Gloom Hill, Dollar, Clackmannan

[NS 964 990]

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Introduction

The geological relationships exposed in the quarry, on the southern margin of Gloom Hill, 0.5 km north of Dollar, are of considerable importance in understanding the relationships between magmatism and tectonism in the Midland Valley during Late Carboniferous to Early Permian times. The Ochil Fault, one of the most important faults in the Midland Valley, is exposed in the quarry along with a quartz-dolerite intrusion that was emplaced along the fault plane. Geochemical evidence (e.g. Macdonald *et al.,* 1981) suggests that this intrusion, and others intruded into the fault zone nearby, are associated with the Midland Valley Sill-complex.

The E–W-trending Ochil Fault is a long-lived structure that is responsible for the impressive escarpment of the Ochil Hills, east of Stirling (Figure 6.4). The tectonic significance of the fault was known long ago and the impressive vertical displacement (up to 4 km) was also recognized (e.g. Geikie, 1900). Nevertheless the tectonic evolution of the region and the sub surface structure of the fault have proved to be intriguing problems up to the present day (e.g. Haldane, 1927; Francis *et al.,* 1970; Gibbs, 1987; Coward and Gibbs, 1988; Rippon *et al.,* 1996). To the north of the fault the Ochil Hills are composed of late Silurian to Early Devonian lavas and volcaniclastic rocks. These are juxtaposed against Westphalian Coal Measures that form the low-lying undulating topography to the south. Although the fault may have been initiated in Early Devonian times, the main movement is believed to have occurred in Late Carboniferous times during a period of north–south extension that was accompanied by intrusion of quartz-dolerite magma along the fault plane (Rippon *et al.,* 1996). Dating of the fault-intrusions at *c.* 303 Ma therefore provides an age for this phase of extension (Forster and Warrington, 1985).

Five quartz-dolerite intrusions occur along the main part of the Ochil Fault near Dollar (termed the West Ochil Fault by Rippon *et al.,* 1996) and these are exposed in the burns running down the southern scarp of the Ochil Hills (Figure 6.16). The Gloom Hill GCR site reveals part of the largest intrusive body, which is over 3 km long and up to 300 m wide. Two other quartz-dolerite intrusions occur in the Arndean Fault which branches south-eastwards off the Ochil Fault to the east of Dollar and probably takes up a large part of the throw.

The area around the Ochil Fault has experienced recent seismic activity and this has been described by a number of authors (e.g. Davison, 1924; McQuillan in Francis *et al.,* 1970).

Description

The quartz-dolerite intrusion in the quarry at Gloom Hill is at least 40 m wide and the northern margin is chilled against scoriaceous, vesicular, purple- and green-tinged andesitic lavas and volcaniclastic rocks of the Ochil Volcanic Formation (Haldane, 1927; Francis *et al.,* 1970). This northern contact of the intrusion hades at 63° to the south (Figure 6.17). The southern contact is not visible but a southerly hade of 72° is revealed at the southern margin of a quartz-dolerite intrusion at Castle Craig Quarry, Tillicoultry, 4 km to the west, where the exposed chilled contact lies against deformed Westphalian strata (Haldane, 1927). There, the contact is undulose and shows how intrusion of the dolerite has distorted the fault plane (Francis *et al.,* 1970).

The quartz-dolerite in the quarry at Gloom Hill is of very similar composition and petrography to those of the Midland Valley Sill-complex, with abundant quartz and micropegmatite (Francis *et al.,* 1970; Macdonald *et al.,* 1981). The grain size clearly increases inwards from the northern margin towards the central part of the intrusion but overall it is finer grained than the usual sub-ophitic variety of the sill-complex. Some leucocratic segregation veins up to 2 cm thick can be seen on the quarry face but they are not a conspicuous feature.

Interpretation

The Ochil Fault plane is seen to be inclined to the south in three separate outcrops, including the quarry at Gloom Hill. However, early seismic evidence, based partly on the location of earthquake epicentres, suggested that the hade is to the north and the fault was therefore interpreted as a reverse fault by Davison (1924). Haldane (1927) discussed the contradictory seismic and geological evidence and suggested a number of solutions: (a) that that the seismic effects may have been caused by simultaneous movements along a series of NNW-trending faults on the north side of the Ochil Fault; (b) that they were caused by movement on a small subsidiary fault; or (c) that the hade of the fault is only to the south near the surface and is to the north at depth. MacQuillen (in Francis *et al.,* 1970) re-emphasized the strong seismic evidence for a northerly hade and proposed that the southerly dip of the fault exhibited at the surface is not a feature in the deeper part of the fracture zone (Haldane's option (c)). Since then, a number of contrasting tectonic models have been proposed. For example, Gibbs (1987) developed a complex tectonic model for the Kincardine Basin and suggested that the Ochil Fault is a reverse fault, dipping to the north, whereas Dentith (1988) proposed that the fault dips steeply to the south. The matter is clearly unresolved, though more recent seismic reflection studies reveal a southerly dipping fault plane to at least a depth of 2.5 km (Rippon *et al.,* 1996).

Estimates of the maximum total displacement on the West Ochil Fault are of the order of 4 km (Geikie, 1900; Francis *et al.,* 1970; Rippon *et al.,* 1996). The fault probably originated in Devonian time, prior to deposition of the Upper Red Sandstone, and acted as a control on subsidence and deposition throughout the Carboniferous Period. However, the main movement on the fault must have been late or post Westphalian in age, since Westphalian strata are juxtaposed against Lower Devonian volcanic rocks. The contact relationships exposed at Gloom Hill and Castle Craig Quarry indicate that the intrusive magma exploited the preexisting fault plane as suggested by Haldane (1927), but Rippon *et al.* (1996) suggested that the presence of magma could also have facilitated later movement on the West Ochil and Arndean faults.

The quartz-dolerite intrusion at Gloom Hill, its margins and an aplitic vein were analysed by Macdonald *et al.* (1981), who confirmed that they are part of the large tholeiitic suite of sills and dykes emplaced during Late Carboniferous times in the Midland Valley of Scotland. Francis (1982) suggested that the Ochil Fault-intrusions may be feeders to the Midland Valley Sill-complex. However, the Ochil Fault only hosts intrusions in its central part and hence does not appear to be the location of a major feeder dyke system. On a more local scale, boreholes have revealed the presence of quartz-dolerite sills at about the level of the Castlecary Limestone (at the top of the Upper Limestone Formation) close to the Arndean Fault on the southern (downthrown) side (Rippon *et al.,* 1996). It seems quite likely that these may be linked to the Ochil Fault-intrusions.

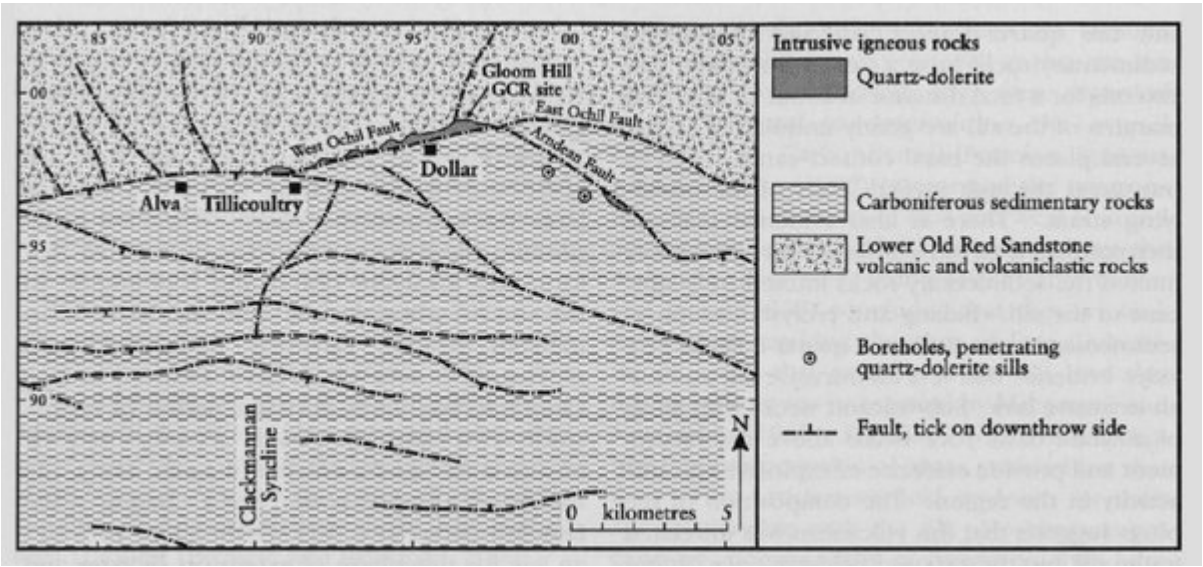
Westphalian coals at Dollar show enhanced ranking which has been interpreted as a localized thermal effect of the Ochil Fault-intrusions (Rippon *et al.,* 1996) and the intrusions have a radiometric age of 303 ± 5 Ma (Forster and Warrington, 1985). It is therefore assumed that emplacement of the quartz-dolerite intrusions throughout the Midland Valley was in response to a brief but important phase of north–south extension in latest Carboniferous times (Rippon *et al.*, 1996).

Conclusions

At the Gloom Hill GCR site the Ochil Fault plane is clearly exposed and is intruded by a 40 m-wide quartz-dolerite body associated with the Midland Valley Sill-complex. The E–W-trending Ochil Fault played a critical role in the tectonic evolution of the Midland Valley in Late Carboniferous and Early Permian times and has had a major effect on the topography of the district. The fault is steeply inclined to the south at present surface levels, but studies of local minor earthquakes suggest that this may not be the case at depth. The maximum vertical displacement of 4 km juxtaposes Siluro–Devonian volcanic rocks against Westphalian coal measures, so the main movement on the fault probably occurred in Late Carboniferous times. At least some of this movement may have been contemporaneous with the intrusion of magma along the fault plane, which may have eased movement along the fault. A radiometric age of *c.* 303 Ma for this fault-intrusion is therefore believed to date the latest extensional movement on the Ochil Fault that coincided with a brief period of regional north-south extension.

[References](#)

(Figure 6.4) View from the air over Stirling. Outcrops of the SE-dipping Stirling Sill (Midland Valley Sill-complex) can be picked out by the tree-covered scarps that bound the golf course in the bottom right, Stirling Castle in the middle distance, and Abbey Craig (topped by the Wallace Monument) beyond. The Ochil Fault, which has fault-intrusions related to the sill-complex (e.g. the Gloom Hill GCR site) is responsible for the prominent south-facing scarp of the Ochil Hills in the distance. (Photo: British Geological Survey, No. D1940, reproduced with the permission of the Director, British Geological Survey, NERC.)



(Figure 6.16) Map of the area around the Gloom Hill GCR site. After Rippon et al. (1996).

(Figure 6.17) View towards the east of the exposures of the Ochil Fault-intrusion in the quarry at Gloom Hill, with Siluro-Devonian lavas on the left, quartz-dolerite of the fault-intrusion on the right, and the contact parallel to the quarry face. (Photo: I.T. Williamson.)