Machrihanish Coast and South Kintyre, Argyll and Bute

[NR 625 201]–([NR 640 208], [NR 629 192])–([NR 651 182] and [NR 688 171])–[NR 707 155]

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Introduction

The Dinantian volcanic rocks that crop out in the south of the Kintyre peninsula belong to the Clyde Plateau Volcanic Formation (Strathclyde Group), the most extensive lava succession within the Carboniferous–Permian Igneous Province of northern Britain. The succession is typical of continental lava plateaux formed by the accumulation of overlapping lava sequences. However, unlike the other lava fields that make up the Clyde Plateau Volcanic Formation the Kintyre sequence lies entirely north of the Highland Boundary Fault and, like the nearby Visean volcanic rocks at Ballycastle in Northern Ireland, is therefore structurally outside the graben of the Midland Valley. The Kintyre sequence is also separated by a considerable distance from coeval lava fields in central Scotland and it is not known if these were ever in physical continuity.

The Machrihanish Coast and South Kintyre GCR site (Figure 2.35) contains some lithologies that are either absent or poorly represented elsewhere within the Clyde Plateau Volcanic Formation. Low-potassium tholeiitic basalt lavas are known only from the Kintyre succession, and benmoreites and trachytes are underrepresented elsewhere.

The earliest accounts of the igneous rocks of this district are rather sketchy and appear in the writings of John MacCulloch (1819); they were shown on his general geological map of Scotland in 1840 as a band extending from Campbeltown to the west coast. These igneous rocks figure briefly in papers by Nicol (1852) and Thomson (1865). Nicol divided them into 'Porphyries' and Augitic traps' and noted their association with the 'red sandstones and Carboniferous strata' of the district. However, it was Geikie (1897) who was the first to recognize that the Kintyre lava field forms an outlying portion of what he termed the Clyde Plateau.

The Kintyre area was first surveyed in detail by R.G. Symes and the map was published at the 1:63 360 scale by the Geological Survey in 1894. Details of the volcanic succession were not known until considerably later, when many of the area's pertinent features were described by McCallien (1927). The most recent mapping is by M.M. Avison and M.K. Carr in 1976, and H.M. Ayles and S.P. Duckworth in 1977, undergraduates at the University of Lancaster supervised by R. Macdonald. Their work has been incorporated in the 1:50 000 scale Provisional Series map of the British Geological Survey (Sheet 12, Campbeltown, 1996).

The Kintyre lavas have been featured in several wide-ranging studies of the geochemistry of Dinantian volcanism across the Scottish part of the Carboniferous–Permian Igneous Province of northern Britain by Macdonald (1975, 1980) and Smedley (1986a,b, 1988a) and consequently over 60 whole-rock analyses are available. They were also the main subject of a specific geo-chemical investigation by Smedley (1988b), highlighting differences in the mantle source of Dinantian magmas across the Highland Boundary Fault.

Description

There are five outcrops of the Clyde Plateau Volcanic Formation in south Kintyre. They comprise a broad belt extending south-eastwards from Machrihanish on the west coast to Tirfergus Hill and Killellan (the 'Machrihanish Lavas' of McCallien, 1927), three relatively small outliers north of Campbeltown, and an outlier on the south-east coast, east of Southend (the 'Southend Lavas' of McCallien, 1927 and Smedley, 1986a). The Machrihanish Coast and South Kintyre GCR site is a composite site made up of three areas selected from the first, and largest, of these outcrops (Figure 2.35). These are the coast section west and north of Machrihanish village [NR 640 208]–[NR 625 201], the area around the hill of Skerry Fell Fad [NR 638 183] and the area around Black Hill [NR 692 162].

In all three areas of the GCR site the Kintyre lavas overlie an unconformity. Along the western margin of the Machrihanish coast section and in the Chiscan Water on the eastern flank of Black Hill, the volcanic sequence rests upon the Kinnesswood Formation of the Inverdyde Group. This comprises white and red cross-bedded sandstones, and red-brown siltstones with nodules and beds of pedogenic limestone ('cornstone'). At Skerry Fell Fad the Kinnesswood Formation is only present in a small area in the west. Elsewhere, the lavas rest directly upon the Stonefield Schists, a unit of the Neoproterozoic Dalradian Supergroup.

The top of the Clyde Plateau Volcanic Formation in Kintyre is marked by a non-sequence, above which there is, in places, a reddish bauxitic deposit. This, the Kirkwood Formation, mostly comprises a diachronous lateritized, coarse- to fine-grained detrital volcaniclastic deposit that is interpreted as having formed by the contemporaneous weathering of the volcanic rocks. Elsewhere, the overlying rocks belong to the Lower Limestone Formation and Limestone Coal Formation of the Machrihanish Coalfield (McCallien and Anderson, 1930).

The Clyde Plateau Volcanic Formation in southern Kintyre comprises up to 400 m of volcanic rocks, predominantly lavas, dipping to the south-east (Figure 2.35). At some stratigraphical levels the lavas are complexly inter-digitated, especially in the lower parts of the Black Hill section. Differences in the mineralogical composition and internal structure of the flows are exploited by weathering to produce a terraced landform ('trap topography') which is particularly well developed on Tirfergus Hill [NR 6645 1722], between the Skerry Feli Fad and Black Hill areas, and near Killellan. By contrast, the areas around Machrihanish and Skerry Fell Fad are characterized by much more rounded and lenticular landscape features, the difference resulting from variations in composition and morphology of the flows. The lava field is cut by a number of NW-trending faults.

The lower part of the lava succession is dominantly olivine basalt that is commonly macro-porphyritic, along with some interbedded olivine-pyroxene-macrophyric (ankaramitic) basalt. The upper part contains most of the more evolved rock-types, including hawaiite, mugearite, benmoreite, trachyandesite and trachyte. Some of these lavas may be composite bodies. Several plugs, sills and dykes with compositions ranging from olivine-dolerite to microsyenite and dacite are also exposed (Macdonald, 1975).

Machrihanish coast

The coastal section from Machrihanish Bay westwards offers the most readily accessible part of the GCR site. Within it, a range of lithologies and structures typical of the Clyde Plateau Volcanic Formation may be examined.

A west to east traverse along the coast from Eudan nan Gallan [NR 6260 2027] to east of Carrick Caban [NR 6400 2085] passes up through the volcanic sequence of more than 20 lavas. The lower two-thirds of the sequence comprises basalt with various olivine, clinopyroxene and plagioclase phenocryst assemblages, interbedded with trachy-andesites. The higher part of the sequence, east of Big Stone [NR 6350 2090], comprises up to seven flows of trachyte, mugearite and trachyandesite with a thin porphyritic basalt near the base. McCallien (1927) stated that 'tuffs and agglomerates are common associates of the lavas' in this section, but these lithologies are not shown on the latest British Geological Survey map.

Most of the lavas are tabular, sheet-like bodies. The wide range of characteristic lava-flow features exhibited include glassy (in places devitrified) flows, porphyritic variants including some with glomeroporphyritic textures, amygdaloidal and massive flow-units, blocky autobreccias, flow-base and flow-top breccias, ramp structures, and a variety of flow-induced structures. Some flows are remarkably fresh, but most are severely weathered or intensely altered. Olivine is almost always seen as pseudomorphs.

Skerry Fell Fad

The lower part of the volcanic succession also crops out on the slopes of Skerry Fell Fad [NR 6375 1820]. The sequence includes olivine-microphyric basalts ('Dalmeny' type), olivine-clinopyroxene-feldspar-macrophyric basalts ('Dunsapie type) and an olivine-clinopyroxene-macrophyric (ankaramitic) basalt ('Craiglockhart' type), succeeded by interbedded basalt and trachyandesite. The ankaramitic basalt is the same flow that occurs close to the base of the Clyde Plateau Volcanic

Formation sequence at Eudan nan Gallan on the coastal section. The more evolved rock-types seen in the upper part of the succession in the coastal section are not present. However, a pale-weathered trachyte forms the summit of Skerry Fell Fad (Figure 2.36).

Apart from supplementing the range of lithologies and volcanic structures observed in the Machrihanish coastal section, this area exhibits the following features:

- The disconformable nature of the base of the Clyde Plateau Volcanic Formation may be demonstrated.
- The trachyte that caps Skerry Fell Fad has an unusual form. The body has both steep-sided and gently inclined basal contacts with at least two different basaltic lavas.
- Close to the base of the succession, southwest of Skerry Fell Fad, a single lava of tholeiitic (hypersthene-normative) basalt is interbedded with aphyric or microporphyritic basaltic lavas (Macdonald, 1975; Smedley, 1986a, 1988b). This basalt has the lowest K_2O content of any analysed Dinantian basalt and also has distinctive trace-element, rare-earth-element and isotopic compositions.
- Locally, there are minor intrusions and pyroclastic breccias, the latter possibly representing the sites of volcanic vents (Figure 2.35). Minor intrusions, mostly thought to be contemporaneous with the Dinantian volcanism, are not particularly widespread in the southern Kintyre lava field. Of note is a sheet, possibly a sill, of albite-phyric microsyenite exposed in a disused quarry [NR 6308 1907], 400 m SSW of High Lossit, which appears to have been intruded along the unconformity below the lavas. South-west of Killypole Loch [NR 6415 1757], a small outcrop of igneous breccia, containing mostly basaltic clasts and mapped as 'vent' agglomerate, is associated with a small plug of olivine-dolerite. Its exact relationship to the rest of the lavas is unclear.

Black Hill

Black Hill, SSW of Campbeltown, is separated from the Skerry Fell Fad area by an extensive tract of relatively poorly exposed ground. The Clyde Plateau Volcanic Formation sequence around Black Hill is broadly similar to that in the other areas, with the proportion of lavas of more evolved composition generally increasing strati-graphically upwards. However, in contrast to the other areas, the lower part of the succession also includes some evolved flows. Trachyte near the base of the formation in the Chiscan Water [NR 7025 1680] about 1.25 km north-east of Black Hill, and benmoreite south of Black Hill [NR 691 163] may in fact be parts of the same flow (Smedley, 1986a). Also, within the higher units on Black Hill, there are aphyric and feldspar-phyric mugearite lavas.

Between Killellan Park [NR 6815 1640] and Killeonan Burn [NR 6970 1770]–[NR 7055 1740], there are lateral stratigraphical variations and other complex relationships between the lavas. The outcrop is much faulted and some lavas appear to be restricted to certain fault blocks. This is especially true of the sequences either side of the major NW-trending fault that runs from Carrick Caban on Machrihanish Bay [NR 6390 2080] to a point [NR 7045 1525] about 1 km east of Achnaclach (Figure 2.35).

Interpretation

The Kintyre sequence of the Clyde Plateau Volcanic Formation shows a broad, two-fold subdivision, with basic lithologies more common in the lower part and more evolved rocks dominating the upper part. Smaller scale variations in lithostratigraphy, such as those suggested by the different fault-block successions in the Black Hill area, may be explained in part by pre-existing topography. Lavas may have been channelled through low-lying areas between older flows and in graben-like structures between contemporaneous volcanic fault scarps. Some of the faults may be re-activations of older, deep-seated (?Caledonian) structures. Similar abrupt varia tions in local successions are also characteristic of the Lower Dinantian Birrenswark Volcanic Formation in the Anglo-Scottish Borders Region (see Langholm–Newcastleton Hills GCR site report). Small-scale fault-control of this type within the lava field may be common throughout the Clyde Plateau Volcanic Formation in the Midland Valley of Scotland.

The basal contact relationships of the trachytic body capping Skerry Fell Fad suggest that it is either a shallow intrusive body or that the underlying lavas had been eroded prior to its emplacement. Trachytic lavas are normally highly viscous

and typically do not travel any great distance from their source. Hence, the trachyte could be interpreted as a lava dome capping its feeder pipe.

The south Kintyre lavas are typical of the transitional tholeiitic to mildly alkaline suite of Dinantian age in northern Britain. The sequence in the Macrihanish Coast and South Kintyre GCR site preserves some of the most basic (olivine-pyroxene-phyric basalt) and the most evolved rocks in the formation. Overall, this is a mildly silica-undersaturated and mildly sodic suite, which includes low Fe-variants and exhibits strong P_2O_5 and TiO_2 enrichment. Macdonald (1975) drew an important petrographical distinction between flows from the Kintyre and Campsie sequences of the Clyde Plateau Volcanic Formation, stating that, while in the Kintyre rocks clinopyroxene persisted as a phenocryst phase into the hawaiites, it is completely absent as phenocrysts from even the most basic Campsie lavas. Further sampling and analytical work by Macdonald (1980) and Smedley (1986a, 1988b) established that the Kintyre lavas may also be discriminated from many other Dinantian suites by geochemical parameters such as incompatible trace elements, rare-earth elements and isotopes. The additional data reported by Smedley (1988b) showed that the basaltic lavas from Kintyre are isotopically distinct from their counterparts in the Midland Valley and southern Scotland, having, in particular, lower Nd and higher Sr values. This correlates well with differences seen in the Siluro–Devonian calc-alkaline igneous rocks over the same terranes (e.g. Thirlwall, 1986) and implies long-term differences in the mantle source regions, which were more enriched in incompatible elements north-west of the Highland Boundary Fault.

Xenocrysts of quartz, surrounded by complex reaction rims of clinopyroxene, are a feature of some Kintyre basalts, and according to Smedley (1986a) represent tangible evidence that a degree of crustal assimilation may have occurred. However, isotopic evidence for crustal contamination has been detected in only one trachyte sample.

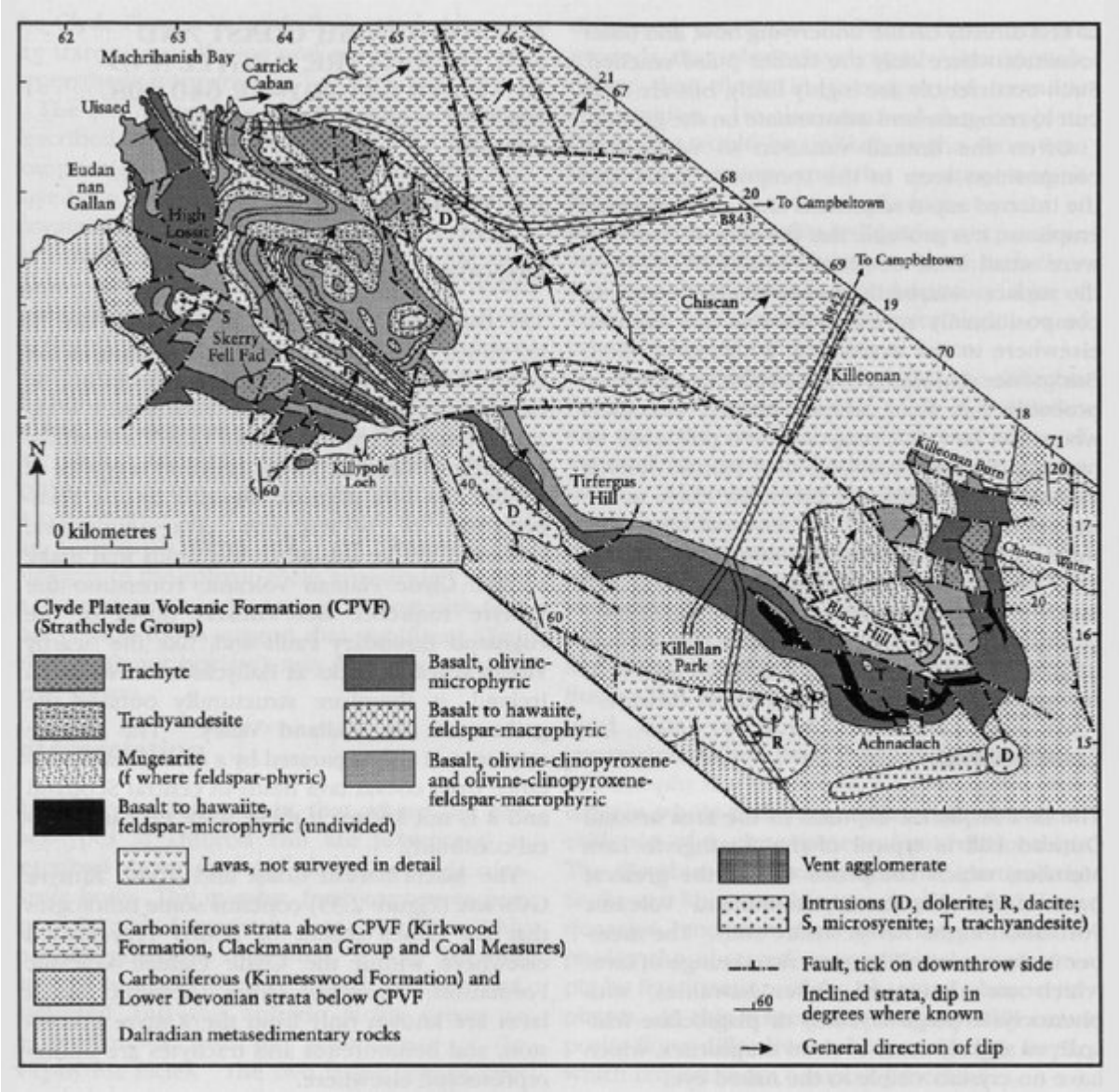
The low-potassium tholeiitic basalt flow within the lowest part of the Kintyre sequence is unique in the Clyde Plateau Volcanic Formation and its presence is fundamental to the overall understanding of the development of the Carboniferous magma types of the Carboniferous–Permian Igneous Province of northern Britain. Macdonald (1975) and Smedley (1986a) have both shown that it is relatively depleted of incompatible elements. This suggests that it was derived from a depleted mantle source, probably from the same type of spinel lherzolite as the other Clyde Plateau Volcanic Formation basalts, but by substantially greater degrees of partial melting. Contamination by crustal material is not thought to have been significant in this case.

Conclusions

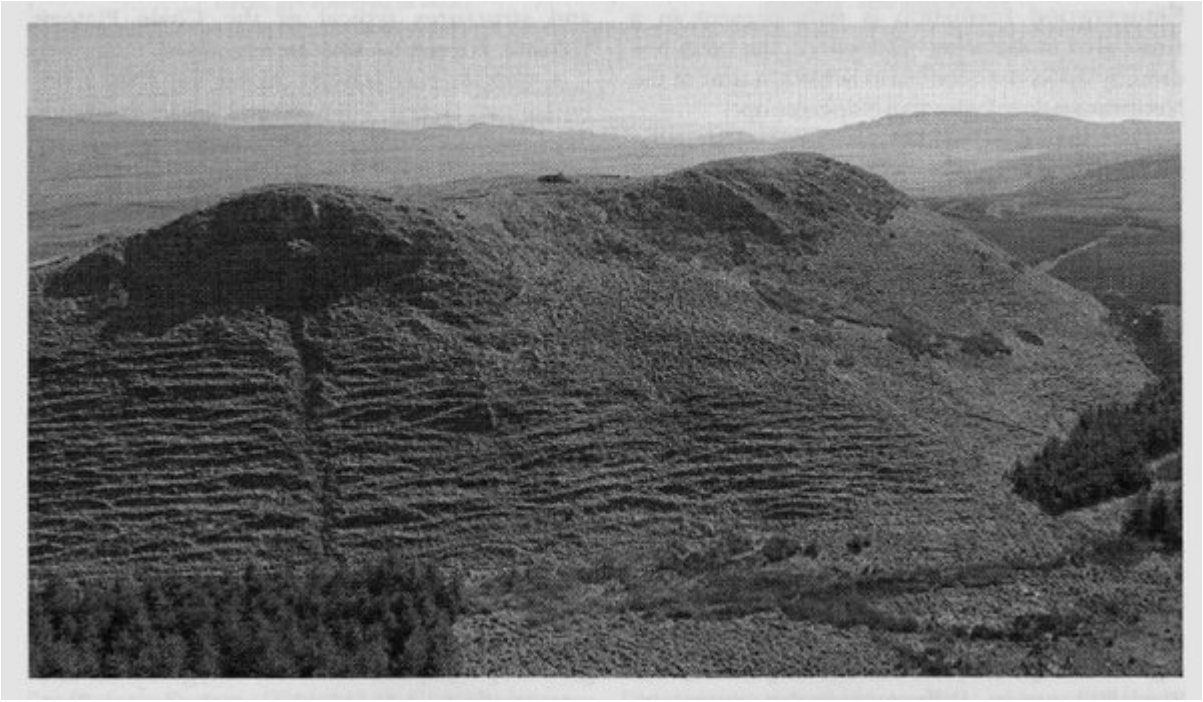
Visean lavas in the Kintyre peninsula, represented by the Machrihanish Coast and South Kintyre GCR site, are the only significant occurrence of the widespread Clyde Plateau Volcanic Formation north of the Highland Boundary Fault. The 400 m-thick succession comprises at least 20 lavas mainly of olivine basalt, but more evolved rock compositions, including mugearite, benmoreite and trachyte, are more common in the upper part. Most of the lavas are extensive sheet-like bodies, but some are lenticular. Some appear to have flowed into contemporaneous topographical hollows, possibly small fault-bound grabens. A trachyte forming the summit of Skerry Fell Fad is a splendid example of a lava dome.

Geochemically, the Kintyre lavas are broadly similar to the transitional to mildly alkaline rocks that constitute the Clyde Plateau Volcanic Formation in the Midland Valley of Scotland, though with some subtle differences. In particular, a single lava of tholeiitic basalt with unusually low potassium content, near the base of the sequence on Skerry Fell Fad, is unique within the formation.

References



(Figure 2.35) Map of the area around the Machrihanish Coast and South Kintyre GCR site. Based on British Geological Survey 1:50 000 Provisional Series Sheet 12, Campbeltown (1996).



(Figure 2.36) Skerry Fell Fad, Macrihanish Coast and South Kintyre GCR site. The summit rocks are trachyte, either infilling an earlier valley feature or possibly forming a lava dome. Note the terracettes due to soil creep on the steep slopes below the summit. (Photo: C. Bond.)