Garleton Hills, East Lothian

[NT 449 764]–[NT 520 763]

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Introduction

The upper part of the Garleton Hills Volcanic Formation in East Lothian, represented by the Garleton Hills GCR site, is the erosional remnant of a lava field, built up of evolved trachytic flows and associated pyroclastic rocks (Figure 2.10). The lower part of the formation, dominated by basaltic rocks, is represented by the North Berwick Coast GCR site.

Early Carboniferous volcanism in the Midland Valley of Scotland was dominated by the construction of basaltic and hawaiitic lava fields. However, mugearite, benmoreite and trachyte flows interbedded with the more basic rock-types also feature in many areas (see for example Machrihanish Coast and South Kintyre, Campsie Fells, and Touch, Fintry and Gargunnock Hills GCR site reports). Discrete trachyte-rhyolite centres were also formed in some areas, most notably the Misty Law Trachytic Centre in the Renfrewshire Hills (Johnstone, 1965; Paterson *et al.,* 1990). Studies of these more evolved members of the suite, such as those exposed in the Garleton Hills GCR site, are therefore important in modelling magma genesis and volcanic processes on a province-wide scale.

The Garleton Hills Volcanic Formation is the basal unit of the Visean Strathclyde Group; it is conformable with both the underlying Ballagan Formation (Inverclyde Group) and the overlying Gullane Formation. The underlying and overlying sedimentary rocks have yielded good biostratigraphical evidence of age. In the Spilmersford borehole [NT 4570 6902], situated 7.25 km south-west of the Garleton Hills, sedimentary rocks from beneath the volcanic rocks have yielded (early Visean) PU zone miospores (Davies, 1974). However, Scott (1990) and Bateman and Scott (1990) reported late-Tournaisian (Courceyan–CM zone) plant assemblages from volcaniclastic rocks within the North Berwick Member at the base of the Garleton Hills Volcanic Formation. Sedimentary rocks above the volcanic succession have yielded Asbian–TC zone miospores (Neves *et al.,* 1973) and hence the volcanism can be fairly confidently assigned to early Dinantian time. Radiometric ages obtained by K-Ar whole-rock determinations from lavas at Skid Hill (349 ± 7 Ma) and Phantassie Hill (342 ± 5 Ma) are compatible with an early Dinantian age (De Souza, 1974). However these dates recalculate to *c.* 355 Ma and 348 Ma using new constants, suggesting an early Tournaisian age which is incompatible with the biostratigraphical evidence. A more precise Ar-Ar date of 342.1 ± 1.3 Ma on sanidine separated from a trachyte at Phantassie Hill is, however, compatible with the biostratigraphy (A.A. Monaghan and M.S. Pringle, pers. comm., 2002).

Early descriptions of these rocks are by Howell *et al.* (1866), Geikie (1880, 1897), Hatch (1892) and Clough *et al.* (1910). The geology of the area has been described more recently by McAdam and Tulloch (1985); accounts of the successions in the Spilmersford and East Linton boreholes are by Davies (1974) and Davies *et al.* (1986). Petrographical aspects of the rocks were described by McAdam (1974). Localities within the GCR site are used frequently for educational purposes and are included in excursion guides for the district (McAdam *et al.* in Upton, 1969; Upton and Macdonald in McAdam and Clarkson, 1986).

Description

The Garleton Hills form an area of low hills and escarpments up to 180 m above sea level, about 2.5 km north of Haddington, and in the southwest part of the outcrop of the Garleton Hills Volcanic Formation. The geomorphology is controlled strongly by the effects of both the strike of the rocks and glacial erosion (Figure 2.11). Former glacial drainage channels are a feature of the site with inferred water flow from west to east, parallel to the direction of ice movement.

The stratigraphy of the Garleton Hills Volcanic Formation is shown below.

Thickness (m)

Bangley Member	
Trachyte, quartz-trachyte and augite-phyric quartz-bearing trachyandesite (formerly 'quartz-banakite') lavas, trachytic tuffs	0–160
Hailes Member	
Feldspar-phyric basalts ('Markle' type) and mugearites	25–70
East Linton Member	
Mostly plagioclase-olivine-clinopyroxene-phyric basalts (Dunsapie type) and olivine-clinopyroxene-phyric basalts ('Craiglockhart' type), mugearites and analcime-bearing hornblende-phyric trachybasalts (formerly 'kulaites)	10–90
North Berwick Member	
Red basaltic tuffs and agglomerates, green basaltic tuffs and agglomerates, beds of freshwater limestone and dolostone	50–150

The Garleton Hills Volcanic Formation is divided into four laterally persistent members (see above). The Garleton Hills GCR site is situated mainly within the outcrop of the Bangley Member, but some of the upper units of the Hailes Member are also present. A few volcanic necks and minor basic intrusions cut the lava sequence. The thickness of individual lavas is difficult to assess because interflow junctions are not easily identified and any interbedded vol-caniclastic rocks are not exposed. In addition, most of the flows have much the same characteristics, making correlation problematical even within this relatively small area. However, many of these lavas are probably more than 20 m thick (Upton, 1982). It is not known if, as seems quite likely, some of the units are shallow intrusions into the lava pile.

The oldest lavas within the area crop out in the relatively poorly exposed ground to the north-east of Kae Heughs (Figure 2.10). Scattered exposures there are of plagioclase ± olivine-phyric basalt belonging to the Hailes Member. Near the top of this unit is a thin unit of mugearite. The basalts are intruded by an ENE-trending quartz-dolerite dyke, interpreted by McAdam and Tulloch (1985) as part of the regionally persistent Prestonpans–Seton Dyke of the Stephanian Midland Valley tholeiitic swarm (see Chapter 6). The dyke is cut by later NW- and NE-trending faults (Figure 2.10).

At Craigy Hill [NT 511 765] the lowest trachyte lava of the Bangley Member seen in the GCR site rests directly upon a basaltic flow of the Hailes Member. Successive trachyte lavas are well exposed on the elongate ridges, which display well-developed stepped or 'trap' features on their northern faces. A particularly fine example of this is exhibited by Kae Heughs [NT 512 762] (Figure 2.11), an E–W-trending ridge composed of two trachyte lavas that are less porphyritic than those higher in the sequence.

The disused quarry cut into the southern flank of Skid Hill [NT 508 763] appears to have been excavated through a single, 20 m-thick lava of massive, but well-jointed, quartz-trachyte. This unit is plagioclase-alkali feldspar-augite-apatite-phyric. A trachyte lava above that at Skid Hill forms Byres Hill [NT 500 764] (180.7 m) and has probably been used in the construction of the Hopetoun Monument, a prominent landmark on the summit. The escarpment at Phantassie Hill [NT 507 758] is composed of at least one thick flow of plagioclase-alkali feldspar-clinopyroxene-apatite-phyric trachyte. Internal structures include patchily developed vesicular facies and zones of alteration and reddening. Yellow Craigs [NT 5115 7585] and Barney Hill [NT 514 760] (179.8 m) expose similar rocks. All of these lavas have developed prominent dip-slopes to the south. Further trachytic lavas and a unit of trachytic tuff in the upper part of the formation crop out to the west of the GCR site. The highest lava is exposed in Bangley Quarry [NT 487 752], which is a GCR site in the Mineralogy of Scotland GCR Block. There, a lava of quartz-trachyte (formerly 'quartz-banakite') is cut by a dyke of trachybasalt that contains phenocrysts or xenocrysts of clear sanidine up to 5 cm long (Day, 1930e).

Near Skid Hill, three small areas [NT 5055 7660], [NT 5080 7645], [NT 5085 7625], up to 100 m by 200 m, of pyroclastic breccia and tuff, may represent volcanic necks cutting the trachytic lavas.

The volcanic rocks are extracted for road metal and were formerly used for building stone. Haematite and baryte veins that cut the lavas were once exploited commercially and traces of the old haematite workings can be seen north-west of

Phantassie Hill, where working ceased in 1876 (Macgregor *et al.,* 1920; McAdam and Tulloch, 1985).

Published analyses of rocks from the Garleton Hills Volcanic Formation in general and their associated intrusions are few, the most recent, including stable isotope data, being those of Smedley (1986a,b, 1988a). Analyses of trachytic rocks are included only by Livingstone and McKissock (1974), Macdonald (1975) and Smedley (1986a).

Interpretation

Max (1976) and Floyd (1994) have both noted that the Garleton Hills lava field lies over the sub-surface extension of the main Southern Upland Fault, and Upton (1982) suggested that this zone of weakness may have acted as a focus for the development of magma chambers large enough to evolve felsic magmas. Magmas of trachytic composition are considerably more viscous and volatile-rich than those of basaltic and hawaiitic composition. Consequently, the trachytes of the Garleton Hills GCR site are likely to have been erupted as viscous lavas of limited aerial extent, and some may have been emplaced as lava domes. Such eruptions are commonly associated with pyroclastic ash-flow and ash-fall deposits. Thin units of bedded tuff and welded tuff, and also some of volcaniclastic sedimentary rocks are present in the Garleton Hills Volcanic Formation, though none are seen in the Garle-ton Hills GCR site. The presence of the sedimentary rocks shows that volcanic activity was intermittent, and that during the quiescent intervals plant and animal communities were established (Bateman and Scott, 1990; Scott, 1990). Upton (1994) has suggested that the Holocene cinder cones and domes in the Massif Central of France are good analogues of both the basaltic and the trachytic volcanism in the Garleton Hills Volcanic Formation (see also North Berwick Coast GCR site report).

Most geochemical studies of Dinantian volcanic rocks of the Midland Valley of Scotland have concentrated upon the basaltic to hawaiitic members (Macdonald, 1975; Macdonald *et al.,* 1977; MacDonald and Whyte, 1981; Smedley, 1986a). This reflects not only their dominance in almost all sequences across the Carboniferous–Permian Igneous Province of northern Britain, but also that the more basic types are of most use in determining the composition and melting characteristics of the underlying mantle. However, understanding the evolution of the more evolved rocks from these suites, such as those seen in the Garleton Hills GCR site, is critical to our understanding of magmatic processes in the upper crust.

The Garleton Hills trachytes, like other more evolved Dinantian lavas of the Midland Valley, are regarded as the intermediate differentiation products of mildly alkaline and transitional olivine basalt magmas that underwent fractional crystallization in relatively high-level magma chambers (e.g. Macdonald, 1975; MacDonald and Whyte, 1981; Smedley, 1986a). Crustal contamination does not appear to have had a major influence, even in the evolved rocks (Smedley, 1986a). Intrusive rocks of even more evolved composition are represented nearby as the phonolitic trachytes of the Bass Rock and North Berwick Law, and the phonolite of Traprain Law. However, these highly evolved rocks are silica-undersaturated, in contrast to the silica-oversaturated trachytes and quartz trachytes of the extrusive sequence. They have been correlated traditionally with the trachytic rocks of the Garleton Hills, but their only likely extrusive associates are the flows of analcime-bearing hornblende trachybasalt that occur locally at the base of the lava sequence. The significance of this possible association is discussed in the Traprain Law GCR site report.

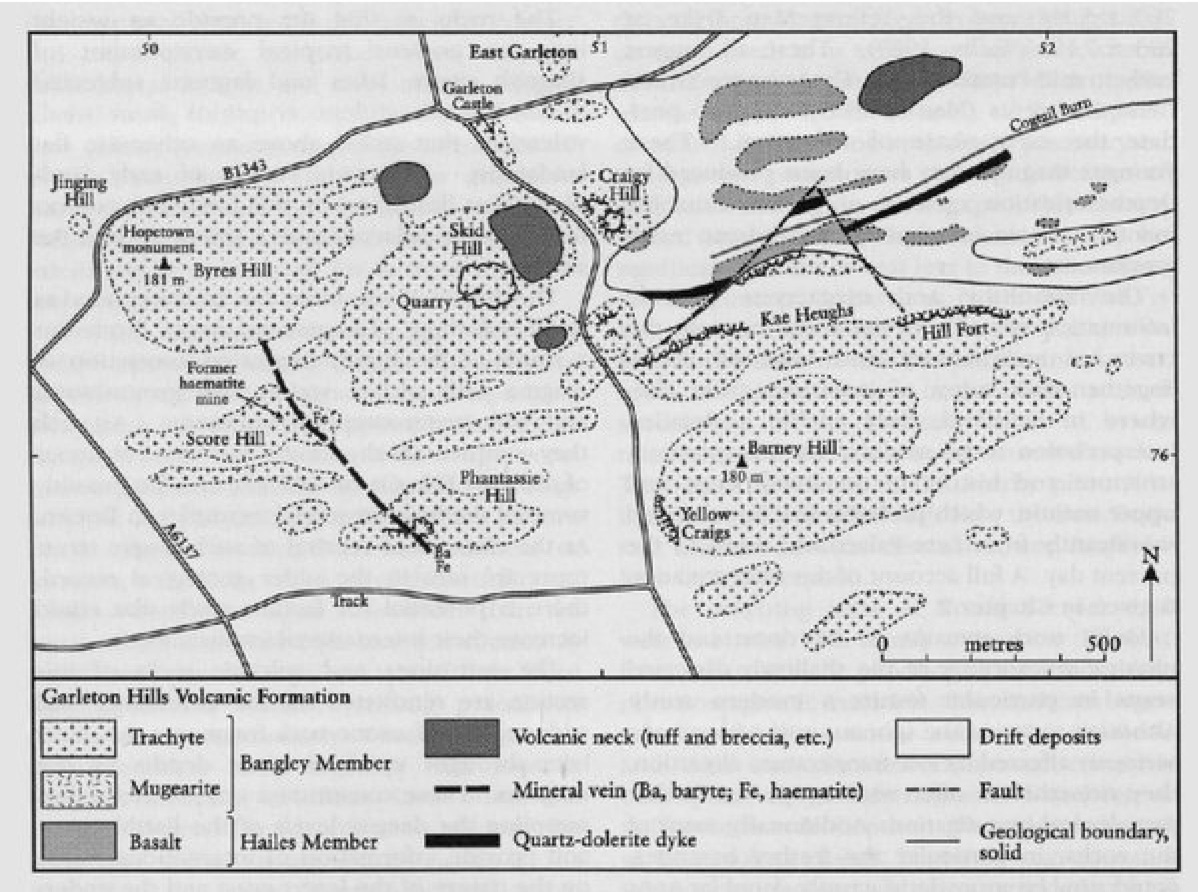
Conclusions

The volcanic rocks exposed in the Garleton Hills GCR site comprise the upper part of the Visean Garleton Hills Volcanic Formation, a sequence of trachyte lavas and minor pyroclastic beds overlying the mainly basaltic volcanic rocks that comprise the lower parts of the formation (see North Berwick Coast GCR site report). Though trachytic lavas are known from other Dinantian lava fields of the Midland Valley of Scotland, the Garleton Hills GCR site has been selected to represent this important group of geochemically evolved rocks and their style of volcanism. Individual trachyte lavas are probably more than 20 m thick, and were probably erupted as highly viscous flows or even as steep-sided domes. The extrusive rocks are cut by the remains of a few small volcanic necks that represent the feeders to the volcanoes.

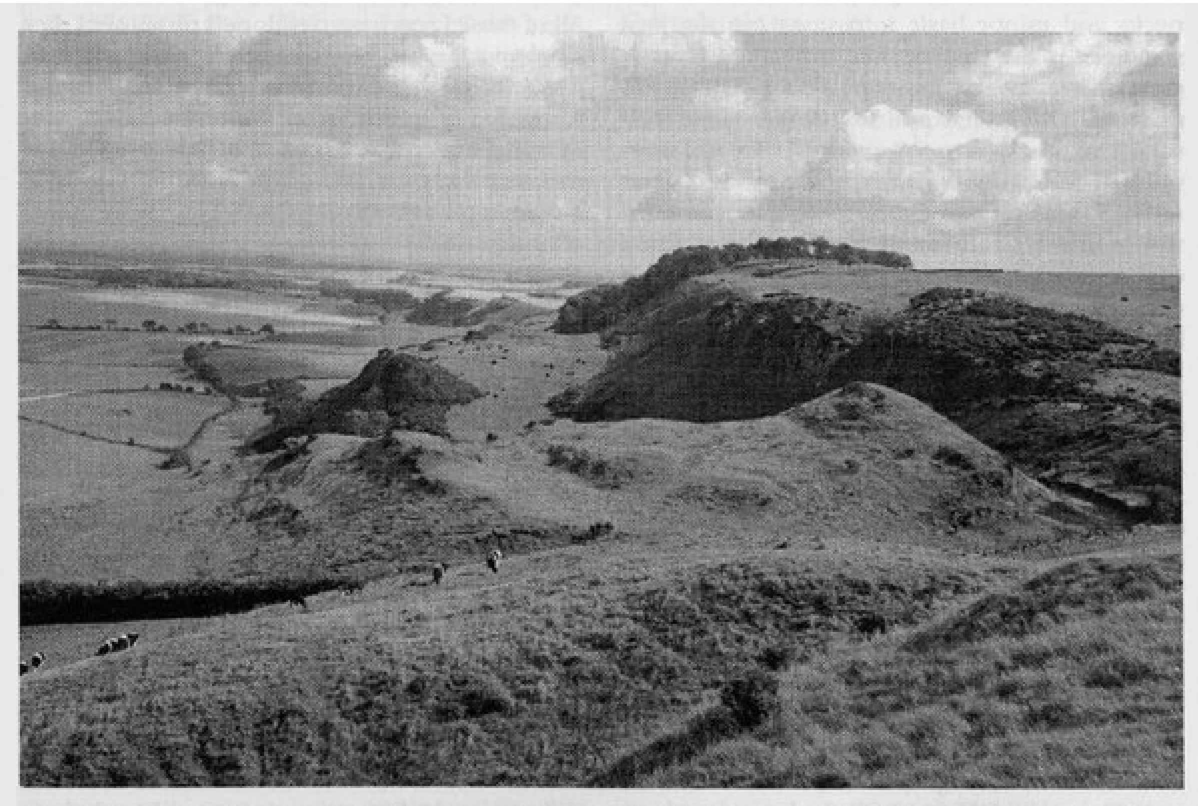
The trachytes probably represent the magma that remained in magma chambers at relatively high crustal levels after the eruption, or crystallization at depth, of basalts (the process known as 'crystal fractionation'). Their abundance in East

Lothian suggests that magma chambers of considerable volume were present beneath the lava field for considerable time in order to generate magmas of this composition. Such magma chambers may have been located along the projected continuation at depth of the Southern Upland Fault.

[**References**](#)



(Figure 2.10) Map of the area around the Garleton Hills GCR site. Based on Geological Survey 1:10 560 mapping by M.F. Howells (1961) and A.D. McAdam (1964).



(Figure 2.11) Trap featuring in trachyte lavas, dipping to the right (south), modified by ice action and glacial drainage, at Kae Heughs, Garleton Hills. (Photo: British Geological Survey, No. D3262, reproduced with the permission of the Director, British Geological Survey, © NERC.)