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## 14 Kilmory Bay

[NR 698 756]–[NR 704 725]

J.L. Roberts and P.W.G. Tanner

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### 14.1 Introduction

The coastline between Kilmory Bay and the Point of Knap, in the Knapdale area of Kintyre, provides a 4 km-long section through the rocks of the Ardrishaig Phyllite Formation and Crinan Grit Formation of the Argyll Group, preserved in the core of the Loch Awe Syncline. These rocks are extremely well exposed along the seaward edges of the raised beaches, which are a characteristic feature of this coastline. The only significant gap in exposure is caused by the Quaternary deposits around the head of Kilmory Bay.

The Kilmory Bay GCR site is of national importance, for providing excellent examples of the geometrical and kinematic relationships between major and minor structures in folded rocks (Roberts, 1959). Mesoscopic fold closures are exposed in three dimensions, and are accompanied by a great diversity of spaced and penetrative cleavages that form pronounced cleavage fans. The interrelationships between these structures remain to be fully explored. In addition, recent research has focussed upon the origin of the sedimentary dykes that are reasonably common in the Ardrishaig Phyllites at this site (Phillips and Alsop, 2003), and upon the effects of fluid flow during the regional metamorphism of the basic sills (Graham *et al.*, 1983; Skelton *et al.*, 1995)

The stratigraphy and structure of the area were established by J.S.G. Wilson of the Geological Survey, as reported by Peach *et al.* (1911). He used graded bedding in the Crinan Grits to show that this formation is younger than the Ardrishaig Phyllites, and recognized that, as the minor folds affecting the Crinan Grits plunge to the north-north-east, this formation must lie structurally above the Ardrishaig Phyllites (Figure 2.31) (see also Bailey, 1913).

Three major folds comprise the compound Loch Awe Syncline in Knapdale (see the *Port Cill Maluaig* GCR report, (Figure 2.34)). The most south-easterly of these folds, the Kilmory Bay Syncline is seen in its type area in Kilmory Bay as a plexus of 5 or more major closures (Figure 2.31). Bailey (1922) interpreted the Kilmory Bay Syncline as a secondary structure that had affected a stack of recumbent folds and intervening slides, formed during the primary deformation. However, more-recent work by Roberts (1959, 1974) has shown that at Kilmory Bay the rocks are affected by only one major deformation (D1), and that the Kilmory Bay Syncline is an early structure (F1), associated with the deformation that elsewhere produced early nappe-like structures. Roberts (1966a), provided a brief account of the sedimentological features of these rocks, and Roberts (1959), and Roberts and Sanderson (1974) discussed the origin of minor F1 folds with curved hinges.

### 14.2 Description

#### 14.2.1 Stratigraphy

The Ardrishaig Phyllite Formation (informally referred to as the 'Ardrishaig Phyllites') is the oldest stratigraphical unit in the area. It lies on the south-east limb of the Kilmory Bay Syncline, and is exposed almost continuously along the seaward edge of the raised beach, which forms the coastline between Port Ban [NR 700 740] and the Point of Knap [NR 697 721]. It consists typically of greenish-grey phyllitic metamudstones and metasiltstones, interbedded with beds of fine-grained quartzite and rare metalimestone, dipping steeply to the north-west (Figure 2.31). Beds of fine-grained quartzite are common locally on the coastline facing Glas Eilean. Ripple-drift bedding is developed in some of the more-silty layers, and sedimentary dykes, up to 25 cm thick, of fine-grained but rather impure quartzite, are found at a

number of localities, including [NR 696 731], where they trend east-north-east and cross-cut the bedding in the Ardrishaig Phyllites (Figure 2.32). Those at [NR 700 743] have been described by Phillips and Alsop (2003), who presented evidence for some of these dykes being of post-D1 age. However, recent work by P.W.G. Tanner has identified features, which clearly indicate that they are all part of a linked system of pre-tectonic injections of mobilized water-saturated sandstone.

Groove and flute casts occur on the soles of fine-grained quartzite beds found immediately to the south-east of [NR 696 731], and indicate that they were deposited by turbidity currents flowing from the north-west. Farther south, a sedimentary breccia, up to 2 m thick, is exposed in the cliffs backing the raised beach at [NR 698 726]. Lying in a matrix of sandy metalimestone, the fragments consist mostly of pale-coloured limestone, flattened parallel to the slaty cleavage, along with less-deformed pebbles of blue quartz, phyllitic metamudstone, and fine-grained quartzite (Peach *et al.*, 1911).

The Ardnoe Member (formerly 'group') is the lowest division of the Crinan Grit Formation at Kilmory Bay. Its base is marked by a thick bed of massive fine-grained quartzite, which is exposed along the north-west side of Port Ban [NR 700 740]. A dolomitic breccia occurs locally at the contact with the underlying Ardrishaig Phyllites, and is at the same stratigraphical level as the Shira Limestone (Figure 2.2). This bed is overlain by a sequence of schistose pebbly quartzites and fine-grained metaconglomerates, which make up the lowest division of the member. At Port Ban, the pebbly quartzites are coarser grained, and the bases of individual beds are commonly conglomeratic. Graded bedding, together with metre-scale cross-bedding in the upper parts of these beds, where they are exposed on the low headland at [NR 699 741], show these rocks to be younger than the underlying Ardrishaig Phyllites (Peach *et al.*, 1911). The upper part of the member consists mostly of slaty metamudstones and fine-grained metalimestones, interbedded with fine-grained quartzites.

The main part of the Crinan Grit Formation (the 'Crinan Grits') crops out north of Kilmory Bay in the core and along the north-west limb of the Kilmory Bay Syncline (Figure 2.31). The base of the 'Crinan Grits' is marked by a massive bed of pebbly metaconglomerate, which is exposed on the coast opposite Eilean a' Chapuill at [NR 696 747]. Traced inland towards the east-north-east, this bed contains pebbles of blue and white quartz, feldspar, and dolomite, said to be the size of 'pigeons' eggs' (Peach *et al.*, 1911), and its base is markedly lobate, either as the result of load-casting, or syn-depositional erosion. This bed is overlain by massive beds of gritty meta-arenite, which were originally pebbly conglomerates and coarse-grained feldspathic sandstones. The pebbles consist of white and blue quartz, microcline, orthoclase, perthite, and oligoclase, listed in order of decreasing abundance. The pebbly metaquartzites are locally interbedded with thin layers of dark slaty metamudstone, and commonly show graded bedding, thus enabling the stratigraphical sequence to be determined. Cross-bedding is developed locally towards the tops of these graded beds, which represent attenuated Bouma sequences. These features are particularly well exposed along the rocky coast south of Port Liath [NR 698 757], where the beds are vertical and strike north-north-east on the north-west limb of the Kilmory Bay Syncline (Figure 2.31).

Both the Crinan Grits and the Ardrishaig Phyllites are intruded by sill-like bodies of basic meta-igneous rock that were folded and deformed, along with their Dalradian host rocks, during D1. The interiors of these basic sills commonly preserve relict igneous textures, whereas their margins are generally highly schistose. The original character of the metasedimentary rocks is best seen where they are protected from the effects of subsequent deformation, having been indurated ('baked') by contact metamorphism adjacent to the thicker sills. All of these rocks are affected by greenschist-facies metamorphism at chlorite grade, contemporaneous with the formation of the S1 slaty cleavage in the more-pelitic rocks.

### 14.2.2 Structure

The closure of the north-westerly syncline of the compound Kilmory Bay Syncline is seen to the north-west of Kilmory Bay at [NR 696 747]. There, the Crinan Grits dip moderately towards the north-north-east, and away from the Ardnoe Member that forms the headland. Traced north along the coast towards Port Liath [NR 689 757], these pebbly quartzites become vertical and trend north-north-east on the north-west limb of this syncline. The outcrop of the conglomeratic bed, where exposed on the coast opposite Eilean a'Chapuill [NR 697 749], defines the closure of the next anticline to the south-east, and part of the succeeding syncline. However, the south-east limb of this major syncline, and the closure of

the major anticline to its south-east, are obscured by superficial deposits in Kilmory Bay. The closure of the following syncline is exposed to the south-east, between Kilmory Bay and Port Ban [NR 700 740], where beds of the Ardnoe Member lie in its core. All of these major F1 folds plunge at a moderately steep angle towards the north-east within axial planes that dip very steeply to the north-west.

The slaty cleavage (S1) developed in the metamudstone beds, strikes consistently north-east and dips at 60–80° to the north-west throughout the area, and is statistically axial planar to both the mesoscopic and major folds. The Ardrishaig Phyllites, with their extreme contrast in lithology, between bands of gritty quartzite up to 2 m thick, and interbedded units of phyllitic metasiltstone, give rise to an extraordinary range of cleavage refraction geometries. Slaty cleavage is represented by a shape- or spaced-cleavage in the coarser grained rocks. It typically shows cleavage refraction as it passes into the coarser grained beds, producing a strongly divergent cleavage fan about the fold hinges. Typically, a fibrous mineral lineation, which Clough (in Gunn *et al.*, 1897) termed the stretching direction, is developed on S1, and pitches steeply down-dip. The stretching lineation is commonly revealed by elongated rusty pyrite blebs.

The minor F1 folds in the Ardnoe Member are co-axial with the major folds that affect the overlying Crinan Grits; most of them plunge at moderate angles to the north-east (although some of them are curvilinear) within axial planes that dip very steeply towards the north-west. The exposures around [NR 700 744], to the south of Kilmory Bay, show a spectacular series of very tight F1 folds affecting three beds of fine-grained quartzite. The anticlinal fold hinges are stripped bare by erosion to form a series of truncated whale-backs in the quartzite beds, plunging gently towards the north-east (Figure 2.33). At low Spring tides, the lowermost bed of fine-grained quartzite can be traced with scarcely a break around a complex series of minor F1 folds. The quartzite beds maintain approximately the same thickness normal to the bedding around the fold-hinges (Class 1C folds of Ramsay, 1967), whereas the intervening layers of less competent rock thicken into the fold cores to form Class 3 folds.

The minor F1 folds in the Ardrishaig Phyllites are coplanar with major and minor folds in the Crinan Grits. Their axial planes dip very steeply towards the north-west, parallel to the slaty cleavage in the metamudstones. However, their fold hinges are strongly curved within a fairly constant axial-plane orientation, giving rise to minor F1 folds plunging to either the north-east or south-west at moderately steep angles. Locally, the hinges of F1 folds change pitch through more than 90° within a short distance, forming curvilinear folds. Wherever graded bedding or ripple-drift bedding allows the stratigraphical order of the sedimentary beds to be determined, its relationship with the slaty cleavage, or its equivalent as a plane of grain flattening, shows that these D1 structures are all upward-facing. No evidence of an earlier, pre-D1, fabric has been noted.

### 14.3 Interpretation

The sedimentological features of the Ardrishaig Phyllites and the Crinan Grits have not been described in any detail from Kilmory Bay, and warrant further study. The Ardrishaig Phyllites probably represent tidal-flat deposits, like the Craignish Phyllites, their stratigraphical equivalent to the north-west of the Loch Awe Syncline (Anderton, 1975), whereas the graded beds of the Crinan Grits were evidently deposited by turbidity currents in deeper water.

Following the injection of sedimentary dykes, and the intrusion of dolerite sills, all of these rocks were affected by the first phase of the regional deformation (D1) under conditions of chlorite-grade metamorphism. The resultant slaty cleavage (S1) is axial-planar to a series of upward-facing major F1 folds with a north-east trend. This geometry is incompatible with the interpretation by Bailey (1922) that the Kilmory Bay Syncline is a later structure, superimposed upon a primary nappe-complex. Although the major F1 folds in the Crinan Grits generally plunge at a moderately steep angle, towards the north-east, the minor F1 folds in the Ardrishaig Phyllites typically have curved hinges, plunging to the south-west, as well as to the north-east. The curvilinear nature of these folds reflects the non-cylindrical nature of the F1 fold-buckles as they formed, subsequently accentuated by the deformation (Roberts and Sanderson, 1974; cf. Roberts, 1959). This has caused the individual fold-hinges to rotate away from the position in which they were formed, at a high angle to the stretching direction, while undergoing a relative increase in their length. Typically, this gives rise to individual folds with curved hinges, pitching away from one another in opposite directions within a common axial plane.

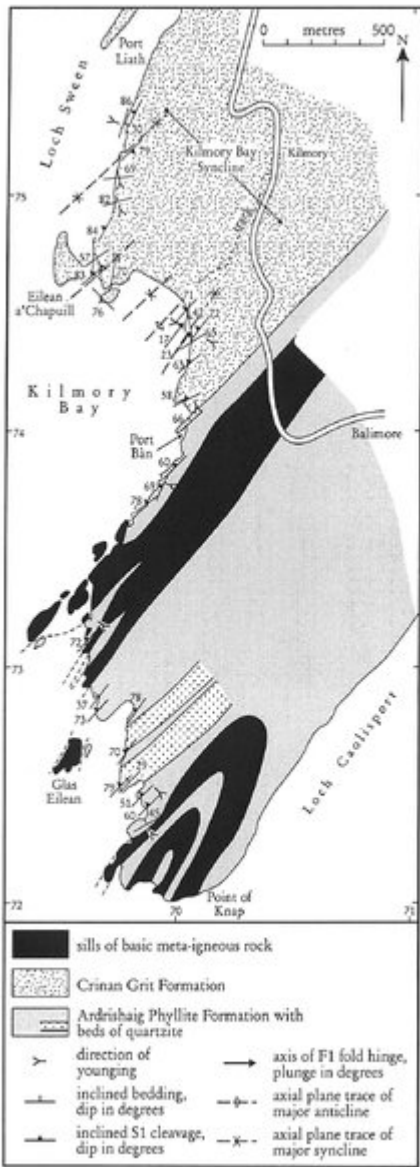
## 14.4 Conclusions

The Kilmory Bay GCR site provides a representative cross-section through the upper part of the Argyll Group, from the Ardrishaig Phyllites (for which the complete sequence is exposed) into the overlying Crinan Grits. Graded bedding in the Crinan Grits can be used to determine that this formation is younger than the Ardrishaig Phyllites, as was first demonstrated by the Geological Survey in 1911, making this site one of historical interest. These two formations are folded by the compound Kilmory Bay Syncline, a major early fold, which is one of the three major folds that comprise the regionally important Loch Awe Syncline.

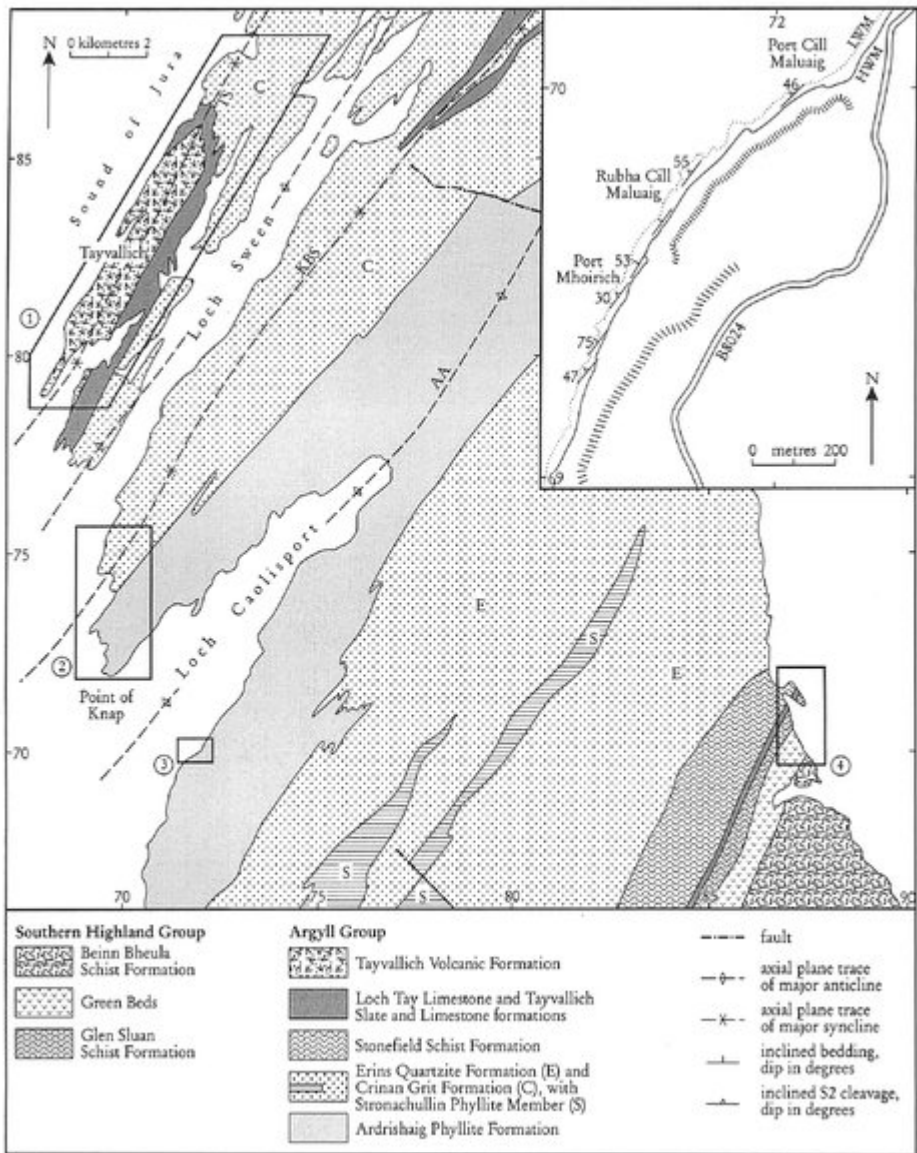
The rocks display a great variety of sedimentary and structural features, some of which are seldom seen with such clarity in the Dalradian, making this site of national interest. Graded bedding, accompanied by channelling and lateral facies changes, together with cross-bedding and cross-lamination, is found throughout the rock succession. Strain in the hinge-zones of the major folds is, in places, sufficiently low that the evidence for the origin of certain rather enigmatic sedimentary structures, such as sedimentary injections and dykes, is preserved in the more competent beds.

In addition, the clean, wave-washed exposures and 3-D nature of some parts of the coastal section, allow the relationships between major and minor fold structures, and a great variety of cleavage types, to be studied with exceptional precision. In the Ardrishaig Phyllites, the extreme contrast in lithology between beds of gritty quartzite, up to 2 m thick, and interbedded units of what was originally a somewhat silty mudrock, gives rise to an extraordinary range of cleavage refraction geometries. Superb examples of minor F1 folds are seen in the Ardnoe Member at the stratigraphical base of the Crinan Grits, with equally good examples of minor F1 folds with curved hinges being found within the Ardrishaig Phyllites.

### [References](#)



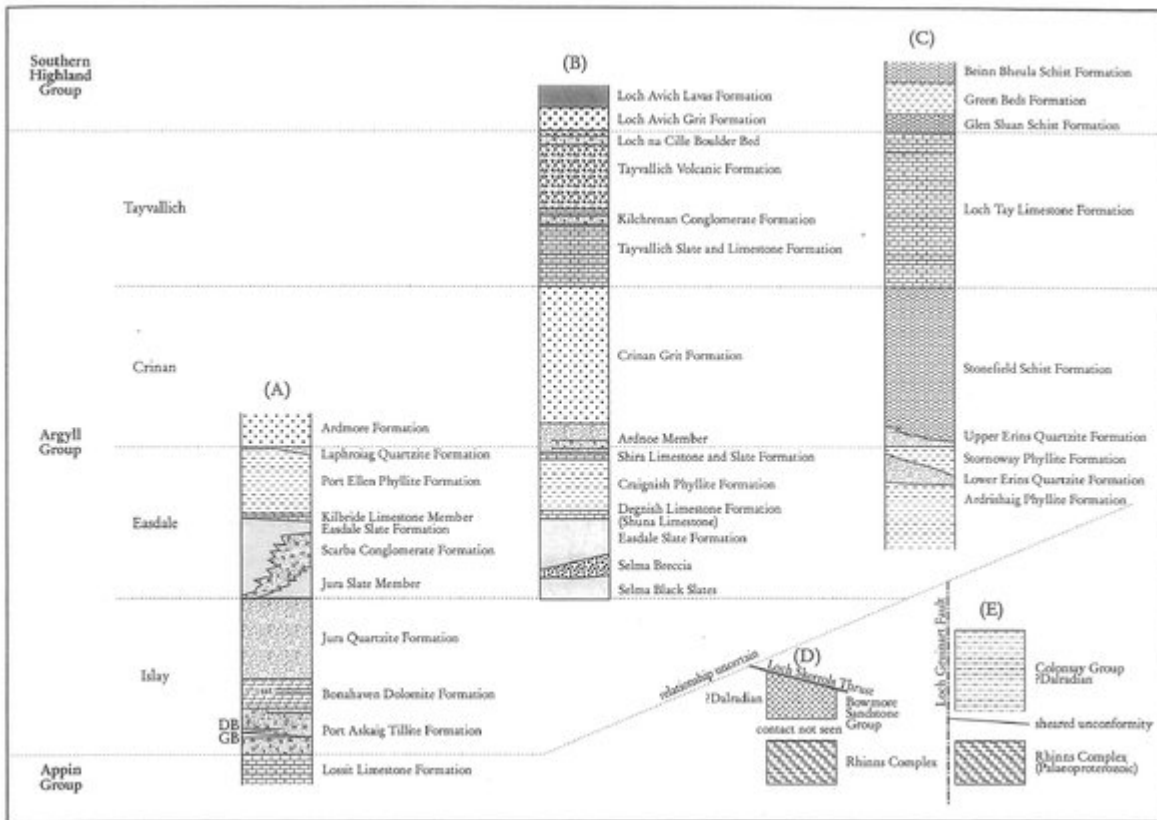
(Figure 2.31) Preliminary map of the area around the Kilmory Bay GCR site with geological boundaries taken from Roberts (1977c).



(Figure 2.34) Map of Knapdale and north Kintyre (based on Roberts, 1977c), showing outcrops of the main Dalradian units and locations of GCR sites: 1 West Tayvallich Peninsula, 2 Kilmory Bay, 3 Port Cill Maluaig, 4 South Bay, Barmore Island. AA Ardrishaig Anticline, KBS Kilmory Bay Syncline, TS Tayvallich Syncline. Inset shows the geology of the Port Cill Maluaig GCR site (3).



(Figure 2.32) Panoramic view of a train of F1 folds with fanned spaced cleavages, plunging north-north-east, Crinan Grit Formation (Ardnoe Member), Kilmory Bay [NR 700 743]. (Photo: P.W.G. Tanner.)



(Figure 2.2) Stratigraphical columns (not to scale) showing lateral correlations between members and formations of the Dalradian Supergroup in the South-west Grampian Highlands. A the islands of Islay, Jura and the Garvellachs, B the Loch Awe Syncline, C the Ardrishaig Anticline, core and south-east limb, D and E rocks of uncertain affinity on Islay and Colonsay, and those forming the basement to the Dalradian Supergroup. GB Great Breccia, DB Disrupted Beds.



*(Figure 2.33) En-echelon segmented sedimentary dyke (centre) parallel to spaced axial planar cleavage, Ardrishaig Phyllite, Kilmory Bay [NR 697 728]. (Photo: P.W.G. Tanner.)*