CRAWTON BAY

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OS Grid Reference: NO880797

Introduction

These coastal exposures are the type locality for the Crawton Volcanic Formation, the youngest formation in the Crawton Group which comprises part of the Lower Old Red Sandstone succession in the Crawton Basin, a precursor to the Strathmore Basin (Figure9.2). The formation consists of olivine-bearing basalts and basaltic andesites and interbedded conglomerates of late Silurian to Early Devonian age. The inter-relationships between the lava flows and intercalated sedimentary rocks of 'Highland origin' have been recorded from this vicinity since Geikie (1897). Subsequently Campbell (1913), Trewin (1987), Carroll (1994) and MacGregor (1996) have described the locality in detail. Of the four lava flows present in Crawton Bay (Figure 9.19), the lower three contain characteristic large, flow-orientated plagioclase phenocrysts (the 'Crawton type' of Campbell, 1913), whereas the uppermost one is aphyric. The distinctive 'Crawton type' lavas have been traced inland around the hinge of the Strathmore Syncline (Haughton, 1988). Some of the lavas have been analysed as part of a geochemical study of the British Lower Old Red Sandstone lavas (Thirlwall, 1979).

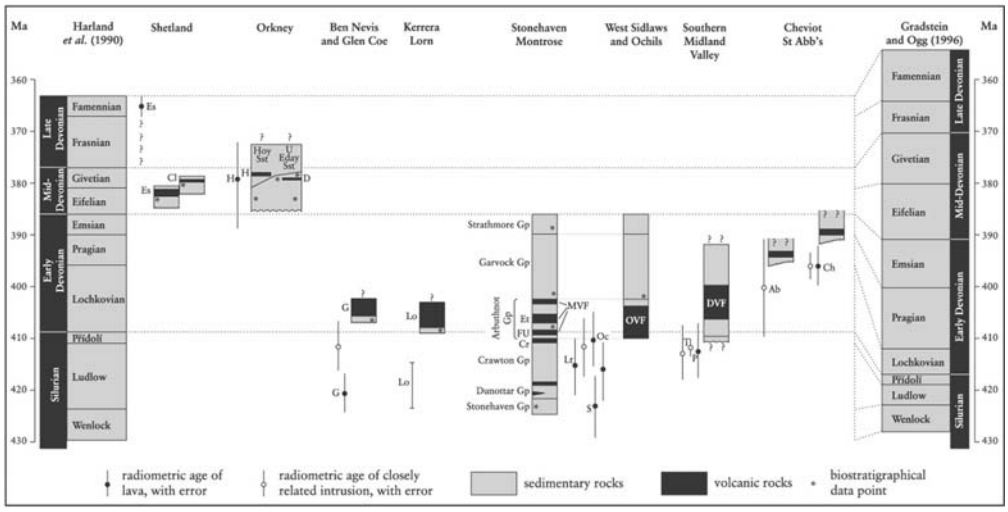

Figure 9.2: Stratigraphical relationships and ages of late-Silurian to Mid-Devonian age volcanic rocks of northern Britain. Biostratigraphical ages (where known) are given precedence and are plotted relative to the time-scale of Harland et al. (1990) (on the left). Note the consistent discrepencies between 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; H, Hoy; Lo, Lorn; Lt, Lintrathen; MVF, Montrose Volcanic Formation; Oc, Ochil Hills; OVF, Ochil Volcanic Formation; P, Pentland Hills; S, Sidlaw Hills; T, Tinto.

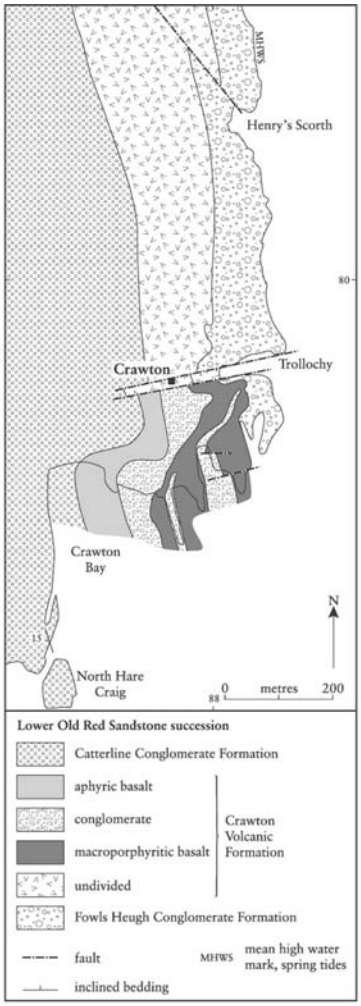

Figure 9.19: Map of the Crawton Bay Volcanic Formation at Crawton Bay.

Description

Carroll (1994) estimated the Crawton Volcanic Formation to be 70 m thick. At Crawton Bay the rocks dip at about 13° to the WSW within the hinge zone of the Strathmore Syncline and are cut by minor normal faults that trend ENE. The parallel alignment of tabular feldspar phenocrysts up to 25 mm in length, gives the macroporphyritic basaltic andesites a platy structure. These flows generally have slaggy upper and lower surfaces. A columnar-jointed central portion commonly has potholes in the centres of the hexagonal columns as the rock close to the cooling joints is more resistant to wave erosion (Figure9.20).

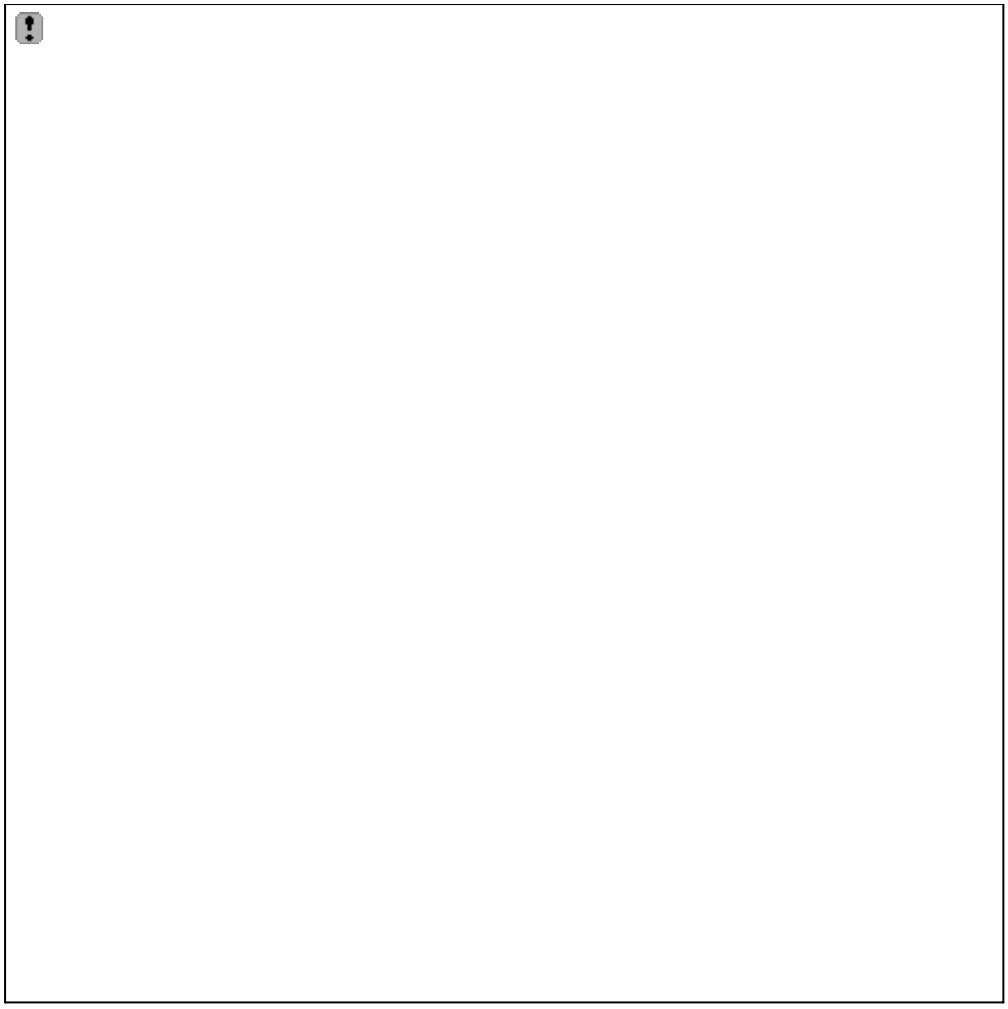

Figure 9.20: Differential weathering in hexagonal columns of Crawton type basalt, Crawton Bay. (Photo: BGS no. D2454.)

The base of the lowest flow, exposed near Trollochy (8805 7970), is more vesicular than the main part of the flow and contains disorientated feldspar phenocrysts. Lenses of laminated sandstone and mudstone underlying this flow have been disrupted in places and are baked by the lava (Trewin, 1987). The flow contains large amygdales filled with chalcedony, clear quartz, amethyst and calcite (MacGregor, 1996).

The second and third flows are separated by a few centimetres of sedimentary rock; the top of the second flow is marked by thin, impersistent red mudstones and blocks of altered lava, the reddening being due to a period of subaerial weathering (Trewin, 1987, fig. 1). Both the flows show a well-developed flow orientation of the feldspar laths. The top of the third flow is irregular, and in places the slaggy top was eroded prior to the deposition of the overlying conglomerate in the potholed surface.

The uppermost flow is a purplish massive basalt with scattered vesicles, which are locally over 10 cm in diameter. The vesicles are generally filled with calcite and quartz, but brick red stilbite is also recorded (Trewin, 1987).

Thick interbeds of clast-supported or matrix-supported conglomerate resting upon irregular eroded surfaces of lava are good evidence of penecontemporaneous erosion. These conglomerates consist of well-rounded pebbles of andesitic lava, psammite and quartzite with lesser amounts of metabasalt and greywacke within a matrix of poorly sorted volcaniclastic coarse-grained sandstone. The coarse fraction is of broadly ‘Highland' provenance (i.e. Highland Border Complex and probably some Dalradian) although there is a component of locally derived lava.

Interpretation

Both types of lava present in the formation contain microphenocrysts of olivine and augite, with the 'Crawton type' also having megacrysts of plagioclase. The few available analyses have SiO_2 in the range 51–53% spanning the basalt/basaltic andesite division (Thirlwall, 1979), and they generally have high K_2O and related elements, making them shoshonitic *sensu* Le Maitre (1989). They are olivine-hypersthene normative, with moderately high alumina (16%), but the one analysed sample of 'Crawton type' shows substantial iron enrichment and hence has tholeiitic tendencies. The variation trends in trace elements may be accounted for by fractional crystallization of the phenocryst phases olivine, plagioclase and clinopyroxene, although some minor opaque oxide may have been involved.

The Crawton Volcanic Formation contains some of the oldest lava flows exposed within the Lower Old Red Sandstone in the northern Midland Valley, and Carroll (1994) considered the formation to be uppermost Silurian in age. This conclusion was reached by combining the evidence from the palynology of the overlying Arbuthnott Group (lowest Devonian according to Richardson *et al.*, 1984) and the age dating of Lower Old Red Sandstone lavas elsewhere in the northern Midland Valley (close to or before 410 Ma according to Thirlwall, 1988). The 'Lintrathen Porphyry', a dacitic ignimbrite in the Alyth area, north of the Highland Boundary Fault, dated at 415.5 ± 5.8 Ma (Thirlwall, 1988) has been correlated with the dacitic 'Glenbervie Porphyry' at the top of the Crawton Group, which gives a possible age for the Crawton Volcanic Formation. Because the Lintrathen Porphyry crops out to the north of the Highland Boundary Fault, Trench and Haughton (1990) considered that the scope for relative movement between the northern Midland Valley and Grampian terranes after Lower Old Red Sandstone deposition is only of the order of tens of kilometres.

Crawton Bay provides an excellent example of a palaeoenvironment in which subaerial/non-marine lavas poured out on land or into shallow water, cooled, cracked and became partially eroded, before being covered by clastic sediment mainly derived from an exotic source. In this case the Lower Old Red Sandstone lavas appear to have accumulated in a subsiding rift basin close to the Highland Boundary Fault, with the Grampian Terrane to the NW of the fault feeding in coarse clastic detritus. Further geochemical studies and age dating of both the lavas and the interbedded 'Highland' clasts could reveal details of the evolution and provenance of the succession.

Conclusions

The Crawton Bay GCR site is the best exposed and type section through the Crawton Volcanic Formation, which forms a significant marker at the top of the Crawton Group. These intercalated Lower Old Red Sandstone lavas and conglomerates have been studied since the end of 19th century because of the fine exposures showing the stratigraphical relationship between volcanic and sedimentary rocks in a marginal rifted basin. They provide important evidence of the environment of deposition of both the lavas and the sediments in the precursor to the Strathmore Basin, which developed within the northern Midland Valley; and also the volcanic setting that heralded the more widespread phase of Lower Old Red Sandstone lava eruption within both the Strathmore Basin and the adjacent Highlands.

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