare euhedral nepheline. Two varieties of black fine-grained segregation vein occur in layer 1: a ferromagnesian-rich variety with ocellar structure, and a modification of this with large phenocrysts of plagioclase and titaniferous augite.

The inland continuation of the Mons Hill Sill was proved in two boreholes sunk during the early decades of the 20th century, one at Easter Dalmeny (*c.* [NT 150 775]) and the other about 320 m farther west (Flett, 1930). These bore-holes proved a layered sequence of over 85 m that includes analcime-gabbro and, notably, some picritic (olivine-rich) variants that are not present in the coastal section of the sill. In neither case was the top of the intrusion seen.

'White trap'

The rocky shoreline between Long Craig Pier [NT 144 789] and Port Neuk [NT 138 784] comprises a succession of mudstones, siltstones, sandstones, oil-shales and ferroan dolostones ('cementstones') belonging to the Calders Member of the West Lothian Oil-shale Formation. Within this succession, there are two thin, slightly transgressive sills, roughly 100 m apart, which have been altered to a light-coloured calcareous clay-rich material known as 'white trap' (Figure 5.8). The eastern sill, 60 cm thick, is a cream-coloured rock with brown margins; the western sill, 90 cm thick, is pale grey and weathers buff-brown. The margins of both sills are indistinct in places because the host sandstones are of a similar pale colour, but the sills may be distinguished by their polygonal jointing. Carbonaceous mudstones, even where bleached, are slightly darker and hence contacts with them are quite distinct; they may be brecciated or smooth (MacGregor, 1973; McAdam and Clarkson, 1986).

The 'white trap' sills are composed almost entirely of calcium-magnesium-iron carbonates, kaolin, muscovite and quartz. Relict igneous textures are preserved in places, but commonly only 'ghosts' of the original feldspar crystals remain, having been altered to aggregates of kaolin, isotropic silica, calcite, chalybite and some dolomite. Skeletal ilmenite and magnetite remain as accessories, particularly in the chilled margins (Stecher, 1888; Flett in Peach *et al.,* 1910; Day, 1930a).

Interpretation

The quartz-dolerite sill at Hound Point is a member of the Midland Valley Sill-complex, which is discussed at length in Chapter 6. Several other component sills of the complex are described as GCR sites and interpretations of their magmatic origin, evolution, structural setting and mode of emplacement apply equally to Hound Point. Consequently they are not repeated here. These tholeiitic sills do not have any known extrusive equivalents and were emplaced along E–W-trending fractures during a brief change in the stress regime that occurred in Late Carboniferous times (Francis, 1978b, 1982).

Walker (1923) described the petrographical variation within Mons Hill Sill in some detail, including the Tmer-grained marginal modifications' between the main rock-types. Despite the finer grain-size he did not observe glassy chilled margins towards the internal contacts and considered this as evidence for differentiation *in situ* rather than for separate injections of magma. Other alkaline basic sills of the Midland Valley are similarly composite, with a lithological range in some cases greater than that at Mons Hill. It is likely that some of the mechanisms that have been proposed for these sills also hold true for the Mons Hill Sill (see Lugar, Ardrossan to Salt-coats Coast and Benbeoch GCR site reports).

Numerous examples of the alteration of dolerite to 'white trap' have been recorded in the Edinburgh district. In most cases the original affinity of the dojerite cannot be determined, but the process is known to affect both alkaline and tholeiitic dolerites. Day (1930a) studied examples of 'white trap' within carbonaceous mudstones, oil-shales and coals from Dalmeny (this site), Granton, Weak Law and North Berwick and observed considerable variations in the chemical composition. He recognized a series of gradations between two end-members; one is clay-rich and retains some original igneous texture and the other is a more carbonated rock in which virtually nothing remains of the original rock. Flett (in Peach *et al.,* 1910) recognized that the presence of remnant igneous textures implies that the rock was fully crystallized prior to alteration. He proposed that heat from the intrusion distilled gases and solutions from the carbonaceous mudstones. Organic gases cannot affect rock-forming silicates at high temperatures and therefore modification occurred after the dolerite had solidified and the temperature had dropped. Day (1930a) proposed that the meta-somatic process took place in two stages; first, kaolin and isotropic silica appeared as a result of the decomposition of feldspars and ferromagne-sian minerals. This was followed by the gradual replacement of the whole rock by carbonates.

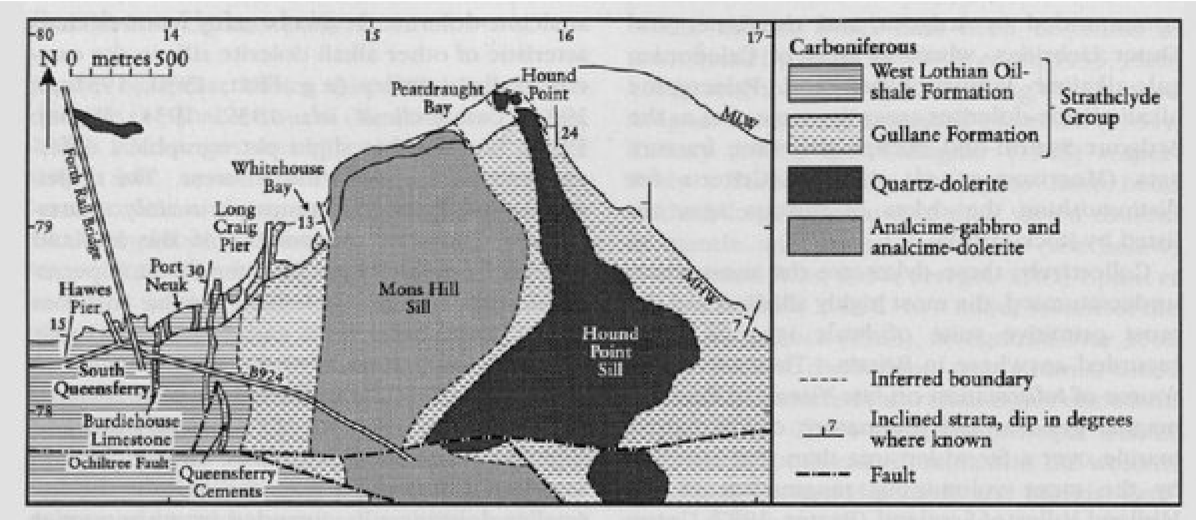
Conclusions

The South Queensferry to Hound Point GCR site contains both a tholeiitic, quartz-dolerite sill and a distinctive alkaline basic ('teschenitic) sill. Each represents a major intrusive suite in the Midland Valley of Scotland and was the subject of early studies. The alkaline Mons Hill Sill was emplaced during latest Visean times, possibly concurrent with volcanic rocks of this age that are preserved in the Bathgate Hills and west Fife. In contrast, the quartz-dolerite sill at Hound Point was emplaced as part of the Midland Valley Sill-complex during a very brief period in early Stephanian time when there was no known surface volcanism in the area (see Chapter 6).

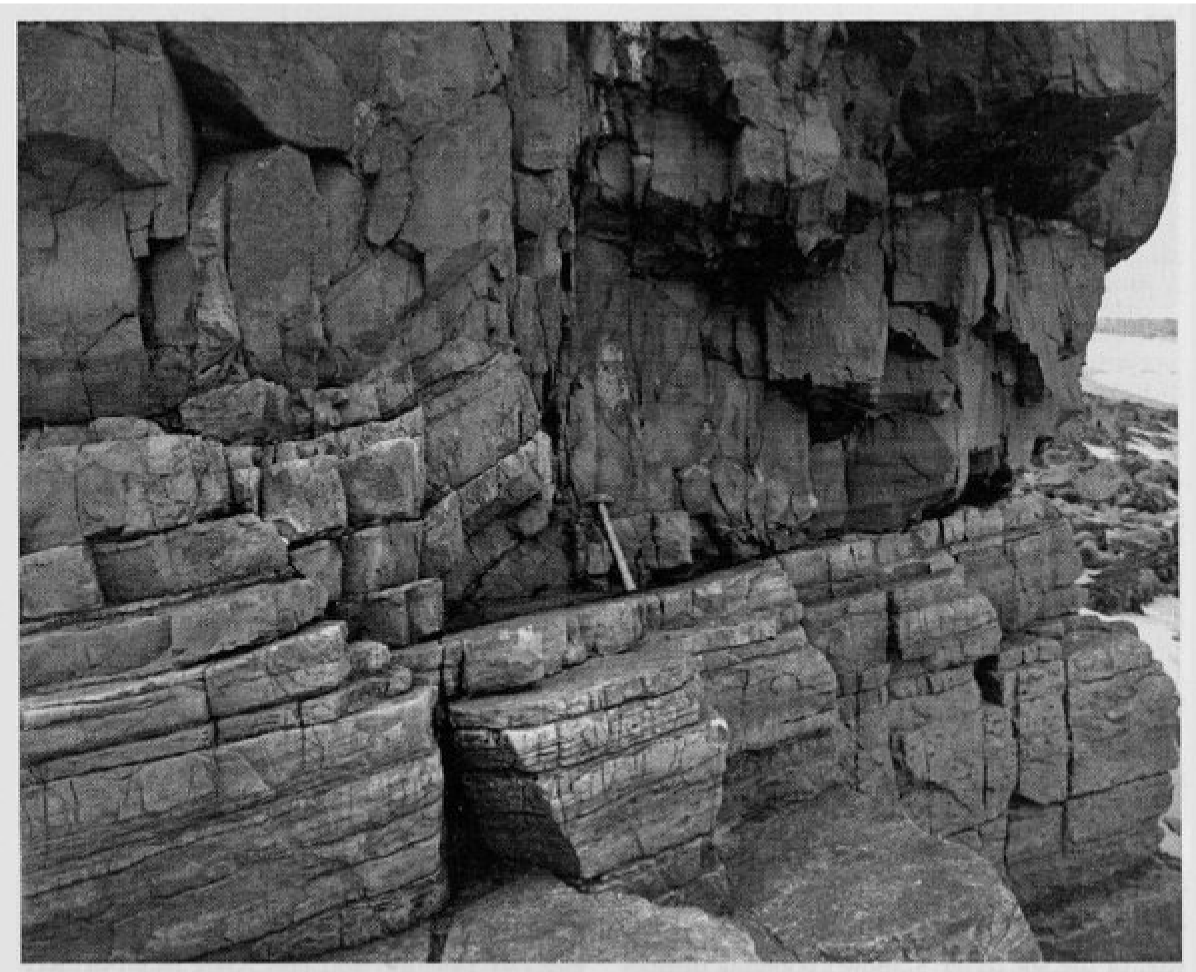
Internal variations in mineralogy and texture are well developed in the Mons Hill Sill and details of internal contact relationships between distinctive lithologies are also clear. The Hound Point Sill exhibits the regular gradational zonation that is typical of Midland Valley quartz-dolerite sills. These factors, coupled with geochemical data, provide many clues as to the processes of magma generation and evolution responsible for both suites. The different geochemical characteristics of the two sills probably reflect magma generation at different depths below the Earth's crust and/or at different pressures and temperatures.

There is abundant evidence of the effect of heat upon the sedimentary host rocks adjacent to the major sills, and smaller sills show excellent examples of the alteration of dolerite to 'white trap', due to fluids and gases distilled out of carbonaceous mudstones and oil-shales by the heat of the intrusions.

[References](#)



(Figure 5.6) Map of the area around the South Queensferry to Hound Point GCR site. After McAdam (in McAdam and Clarkson, 1986).



(Figure 5.7) Base of the Hound Point quartz-dolerite sill at Hound Point, forcing up the underlying beds of sandstone. The hammer shaft is about 35 cm long. (Photo: British Geological Survey, No. D1917, reproduced with the permission of the Director, British Geological Survey, © NERC.)

(Figure 5.8) Basic sill intruding and transgressing sedimentary rocks of the West Lothian Oil-shale Formation and altered to 'white trap', South Queensferry shore. The hammer shaft is about 35 cm long. (Photo: A.D. McAdam.)