Crawton Bay, Aberdeenshire

[NO 897 797]

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Introduction

The coastline of Crawton Bay (Figure 3.14) exposes a succession of Lower Old Red Sandstone conglomerates and is the type locality of the Crawton Volcanic Formation, the youngest, formation in the Dunnottar–Crawton Group (Browne *et al.,* 2002). This formation is Late Silurian to Early Devonian in age and comprises olivine basalts, basaltic andesites and interbedded conglomerates, described in the GCR volume on the Caledonian igneous rocks (Smith, 1999b). The underlying alluvial conglomerates, intercalated volcaniclastic beds and overlying boulder conglomerates are the subjects of this description. The cliff sections, particularly at Crawton Ness and Trollochy, show superb examples of large braid bars with high-stage coarse gravels and low-stage cross-stratified sands. The braided stream character and the large scale of the river system that deposited the detritus in the Midland Valley of Scotland can be appreciated at this locality. The large proportion of quartzite and granite clasts in the conglomerates, in contrast to the last types in the conglomerates elsewhere in the Dunnottar–Crawton Group (Haughton, 1988), suggests that the source was the Grampian Highland Terrane to the north. This evidence contributes to our knowledge of the unroofing history of the Grampian Highland Terrane and the development of the Midland Valley.

Description

The inter-relationships between the lava flows and the intercalated sedimentary rocks of 'Highland origin' were first noted by Geikie (1897). The locality has since been described in detail by Campbell (1913), Trewin (1987b), Carroll (1995b) and MacGregor (1996a). Carroll (1995b) divided the section, in ascending sequence, into the Whitehouse (Fowls Heugh) Conglomerate Formation (exposed at Crawton Ness), the Crawton Volcanic Formation (interbedded conglomerates and lavas) and the Catterline Conglomerate Formation, which is the basal formation of the Arbuthnott–Garvock Group. The provenance of the clasts in the conglomerates of the Dunnottar–Crawton Group conglomerates at the site has been studied by Haughton *et al.* (1990).

The oldest conglomerates at the site belong to the Whitehouse Conglomerate Formation of Browne *et al.* (2002) (the Fowls Heugh Conglomerate Formation of Carroll, 1995b), which dips gently to the WSW below the Crawton Volcanic Formation. The cliffs to the north and south of Trollochy [NO 881 798], the inlet east of Crawton, are eroded along ENE-trending faults cutting the Whitehouse Conglomerate Formation (Figure 3.14). The conglomerates of the formation are clast-supported and have weak bedding picked out by grain-size differences. Intercalated sandstone lenses are trough- and planar cross-bedded, moderately well-sorted and locally scoured below conglomerate beds. At the base of the cliff on the north side of Trollochy, sandstone rests on an inclined surface of conglomerate, and cross-stratification can be seen in the conglomerates nearby. A few metres up the cliff, a conglomerate that originally had open interstices, is now cemented by micritic calcite (Trewin, 1987b). Coarse conglomerates immediately below the Crawton Volcanic Formation [NO 881 798] occur in units that coarsen upwards overall (Haughton *et al.,* 1990) and have imbricate fabrics indicating palaeoflow from the north. Clast types depend on their sizes, which range up to 1 m. Volcanic rocks similar to those in the Crawton Volcanic Formation predominate, with lesser amounts of psammites, granites, granodiorites, hypabyssal rocks, quartzites and vein quartz. Of the granitic rocks, biotite-muscovite granite, porphyritic granite and equigranular red granite are the commonest in the boulder-size fraction, other granitoids and porphyries are common in the cobble to pebble fraction. Rb-Sr muscovite whole-rock ages for biotite-muscovite granite boulders from the top of the Dunnottar–Crawton Group are 473–457 Ma; a U-Pb age of 475 ± 5 Ma was obtained from a monazite in one of the clasts (Haughton *et al.,* 1990). A Rb-Sr biotite age of 412 ± 4 Ma was obtained from a clast of porphyritic biotite granite. Mica whole-rock ages for the accompanying psammitic clasts suggest that their source included metamorphic rocks that were uplifted at the same time as the intrusion of the granites. Haughton *et al.* (1990) concluded that the source resembled the

Grampian Highland Terrane of north-east Scotland, and that the north Midland Valley Terrane was juxtaposed within tens of kilometres of its present position with the Grampian Highland Terrane at the time of deposition. South of Trollochy [NO 8805 7970], laminated sandstone and mudstone immediately below the first lava flow are locally disrupted and baked by the lava (Trewin, 1987b).

The Crawton Volcanic Formation, which is up to 70 m thick (Carroll, 1995b), has conglomerates above the first and third lava flows. There is evidence of penecontemporaneous erosion of the third lava flow where it was partly eroded and potholed prior to deposition of the thick overlying conglomerates (Figure 3.15). These are clast- and matrix-supported, and consist of well-rounded clasts ranging from pebbles to boulders about 1 m set in a coarse-grained, poorly sorted, volcaniclastic sandstone matrix. The clasts comprise macroporphyritic andesite lava, psammite and quartzite, with lesser amounts of metabasalt, felsite, chert and greywacke. The coarse fraction of the clast suite is of broadly 'Highland' provenance (i.e. Highland Border Complex and probably some Grampian Highland Terrane), with a significant component of local lavas.

The overlying Catterline Conglomerate Formation is exposed in a steep cliff on the west side of Crawton Bay [NO 877 796]. It comprises red-brown and grey, thickly bedded, pebble- to boulder-grade conglomerates that show weak grain-size stratification. They are mainly clast-supported, with well-rounded pebbles set in a matrix of less well-rounded, volcaniclastic, coarse sand grains and granules. Volcanic pebbles are more common than in the underlying conglomerates, and include massive basalt and vesicular and porphyritic andesites, probably of local derivation. Quartzite, vein quartz, greywacke sandstone, granitic rocks, jasper and metabasalt are also present. The last two rock types are typical of the Highland Border Complex and the greywacke sandstone has a spaced cleavage similar to that in the Dalradian Southern Highland Group north of the Highland Boundary Fault. Cross-beddedsandstones within the conglomerates with an apparent seaward dip are exposed towards the top of the cliff and form part of a southerly dipping fan (Trewin, 1987b).

Interpretation

Earlier models for Lower Old Red Sandstone deposition (Bluck, 1978) suggested that axial alluvial sedimentation in an elongate basin was dominant over lateral, coarse alluvial-fan deposition. Detailed work on the Dunnottar–Crawton Group (Haughton, 1988, 1989; Marshall *et al.,* 1994) showed that other depositional packages, with clastic material derived from sources within the Midland Valley and the penecontemporaneous volcanic rocks, were present in the Crawton Basin, together with the polycyclic alluvium from a 'Highland' source (Haughton and Bluck, 1988).

The alluvial gravel overlying the top of the third lava flow (Figure 3.15) indicates that a short period of erosion removed any hematized bole, such as that developed between the second and third flows, but not all of the vesicular top to the lava. The gravels were carried by large, complex river systems from both local and distant 'Highland' sources. The large size of the cobbles and coarsening-upward units in the river gravels suggest that the sporadic, relatively thin and sheet-like Crawton lavas only temporarily diverted these powerful rivers.

All the conglomerates at this site contain varying proportions of locally derived volcanic rocks and northerly derived 'Highland' rocks. This contrasts with conglomerates derived from the south and east within the Midland Valley Terrane (Haughton, 1988), which contain first-cycle clasts of lithic arenite, granodioritic rocks and metagreywacke, as well as limestone clasts with Early Ordovician faunas. This cryptic Midland Valley source is distinct from the Southern Uplands Terrane and may have originally comprised displaced fore-arc slivers to the south of the Laurentian continental margin.

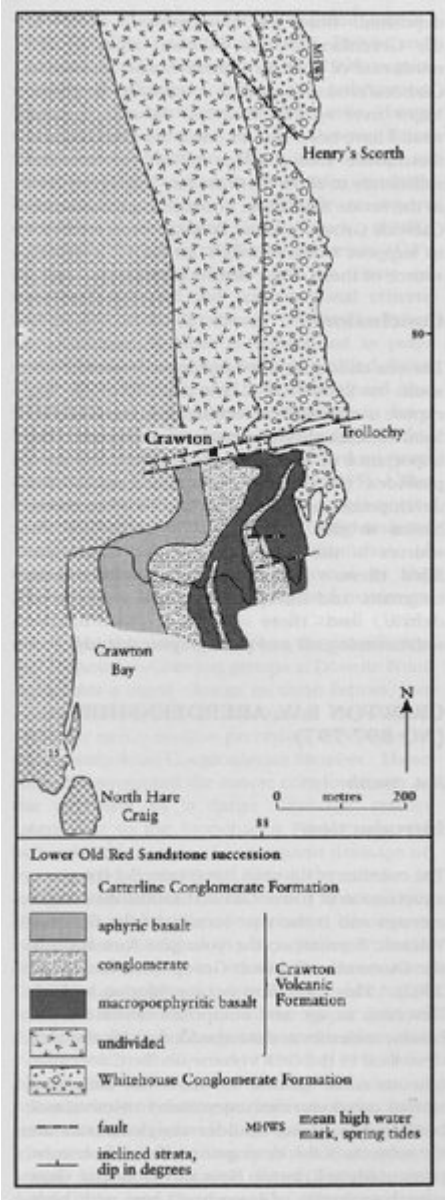
Carroll (1995b) considered the Crawton Volcanic Formation to be Late Silurian in age. This was based on an earliest Devonian age (on palynological evidence) for the overlying Arbuthnott–Garvock Group (Richardson *et* al., 1984) and a date of 415 ± 5.8 Ma for a dacitic ignimbrite (the Lintrathen Tuff Member) north of the Highland Boundary Fault (Thirlwall, 1988; Bluck, 2000). This is correlated with the Glenbervie 'Porphyry' at the top of the Crawton Volcanic Formation, and because it crops out north of the Highland Boundary Fault, Trench and Haughton (1990) considered that the relative lateral movement between the northern Midland Valley and the Grampian Highland terranes from Early Devonian time onwards could have been only of the order of tens of kilometres. This has an important bearing on the provenance of the intercalated sedimentary clasts. The Lower Old Red Sandstone lavas appear to have accumulated in a subsiding rift

basin close to the Highland Boundary Fault, with the Grampian Highland Terrane to the northwest of the fault providing a source of coarse clastic detritus. The succeeding Arbuthnott–Garvock Group lacks any clasts known to be derived from the cryptic Midland Valley source and heralds the development of the more extensive Strathmore Basin. Further work on the provenance of the sedimentary rocks, Including dating studies of heavy mineral suites, may identify more precisely the clastic sources. Geochemical studies may reveal the extent of the contribution from local volcanic, as opposed to other volcanic, sources. Sedimentological studies will refine our understanding of the relationship between the high-energy alluvial deposition and the penecontemporaneous volcanic eruptions. The development of the Crawton Basin, including syndepositional fault control on its subsidence, is a further topic of future research.

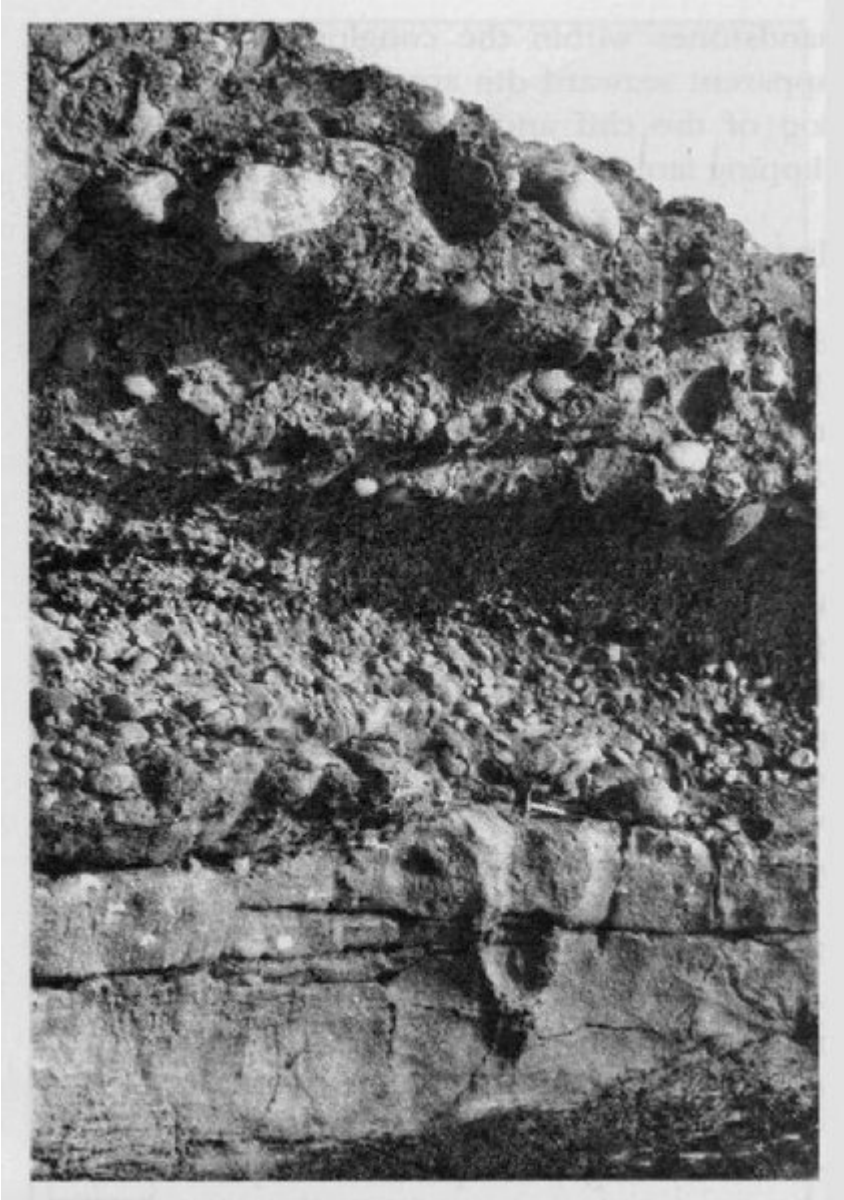
Conclusions

The Crawton Bay GCR site provides the best exposures of the Crawton Volcanic Formation and its type section. This is a significant marker horizon at the top of the Dunnottar–Crawton Group, and its relationship with the conglomerate formations above and below can be seen at the site. The intercalated lavas and conglomerates here have been studied since the late 19th century, because of the fine exposures, which demonstrate the relationship between volcanic and sedimentary rocks in a rifted marginal basin. The sedimentary rocks provide important evidence for the large size of the river systems, which were interrupted by calc-alkaline volcanic outpourings in Late Silurian to Early Devonian times. The Crawton Basin was the precursor to the larger Strathmore Basin that developed within the northern Midland Valley. However. unlike the Crawton Basin, the Strathmore Basin lacks clasts derived from cryptic sources within the Midland Valley.

References



(Figure 3.14) Geological sketch map of the Crawton Bay area. After Stephenson et al. (1999, fig. 9.19).



(Figure 3.15) Coarse conglomerates of the Crawton Volcanic Formation resting on the eroded top of the third lava. (Photo: N.H. Trewin.)