North Berwick Coast, East Lothian

[NT 496 858]–[NT 624 829]

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Introduction

The North Berwick Coast GCR site, extending for some 17 km between Fidra and Dunbar along the coast of East Lothian, exposes a succession from sedimentary rocks of the Ballagan Formation up through the dominantly volcanic Garleton Hills Volcanic Formation to the unconformity with the overlying sedimentary Gullane Formation. The volcanic rocks form part of the East Lothian volcanic field that crops out between the extrapolation at depth of the main splay of the Southern Upland Fault and the Dunbar–Gifford Fault (Figure 2.2). This down-faulted area of Carboniferous strata lies within the Southern Uplands Terrane and is not strictly part of the Midland Valley (Max, 1976; see Chapter 1). However, the siting of the Carboniferous and Permian volcanoes, whose eroded relics form much of the scenic coastline, was almost certainly dictated by faulting related to the southern boundary of the Midland Valley. Volcanism was mainly of latest Tournaisian to early Visean age but with a probable recurrence in Permian times some 50 million years later.

In simplest terms, the Garleton Hills Volcanic Formation (520 m thick in the Garleton Hills; McAdam and Tulloch, 1985) consists of a basal sequence of bedded tuffs, tuffites and volcani-clastic sedimentary rocks (the North Berwick Member), overlain by predominantly basic lavas (the East Linton and Hailes members) which, in turn, are overlain by felsic (trachytic) tuffs and lavas (the Bangley Member) (see Garleton Hills GCR site report). The strata have a generalized dip towards the west so that the basic tuffs and lavas predominate in the east and the felsic products in the west. Whereas most of the basaltic tuffs were erupted through a large number of small volcanoes whose eroded relics are now seen as vents, larger volcanoes, from which the lavas and trachytic tuffs were erupted, developed at a later stage. Some 14 volcanic vents have been recognized along this coast and it may be supposed that many more lie both out to sea and inland beneath drift deposits.

Inland exposures, other than of trachytes in the Garleton Hills, are generally poor whereas the largely unspoiled and rocky coast affords excellent sections. Although some of the outcrops are above high-water mark, many lie in the intertidal zone. Four prominent islands lie off this coast and outwith the North Berwick Coast GCR site; these are, from west to east, Fidra, The Lamb, Craigleith and Bass Rock. Of these, the first three consist of alkali basalt or dolerite sills whilst the Bass Rock is made of phonolitic trachyte, probably forming a sub-cylindrical stock.

Studies of the East Lothian volcanic rocks have not made the same impact on the history of geology as those closer to Edinburgh (see Arthur's Seat Volcano GCR site report) or on the opposite side of the Firth of Forth (see East Fife Coast GCR site report). However, they are of first-order importance in presenting (1) a superb set of shallowly eroded Late Palaeozoic tuff-rings, (2) some remarkable welded ash-fall tuffs, and (3) inclusions of middle- to lower-crustal and upper-mantle material, allowing insight into the rock-types present at depth that have been sampled by rising magmas. The North Berwick Coast GCR site also includes two localities, Oxroads Bay and Weaklaw, where plant remains of international importance are preserved in the volcaniclastic rocks (Cleal and Thomas, 1995). The earliest descriptions of the volcanic rocks were in the Geological Survey sheet memoir (Howell *et al.,* 1866), but considerably more detail was given in the second edition (Clough *et al.,* 1910). The section was subsequently investigated by T.C. Day, who was responsible for the identification of many of the volcanic vents and published a series of detailed papers between 1916 and 1936. The most recent Geological Survey revision of the area led to an overall appraisal of the volcanism by Martin (1955), which synthesized the work of Day and formed the basis for the current maps and memoirs (McAdam and Tulloch, 1985; Davies *et al.,* 1986). More recent work has concentrated upon the inclusions of crustal and upper-mantle material that are common in many of the vents and intrusions (Upton *et al.,* 1976, 1984, 1999; Graham and Upton, 1978; Halliday *et al.,* 1984; Hunter *et al.,* 1984; Aspen *et al.,* 1990). The section is a popular venue for field excursions and is described in various field guides (McAdam *et al.* in Upton, 1969; McAdam in McAdam and Clarkson, 1986).

Description

Since there is a generalized younging of strata from east to west, the sites are described in this sequence (Figure 2.5).

Scoughall Rocks, at the south-east extremity of the GCR site [NT 623 829], expose the 'Pilmour Volcano', a 900 m-broad vent containing blocks of bedded pyroclastic rock, tuffite, marl and sandstone, up to 100 m across, together with several small basaltic intrusions (McAdam and Clarkson, 1986; Davies *et al.,* 1986). Between Scoughall Rocks and The Car peninsula [NT 610 850] are marls and sandstones with intercalations of fine-grained volcaniclastic sedimentary rocks and tuffites. The concentration of clasts of tuffite and lava increases and boulders of lava with big augite phenocrysts become abundant towards The Car. Igneous clasts, present in abundance along particular horizons in the red marls outside the vents, give them the appearance of agglomerates but they were thought by Clough *et al.* (1910) to have been deposited from 'sheet-floods' of great violence. The bedded rocks are transected by two small vents known as the Scoughall and Seacliff Tower vents. The eastern part of the Scoughall Vent contains red unbedded tuffite, blocks of sandstone and basaltic bombs. The exposed eastern part of the Seacliff Tower Vent is occupied by red pyroclastic breccia. Large tuffite blocks are prominent in this vent, together with basaltic bombs and fragments of sandstone and dolostone ('cementstone).

Day (1930b) described two vents at The Car, which cut sandstones, tuffites and ostracode-bearing marls (Clough *et al.,* 1910). The older of the two vents forms the end of the tidal peninsula whilst the cross-cutting younger vent forms the eminence known as 'Great Car'. The older vent contains stratified tuffite and volcaniclastic breccias dipping uniformly towards the northwest at *c.* 50°. The younger vent is likewise occupied by stratified pyroclastic materials that dip inwards to the north or north-west at 30°–70°. The clasts in these vents are highly scoriaceous with conspicuous augite phenocrysts. Described by Day (1930b) as limburgitic, they were re-defined as leucite basanites by Balsillie (1936). The same rock-type also occurs as irregular masses intruding the northern vent and one of these forms the islet of St Baldred's Boat to the east of The Car. A third vent on the southeast side of the peninsula, partially exposed at very low tide, was recorded by Day (1930b).

Some 500 m south-west of The Car, further exposures of pyroclastic rocks form The Gegan [NT 603 848] and the headland at Seacliff Harbour. At the latter, red tuffites show large-scale cross-bedding. Immediately inland, on the steep coastal slopes, are two basaltic intrusions. Whereas the Primrose Bank body is an olivine-augite-phyric basaltic sill, it is unclear whether the aphyric basalt around the old quarry at Auldhame is part of a plug or a sill. The intrusion contains celestine-bearing veins.

Between The Gegan and Oxroad Bay is a down-faulted mass of mainly greenish tuffites with intercalated dolostones ('cementstones), ripple-bedded sandstone and impure limestone that correlates with strata cropping out farther west near North Berwick. Bedding is highly disturbed by faulting, with dips of up to 60° in varying directions. The green colouration is due to the presence of chlorite; more oxidized equivalents are red owing to the presence of haematite. At least some of the oxidation is believed to have been due to penecontemporaneous weathering. Several bedding planes in the reworked volcaniclastic sedimentary rocks at Oxroad Bay reveal important plant fossil assemblages indicative of a late Tournaisian to early Visean age (Bateman *et al.,* 1995). Some of these assemblages formed in lacustrine environments whereas another overlies a mass-flow deposit. An important SW-trending fault, throwing down to the south-east (the Oxroad Bay Fault), separates green tuffites from coarser pyroclastic breccias of the Tantallon Vent. This vent is filled with unbedded green tuffite and pyroclastic rocks containing small basanite bombs (Figure 2.6). A sandstone lens high in the cliff section may represent sedimentation within the vent during a dormant phase (McAdam and Clarkson, 1986). Beds below the volcaniclastic rocks are exposed locally as a result of faulting between Tantallon Castle and Gin Head where white sandstone is exposed.

To the west, cutting red and green tuffites, lies the Gin Head Vent, full of coarse pyroclastic breccia, rounded basaltic bombs, large masses of sandstone several metres across, and a fossili-ferous limestone (Davies *et al.,* 1986). The pyroclastic breccia here is cut by an irregular sill of aphyric basanite that forms the Tapped Rock and Saddle Rock stacks and the Podlie Craig islet.

Farther west, green tuffites are a dominant component of the coastal outcrops for some kilometres between Canty Bay and North Berwick. They contain highly vesicular particles, originally of basaltic glass but now much chlori-tized. The basaltic clasts are accompanied by detrital quartz, mica and feldspar, much of the latter being microcline (Clough *et al.,* 1910). All are commonly cemented by calcite. They are intersected by numerous small reversed faults, slides and low-angled accommodation planes and have been folded into open dome and basin structures. Close to North Berwick the tuffites show various facies changes, the most important being due to the incoming of larger basaltic clasts (some over 1 m), which vary from rounded to angular. The interbedding of vocaniclastic and non-volcaniclastic sedimentary rocks is further evidence that the bedded rocks accumulated in an aqueous environment.

Some 500 m west of Canty Bay, the Horseshoe Vent is one of the larger vents on this coast section. It contains basanite bombs and coarse-grained, poorly bedded material. Blocks of highly scoriaceous basalt are characteristic (Day, 1928a), together with blocks of sedimentary and tuffaceous rock and fragments of wood. Intersecting the Horseshoe Vent on its northwest side is the small Yellow Man Vent, notable for its basanite bombs and the large size (up to 3 m) of its blocks of tuff (Day, 1925). Some layers of coarse-grained material within the vent may represent debris flows. The vent is transected by irregular basanite dykes (Figure 2.7).

Some 200 m north-west of the Horseshoe Vent lie The Leithies [NT 573 858], a group of small islets exposed at low tide that are formed by a columnar-jointed basanite sill. South of The Leithies and close to the western margin of the Horseshoe Vent is the Partan Craig Vent (Day, 1925), containing blocks of bedded tuffite, silt-stone and dolostone together with bombs of nepheline basanite (Day and Bailey, 1928). This vent has been the most prolific source of lower-and middle-crustal xenoliths in Britain (Upton *et al.,* 1976; Graham and Upton, 1978) (see Chapter 1). A prominent debris-flow layer comprising blocks of bedded tuffite is well exposed on its west side. For approximately 1 km west of Partan Craig there are intermittent outcrops of bedded pyroclastic rocks (Figure 2.8) and intercalated sedimentary rocks, cut by the Lecks Vent. The Yellow Man is an irregular NE-trending dyke-like intrusion of olivine basalt that forms a rocky prominence above the beach. A wave-cut platform close by reveals a *c.* 3 m-thick sequence of dolostone with possible algal growths. This is a major stratigraphical marker within the North Berwick Member, separating green tuffites below from red tuffites above (Martin, 1955).

The overlying lavas of the East Linton Member, dipping west at *c.* 20°, are very well exposed between North Berwick harbour [NT 554 856] and the paddling pool some 100 m to the east. The lowest flow is *c.* 4 m thick and intensively altered. It has been described as a 'kulaite', an analcime trachybasalt containing relict phenocrysts of both augite and hornblende. According to Bennett (1945), the analcime is secondary after leucite. Bennett also noted the presence of granitic xenoliths and fragments of quartz, orthoclase, microcline and oligoclase. This lava is overlain by tuffite, several metres thick, succeeded by a 7 m-thick basaltic lava containing phenocrysts of plagioclase, augite and pseudomorphed olivine as well as scarce inclusions (?autoliths) of gabbro.

The basaltic lava is directly overlain by a mugearite lava some 10 m thick with a well-preserved autobrecciated upper surface that marks the base of the Hailes Member (Figure 2.9). The vesicles (now amygdales) in this flow top have been stretched out into elongate, tubular forms, and individual lava blocks have been rotated during flow. The original surface clearly experienced minimal weathering before it was over-ridden by the next lava flow. The latter is *c.* 17 m thick and contains an abundance of plagioclase phenocrysts in association with smaller, scarcer phenocrysts of iddingsitized olivine. This flow is a hawaiite whose uppermost facies contains large (up to 20 cm) calcite-filled amygdales. This lava succession is repeated by faulting to the west at Cowton Rocks, where a porphyritic hawaiite overlain by a mugearite flow whose fissile nature and diagenetic ovoid structures, produced by concentric bands of haematite, are similar to those seen in the mugearite at North Berwick. The mugearite lava can be followed west as far as Marine Villa [NT 503 859] where the original rough and jagged flow top is perfectly preserved beneath bedded trachytic tuffs.

These lavas are cut by the Yellow Craig Plantation Vent, composed of poorly stratified tuffite with associated basanite intrusions, the more prominent of which form Longskelly Point [NT 522 863] and the hillock of Yellow Craig (Day, 1932c). Fidra island, lying north-west of the Yellow Craig Plantation Vent, consists of a thick, columnar-jointed basanite sill. The cobble beach on the mainland south-west of the island is largely composed of basanite pebbles, which are almost certainly derived from Fidra or its offshore extensions.

Bedded trachyte tuffs (*c.* 10–15 m thick) at the base of the Bangley Member crop out from Marine Villa westwards. Their original compositions have been largely obscured by later carbonation and oxidation to haematite. Mugearitic and trachytic clasts in these tuffs are mainly angular but some layers are rich in lenticular particles flattened parallel to the bedding. These lenticles were probably lapilli of very fluid pumice that were deformed beneath accumulating tuff layers above, i.e. they are welded ash-fall tuffs.

The Weaklaw Vent, which cuts the bedded trachytic tuffs, contains poorly bedded sandy tuffaceous breccia. Basaltic rocks in the vent have been intensely carbonated. Plant fossils are particularly well preserved (Bateman *et al.,* 1995) and Gordon (1935) considered that the plants grew on the flanks of an active volcano and were killed by ash flows. Immediately west of the vent a 5 m-thick flow of vesicular porphyritic trachyte overlies the bedded trachytic tuffs and is itself overlain by sedimentary rocks that mark the start of a prolonged period of magmatic inactivity.

Apart from shallowly derived fragments of volcanic and sedimentary rock, xenoliths representing rock-types present at deep levels in the crust and upper mantle are common within the East Lothian basanites. Xenoliths of granulite-facies quartzo-feldspathic gneisses occur in intrusions at Quarrel Sands, Canty Bay and Weaklaw but are most abundant in the coarse pyroclastic strata on the foreshore west of Partan Craig. Some of the xenoliths contain garnet, kyanite and rutile. The microcline recorded in the bedded tuffites (Clough *et al.,* 1910) probably came from disaggregation of these gneisses. Xenoliths of other, more basic granulite-facies gneisses, comprising plagioclase together with one or two types of pyroxene and subordinate magnetite, are also present, especially in the Fidra basanite.

Peridotite inclusions occur at Weaklaw and Fidra ((Figure 1.8), Chapter 1). Those in the Weaklaw Vent are foliated, highly altered and up to 15 cm in diameter. Spinel is the only primary constituent in these that has not been altered by low-temperature processes. In contrast, the Fidra basanite contains abundant xenoliths of fresh spinel lherzolite, commonly foliated and with orthopyroxene porphyroclasts. Xenoliths of wehrlite grading to clinopyroxenite are also common here. The Fidra basanite is also remarkable for its content of large (up to 3 cm) discrete anhedral crystals (megacrysts), principally of anorthoclase but also of sanidine and magnetite. Rare xenoliths of related apatite-magnetite rock also occur. Peridotite xenoliths have not been found along the coast east of Fidra but xenoliths of biotite-rich ultramafic rock are known from Partan Craig and Beggar's Cap.

Interpretation

The chief distinction between the mapped vents and the surrounding tuffites and volcaniclastic sedimentary rocks is that the latter represent widely distributed (distal facies) fragmental material on and around the volcanic cones, which were subject to water-sorting and admixture with fluviatile detritus, whereas the vent material represents the generally coarser and more chaotic (proximal facies) material collecting as fall-out and talus on the steeper inward-facing slopes. Listric faulting and mass-flow (lahar) processes would have contributed to the complexity. The extreme alteration (dolomitization) of the pyroclastic rocks at Weaklaw may have resulted from extended exhalation of carbonated fluids from the post-eruptive vent.

In Early Carboniferous time the region lay within equatorial latitudes, with the evidence indicating a low-relief lagoonal landscape lying little above sea level, and supplied by fine clastic sediment from slow-flowing rivers. The vents probably represent shallowly dissected tuff-rings created by phreatomagmatic activity where rising magmas encountered wet sediment or standing water. The diameter of these tuff-rings, which would have been little wider than the vents, rarely exceeded 1 km and was commonly significantly less. Eruptions would have been short-lived and violent, yielding pyroclastic products composed mainly of broken fragments of near-surface rocks together with juvenile tephra, including at times lava bombs of substantial size. The identification of lacustrine sediment within some vents suggests the probability that lakes ('maars') formed within the craters. The presence of plant fossils suggests that the emergent slopes were colonized by ferns, equisitales and club-mosses, fragments of which are common in the tuffites and which are well preserved in places, such as at Oxroad Bay and Weaklaw. Dolostone lenses (free of organic remains) within the green tuffs have been regarded as evaporites produced under more arid conditions. Martin (1955) divided the vents into a younger Green Group and an older Red Group, showing that the Red Group vents were active before the eruption of the lavas whereas those of the Green Group cut higher strata and contain fragments of the hawaiite and mugearite lavas.

The Quarrel Sands Vent is representative of the older Red Group whereas the Yellow Craig Plantation, Partan Craig, Yellow Man and Horseshoe vents are among the younger Green Group.

The early magmas, represented by tuff fragments and 'bombs', all appear to have been strongly silica-undersaturated basaltic varieties. The compositions of many were primitive, with olivine as the sole phenocryst species. Ascent rates of these magmas were frequently high and uninterrupted, as is evidenced by the common occurrence of ultramafic xenoliths of probable mantle origin. However, some of the magmas contained both olivine and augite phenocrysts, as large and conspicuous crystals, indicative of stagnation and slower cooling (probably at deep crustal levels) during their ascent. It may be significant that the lowest lava in the succession, the analcime trachybasalt at North Berwick, is also silica-undersaturated. This, and a similar lava at the base of the lava succession farther south, are almost unique in the Dinantian lava successions of the Midland Valley in being relatively evolved silica-undersaturated rocks. They may be related to the nearby phonolitic intrusions of North Berwick Law, the Bass Rock and Traprain Law (for discussion, see Traprain Law GCR site report).

The overlying lavas at North Berwick and west to Marine Villa signify a situation different from that which produced the foregoing phreatomagmatic materials. They indicate larger volume eruptions under subaerial conditions and their less silica-undersaturated compositions point to greater degrees of melting at shallower mantle depths. The compositional variation (olivine basalt, hawaiite, mugearite and subsequent trachytes) implies extended crystal fractionation in magma chambers, probably in the deep crust. Since the greatest thickness of volcanic rocks in East Lothian is around Haddington (McAdam and Tulloch, 1985), it was probably in this area, some 20 km distant, that the principal volcanoes were sited. The thick trachyte lavas of the Garleton Hills (see GCR site report) may well be caldera-filling flows, and the thick trachytic tuff sequence at Marine Villa and Weaklaw could well signify a major pyroclastic eruption from a high-level magma chamber prior to caldera collapse. The disconformity above the trachytes heralded long-term volcanic quiescence in the region.

Basanite sills such as those at The Leithies and Fidra mark a later rejuvenation of activity. At Brigs of Fidra a small basanite sheet, believed to be correlative with that on Fidra Island, cuts hawaiite lava and may be assumed to post-date the trachyte episode. A recent K-Ar date on the Fidra basanite gave its age as 264 ± 10 Ma (Downes *et al.,* 2001). Other recent K-Ar dates include a dyke in the Gin Head Vent at 267 ± 5 Ma and the Yellow Man Dyke at 293 ± 7 Ma (Wallis, 1989). These all suggest early to mid-Permian ages. The younger 'Green Group' of vents (Martin, 1955) may also postdate the early phase of volcanism. These younger magmas may have been produced by depressurization melting of garnet lherzolite mantle sources in response to Variscan earth movements.

The xenoliths and megacrysts provide information concerning the rocks beneath the cover of sedimentary and volcanic rocks. Together with suites of inclusions from elsewhere in Scotland, they enable a detailed interpretation to be made of the composition, structure and history of the lower crust and upper mantle, which probably has not changed significantly from Late Palaeozoic times to the present day. A full account of this interpretation is given in Chapter 1.

Much work remains to be done and the physical volcanology of the shallowly dissected vents in particular awaits a modern study. Although many of the igneous rocks have been seriously affected by low-temperature alteration, they nonetheless offer wide scope for further petrological investigation. Additionally, many of the rocks, in particular the fresher basanites, could now be more satisfactorily dated by Ar-Ar techniques. Deep crustal xenoliths containing zircon invite more precise dating using the U-Pb method. Lastly, the petrology of the xenoliths within the volcanic rocks is being actively studied to learn more of the nature of the rocks at depth below this critical area, close to the junction of the Midland Valley and Southern Upland terranes.

Conclusions

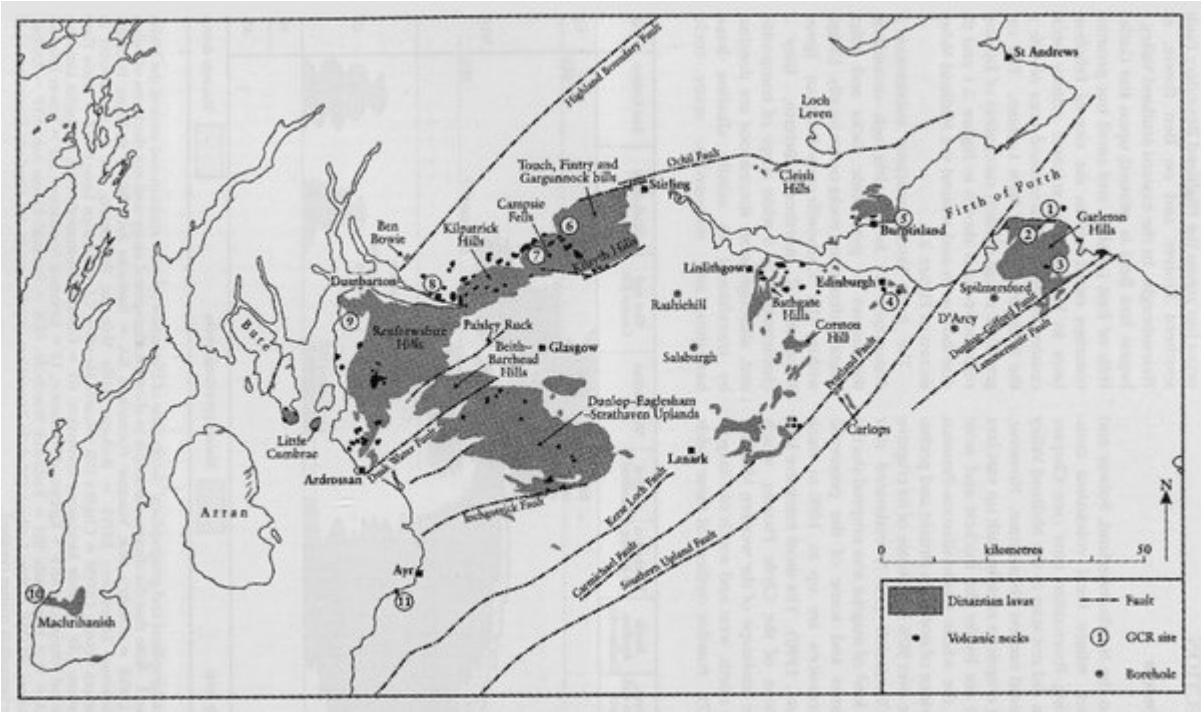
The North Berwick Coast GCR site, covering the coast to the east and west of North Berwick is representative of the Visean Garleton Hills Volcanic Formation, but shows particularly the fragmental and intrusive products of numerous small basaltic volcanoes that characterize the earliest local volcanic activity; before the eruption of lavas and tuffs from larger volcanoes sited in the region of the Garleton Hills GCR site. Radiometric dates on later intrusions suggest that small-scale magmatism resumed in the Early Permian, possibly more than 50 million years later.

The rocks at this site provide an insight into an ancient tropical environment of sluggish rivers, lakes and lagoons subjected to short-lived, violent eruptions from small volcanoes that stood above an otherwise flat landscape. The wide variety of early land-plants that flourished on this landscape confers international palaeobotanical importance to the site.

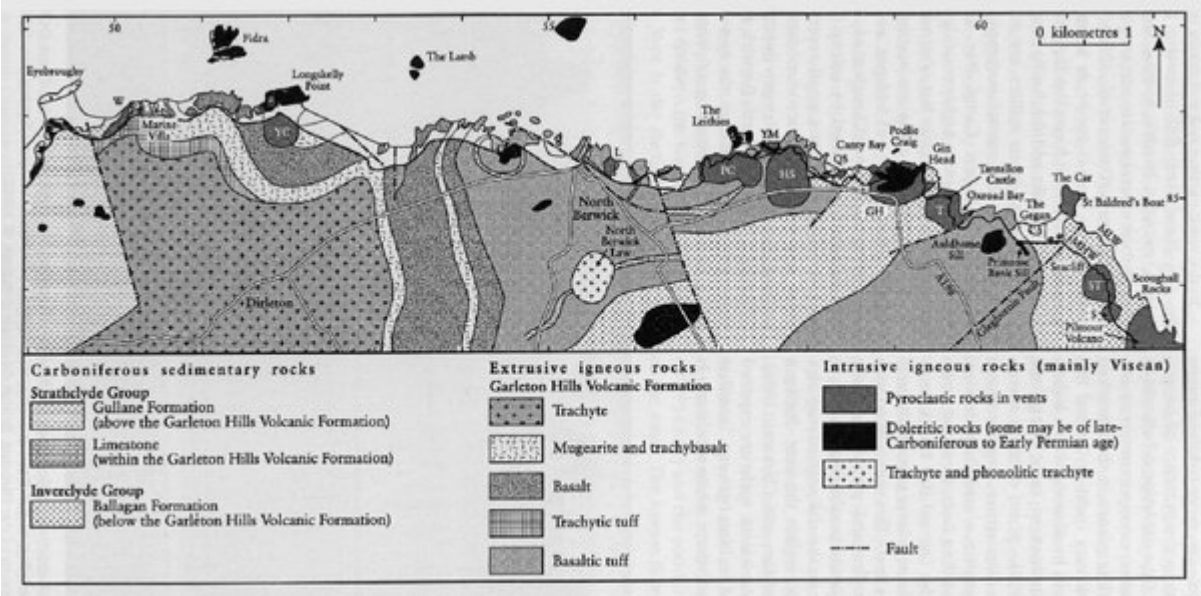
The dissected volcanoes can be interpreted as small 'tuff-rings' of fragmental ejecta, formed as a result of the highly explosive interaction of magma with surface water, with groundwater and with water-saturated sediments. As such they complement the similar, but later volcanoes of the East Fife Coast GCR site and are possibly some of the best-preserved examples in Britain. As the chances of survival of such fragile structures are rare in the older geological record, there is potential for further study that could increase their international importance.

The intrusions and volcanic rocks of this section are renowned for the abundance and wide variety of exotic rock fragments that have been brought up from great depths by the magmas. These constitute a unique method of sampling the deeper levels of the Earth's crust and provide information of international value on the nature of the lower crust and the underlying upper mantle.

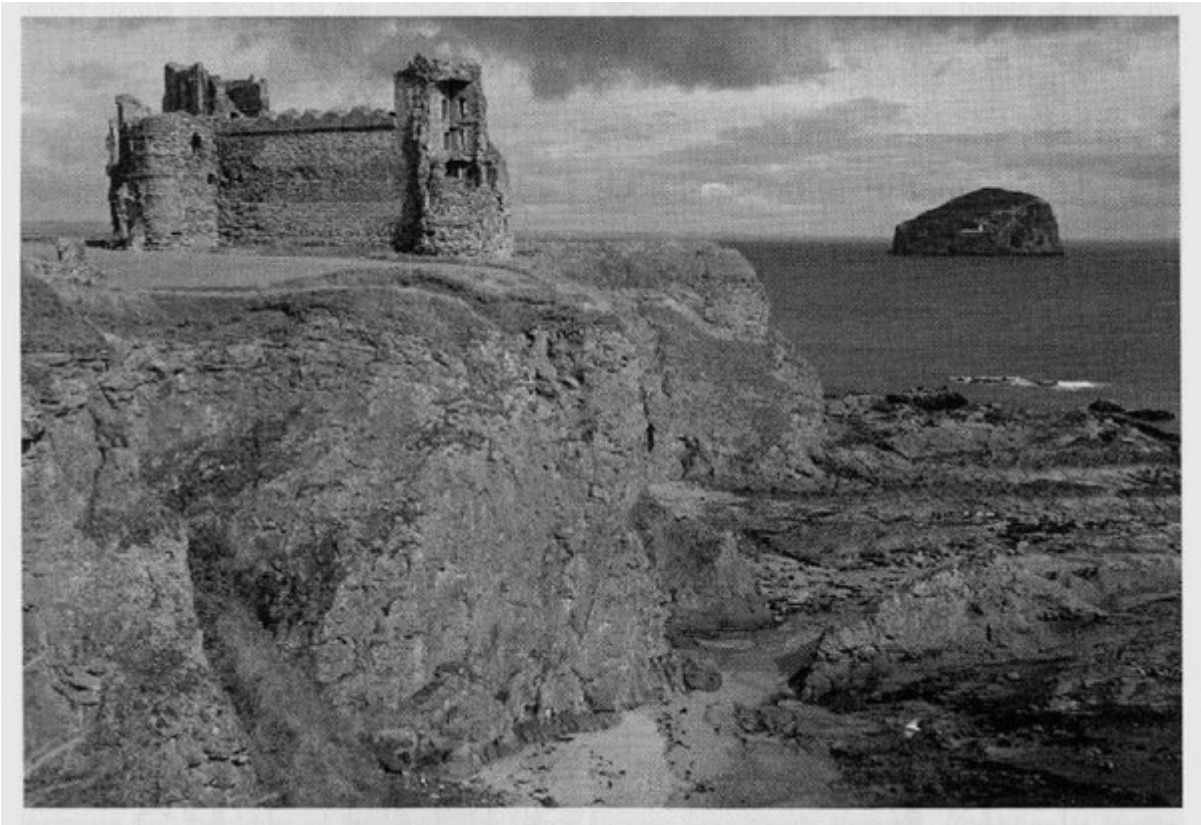
References



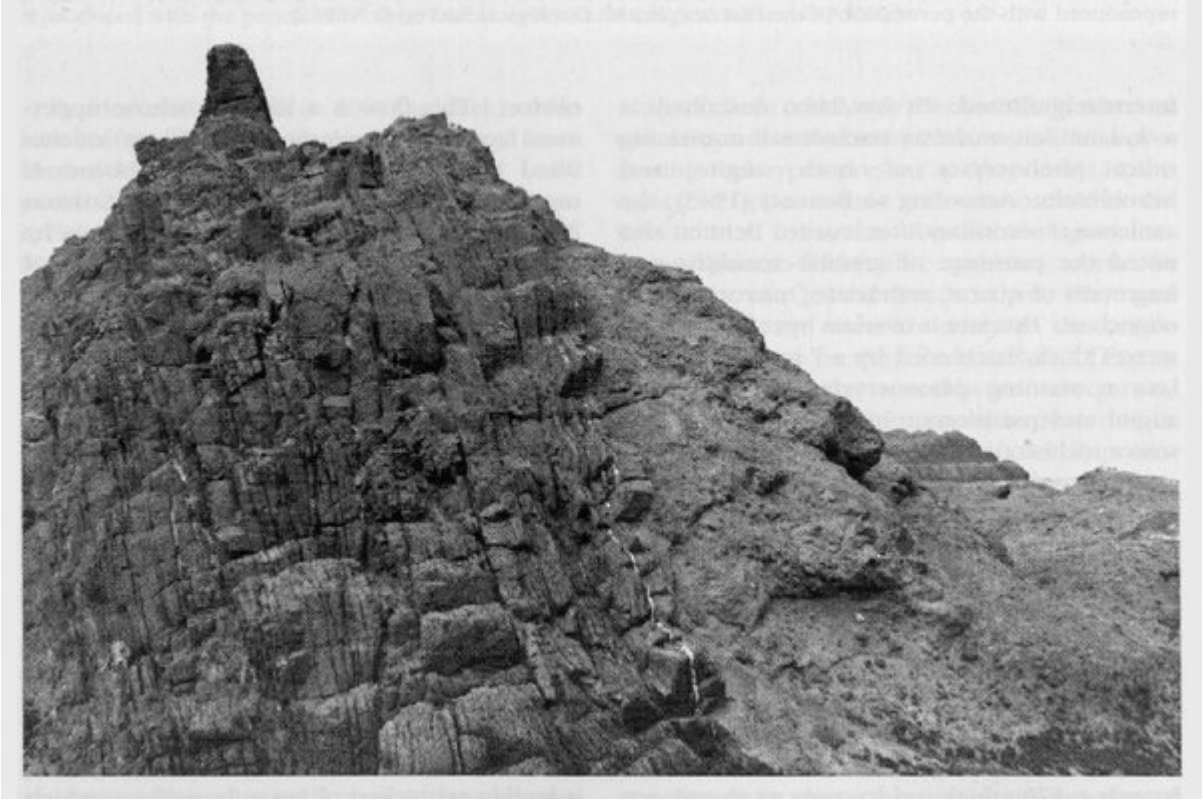
(Figure 2.2) Map of the Midland Valley showing the outcrops of Dinantian volcanic rocks and the major structural components. GCR sites: 1 = North Berwick Coast; 2 = Garleton Hills; 3 = Traprain Law; 4 = Arthur's Seat Volcano; 5 = Burntisland to Kinghorn Coast; 6 = Touch, Fintry and Gargunnock Hills; 7 = Campsie Fells; 8 = Dumbarton Rock; 9 = Dunrod Hill; 10 = Macrihanish Coast and South Kintyre; 11 = Heads of Ayr. After Cameron and Stephenson (1985).



(Figure 2.5) Map of the area around the North Berwick Coast GCR site. (GH = Gin Head Vent; HS = Horseshoe Vent; L = The Lecks Vent; PC = Partan Craig Vent; QS = Quarrel Sands Vent; S = Scoughall Vent; ST = Seacliff Tower Vent; T = Tantallon Vent; W = Weaklaw Vent; YC = Yellow Craig Plantation Vent; YM = Yellow Man Vent.) After McAdam (in McAdam and Clarkson, 1986); and British Geological Survey 1:50 000 sheets 33W, Haddington (1985); and 33E, Dunbar (1986).

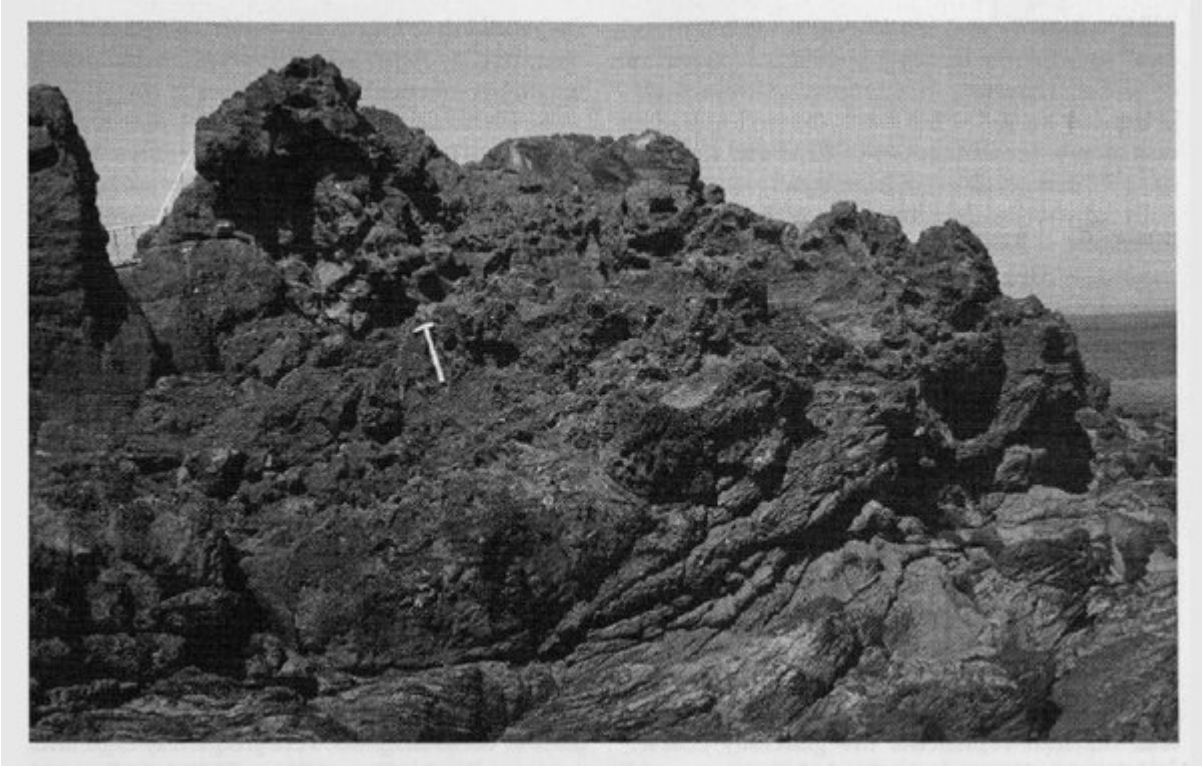


(Figure 2.6) Tantallon Castle, on agglomerate cliffs of the Tantallon Vent, North Berwick Coast GCR site, with the phonolitic trachyte plug of the Bass Rock beyond. (Photo: British Geological Survey, No. D3665, reproduced with the permission of the Director, British Geological Survey, NERC.)



(Figure 2.7) Basanite dyke (left) cutting vent agglomerate of the Yellow Man Vent, North Berwick Coast GCR site. The cliff is about 6 m high. (Photo: British Geological Survey, No. D1113, reproduced with the permission of the Director, British Geological Survey, © NERC.)

(Figure 2.8) Basaltic bombs (rounded) and blocks (angular) in red, bedded basaltic tuffs at The Lecks, North Berwick Coast GCR site. The hammer head is about 15 cm long. (Photo: British Geological Survey, No. D3044, reproduced with the permission of the Director, British Geological Survey, © NERC.)



(Figure 2.9) Mugearite lava at North Berwick, showing flow lamination in the main body of the flow and a slaggy, amygdaloidal flow top. The hammer shaft is about 35 cm long. (Photo: British Geological Survey, No. D3041, reproduced with the permission of the Director, British Geological Survey, © NERC.)

(Figure 1.8) Peridotite xenolith with a thin rim of altered chilled basalt in the Weaklaw Vent, North Berwick Coast GCR site. The coin is 24 mm in diameter. (Photo: B.G.J. Upton.)