Black Rock to East Comb

[NO 694 488]–[NO 703 476]

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Introduction

This section of the Angus coast exposes the 'Ethie lavas', the upper part of the Montrose Volcanic Formation in the Arbuthnott Group of the Old Red Sandstone succession in the Strathmore Basin (Armstrong and Paterson, 1970) (Figure 9.2). The three-dimensional exposure makes the section eminently suited to detailed study of sediment–lava contacts. These volcanic rocks and interbedded sandstones were first described by Fleming (1818). He used their complex relationships as an argument in favour of the Wernerian hypothesis, which considered that basalt was deposited from an aqueous fluid (see the Forest Lodge GCR site report). Subsequently the lavas were described by Geikie (1897) as sheets of andesite or 'porphyrite' erupted from the Montrose Volcanic Centre. Jowett (1913) produced a more detailed geological description and map (Figure 9.23). The lavas were placed at the base of the former 'Red Head Series' by Robson (1948) but he did not study them in detail. Although down-faulted Devono-Carboniferous rocks intervene between the 'Ethie lavas' and the lower part of the Montrose Volcanic Formation (see the Scurdie Ness to Usan Harbour GCR site report), the 'Ethie lavas' are clearly the younger and are succeeded by elastic red beds of the Red Head Formation of the Garvock Group. Some of the Ethie lavas have been analysed by Thirlwall (1979) as part of a regional geochemical study of Lower Old Red Sandstone lavas.

Description

The lavas are dull purplish-grey to green in colour and vary from compact to extremely amygdaloidal with large cavities. Some have roughly polygonal cooling cracks. Their most striking features are the detailed contacts with the intercalated sedimentary rocks. Fissures and large cavities in the lavas have been filled with pale-green and red sandstone and some of the slaggy lava tops, which can be 3–4 m thick, have interstices filled by horizontally stratified pale-green sandstone.

In his petrological study of the area, Jowett (1913) described all the lavas as olivine basalts', most of which could not be distinguished in the field except for one feldspar-phyric type exposed in the lower part of the cliff at Ethie Haven [NO 698 488] and which continues west for about 300 m. The typical 'Ethie lavas' are probably basaltic andesites; they contain phenocrysts of altered olivine and microphenocrysts of labradorite, augite and magnetite, set in a holocrystalline to partly glassy groundmass. All the olivine has been pseudomorphed by serpentine and haematite. Some of the youngest lavas in the succession, around Auld Mains [NO 706 478] and in the bay to the SW [NO 703 476], are less basic and contain glomeroporphyritic aggregates of olivine, augite and labradorite (Jowett, 1913). No orthopyroxene has been found in the Ethie lavas (cf. the Ferryden lavas of the Scurdie Ness to Usan Harbour GCR site). A flow structure is seen in some of the lavas due to the alignment of small feldspar laths.

The section is here described from north to south, which is generally up the sequence (Figure 9.23). Black Rock is a breccia within red sandstones of Devono-Carboniferous age that are presumed to be unconformable on the Lower Old Red Sandstone lavas. The latter are well exposed in the cliffs to the SE of a major fault trending ENE. Above the basaltic andesites and the feldspar-phyric basaltic andesite at Ethie Haven [NO 699 487], there is a local unconformity overlain by a thick red conglomerate. Within the conglomerate are at least two thin flows of fine-grained basaltic andesite. The top surface of the conglomerate is irregular and it is overlain by fine-grained basaltic andesite.

Rugged coastal scenery has developed to the south, where the softer amygdaloidal zones of the basaltic andesites have been eroded away. The bases of some flows are pillowed and, locally, rounded blocks of highly amygdaloidal lava are set in scoriaceous lava or volcaniclastic breccio-conglomerate. The slaggy and brecciated parts of the flows are commonly paler coloured due to replacement by calcite. Thick beds of conglomerate, comprising lava fragments in a pale-green medium-grained sandstone matrix, are intercalated with the lavas near Spectacle [NO 705 484]. North of Kirk

Loch [NO 705 481], elongate, flow-orientated amygdales occur within the base of a lava flow overlying a volcaniclastic breccia (Figure 9.24).

South-west of Auld Mains at [NO 704 477], there are excellent exposures showing the relationship between a clast-supported conglomerate containing large rounded boulders of volcanic rock and an underlying, irregularly eroded lava surface. At Auld Mains [NO 706 478], a resistant flow of lava infills and covers the uneven surface

of the same conglomerate. The lower part of this lava is platy with partings parallel to the surface of the conglomerate. The compact part of the lava is at least 10 m thick and has rough columnar-jointing, but the slaggy top has been eroded away locally beneath the next conglomerate. The irregular slaggy top of the uppermost lava flow is overlain disconformably by volcaniclastic conglomerate and red sandstone of the Red Head Formation; this exposure has been figured by Geikie (1897).

Interpretation

The Black Rock to East Comb GCR site contains a well-exposed section through the lavas at the top of the Montrose Volcanic Formation which means that, except for minor outpourings in the overlying Garvock Group, these lavas are the youngest in the main Lower Old Red Sandstone lava sequences of the northern Midland Valley (Figure 9.2). Spores of Early Devonian age have been found in the intercalated sedimentary rocks of the Arbuthnott Group in Angus (Richardson *et al.,* 1984).

Thirlwall (1979) analysed phenocrysts from the Ethie lavas (his Ethie Haven Member); the olivines are Mg- and Ni-rich, the clinopyroxenes are low-Na diopsidic augites, and all but one of the analysed samples has bytownite–labradorite microphenocrysts. The analysed samples are quartz- or slightly olivine-normative, and the $Si0_2$ content ranges from 53.8–55% (Thirlwall, 1979). The lavas may therefore be classified as basaltic andesites. The 'Ethie lavas' have high MgO, Ni (*c.* 150 ppm) and Cr (350–540 ppm) contents (Thirlwall, 1979), suggesting that they are derived from primitive, mantle-derived magmas. The Ni and Cr contents are much higher than those for the Dunnichen and East Hills lavas in the Montrose Volcanic Formation to the west, and according to Thirlwall the two lava successions could be related by fractional crystallization with olivine and clinopyroxene as the major crystallizing phases.

The lavas are thought to have emanated from the Montrose Volcanic Centre, which lay to the NE, now under the North Sea, and to have accumulated in a slowly subsiding basin in which the interplay of successive lava flows with the intercalated sediments was complex. The fissured and scoriaceous zones permeated by fine-grained laminated siltstones could suggest that the sediment was washed in by shallow current action after the flow had cooled and cracked. However, the local development of pillow structures and the development of amygdales in the incorporated sediment suggests that the lavas flowed on to wet sediment. Hence, some of the lavas may have locally ploughed or intruded into wet sediment and caused fluidization of the sediment (cf. Kokelaar, 1982; and see the Port Schuchan to Dunure Castle, Culzean Harbour and Turnberry Lighthouse to Port Murray GCR site reports), which would account for the examples where the sediment has been homogenized and forced along a maze of narrow cracks. Because of the widespread reddening of the tops of the lavas and the local unconformities described at their tops, it is thought that most of the basaltic andesites are lava flows and not intrusive sheets into wet sediments, although this is an aspect of the geology that would require future study.

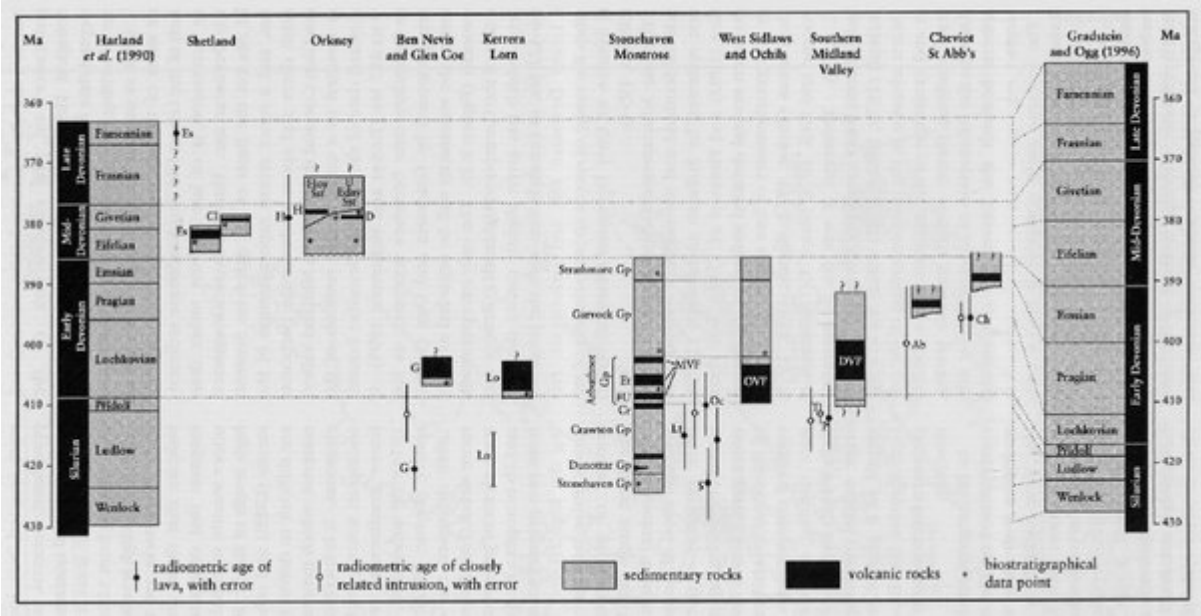
The intercalated conglomerates include boulders of volcanic rock and this indicates that during the longer periods between lava eruptions, strong currents deposited lenticular bodies in channels cut into the lava pile. The sandstones, siltstones and mudstones were probably deposited on the adjacent banks during periodic floods. South of Auld Mains, increasing amounts of mainly volcaniclastic sedimentary rocks occur within the succession, and above a local unconformity at [NO 702 477], the Red Head Formation begins. This elastic formation coarsens upwards towards the south, and the higher beds contain pebbles of quartzite (Jowett, 1913); it is therefore inferred that larger river systems became established, which eventually managed to bring in well-rounded quartzite pebbles from the Highlands to the north.

Conclusions

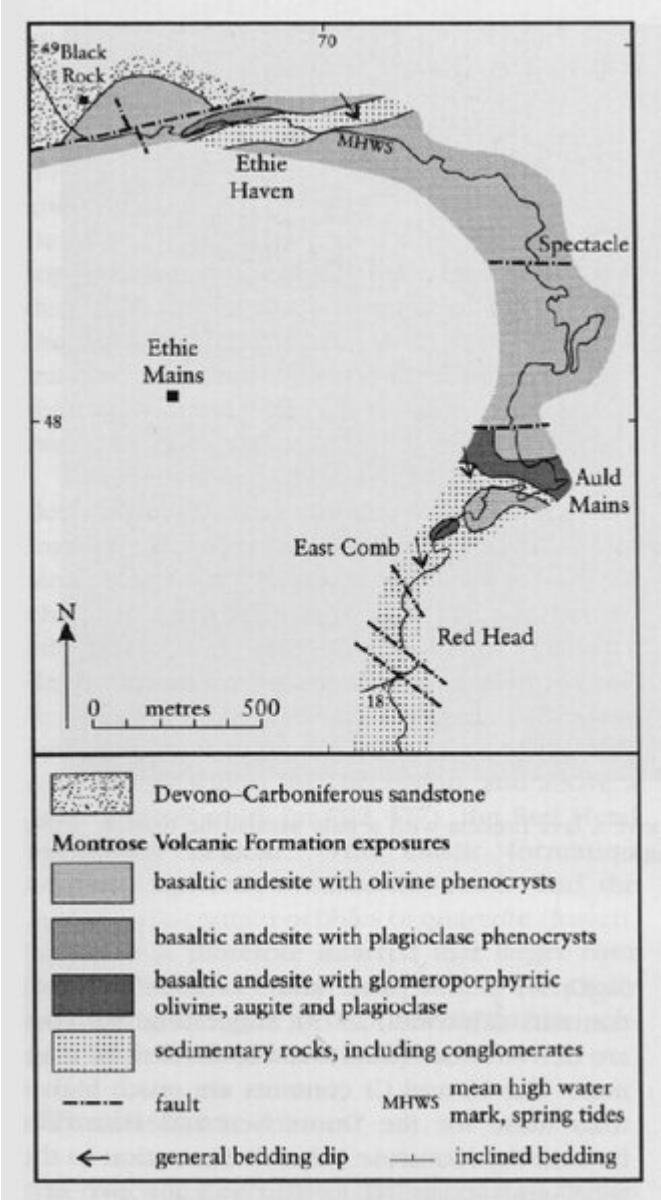
The Black Rock to East Comb coastal section is of national importance as a representative of the Ethie lavas, which are the youngest in the Lower Old Red Sandstone Montrose Volcanic Formation. The section provides an excellent opportunity to examine the relationships between the lavas and intercalated sedimentary rocks at the transition between the Arbuthnott and Garvock groups.

The lavas were probably erupted from a volcanic centre now under the North Sea. Most are probably basaltic andesites but the youngest ones may be less basic; as such they are typical of the calc-alkaline suite of Lower Old Red Sandstone lavas in the northern Midland Valley. They were erupted in a terrestrial shallow-water environment and have complex relationships with intercalated sedimentary rocks, partly due to the interaction of hot lava with wet sediment. The intercalated lenses of coarse conglomerate, composed mainly of volcanic detritus, indicate that initially the local drainage channels were sourced within the Strathmore Basin, but with the cessation of volcanic activity in this area, rivers draining the higher land to the north entered the basin.

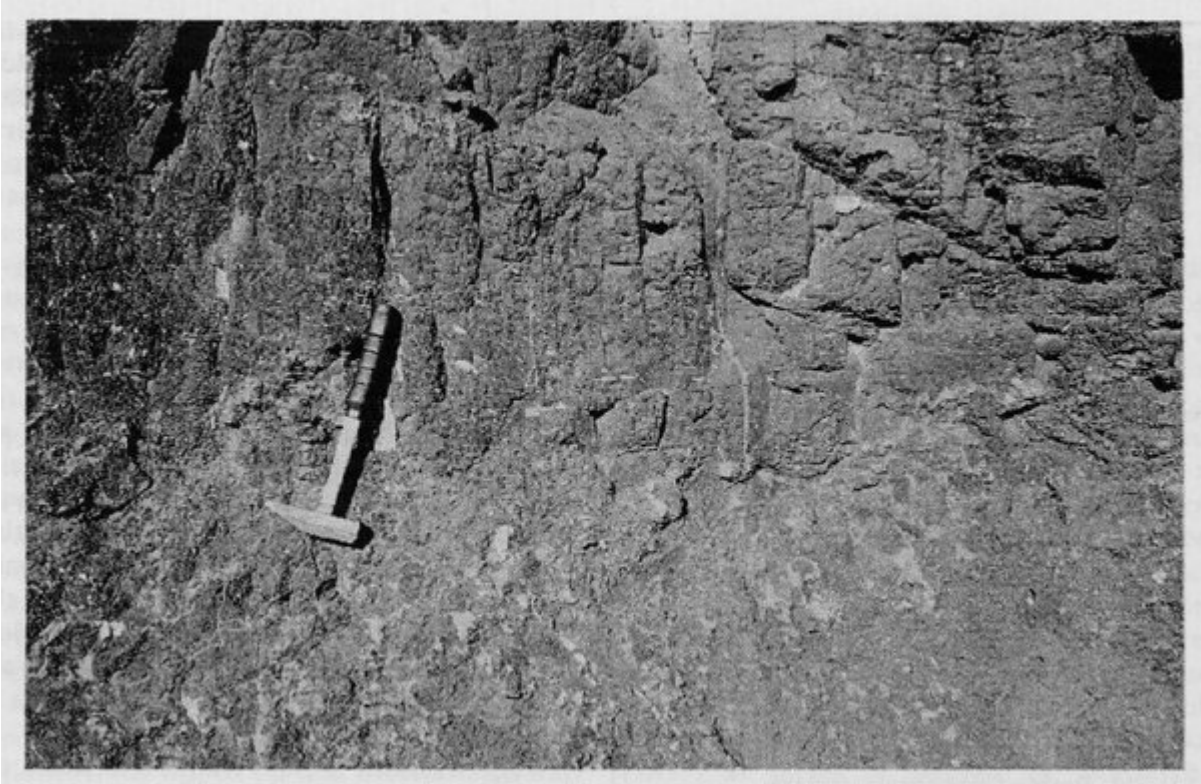
References



(Figure 9.2) Stratigraphical relationships and ages of late-Silurian to Mid-Devonian age volcanic rocks of northern Britain. Biostratigraphical ages (where known) are given precedence and are plotted relative to the time-scale of Harland et al. (1990) (on the left). Note the consistent discrepencies between the biostratigraphical ages and the radiometric ages, which are not present if the time-scale of Gradstein and Ogg (1996) (on the right) is used. Where there is no biostratigraphical control (i.e. Southern Midland Valley, St Abb's and Cheviot), the volcanic sequences are projected from the radiometric dates. For example Cheviot at 396 Ma is early Emsian on the Gradstein and Ogg timescale, so it is plotted in the early Emsian position on the Harland et al. time scale. Ab, St Abb's; Ch, Cheviot; Cl, Clousta; Cr, Crawton; D, Deerness; DVF, Duneaton Volcanic Formation; Es, Eshaness, Papa Stour and Melby; Et, Ethie; FU, Ferryden and Usan; G, Glen Coe; F1, Hoy; Lo, Lorn; Lt, Lintrathen; MVF, Montrose Volcanic Formation; Oc, Ochil Hills; OVF, Ochil Volcanic Formation; P, Pentland Hills; S, Sidlaw Hills; T, Tinto.



(Figure 9.23) Map of coastal exposures of Montrose Volcanic Formation between Black Rock and East Comb, adapted from Jowett (1913).



(Figure 9.24) Base of lava with elongate amygdales above a lava breccia with a pale sandstone matrix. Ethie lavas, north of Kirk Loch at [NO 705 481]. (Photo: R.A. Smith.)