Campsie Fells, Stirling and East Dunbartonshire

[NS 572 800]–[NS 535 825]–[NS 609 867]

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Introduction

The Visean lavas and pyroclastic rocks of the Clyde Plateau Volcanic Formation, together with associated vents and intrusions, form the hilly areas that lie to the north, west and south of Glasgow. In the northern part of the Clyde Plateau the steep slopes that bound the Campsie Fells provide extensive exposures (Figure 2.26) and (Figure 2.27). Glacial erosion has produced escarpments, which afford well-exposed sections through the lower part of the lava succession. The spectacular escarpment on the northwestern margin of the Campsie Fells is carved out of the largest concentration of vents and intrusions in the Clyde Plateau, the North Campsie Linear Vent System (Figure 2.28).

The Campsie Fells GCR site extends for 8 km along the NW-facing escarpment, from Dunmore, above the village of Fintry, as far as the twin volcanic plugs of Dumgoyne and Dumfoyne. From there it continues south-eastwards along a 4.5 km stretch of the SW-facing escarpment of the Strathblane Hills between Dumfoyne and the Spout of Ballagan. As well as the volcanic features of the area, localities of stratigraphical and palaeontological interest have been notified at the Balglass corries in the north and at Ballagan Glen in the south (see Cossey *et al.,* in prep.).

The earliest detailed description of the geology of the Campsie Fells by Young (1860) proved to be so popular that it was reprinted in 1868 and 1893. More recent sources of information (Clough *et al.,* 1925; MacDonald, 1967; Whyte and MacDonald, 1974; MacDonald and Whyte, 1981; Hall *et al.,* 1998) provide a general picture of the petrography and geochemistry of the volcanic rocks, which vary in composition from mafic basalt to trachyte. Most of these accounts draw upon more detailed information in PhD theses by MacDonald (1965) and Craig (1980). Excursions to parts of the Campsie Fells outwith the GCR site are described by MacDonald and Whyte (in Upton, 1969) and MacDonald (in Lawson and Weedon, 1992). The mildly alkaline chemistry of the rocks, their range of composition, the relationships of vents to lava flows, and the presence of a flow of relatively fresh hawaiite that exhibits interesting internal variations, afford a potential for further research in the area, which could be of international significance.

Whole-rock K-Ar radiometric dates from vent intrusions in the western Campsie Fells (De Souza, 1979) include 329 ± 7 Ma (Dumgoyne) and 316 ± 5 Ma (Dunmore) (*c.* 336 Ma and 323 Ma respectively using new constants). Ages in the range 315 ± 7 Ma to 303 ± 7 Ma were obtained from lavas farther east but De Souza considered that, given the probability of argon loss during alteration, the age of eruption is likely to be in the vicinity of, or older than, 330 Ma (*c.* 337 Ma using new constants).

Description Inverclyde Group (Figure 2.4) and (Figure 2.28). The lavas form a plateau, dipping gently to the *The lava succession* south-east and deeply dissected by Ballagan Glen [NS 565 830]–[NS 573 795] and Fin Glen Throughout the Campsie Fells the lavas rest [NS 583 833], where exposures of extensive directly upon the Clyde Sandstone Formation, parts of the succession supplement a continuous the topmost division of the Tournaisian section in the steep cliffs at Black Craig [NS 552 818], above Strath Blane. The overall succession is shown in (Table 2.2). The lava plateau is cut by ENE-trending normal faults, which are displaced by a set of N–S-trending faults. To the south, the E–W-trending Campsie Fault downthrows to the south by some hundreds of metres, bringing the top of the Kilpatrick Hills succession into juxtaposition with the lower part of the Campsie succession (Figure 2.28).

The lavas vary in thickess from flow to flow and within flows, averaging about 10 m but in some instances exceeding 20 m. They generally take the form of single flow units, vesicular on top and in some cases displaying well-developed red bole between flows, the product of lateritic weathering. There are no clear indications of the development of multiple flow units or of other features typical of pahoehoe, so it is likely that the lavas were erupted as aa. The upper parts of the three lowest flows at Black Craig are particularly vesicular and slaggy, with drusy cavities, calcite veining, chalcedony veins and jasper lenses. The latter were at one time exploited as a source of material for the manufacture of jewellery in Edinburgh.

The basal lava at Black Craig is the most basic in the western Campsie sequence, being an olivine basalt containing abundant, randomly orientated, laths of labradorite (An_{66}), which comprise 55% of the rock. Olivine (12%) has been completely replaced by secondary minerals. A microcrystalline mesostasis contains small amounts of nepheline. The remainder of the succession in the Strathblane Hills is made up of flows that vary in composition from basaltic hawaiite to hawaiite. They are characteristically feldspar-rich, commonly display marked flow orientation of the feldspar, and contain variable amounts of augite which generally comprises less than 10% of the rock.

Studies of the petrology of the lavas are complicated by the almost ubiquitous replacement of olivine by secondary minerals such as 'serpentine', green pleochroic bowlingite and, in extreme cases, calcite. The oxidation state of the opaque oxides has also been effected to varying degrees so that titanomagnetite, which in some flows exceeds 9%, has undergone alteration resulting in the transformation of exsolved magnetite to maghemite (Goswami, 1968). This has the effect of distorting the ratio of ferrous to ferric iron in whole rock chemical analyses to the extent that some nepheline-bearing rocks appear to be silica-oversaturated in their normative composition. Most of this alteration can be explained by reaction if the early-formed minerals with the volatile reaction of the magma during the late stages of crystallization.

The distinctive texture of a hawaiite flow that occurs near the base of the succession in the Strathblane Hills allows it to be traced along the Campsie escarpment for at least 2.4 km (MacDonald, 1967). At Jenny's Lum [NS 562 806] it has a thickness in excess of 18 m of which the lowest 15 m are fresh, almost free of vesicles and display better developed columnar joints than is iormal in the Campsie lavas (Figure 2.29). It is rich in andesine feldspar, much of it in the form of platy microphenocrysts; it has a small amount of nepheline in the mesostasis, and has both normative andesine and nepheline. Augite occurs only as microlites in the groundmass. It displays an unusually systematic gradational variation in its petrography, geochemistry and texture. This is most marked at Jenny's Lum where there is an overall tendency towards increasingly basic compositions in successively higher parts of the flow. There is a corresponding upward increase in the amount of augite and in the calcium content of the plagioclase, matched by a systematic increase in the size of the feldspar microphenocrysts. In the upper part of the flow especially, the feldspar crystals impart a pronounced platy fabric, parallel to strongly developed flat-lying joints (Figure 2.29). In the very top of the flow these trends are partly reversed.

(Table 2.2) Succession of the Clyde Plateau Volcanic Formation in the western Campsie Fells. (After Hall *et al.,* 1998. table 4)

	Lava types	**Source**
Holehead Lava Member	Mainly feldspar-macrophyric basalt ('Markle type')	Waterhead central volcano
Fin Glen Lava Member	Microporphyritic basalt, mugearite, trachybasalt and a persistant phonolitic trachyte	Local centres and North Campsie Linear Vent System
Upper and Lower North Campsie lava members	Microporphyritic basalt, basalticCampsie lava members hawaiite and hawaiite	North Campsie Linear Vent System

The gradational variations and apparent absence of internal discontinuities are very similar to those observed in hawaiitic flows in the northern part of the Renfrewshire Hills (Kennedy, 1931; see Dunrod Hill GCR site report). However, they are in contrast with composite lava flows involving two markedly different components, such as those described by Kennedy (1933) from elsewhere in the Renfrewshire Hills. One could argue that the Jenny's Lum and Dunrod Hill hawaiites are not truly composite but display gradational variations in composition, suggesting an orderly mode of emplacement of a magma that progressively changed in composition during the course of eruption. Such progressive variation in the composition of lava during the course of an eruption has been observed in historical activity in Iceland (Thorarinsson and Sigvaldason, 1972).

A distinctive phonolitic trachyte flow to the east of Fin Glen has petrographical similarities to an irregular intrusion of phonolite near Fintry (Hall *et al.,* 1998). This flow and a few analcime trachybasalts near North Berwick are the only silica-undersaturated evolved lavas known within the Carboniferous and Permian volcanic sequences of Britain. Elsewhere, any more evolved compositions trend towards quartz-trachytes and rhyolites (for discussion see Traprain Law GCR site report). The phonolitic trachyte marks the base of the Fin Glen lavas, which are, on average, more felsic than the underlying flows; in addition to basalt they include trachybasalt and mugearite. The topmost part of the succession in the western Campsie Fells consists of feldspar-macrophyric basalts ('Markle' type) of the Holehead Lava Member.

The North Campsie Linear Vent System and associated intrusions

Within the area of the Campsie Fells GCR site there are four major agglomerate-filled vents, a number of smaller ones and many associated intrusions that together form a continuous 7 km-long linear feature. This North Campsie Linear Vent System trends WSW from Dunmore [NS 606 865] to Garloch Hill [NS 553 836] (Figure 2.28). The volcanic plugs of Dumgoyne [NS 542 828] and Dumfoyne [NS 547 825] (Figure 2.27) are situated on this trend, which continues beyond the confines of the GCR site, through Dumgoyach, and to the WSW through the Kilpatrick Hills as far as Dumbarton (the Dumbarton–Fintry Line of Whyte and MacDonald, 1974; (Figure 2.3); see Dumbarton Rock GCR site report). In close proximity to the vents, outcrops of bedded tuff and scoria represent the remains of cinder cones produced by lava fountaining.

The intrusive rocks associated with the vents vary in composition from basalt to hawaiite and mugearite. The basaltic types most commonly include microlitic and feldspar-microphyric varieties ('Jedburgh' type), and less commonly feldspar-macrophyric 'Markle' types. The more mafic varieties, rich in phenocrysts of olivine and augite, which occur in vents in the Kilpatrick Hills to the south of the Campsie Fault, are not represented in the Campsie vents. In general, the basalts and related rocks of the vent intrusions have suffered less immediate post-eruptive alteration than the lavas; olivine is much more commonly preserved, for example (see Dumbarton Rock GCR site report). It is likely that many vent intrusions represent fractions of magma that were emplaced at a late stage in individual eruptive sequences. As such they would commonly have been depleted in volatile constituents that had escaped to the surface through the open vent or had risen as gas bubbles to higher levels, now removed by erosion.

Whereas the North Campsie vents have an almost continuous outcrop that forms the northwestern boundary of the lava plateau, Dumgoyne, Dumfoyne and a number of smaller vents and intrusions lie to the west of the main mass of lavas, forming isolated features. These plugs cut sedimentary rocks of the Ballagan Formation and, in the case of Dumgoyne, the underlying red and white cross-bedded sandstones of the lowermost Carboniferous Kinnesswood Formation. No part of the sub-aerial cone of these volcanic edifices is preserved *in situ* but both Dumgoyne and Dumfoyne are composed mainly of agglomeratic material, some of which may have slumped back into the volcanic conduit from higher levels at the end of eruptive episodes. At Dumgoyne, basaltic intrusions cut the agglomerates, especially on the eastern side of the vent where a major dyke-like mass occurs. Dumfoyne has only one small vent intrusion on the north side.

Within the western Campsie Fells a number of dykes have trends similar to that of the North Campsie Linear Vent System and coincide with ENE-trending normal faults. Some of these dykes are of feldspar-macrophyric ('Markle' type) basalt. Whyte and MacDonald (1974) have suggested that these could have been feeders for fissure eruptions of feldspar-phyric lavas, the latter having been subsequently removed by erosion of the top of the succession in the western Campsies.

Interpretation

The underlying structural control of the ENE-trending North Campsie Linear Vent System is probably related to a Caledonian lineament in the pre-Carboniferous basement (see 'Introduction' to this chapter). This trend is sufficiently similar to that of the feldspar-phyric dykes and associated normal faults to suggest that all three features are related to a common stress system. The high concentration of magmatic activity along the linear vent system is likely to have been accompanied by corresponding local swelling of the Earth's crust during periods of maximum magmatic activity. Such conditions are conducive to normal faulting, facilitating the intrusion of dykes, parallel to the elongation of the vents, as is seen in many areas of recent active volcanism. The swelling could also have created the palaeoslope, down which the lavas flowed away from the vents.

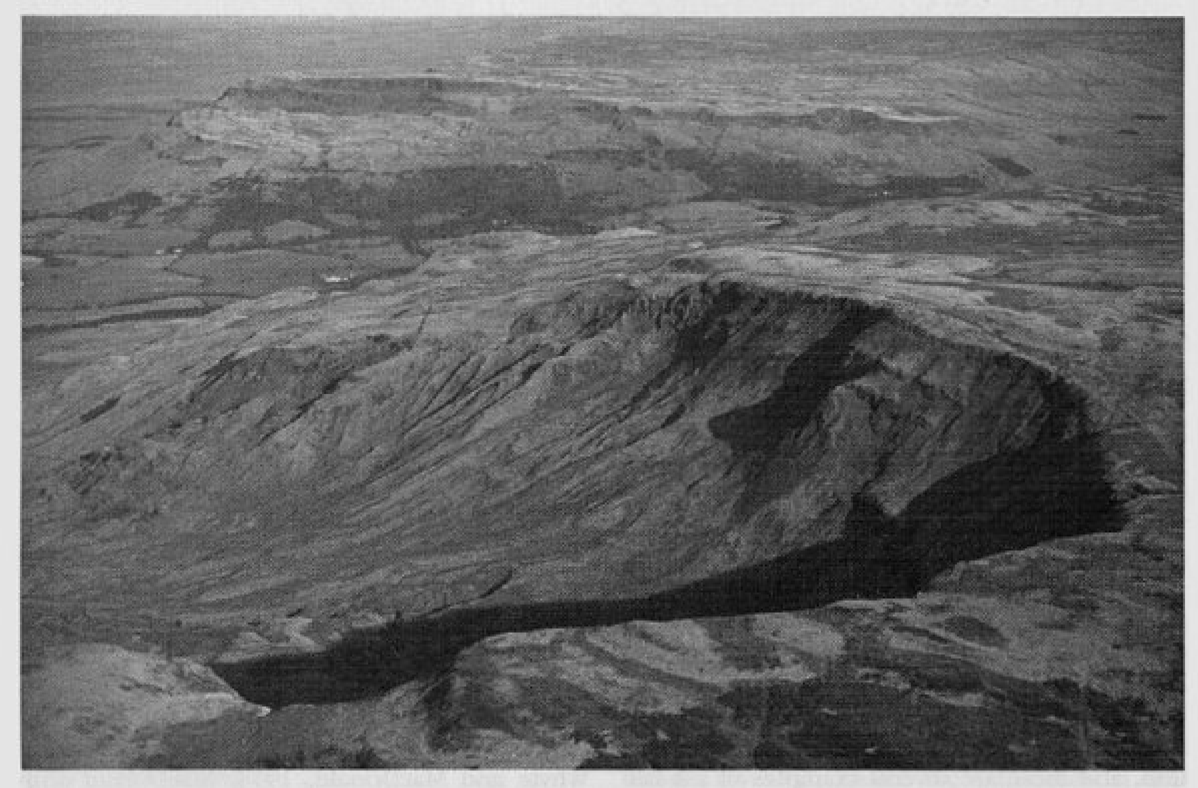
The similarity in petrography and geochemistry between the vent intrusions and the lavas of the western Campsie Fells (MacDonald and Whyte, 1981) make it appear likely that the bulk of the succession, comprising the Fin Glen Lava Member and the Upper and Lower Campsie lavas, were derived from the North Campsie Linear Vent System and its continuation in Dumgoyne and Dumfoyne. It is difficult to correlate individual lavas precisely with particular vents, but Dumfoyne, although mainly composed of agglomerate, features a vent intrusion of hawaiite on its north side that is similar in its geochemistry and petrography to the Jenny's Lum hawaiite (MacDonald and Whyte, 1981). It is thus possible that the latter could have been erupted from this vent and hence flowed to the south-east for a minimum distance of nearly 4 km from its point of eruption. The phonolitic trachyte flow that marks the base of the Fin Glen Lava Member has a present-day extent of about 10 km^2. If the source of this flow is the Fintry phonolite intrusion (Hall *et al.,* 1998) it could originally have had an aerial extent in excess of 20 km^2 and flowed south for at least 6 km from its source. The dominantly felspar-phyric basaltic Holehead lavas at the top of the succession were most probably erupted from a large central volcanic complex at Waterhead, some 3.5 km to the east of the area covered by (Figure 2.28), which has been described by Craig (1980) and Forsyth *et al.* (1996).

Conclusions

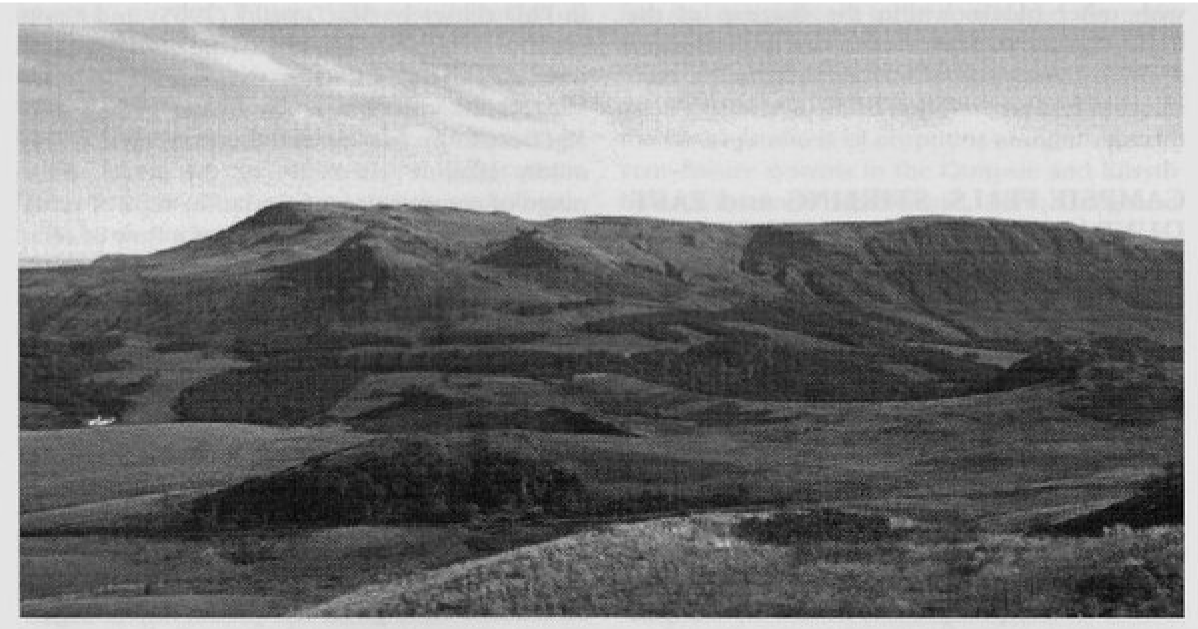
The Campsie Fells GCR site exhibits the lower part of the volcanic succession in the Campsie Fells; it is typical in many respects of the northern outcrops of the Visean Clyde Plateau Volcanic Formation. The lava pile is bounded to the north-west by a line of deeply eroded volcanic vents, representing the roots of small volcanoes, and a continuous apron of fragmental rocks formed from the ash and cinders of the volcanic cones. The vents consist of coarse blocky material that collapsed back into the conduit of the volcano at the end of each eruption, and many are intruded by volcanic plugs, formed as fresh magma forced its way towards the surface.

The North Campsie Linear Vent System is the most concentrated example of multiple volcanic vents preserved in Dinantian times in the Midland Valley, and the lava sequence of the Campsie Fells is one of few for which the general source area and hence the type of eruption can be clearly identified. It has even been possible to tentatively suggest specific vents as the sources for some individual lavas. Some of the more distinctive lavas can be traced for considerable distances. The lavas and intrusions have been the subject of several geochemical investigations and could provide material for a variety of further studies into magmatism in the Midland Valley and the origin and evolution of magmas in general. The volcanic plugs in particular could provide fresh rocks suitable for radiometric dating, which would have wider significance for the timing of events in the Midland Valley.

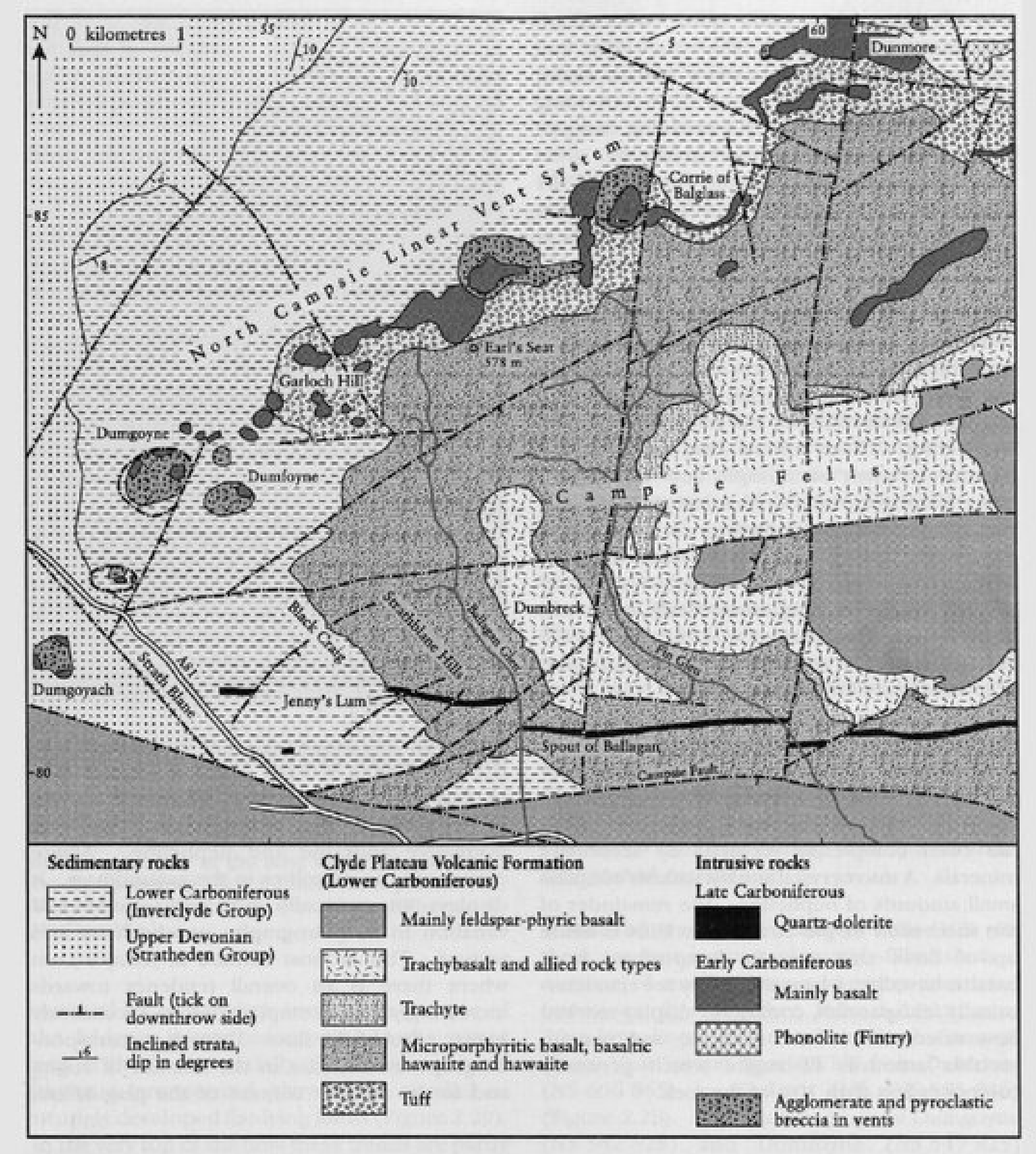
References



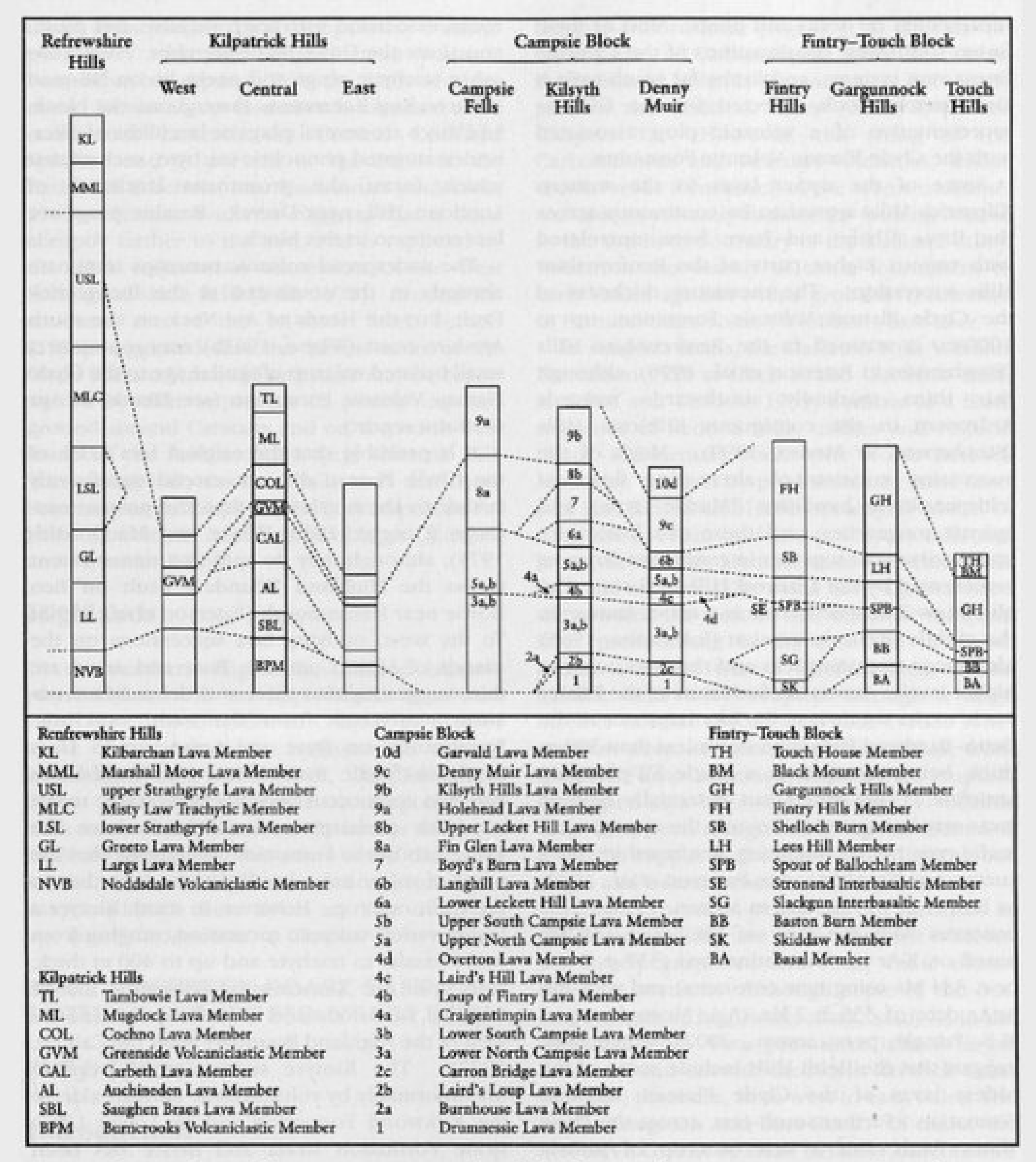
(Figure 2.26) Corrie of Balglass on the northern escarpment of the Campsie Fells, with the Fintry Hills in the background. Largely microporphyritic basalts and hawaiites of the Lower North Campsie Lava Member forming the steep wall of the corrie, overlie volcaniclastic rocks derived from the North Campsie Linear Vent System. (Photo: P Macdonald.)



(Figure 2.27) The western end of the Campsie Fells viewed across Strath Blane from the south-west. The Dumfoyne Vent is the feature in the centre of the photograph; the Dumgoyne Vent is to the left of it. The high ground on the skyline above Dumgoyne marks the south-west end of the North Campsie Linear Vent System. (Photo: J.G. MacDonald.)



(Figure 2.28) Map of the area around the Campsie Fells GCR site. Based on British Geological Survey 1:50 000 Sheet 30E, Glasgow (1993).



(Figure 2.4) Correlation of composite sections in the Clyde Plateau Volcanic Formation. Based on information in Forsyth et al. (1996); Hall et al. (1998); and Paterson et al. (1990). N.B. formal designation of these units as members is currently in progress.

	Lava types	Source
Holehead Lava Member	Mainly feldspar-macrophyric basalt ('Markle type')	Waterhead central volcano
Fin Glen Lava Member	Microporphyritic basalt, mugearite, trachybasalt and a persistant phonolitic trachyte	Local centres and North Campsie Linear Vent System
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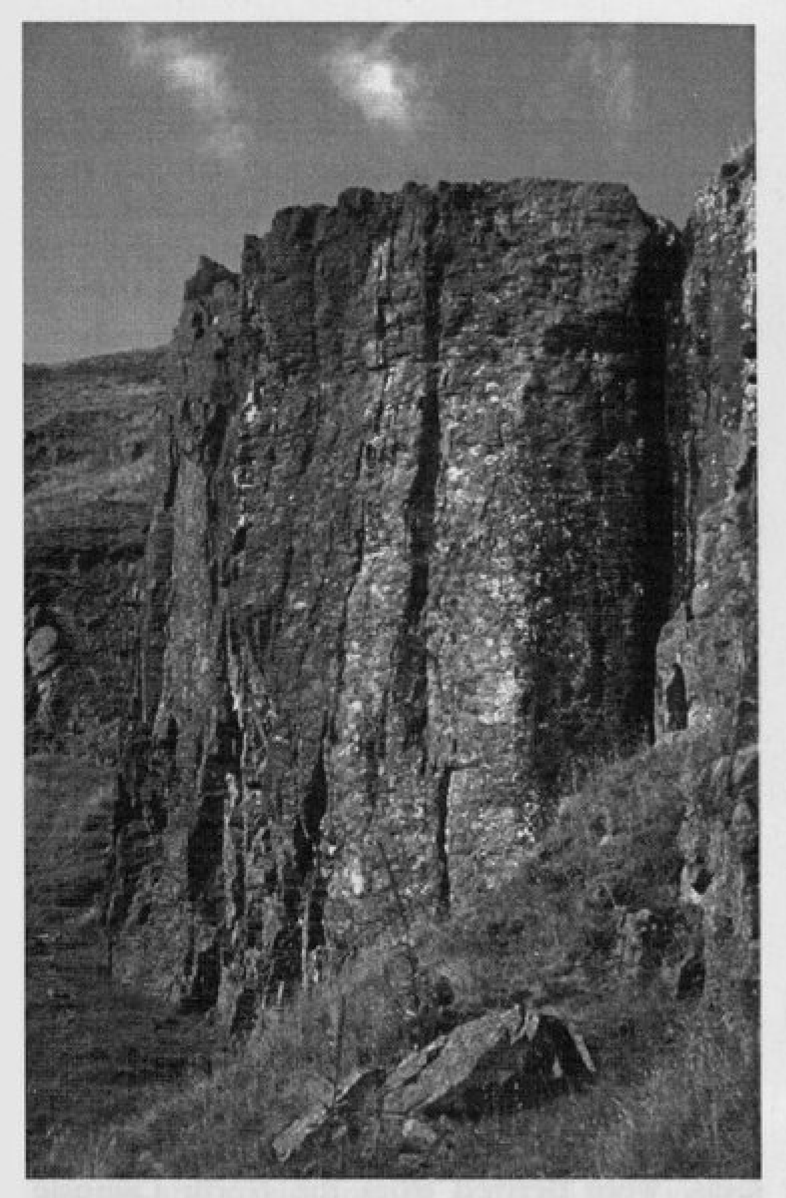
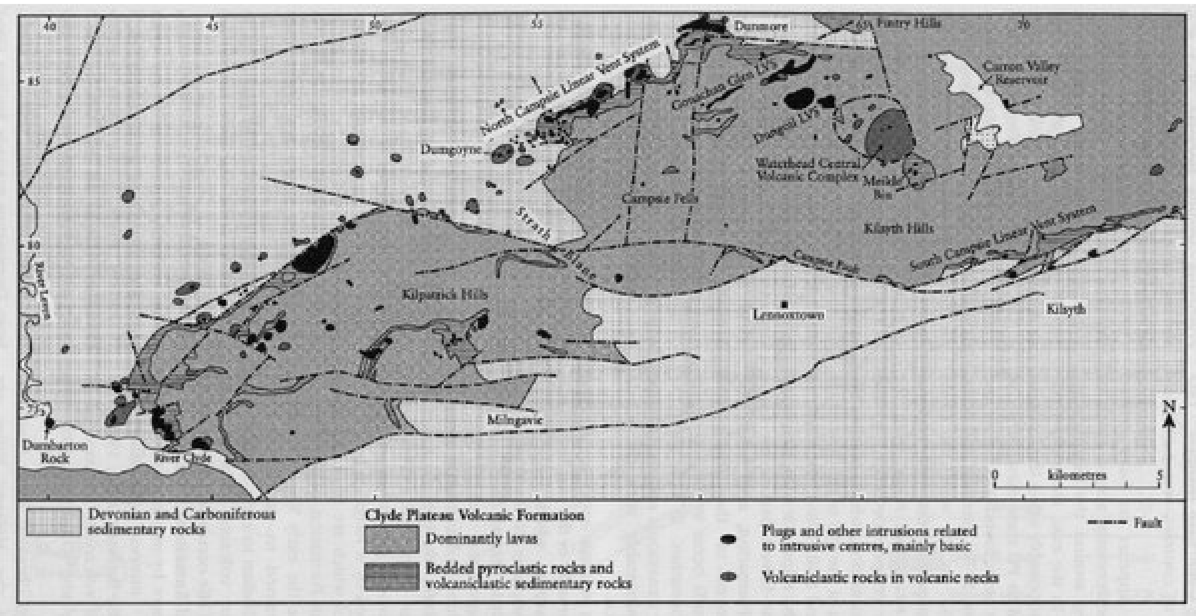


(Figure 2.29) Hawaiite lava at Jenny's Lum, western Campsie Fells. Note the flat-lying joints, particularly in the upper part of the flow, which are parallel to the flow texture of platy andesine microphenocrysts. The height of the cliff is over 15 m. (Photo: J.G. MacDonald.)



(Figure 2.3) Map of the Kilpatrick Hills and Campsie Fells, showing outcrops of the Clyde Plateau Volcanic Formation and volcanotectonic lineaments defined by plugs, necks and proximal volcaniclastic beds. The most prominent lineament, along the north-west edge of the volcanic outcrops, is the Dumbarton–Fintry Line of Whyte and MacDonald (1974). Based on British Geological Survey 1:50 000 sheets 30W, Greenock (1990); 30E, Glasgow (1993); and 31W, Airdrie (1992).