Basement of the Grampian Highlands

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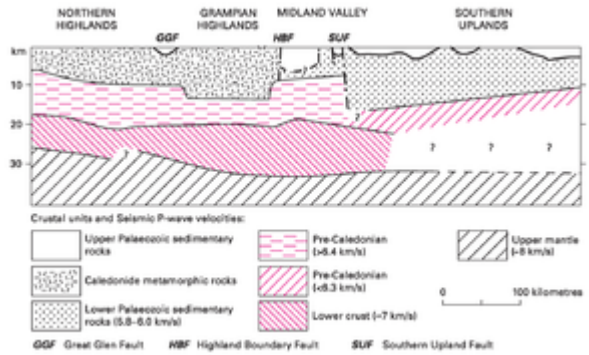
Introduction

Our knowledge of the basement to the Dalradian rocks of the Grampian Highlands is still very limited and in the previous edition of this handbook the analogy drawn by the original surveyors between the pre-Dalradian of Islay and Colonsay and the Lewisian and Torridonian of North-west Scotland was generally accepted. Recent work, however, has indicated that the exposed basement rocks are not Lewisian but represent new, 1800 Ma-old, Proterozoic crust, and that the overlying Colonsay Group is not equivalent to the Torridonian. The affinity of the Bowmore Sandstone of Islay likewise remains uncertain. These findings have major implications for the pre-Dalradian history of the area, and suggest that the Great Glen Fault may be a very old structure.

Seismic profiling indicates two crustal layers beneath the surface metamorphic rocks of the Grampians, a high-grade metamorphic upper crustal basement with P-wave velocities greater than 6.4 km/sec at depths of 6 to 14 km and a lower crust of mafic/ultramafic rocks with a P-wave velocity of approximately 7 km/sec (P915412; Bamford, 1979). The precise nature of these crustal materials is not known, but they may be partly represented by the quartzofeldspathic gneisses and basic granulites respectively occurring as xenoliths in volcanic rocks of the Midland Valley and western Grampians. The xenoliths also indicate that the mantle under at least the western part of the Grampians consists of harzburgite, lherzolite and cumulate ultramafites (Upton et al., 1983).

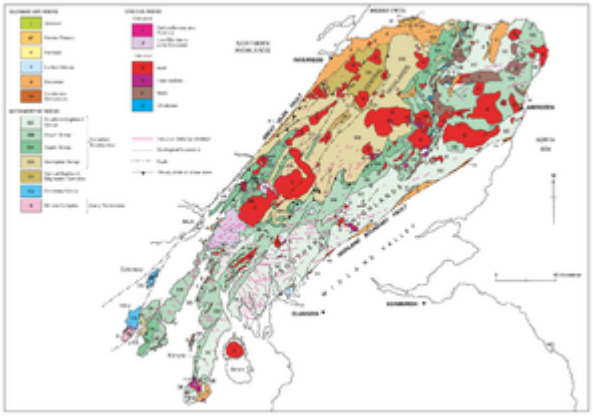


Schematic cross-section through the crust

and uppermost mantle of northern Britain
(modified after Bamford, 1979). P915412.

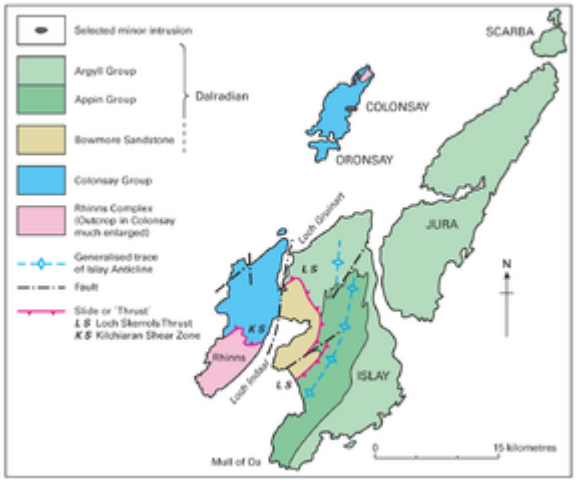
Sub-Dalradian of Islay and Colonsay

The eastern part of the island of Islay is made up of undoubted Dalradian rocks, a continuation of those found on neighbouring Jura and the mainland, and also of probable Dalradian rocks—the Bowmore Sandstone. These are separated from the older rocks of western Islay and Colonsay by the Loch Gruinart Fault, a splay from the Great Glen Fault (P915411). These older rocks consist of a gneissic basement overlain by a 5.5 to 6 km-thick suite of low-grade metasedimentary rocks, the Colonsay Group.



Solid geology of the Grampian Highlands.
P915411.

The basement rocks, called the *Rhinns Complex* by Muir et al. (1992), crop out over an area of about 20 km^2 on the Rhinns of Islay and as a very small inlier at the north end of Colonsay (P915413). Similar rocks occur 50 km south-west of Islay on Inishtrahull Island near the northern coast of Ireland (Dickin and Bowes, 1991).



Geological sketch map of Islay and
Colonsay. P915413.

The Rhinns Complex on Islay consists of two main components, respectively acid and basic gneisses (Wilkinson, 1907). These constitute an alkali igneous complex which has suffered intense multiple deformation and has been intersliced with the overlying Colonsay Group rocks (Muir et al., 1992). Examination of a low-strain zone on the south-west side of the Rhinns has shown that the acid gneisses were derived from a coarse, pink alkali-feldspar syenite with minor bodies of granite, and

the basic gneisses from coarse gabbros. The original igneous rock was subject to pervasive ductile deformation soon after its formation, resulting in development of the gneissic banding. Wilkinson (1907) noted that the rocks had suffered considerable crushing, mylonitisation and metamorphic downgrading; the basic rocks, for example, are now represented mainly by amphibolites. He also noted that the intensity of the cataclastic and mylonitic effects increased as the contact with the overlying Colonsay Group is approached.

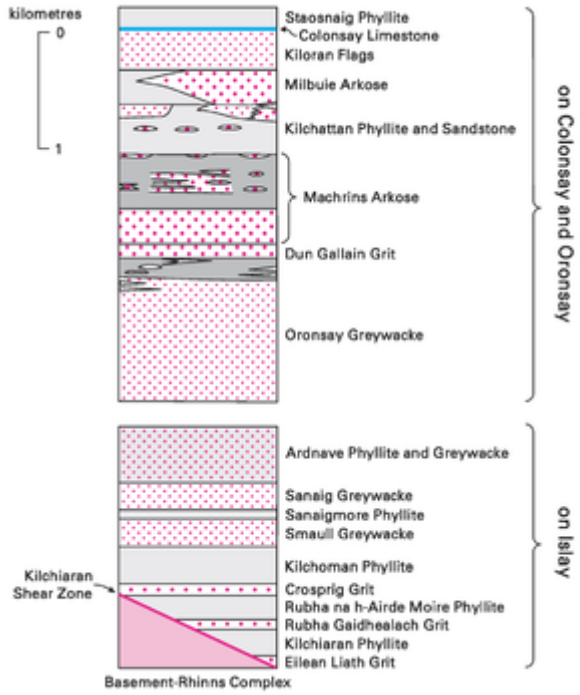
The basement inlier on north Colonsay covers only about 0.3 km^2 and is largely obscured by blown sand. The exposures are of quartzofeldspathic gneisses, much of it coarse grey pegmatite, with dark knots, streaks and layers which are amphibolitic and all are now brecciated and sheared (Cunningham Craig et al., 1911). The contact with the Colonsay Group is rarely seen but, where exposed, it is marked by a high-strain zone of phyllonitisation and mylonitisation several centimetres thick, originally interpreted as a thrust plane.

Isotope studies of rocks from the Rhinns of Islay have shown that the syenites and gabbros were emplaced during the early Proterozoic (about 1800 Ma) and that they are juvenile, mantle-derived material, not reworked Archaean crust (Marcantonio, 1988; Muir et al., 1992); similar ages have been obtained from acid and basic material from Inishtrahull (Dickin and Bowes, 1991). These isotope studies have effectively ruled out any direct correlation between the Rhinns rocks and the Lewisian Complex of north-west Scotland, in which there is no evidence for major crustal addition of mantle material at about 1800 Ma, although the Laxfordian tectonothermal cycle resulted in reworking of the Lewisian at about that time (Fettes et al., 1992). The Islay–Colonsay basement, an early Proterozoic mantle-derived terrane devoid of Archaean material, has analogies with the Ketilidian belt of South Greenland and the Svecofennian of Scandinavia (Marcantonio et al., 1988) and may form a link between these two segments of the early Proterozoic mobile belt around the southern margin of Laurentia (Muir et al., 1989; 1992). Dickin and Bowes (1991) interpreted the isotopic data on Grampian Highlands granites as indicating that the Rhinns Complex terrane extended at depth to the North-east Highlands and to western Ireland, forming a block measuring at least 600 100 km.

These observations have raised the question of the relationship between the Rhinns rocks and the Lewisian. The fact that true Lewisian occurs on Iona, only 20 km north-west of Colonsay, raises the possibility that their present close juxtaposition is not original. Bentley et al. (1988) suggest that the Rhinns Complex might represent an allochthonous terrane transported to its present position by strike-slip movements on the Great Glen Fault. This is not yet proven. What is clear, however, is that the Rhinns terrane was in its present position relative to the Dalradian by about 620 Ma, the age of intrusions that were foliated by events which affected the Dalradian.

Colonsay Group

The Colonsay Group consists of a 5.5 to 6 km-thick sequence of low-grade, strongly deformed metasandstones and phyllites, with minor calcareous beds, overlying the basement rocks and exposed on Islay to the north of the Rhinns, and on Colonsay. The overall strike of the beds is north-easterly so that the succession exposed, younging generally towards the north-west, presents an oblique section through the basin of accumulation (Bentley, 1988). Stewart (1962) and Stewart and Hackman (1973) divided the sequence into 18 lithostratigraphical units, the lower ten on Islay and the upper eight on Colonsay (P915414); it is probable that part of the succession is covered by sea between Islay and Colonsay but the stratigraphical gap is thought to be no more than a kilometre (Bentley, 1988). Stewart's maps and sections indicate considerable vertical and lateral facies variations, a situation complicated by some structural repetition.



Lithostratigraphical units of the Colonsay Group (modified after Stewart and Hackman, 1973, and Bentley, 1988). P915414.

The lowest 800 m of the succession, exposed on Islay, consist of meta-arkoses and phyllites, interpreted as representing delta-top sheet sands and interdistributary muds. The upper part of the succession on Islay and the lower part of the Colonsay succession are quartz-rich metagreywacke sandstones and phyllites suggesting deeper-water, delta-slope turbidite accumulation. The upper part of the succession on Colonsay shows a change back towards shallow-water, mainly siliciclastic sedimentation but with several calcareous developments, notably the 1 to 5 m-thick dolomitic Colonsay Limestone and some calcareous phyllites.

The Colonsay Group sediments were derived mainly from the south, from an area containing deformed high-grade gneisses with sedimentary cover. Saha (1985) pointed out that the source area could not have been remote— the feldspar clasts are angular and fresh—and may have exposed granulite facies rocks which produced the blue quartz clasts found in the Colonsay Group rocks. Their provenance is uncertain since the basement rocks of the Rhinns of Islay are not of granulite facies and lack blue quartz.

The contact of the Colonsay Group with the underlying gneisses on Islay is highly deformed.The units close to the contact are generally coarser grained than elsewhere with local developments of conglomerate. Consequently Wilkinson (1907) and Bentley (1988) interpreted it as a sheared unconformity. However, Stewart and Hackman (1973) recognised that the five lowest units in the Colonsay Group are truncated against the basement without any signs of a basal facies. They also did not identify Wilkinson's basal conglomerate. They therefore interpreted the highly deformed contact to be a tectonic break which they referred to as the Bruichladdich Slide. More recent work (Muir et al., 1995) has confirmed this view and has recognised Colonsay Group–basement tectonic interleaving close to the slide, now renamed the Kilchiaran Shear Zone. On North Colonsay, the contact is also highly sheared with a conglomeratic cover sequence containing rounded quartzite clasts and only 'some fragments reminiscent of the local basement' (Bentley, 1988). On this basis it is interpreted as a sheared unconformity by Bentley. However, the cover rocks belong to the Kilchattan Formation (P915414), about 4 km above the base of the succession on Islay, thereby

requiring a very uneven basement topography.

Stewart (1975) noted that the Colonsay Group cannot be shown to correlate with the Torridonian 'in any sense', although this had been its traditional correlative since the original Geological Survey work, when the basement was thought to be Lewisian. The presence of limestone and dark phyllite in the upper part of the Colonsay Group suggested to Litherland (*in* Stewart and Hackman, 1973) that there could be a correlation with the Appin Group Dalradian, a correlation supported by Rock (1985) who suggested that the chemistry of the Colonsay Limestone was similar to that of the Ballachulish Limestone. Such a correlation would imply that the lower parts of the Colonsay Group were lateral equivalents of the Lochaber Subgroup and the Grampian Group.

The main objection to a correlation with the Dalradian has been on structural grounds, the first phase of deformation of the Colonsay Group apparently being unrepresented in the nearby undoubted Dalradian rocks. Muir et al. (1992) concluded that the stratigraphical affinities of the Colonsay Group remain unclear.

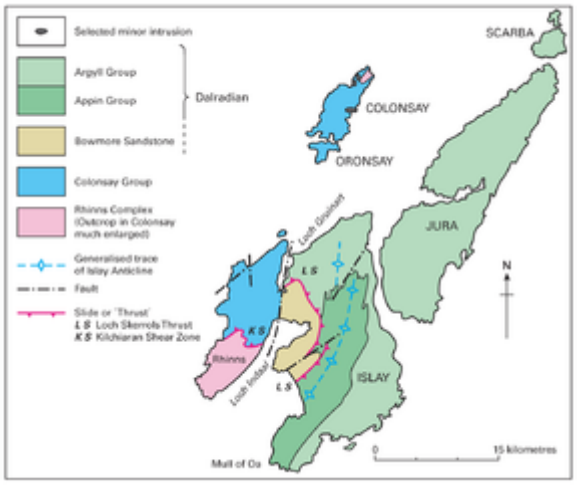
Structure

Fitches and Maltman (1984) considered Islay and Colonsay to lie within the zone of the Caledonian Front, comparable to the zone of thrusts in the North-west Highlands but with more ductile deformation.

Wright (1908) noted two main periods of movements on Colonsay; subsequent workers have subdivided them. The early events (D_1 and D_2 of Fitches and Maltman, 1984) result from heterogeneous, subhorizontal NNE-directed shear, which produced a grain alignment parallel to bedding and the development of small-scale assymmetrical, and typically recumbent, folds; no large-scale early folds are known. The later events (D_3 and D_4) are typified by upright folds accompanied by spaced, planar fabrics. The D_3 folds are on scales of up to several hundred metres wavelength with NE-trending axial planes which are upright or dip steeply south-east. They are common on Colonsay and control the main outcrop pattern. D_4 is sporadically developed and is represented by chevron folds, kink bands and crenulation cleavages and causes regional swings of the outcrops in the north of Colonsay.

Intrusions

Apart from the late Caledonian lamprophyre and felsite dykes, and Palaeogene basalt dykes, there are intruded into the Colonsay Group of Colonsay a number of small plutonic masses (P915413), the main ones of which were described by Cunningham Craig et al. (1911) as the Kiloran Bay syenite, the Scalasaig diorite and the Balnahard kentallenite (olivine-augite-syenogabbro). Each is associated with a more basic margin (respectively of hornblendite, augite-lamprophyre and augite-diorite) and, in the case of the first two, marginal explosion breccias. Clasts in these breccias contain folds and fabrics attributable to the early deformation of the Colonsay Group, while the intrusions themselves are, in part, foliated by the late deformation, indicating intrusion taking place between the early and late deformation events. This age of intrusion is taken to be about 620 Ma, a result obtained from $^{40}Ar/^{39}Ar$ step-heating of hornblendes from the Kiloran Bay intrusion (Bentley, 1988).



Geological sketch map of Islay and Colonsay. P915413.

Bowmore Sandstone

The Bowmore Sandstone is separated from the Colonsay Group of western Islay by the Loch Gruinart Fault and from the Dalradian succession of eastern Islay by the Loch Skerrols Thrust (P915413; Green, 1924; Amos, 1960; Stewart, 1969; Fitches and Maltman, 1984). The rocks are tightly folded but the locally developed tectonic fabrics are weak and metamorphism is slight. Bedding is generally indistinct and younging indicators are rare. Consequently the stratigraphical age of the Bowmore Sandstone is uncertain and it has been correlated variously with the Moine, the Torridonian and the Dalradian (Fitches and Maltman, 1974, table 1). Those workers who have regarded the Loch Skerrols Thrust as a major structure, possibly equivalent to the Moine Thrust, have correlated the Bowmore Sandstone mainly with the Torridonian, by analogy with the structure of the North-west Highlands (e.g. Johnstone, 1966; Stewart, 1975). More recent work has led to the suggestion that the Loch Skerrols Thrust is a structure of local importance only and hence the Bowmore Sandstone is more likely part of the Dalradian succession. Fitches and Maltman (1984) argue that it is the lateral equivalent of the Crinan Grit on the lower, inverted limb of the Islay Anticline; it could also be argued that the lithologies are consistent with the Grampian Group.

Lithologies are predominantly grey-brown, feldspathic sandstones which have been divided into two formations, each exceeding 2 km in thickness. The lower, *Laggan Formation*, consists of fine- to medium-grained sandstones with silty and shaly partings, but the upper, *Blackrock Formation*, is mainly coarse-grained sandstones, with pebbly bands. A provenance study of clasts in the Bowmore Sandstone and Colonsay Group has revealed quartz-granulites, acid gneisses, pegmatites and vein quartz of Lewisian type (Saha, 1985). Distinctive blue quartz, characteristic of early Lewisian (Scourian) granulites, is present in both the Bowmore Sandstone and the Colonsay Group and also in Dalradian rocks of north-east Islay. The Blackrock Formation contains in addition pebbles of chert, jasper and ferruginous sandstone, indicative of non-metamorphic or low-grade supracrustal rocks (e.g. Torridonian) in the source area.

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