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The Dalradian rocks of the south-west Grampian Highlands of Scotland

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ABSTRACT

The south-west Grampian Highlands, as defined here, include the Inner Hebridean islands of Islay and Jura, and extend north-east as far as Dalmally at the northern tip of Loch Awe. Due to a favourable combination of excellent coastal exposures and low tectonic strain, the late-Neoproterozoic rocks of the Dalradian Supergroup in this region are ideal for studying sedimentary structures. In addition, the diversity in protolith lithology from carbonate rocks to siliciclastic rocks of all grain sizes and volcanic rocks makes it possible to establish a very detailed lithostratigraphical succession and to recognize lateral facies changes. The stratigraphical range extends from the base of the Appin Group to the base of the Southern Highland Group and the area provides type localities for many regionally extensive formations of the Argyll Group. Rocks forming part of the basement to the Dalradian basins, the Rhinns Complex, are seen on Islay, where they are overlain by the Colonsay Group, a thick metasedimentary siliciclastic sequence of uncertain stratigraphical affinity.

The structure of the Dalradian rocks in the south-west Grampian Highlands is controlled by early (D1) major folds (Islay Anticline, Loch Awe Syncline, and Ardrishaig Anticline), associated with a ubiquitous, penetrative, slaty or spaced cleavage. Most of the Dalradian rocks have been regionally metamorphosed under greenschist-facies conditions and amphibolite-facies (garnet zone) assemblages occur only in a narrow central zone, strongly affected by the D2 deformation.

The area provides GCR sites of international importance for studying Neoproterozoic glacial deposits, splendidly preserved stromatolite bioherms and calcite pseudomorphs after gypsum. Deformed and undeformed sandstone dykes and interstratal dewatering structures are well displayed at several sites. Other features include thick sills of basic meta-igneous rock with unusual minerals such as stilpnomelane, and greenschist-facies rocks containing regional metamorphic kyanite. The area is of historical interest for the first recognition in Scotland, prior to 1910, of sedimentary way-up structures and pillow lavas in regionally deformed and metamorphosed rocks.

Contents

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1. Introduction (P.W.G. Tanner)

The south-west Grampian Highlands region, as defined in this paper, includes the islands of Islay, Jura, and the Garvellach Isles in the north-west. It is bounded to the south-east by the base of the Southern Highland Group, which runs from Campbeltown along the Kintyre Peninsula and the south-east side of Loch Fyne, to Ben Lui (Fig. 1). The north-eastern boundary follows the lower part of Loch Etive and the A85 road to Dalmally and Ben Lui. The region has an extremely long, indented coastline that faces into the prevailing south-west wind, which results in many kilometres of clean, well-scoured, coastal rock exposures being available for detailed study. Thus, 19 out of 21 of the GCR sites reported here are on coastal exposures.

The primary survey of the south-west Grampian Highlands was begun in 1880 and culminated in the publication of 'The Geology of the Seaboard of Mid-Argyll' (Peach et al., 1909). The Geological Survey memoirs and accompanying geological maps produced during this period remain the sole source of reference to the distribution of rock types, and their petrography, for a considerable part of the region. This work was carried out whilst major advances were being made in structural geology and sedimentology worldwide, but much of this work came too late to help define and resolve some of the more fundamental problems in Highland geology. For example, the stratigraphical sequences established by the early workers such as Green (1924), Hill (1899), Hill et al. (1905) and Wilkinson (1907) were later shown to be wrong, as these geologists did not have the tools to identify way-up, and based their interpretations on Uniformitarian principles, such as the Law of Superposition, and the dip direction. This approach was successful in areas with simple upright, open folds but obviously failed in situations where the rocks had, for example, already been inverted by regional-scale folding. As a result, some parts of the stratigraphical sequence had to be revised when way-up techniques were first applied (Vogt, 1930; Bailey, 1930; Allison, 1933).

Despite the progress made by Pumpelly et al. (1894) in interpreting bedding/cleavage relationships in the USA, and by Clough (in Gunn et al., 1897) in recognizing the effects of polyphase deformation in the Cowal peninsula, there is no indication from the work published prior to 1909 that these techniques were used in the areas described in this paper. The overall structure of this region was finally established by Bailey (1922); this framework has not been superseded but was progressively modified as modern techniques of structural geology were applied from the late 1950s onwards (i.e. Shackleton, 1958; Knill, 1960; Rast, 1963; Borradaile, 1970, 1973; Roberts, 1974).

The Dalradian rocks of this region, with their great diversity in lithology, relatively simple structure and low-grade regional metamorphism, have played a very important part in establishing the overall stratigraphical sequence in the Grampian Highlands as a whole. All subgroups of the Argyll Group are named after localities in this region, and these encompass a wide range of metamorphosed rock types from tillites to carbonate rocks and basic igneous rocks, and mudrocks to conglomerates. The Argyll Group includes two important marker horizons: the Port Askaig Tillite Formation at the base, and the Loch Tay Limestone Formation at the top (see Stephenson et al., 2013 for discussion) (Fig. 2).

The environment in which the Argyll Group was deposited shows increasing tectonic instability with time (Anderton, 1985). Syndepositional basin-bounding faults became increasingly active throughout this period, as witnessed by marked lateral variations in the thickness and facies of both members and formations, together with the incoming and increasing frequency of debris flows and coarse-grained turbidite-facies rocks. Sediments of the Islay Subgroup were deposited in shallow water, some even in the intertidal zone, as indicated by storm deposits in the Jura Quartzite Formation, and pseudomorphs after gypsum in the Craignish Phyllite Formation. Deepening of the basin in Easdale Subgroup times is indicated by the deposition of a considerable thickness of black, euxinic mudrock, which was followed by a thick sequence of coarse-grained quartzofeldspathic turbidites in Crinan Subgroup times. Volcanicity reached a peak during Tayvallich Subgroup times as the now sediment-starved basin subsided further and the underlying lithosphere thinned and finally ruptured.

In view of the possibility that one or more orogenic unconformities is present in the Dalradian rocks of the south-west Grampian Highlands (Dempster et al., 2002; Hutton and Alsop, 2004; but see Tanner, 2005), emphasis in this paper is placed upon relationships between the various stratigraphical units, and especially on the nature of the contacts between subgroups, including the critical junction between the Jura Quartzite and the Easdale Slate.