Geological framework of the North-west Highlands - Igneous rocks

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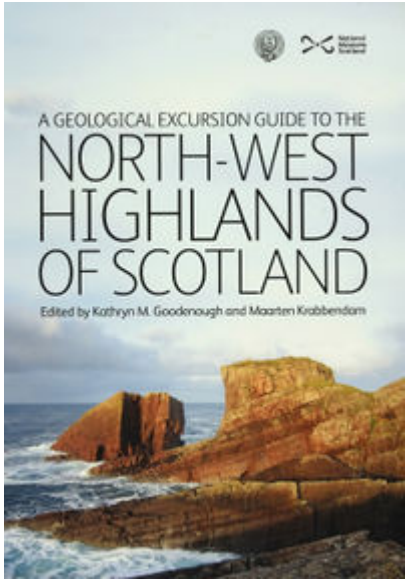

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Introduction

The Assynt district contains a considerable range of igneous rocks, some of extreme composition and many unique in the British Isles, which were emplaced during the Caledonian orogeny and provide both relative and absolute chronology of displacements in the Moine Thrust Zone. The literature is complicated by archaic terminology as well as great minera-logical variety, summarised in Table B. A comprehensive overview has been provided by Parsons (1999).

The Loch Borralan Pluton (Excursion 10) is the only alkaline pluton in the British Isles that includes nepheline syenites. It also contains exotic, strongly ultrapotassic units and is associated with a small body of carbon-atite. The smaller Loch Ailsh Pluton (Excursion 9) is composed mainly of silica-saturated syenite. Abundant dykes and sills, ranging from calc-alkaline lamprophyres to peralkaline rhyolites, are found throughout the thrust sheets. In the foreland to the west, the Canisp Porphyry forms a large sill complex of quartz-microsyenite; and two mafic phonolite dykes, focussed on the Loch Borralan intrusion, reach the coast NW of Achiltibuie and near Achmelvich. Deformed sills of quartz-microsyenite (‘nord-markite’) occur close to the Moine Thrust, and extend eastwards into the Moine psammites. It must be borne in mind that crustal shortening of several tens of kilometres may have occurred between the intrusions near the Moine Thrust and the compositionally similar Canisp

Porphyry Sills in the foreland.

Current rock names	Early names	Mineralogy
Units in the Loch Borralan Complex		
Late suite		
Cnoc na Sroine quartz-syenite	Nordmarkite	Alkali feldspar, quartz, aegirine-augite and/or alkali amphibole, ± melanite garnet
Altnacealgach alkali-feldspar-syenite	Perthosite	Nearly monomineralic alkali-feldspar rock. Minor melanite.
Early suite		
Ledmore nepheline-syenite	Ledmorite	Alkali feldspar, nepheline, melanite garnet, diopsidic augite, biotite
"Allt a'Mhuilinn pseudoleucite-syenite and associated rocks"	Borolanite	Alkali feldspar, nepheline, melanite garnet, biotite in matrix. Alkali feldspar and nepheline intergrowths as pseudomorphs after leucite
	Shonkinite	Diopsidic pyroxene in a matrix of alkali feldspar and zeolite replacing nepheline
Bad na h-Achlaise ultramafic rocks	Cromaltite	Diopsidic pyroxene and/or hornblende, ilmenomagnetite, biotite, apatite and melanite garnet
Sövite (calcite carbonatite)		Calcite ± phlogopite and apatite
Dykes and sills		
Porphyritic trachyte swarm		Plagioclase phenocrysts in matrix of aligned alkali feldspar laths
Ledmorite swarm (nepheline-syenite)	Ledmorite	Phenocrysts of euhedral melanite garnet, aegirine and biotite in orthoclase and nepheline matrix
Nordmarkite swarm (quartz-microsyenite)	Nordmarkite	Alkali feldspar phenocrysts in matrix of alkali feldspar, quartz, biotite ± aegirine-augite, alkali amphibole
Peralkaline rhyolite swarm	Grorudite	Alkali feldspar and aegirine phenocrysts in quartz, feldspar, aegirine matrix
Canisp Porphyry (quartz-microsyenite)	Canisp Porphyry	Alkali and plagioclase feldspar phenocrysts in feldspar, quartz matrix
Hornblende-microdiorite swarm	Hornblende porphyrite	Phenocrysts of hornblende and plagioclase, ± biotite, in feldspathic matrix
Vogesite swarm	Vogesite	Hornblende phenocrysts, ± diopside, in plagioclase, hornblende, quartz matrix
Units in the Loch Ailsh Pluton		

Loch Ailsh syenite S3	Aegirine-melanite-syenite	Nearly monomineralic alkali feldspar-syenite with small amounts of alkali pyroxene and melanite garnet
	Perthosite	Nearly monomineralic alkali feldspar rock with small amounts of aegirine-augite
Loch Ailsh syenite S2	Pulaskite and nordmarkite	Alkali feldspar syenite with aegirine-augite, ± riebeckite ± minor quartz
Loch Ailsh syenite S1	Pulaskite and nordmarkite	Alkali feldspar syenite with augitic pyroxene
Melanocratic pyroxene-syenite	Shonkinite	Diopside and biotite, ± hornblende, in clusters set in alkali feldspar.
Loch Ailsh ultramafic rocks	Pyroxenite and hornblendite	Diopsidic pyroxene, ilmenomagnetite, apatite, biotite. Hornblende sometimes replaces diopside

The alkaline plutons are part of a strip of late Caledonian intrusions that occur along, and slightly to the east of, the Moine Thrust Zone, extending from Loch Loyal in the north to Glen Dessary in the south. The alkaline igneous activity represents the north-west edge of the slightly younger, calc-alkaline granitic magmatism that dominates the remainder of the Highlands and Southern Uplands. Like alkaline magmatism else-where it extended over a long period of time, from 448 ± 2 Ma at Glen Dessary (van Breemen *et al*., 1979b; Goodenough *et al*., 2011) to 425 ± 3 Ma at Ratagain (Rogers and Dunning, 1991). Alkaline magmatism is most commonly associated with extension of the crust, as in the rift-valleys of present-day East Africa, but the North-west Highlands are a region of marked crustal shortening. A westward-dipping subduction zone has been postulated to exist beneath the Scottish Caledonides and many of the alkaline igneous rocks in the North-west Highlands have affinities with shoshonites, subduction-related basaltic rocks unusually rich in potassium (Thompson and Fowler, 1986; Thirlwall and Burnard, 1990). The source of ultrapotassic magmas and carbonatites is usually placed in the mantle. It is possible that the alkaline magmas arose by partial melting, during subduction, of mantle enriched in alkalis during an earlier phase of carbon-atitic metasomatism, as has been postulated for subduction-related ultra-potassic rocks in Italy. However, this does not explain the localisation of alkaline magmatism to a narrow band near the Moine Thrust Zone.

The Loch Borralan Pluton, in southern Assynt, is divided into early and late suites (Woolley, 1970), the former being dominated by silica-undersaturated rocks that include pyroxenites and nepheline syenites (see Table B). Ultrapotassic rocks (‘pseudoleucite syenites’), containing white spots made of nepheline and potassium-rich feldspar replacing the potas-sium-rich feldspathoid leucite, are mainly confined to the eastern end of the outcrop of the early suite. A carbonatite, which contains xenoliths of nepheline syenite, is emplaced in Durness Group dolostones 400m outside the main Loch Borralan Pluton, but is most probably related to the early suite (Young *et al*., 1994). The late suite cuts through the undersaturated units and is composed of silica-saturated or quartz-bearing alkali feldspar syenites. The relationships between the multiplicity of rock types in the early suite are difficult to establish because of poor exposure, but strong crystal fractionation, much of it in magma chambers below the present level, is likely to have been involved. The quartz-bearing late suite cannot, however, have been derived directly from the early suite by crystal fractionation; no amount of fractionation can change a magma from being silica undersaturated to silica saturated.

The Loch Ailsh Pluton is less diverse and composed largely of very leucocratic alkali feldspar

syenites, some with small amounts of quartz, formed in three magmatic pulses termed S1, S2 and S3 (Parsons, 1965a). As at Loch Borralan, ultramafic pyroxenites occur only where the magmas were in contact with Durness Group dolostone. In places there is clear evidence that some pyroxenites have been produced by reactions between silicate magma and dolomite, but at Loch Borralan there is good evidence that the main mass of biotite pyroxenite is intrusive. The reason for the association with dolostone is not understood. It would require extremely high temperatures to produce magmas of the composition of the diopside-biotite pyroxenites and emplacement as a cumulate mush is probable.

Dykes and sills of the North-west Highlands Minor Intrusion Suite are abundant throughout the Assynt Culmination, but are rare elsewhere (Sabine, 1953; Goodenough *et al*., 2004). The main suite of minor intrusions varies in composition from lamprophyres, through hornblende diorites to per-alkaline rhyolites, all of which have been deformed and were clearly intru-ded prior to thrusting. These intrusions are unevenly distributed through the thrust sheets. The most basic type comprises dark grey-weathering vogesites (hornblende-bearing lamprophyres) that occur predominantly in the Durness Group dolostones in the Sole Thrust Sheet. In contrast the most evolved type, the brick-red peralkaline rhyolites, mainly occur above the Ben More Thrust, and cut the slightly earlier Loch Ailsh Pluton. There is therefore a hint of regional variation in magmatism prior to crustal shortening. The various types of minor intrusive include both calc-alkaline and alkaline compositions, and are thought to have formed by fraction-ation from a common parental magma, formed in a mantle source modified by subduction-related components (Goodenough *et al*., 2004).

References

> At all times follow: The Scottish Access Codeand Code of conduct for geological field work

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