SHOULDER O'CRAIG

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OS Grid Reference: NX663491

Introduction

The Shoulder O'Craig GCR site exposes an Early Devonian volcanic vent that cuts Silurian turbidite beds. An intrusion breccia represents the earliest intrusive phase and this is cut by a later intrusion of basalt. Both vent and country rocks are cut by a series of lamprophyre dykes thought to be only slightly younger than the vent itself. The Silurian strata are sandstone turbidites (greywackes) of the Carghidown Formation (Hawick Group) which, although not fossiliferous at Shoulder O'Craig, elsewhere in the region contain a graptolite fauna indicative of a late Llandovery age (White *et al*., 1992). The turbidite beds were deformed and rotated to the vertical during the development of the Southern Uplands accretionary thrust belt (see Chapter 2, Introduction). The later stages of this deformation were accompanied by a range of minor intrusions and igneous activity continued after tectonism had ended, culminating in the emplacement of granitic plutons of the Galloway Suite at about 400 Ma (see Chapter 8). A number of late Silurian or Early Devonian volcanic vents are among the intrusive bodies seen. They appear to be entirely post-tectonic but for the most part are small and poorly exposed. The Shoulder O'Craig vent is one of the larger examples and its coastal locality provides excellent sea-cliff exposures illustrating the varied lithologies and textures within the vent itself, its relationship with the sedimentary country rock, and the morphology of slightly younger, but probably related, lamprophyre dykes. The site thus provides a rare opportunity to examine in detail the characteristics of a Caledonian volcano. A detailed description is provided by Rock *et al*. (1986a).

Description

The outline geology of the Shoulder O'Craig area is shown in Figure9.43. The vent probably extends for a short distance inland beneath the caravan park. The country rock of the vent consists of beds grading upwards from sandstone to siltstone, each formed by deposition from a single turbidity current. In the immediate vicinity of the vent they strike approximately NE–SW and are vertical or dip steeply towards the NW, with sporadic zones of small-scale tight to isoclinal folding. A penetrative slaty cleavage is widely developed sub-parallel to bedding but terminates at the cross-cutting vent margin. This relationship establishes the vent as a post-tectonic intrusion.

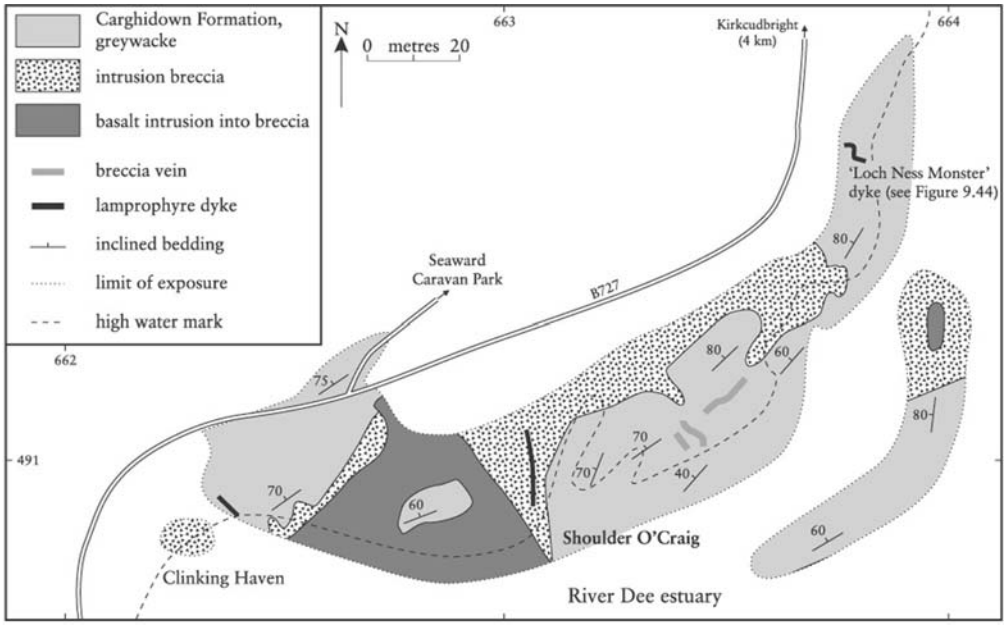

Figure 9.43: Map of the Shoulder O'Craig volcanic vent, after Rock et al. (1986a).

The most striking aspect of the vent is the texture shown by the coarse breccia forming the earliest intrusive component. This is best examined on the wave-polished surfaces to the north of Clinking Haven where both matrix-rich and clast-rich varieties can be identified. The cliff sections provide more extensive exposure in three dimensions and confirm that the breccia consists principally of variably rounded to subangular clasts of sandstone, siltstone and rare basaltic or microdioritic lithologies set in a fine-grained matrix. The latter is pervasively altered to chlorite and carbonate but traces of a relict texture suggest an original igneous (basaltic?) composition. Most of the clasts seem likely to have been derived from the country rocks and in the cliff sections their size ranges up to rafts several metres in length. This part of the vent fill is an intrusion breccia (*sensu stricto)* although it has been generally referred to in the literature as a vent agglomerate (e.g. Rock *et al*., 1986a). It is cut by at least two irregular and fractured masses of lamprophyric biotite-olivine basalt, the larger of which occupies much of the western end of the vent. The basalt is generally clast-free and its contacts with the adjacent intrusion breccia vary from sharp to diffuse and gradational. Oval, pillow-like textures and possible flow fractures may suggest intrusion in a semi-solid state (Rock *et al*., 1986a). Breccia veins up to about a metre across cut the country rock in the vicinity of the vent and seem likely to be related to the intrusive episode.

Both vent and country rock are intruded by a suite of lamprophyre dykes, mostly kersantites in which large phenocrysts of biotite are contained in a melanocratic groundmass rich in plagioclase. The dykes range up to about 1.5 m wide but are commonly sinuous and highly irregular in shape. A particularly fine example occurs just beyond the NE extremity of the vent; its bizarre outcrop pattern has earned it the colloquial title ‘the Loch Ness monster' (Figure 9.44). A fresh kersantite body cutting the intrusion breccia of the vent has given a K-Ar biotite age of 410 ± 10 Ma (Rock *et al*., 1986b).

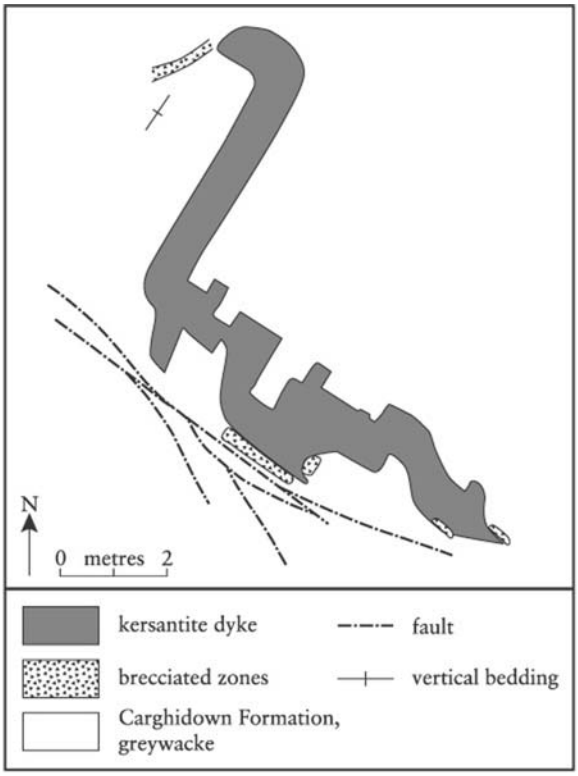

Figure 9.44: Sketch of the 'Loch Ness Monster' lamprophyre dyke, just north of the margin of the Shoulder O'Craig vent, after Rock et al. (1986a). (For location see Figure 9.43.)

Interpretation

The Shoulder O'Craig vent contains two intrusive phases. The most abundant lithology is the vent-filling intrusion breccia, which consists largely of sandstone and siltstone country rock clasts carried into place within a fine-grained basaltic matrix. This has been intruded by a later basaltic mass containing very few xenoliths but enclosing one very large sandstone raft. Contacts between the basalt and the intrusion breccia are largely obscured but in places they appear to be gradational suggesting a continuum of intrusion rather than two separate episodes. Pillow-like textures and some possible flow-fractures could arise from emplacement of the basalt as a semi-solid mush (Rock *et al.*, 1986a). The basalt intrusion is altered, with chlorite generally replacing olivine, but some relict olivine remains together with a little biotite and augite. From this petrography and the abundances of trace elements such as Ti, Y and Zr, Rock *et al.* (1986a) classified this rock as a calc-alkaline basalt. The basaltic matrix of the earlier intrusion breccia is much more pervasively altered suggesting that this intrusive phase was more hydrous and volatile-rich. Breccia veins cutting the country rock close to the vent margin have been described as explosion breccias byRock *et al.* (1986a) and may also relate to the earliest intrusive phase. However, they have an ambiguous relationship with the lamprophyre dykes which are demonstrably intrusive into the intrusion breccia. The dykes themselves are biotite-rich kersantites and most have highly irregular forms thought to reflect high volatile pressure during emplacement. They are an expression of deep-seated K-rich magmatism.

The calc-alkaline nature of the intrusions suggests subduction-related magmatism. However, that is difficult to reconcile with either of the proposed tectonic models for development of the Southern Uplands Terrane (see Chapter 1). The problem has been discussed byRock *et al.* (1986b) and two points are particularly pertinent:

1. On a regional scale, volcanic, subvolcanic and plutonic magmatism is juxtaposed in both space and time; volcanic vents, mantle-derived dykes and granite plutons were all intruded at about 410–400 Ma and are now seen at the same level of erosion.

2. The lamprophyres in particular are too K-rich and of too deep a mantle source for their close

proximity to the putative trace of the Iapetus Suture, only some 30 km to the south beneath the Solway Firth.

In this context Shoulder O'Craig is the counterpart to the vent intrusion of similar age at the Pettico Wick to St Abb's Harbour GCR site in SE Scotland (see report); the similarities and contrasts between these two bodies are particularly instructive and have been discussed by Rock *et al*. (1986 a, b).

Conclusions

The Shoulder O'Craig locality provides the largest and best-exposed example in SW Scotland of a late Caledonian volcanic vent. The vent contains at least two components, an earlier intrusion breccia of country-rock sandstone clasts in a highly altered basaltic matrix, and a later basaltic plug-like intrusion. Possible explosion breccia forms veins cutting the country rock adjacent to the vent. Both vent and country rock are cut by lamprophyre dykes, which may assume highly irregular intrusive forms. A radiometric age of about 410 Ma from one lamprophyre dyke provides a minimum age for vent intrusion. The maximum age is constrained by the late Llandovery age (about 430 Ma) of the country rocks. These are turbidite sandstones and siltstones that were folded and cleaved prior to the emplacement of the intrusion breccia. Textures within the vent and its relationship with the country rock are exposed with unusual clarity.

The late Caledonian intrusive suite, of which the Shoulder O'Craig vent complex is a particularly fine example, is of regional tectonic significance in respect of subduction models for the closure of the Iapetus Ocean.

Reference list

Rock, N. M. S., Cooper, C. and Gaskarth, J. W. (1986a) Late Caledonian subvolcanic vents and associated dykes in the Kirkcudbright area, Galloway, south-west Scotland.*Proceedings of the Yorkshire Geological Society*, **46**, 29–37.

Rock, N. M. S., Gaskarth, J. W. and Rundle, C. C. (1986b) Late Caledonian dyke-swarms in southern Scotland: a regional zone of primitive K-rich lamprophyres and associated vents. *Journal of Geology*, **94**, 505–21.