Tertiary igneous intrusions, Midland Valley of Scotland

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Tertiary igneous intrusions

Igneous intrusions of Tertiary age in the western part of the Midland Valley. P915546.
Lion Rock, Great Cumbrae. Tertiary age tholeiitic andesite dyke of cumbraeite type intruded into Upper Devonian sandstones. P001078.

Tertiary dolerite dykes, of both tholeiitic and alkali basaltic affinities, with a general NW–SE trend are relatively abundant in the Midland Valley, south-west of a line from Gourock to Douglas (P915546). A group of alkali dolerite sills in the Prestwick–Mauchline area are also of Tertiary age.

**Dykes**

Tertiary dykes of the British Isles occur either in regional linear swarms or in more localised sub-swarms in the vicinity of central intrusive complexes. The majority of the dykes in the Midland Valley are a continuation of a regional swarm, centred upon Mull. On the north-east margin of the swarm a group of wide, persistent dykes traverse the full width of the Midland Valley, extending into the Southern Uplands and some may be traced via intermittent outcrops for over 200 km to the Northumberland coast. To the north-east of this group, Tertiary dykes occur rarely (e.g. east of Glasgow) but to the south-west, many occur sporadically over a width of 30 km. Near the south-west edge of the swarm, the Cumbrae–Stevenston dyke has been traced for almost 300 km to north Yorkshire. It is also one of two dykes which are deflected into an ENE trend for up to 20 km close to the Southern Upland Fault.

The more persistent dykes are commonly 6 to 10 m wide and greater widths of up to 37 m have been recorded from those which extend into northern England. Many impersistent 2 to 3 m-wide dykes, usually of tholeiitic character, are also present. Columnar jointing is typically well developed perpendicular to chilled dyke margins and the rocks are characteristically very fresh and hard (P001078).

Most of the dykes of the Mull regional swarm are tholeiitic. They are composed of labradorite laths and augite, with varying amounts of glassy mesostasis, often devitrified and darkened by finely disseminated iron-titanium oxides. The larger, more persistent dykes are varieties of tholeiite, quartz-dolerite or tholeiitic andesite which vary considerably in texture along their length. They frequently contain orthopyroxene or pigeonite and generally have a higher silica content than the smaller dykes. The Cumbrae–Stevenston dyke is the most siliceous of this group and is characterised by numerous large phenocrysts of anorthite-bytownite set in an acidic, glassy groundmass constituting the rock type cumbraeite.

Most of the NW–SE and NNW–SSE-trending dykes exposed along the Clyde coast from Troon to beyond Girvan probably belong to a separate Arran sub-swarm or to continuations of regional
swarms passing through Jura and Islay. The majority of these dykes are alkali olivine-dolerites, but tholeiitic dykes are also present. Most of the olivine-dolerites contain small amounts of analcime or zeolites and consist essentially of ophitic purplish titanaguate enclosing labradorite laths, olivine and iron-titanium oxides. Such rocks are similar to finer-grained dykes and sills of Kintyre and Arran which have been termed crinanites.

Members of the dyke swarms cut post-Coal Measures alkali dolerite sills, E–W quartz-dolerite dykes, Permian volcanic necks, the Permian Mauchline Sandstone and the Triassic sandstones of Arran. The contemporaneous Cleveland Dyke of north Yorkshire cuts Jurassic sediments and the obvious association of the swarms with the Mull and Arran central complexes leaves the Tertiary age in no doubt. Evidence from Arran indicates that the alkali dolerite (crinanitic) dykes and sills are earlier than the Northern Granite and Central Ring Complex, all of which are cut by tholeiitic dykes.

Sills

Several extensive outcrops in the Mauchline basin of ophitic, analcime-bearing olivine-dolerite (crinanite), cut by analcime-syenite veins, are continuous at depth and form the Prestwick–Mauchline Sill-Complex. The complex has a maximum thickness of 60 m and is believed to consist of between one and three leaves, up to 500 m apart, connected by dykes or steeply inclined sheets. Several transgressions elevate the sill from the top of the Middle Coal Measures in the west, through the Upper Coal Measures, to the Mauchline Volcanic Group in the east and the Mauchline Sandstone in the north-east.

The petrographic similarity to the Tertiary crinanite sills of Arran and to some of the thicker Tertiary dykes of Ayrshire suggests a Tertiary age and this has been supported by palaeomagnetic measurements and a K-Ar mineral date of 57 ±1.4 Ma.

Magma genesis and tectonic setting

Recent unpublished investigations reported by Thompson (1982a, p.470) reveal that most of the dykes in the Midland Valley of the Mull regional swarm are magnesium-poor basalts and tholeiitic andesites, corresponding to varieties of the ‘Non Porphyritic Central’ magma type first defined from Mull and subsequently recognised in the NE England dykes. Significant numbers of the tholeiitic dykes have the diagnostic chemistry of the magnesium-rich, low-alkali ‘Preshal Mhor’ magma type of Skye, which is close in composition to ‘Mid Ocean Ridge Basalt’ and is now widely recognised in the British Tertiary province. Alkali olivine-basalts of the Mull ‘Plateau’ magma type are represented by the crinanites and allied rocks which are particularly abundant in the Arran sub-swarm.

Current theories summarised by Thompson (1982a,b) suggest that the alkali ‘Plateau’ magmas were generated by partial melting of mantle material at the base of the lithosphere. The tholeiitic ‘Preshal Mhor’ magmas were probably generated by further melting of upper mantle already depleted by earlier melting episodes and may have evolved the ‘Non Porphyritic Central’ magmas, which occupy so many of the regional dykes, by fractionation in the upper crust.

The persistent NW–SE trend of the regional dyke swarm indicates that it is controlled by fundamental deep crustal fractures. It has been suggested that such fractures may have been in existence throughout the late Palaeozoic and Mesozoic, when they exerted control on sedimentary basins and igneous activity and possibly acted as channels for mineralising solutions (p. 152). The regional dykes most likely originated as vertical intrusions from ridge-like magma chambers aligned along the fractures.
Palaeocene igneous activity in the British Isles was concentrated over the period between 60 and 52 Ma. The regional dyke swarms were probably intruded during the later part of this activity which is thought to be coincident with the initiation of the final stage of opening of the NE Atlantic between Greenland and NW Europe. It may be that the dyke swarms follow rift-normal tenseional fractures associated with the spreading, which extend well into the continental margin.

Bibliography


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