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# 1 The Dalradian rocks of Rosneath and south-east Cowal

By J.L. Roberts

## Maps

Ordnance Survey, 1:50 000, sheet 56 (Loch Lomond) and sheet 63 (Firth of Clyde).

Geological Survey, one inch to one mile: 29 (Rothesay) and 30 (Glasgow).

(Figure 1) Geological map of Rosneath and south-east Cowal (after sheets 29 (Rothesay) and 30 (Glasgow) of the Geological Survey of Scotland).

## Introduction

This excursion guide deals with the Upper Dalradian rocks which are exposed northwest of the Highland Boundary Fault in the South-west Highlands of Scotland. The exposures to be described are formed by the shores of Loch Long, and by the coast of the Firth of Clyde. The excursion based on Rosneath is largely independent of the state of the tide since the exposures are mostly above the high-water mark on raised beaches. However, the excursion based on Dunoon should be undertaken when the tide is low at localities 16 and 17.

## General geology

The Dalradian rocks exposed to the north-west of the Highland Boundary Fault form four stratigraphic groups in the South-west Highlands. The first group is exposed in the north-west of the area under consideration as a thick series of schistose grits, quartzose mica-schists and pelitic schists. These rocks are known as the Beinn Bheula Schists. They are succeeded to the south-east by a varied series of rocks forming the Dunoon Phyllites. This group include schistose pebbly grits, schistose grits and greywackes, schistose semi-pelites and pelites, together with purple or black phyllites and dark fine-grained limestones. The last two rock-types are characteristic of the Dunoon Phyllites. These rocks are followed to the south-east by the Bullrock Greywacke which consists mainly of massive schistose grit. Finally, the Innellan Group of schistose pebbly grits and phyllites is found to the south-east of the Bullrock Greywacke in south-east Cowal. The rock-types in this group are similar to those forming the Dunoon Phyllites. An inner branch of the Highland Boundary Fault cuts out the Innellan Group to the north-east in Rosneath.

The stratigraphic relationships of these groups are not entirely clear. The Beinn Bheula Schists are definitely younger than the Dunoon Phyllites while it appears likely that the Beinn Bheula Schists are equivalent in part to the Bullrock Greywacke. The Innellan Group appears to be younger than the Bullrock Greywacke, even although this requires that the Innellan Group is equivalent to that part of the Beinn Bheula Schists younger than the Bullrock Greywacke. Such difficulties are encountered because only the junction between the Beinn Bheula Schists and the Dunoon Phyllites is clearly exposed.

The rocks are affected by a series of deformation phases which can be classified as primary or secondary in character. The primary phases are related to the development of early, but not necessarily recumbent, major folds which control the overall disposition of the Dalradian rocks. These phases are associated with a penetrative deformation which results in the stretching or extension of the rock-mass in a NW–SE. direction. The primary deformation in the area under consideration consists of two phases known as the  $B_1$  deformation and the  $B_{2a}$  deformation. The  $B_1$  deformation results in the development of a slaty cleavage axial planar to folds of bedding while the  $B_{2a}$  deformation results in the formation of a penetrative strain-slip cleavage axial planar to folds of bedding and the slaty cleavage. Both phases of primary deformation result in folds with axes which are commonly oblique to the stretching direction developed as a fibrous mineral lineation on the cleavages parallel to their axial planes. Although the  $B_1$  folds affecting the Bullrock Greywacke have a Caledonoid trend at right angles to the regional stretching direction, the  $B_{2a}$  folds affecting the Dunoon Phyllites

and the Beinn Bheula Schists farther to the north-west have non-Caledonoid trends at an oblique angle to the regional stretching direction.

The secondary deformation occurs after the primary deformation to form strain-slip cleavages axial planar to folds of bedding and the primary cleavages. These folds are typically Caledonoid in trend. These secondary structures are superposed on the primary structures, modifying the overall disposition of the Dalradian rocks to only a limited extent. The secondary deformation consists of several fold phases which together constitute the B<sub>2b</sub> folding.

The primary structures found in the Dalradian rocks immediately to the north-west of the Highland Boundary Fault are related to the development of the Aberfoyle Anticline as the downward-facing nose of the Tay Nappe. The axial trace of the Aberfoyle Anticline appears to lie within the Dunoon Phyllites, close to their contact with the Bullrock Greywacke to the south-east. This contact is likely to be a zone of sliding. Since the Aberfoyle Anticline faces downwards to the SE. at a moderate angle, the rocks lying to the south-east of its axial trace form a sequence that is generally, if not always, right-wayup. Likewise, the Dunoon Phyllites and the Beinn Bheula Schists lying to the north-west of its axial trace form an inverted sequence on the lower limb of the Aberfoyle Anticline. These inverted rocks form part of the Loch Tay Inversion which extends across the Cowal Antiform as far north-west as the axial trace of the Ardrishaig Anticline as the root of the Tay Nappe.

Although the B<sub>1</sub> deformation affects all the rocks of the area under consideration, the B<sub>1</sub> structures are only clearly seen in the Bullrock Greywacke and the Innellan Group to the south-east. These structures face downwards to the south-east on the upper limb of the Aberfoyle Anticline. They become increasingly obscured to the north-west across the axial trace of the Aberfoyle Anticline, partly because the B<sub>1</sub> deformation becomes more intense in this direction and partly because the rocks concerned are increasingly affected by the later B<sub>2a</sub> deformation. The B<sub>2a</sub> structures developed on the lower limb of the Aberfoyle Anticline face downwards to the south-east in a similar manner to the B<sub>1</sub> structures developed on its upper limb. Although direct evidence is lacking, it is likely that the Aberfoyle Anticline is a B<sub>1</sub> fold and that the B<sub>2a</sub> folding is a "symmetry-constant continuation" of the B<sub>1</sub> folding. This would mean that the minor structures produced by both these stages in the deformation history are congruent to the Aberfoyle Anticline as a major B<sub>1</sub> fold.

The primary structures facing downwards to the south-east along the Highland Border become recumbent to the north-west across the axial trace of the Ben Ledi Monoform. Accordingly, this fold can be considered to form a link between an area to the south-east, where the primary structures face downwards to the SE., and an area to the north-west, where the primary structures are recumbent. These areas are known, respectively, as the Highland Border Steep Belt and the Cowal Flat Belt. The Ben Ledi Monoform has an axial plane dipping at a moderate angle towards the north-west, forming a fold which closes upwards to the south-east. The rocks in the hinge of this fold are strongly affected by a phase of secondary deformation which produces structures congruent with the fold itself. These structures are superposed on structures produced by an earlier phase of secondary deformation, while they are also affected by structures produced by a later phase of secondary deformation. Accordingly, there are three phases of secondary deformation which can be recognized in these rocks. It can be noted that south-east Cowal has an historical interest in that C. T. Clough, mapping the Dalradian rocks for the Geological Survey, was able to demonstrate on the basis of structural relationships between cleavages and folds that the rocks were affected by more than one phase of deformation. Although this work was published in 1897, its importance was not fully recognized until the 1950s when a resurgence of interest in structural mapping took place.

## **Excursion 1 : The Rosneath Shore Section**

The Rosneath peninsula lies between Loch Long to the west and Gareloch to the east. It can be reached from the main A814 road from Helensburgh to Arrochar by turning south along the B833 road from Garelochhead.

### **Locality 1 [NS 258 823]**

This locality is a quarry situated to the west of the B833 at a point 1 km south of Rosneath village, where the road gains the shore of Rosneath Bay. Exposures at the back of the quarry show thick beds of schistose pebbly grit interbedded with

laminated siltstones, forming part of the Bullrock Greywacke. The beds are affected by a series of  $B_1$  folds which plunge at a low angle to the NE. Graded bedding in the schistose pebbly grits, and ripple-drift bedding in the silty layers, indicates that the bedding is inverted, at least overall. A slaty cleavage dipping at a moderate angle towards the SE. is developed in the silty layers axial planar to the  $B_1$  folds. A plane of grain-flattening is found as the corresponding structure in the schistose pebbly grits. The sedimentary structures such as grading and ripple-drift bedding indicate that the  $B_1$  folds face downwards at a moderate angle towards the SE. in the slaty cleavage. A fibrous mineral lineation is developed as the stretching direction on the slaty cleavage at a high angle to hinges of the  $B_1$  folds.

## Locality 2

Continue along the B833 road to Kilcreggan and park near the pier. Walk south-east along the track towards Portkil Bay, turning left after 200 m to gain the cliffs backing the raised beach at the far side of a small playing-field [NS 248 805]. Interbedded conglomerates and red sandstones are exposed by these cliffs to form part of the Upper Old Red Sandstone outcropping to the SE. of the inner branch of the Highland Boundary Fault. The fault-line crosses the Rosneath peninsula from the south side of Rosneath Bay to Kilcreggan. Returning to Kilcreggan across the fault-line, exposures of the Bullrock Greywacke can be examined along the shore near the pier [NS 242 804].

## Locality 3

Continue for 600 m to the west along the B833 to an exposure of coarse schistose grits on the shore at [NS 234 803]. The exposure can be found 100 m to the east of a painted glacial erratic known locally as Tut-Tut. The coarse schistose grits show graded bedding which indicates that the bedding, dipping at a moderate angle to the SE., is right-way-up. The first cleavage in these rocks is formed by a plane of grain flattening which appears to be parallel to bedding.

## Locality 4

Walk along the shore as far west as the glacial erratic previously mentioned to examine exposures of a slate band interbedded with schistose greywackes. The bedding of the slate band dips at a moderate angle to the SE. and appears to be cut by a slaty cleavage at a slightly lower angle. Ripple-drift bedding indicates that the beds are right-way-up, and that the  $B_1$  structures face downwards to the SE. at a moderate angle.

## Locality 5

Walk 300 m along the shore to reach a small quarry on the shore close to the northwest margin of the Bullrock Greywacke at [NS 230 804]. The quarry has been excavated in coarse schistose grits. Graded bedding indicates that the rocks have an inverted dip at a moderate angle to the SE. The grits are cut by a plane of grain-flattening dipping SE. at a steeper angle than bedding. This planar structure can be traced into a more pelitic bed where it becomes a slaty cleavage. Accordingly, the  $B_1$  structures face downwards at a moderate angle to the SE. in the slaty cleavage. The intersection of this slaty cleavage with bedding is approximately horizontal in a NE.-SW. direction.

(Figure 2) Geological map (after Roberts 1966) of the southern end of the Rosneath Peninsula showing the various lithologies developed within the Beinn Bheula Schists, the Dunoon Phyllites and the Bullrock Greywacke.

## Locality 6

The rocks are next exposed on the shore at a point some 350 m to the north-west of the of last locality. They consist of black quartzose slates interbedded with thin bands of fine-grained limestone, followed immediately to the north-west by a series of schistose grits interbedded with grey-green slates. These rocks form the first exposure of the Dunoon Phyllites. The dark slates and limestones are affected by a series of  $B_{2a}$  folds plunging steeply towards the SE. and verging towards the SW. A strain-slip cleavage is developed axial planar to these folds. The schistose grits to the NW. show grading which indicates that the beds have overall an inverted dip at a moderate angle to the SE. These beds are

affected by a series of  $B_{2a}$  folds plunging at a moderate angle to the south and verging towards the west. Graded bedding indicates that these  $B_{2a}$  structures face downwards to the SE. in the plane of the strain-slip cleavage axial planar to these folds.

## Locality 7

Continue along the shore for 300 m to reach the south side of a slight beach south-east of Barons Point [NS 223 809]. The exposures are located 100 m NW. of the village hall. The rocks consist of schistose greywackes, affected by a series of open.  $B_{2a}$  folds plunging at a moderate angle to the south and verging towards the west. A strain-slip cleavage is developed axial planar to these folds in the more pelitic bands. A fibrous mineral lineation affecting the schistose greywackes represents the stretching direction which is developed on the cleavage axial planar to these  $B_{2a}$  folds. Graded bedding indicates that the  $B_{2a}$  structures face downwards to the SE., and that the rocks are inverted, at least overall.

## Locality 8

Continue around Barons Point as far north-west as Cove Post Office to examine a representative selection of the lithologies found in the Dunoon Phyllites.

## Locality 9

Follow the B833 along the shores of Cove Bay to examine the north-west contact of the Dunoon Phyllites with the Beinn Bheula Schists at Glen Duallt [NS 220 828]. Cars can be parked at the roadside just before a small bridge is crossed at the northern end of Cove Bay. Walk north-west along the shore across exposures of purple and green slates affected by  $B_{2a}$  folds. These rocks pass into schistose greywackes and green slates belonging to the Beinn Bheula Schists at a point 200 m NW. of the bridge. These schistose greywackes and slates are affected by  $B_{2a}$  folds plunging towards the south and verging towards the west, while graded bedding indicates that, overall, the rocks have an inverted dip at a moderate angle to the SE. Good examples of  $B_{2a}$  structures are seen 100 m NW. of the contact where a series of  $B_{2a}$  strain-bands are developed in schistose greywackes. Graded beds of coarse schistose grit can be examined in exposures 200 m farther to the north-west. These beds are affected by a series of  $B_{2a}$  folds, plunging moderately to the S. and verging towards the W., which clearly face downwards in their axial planar cleavage

Locality 10 Continue north-west along the B833 to a point 200 m past the entrance to Knockderry Castle. Cars can be parked at the roadside. Good examples of  $B_{2a}$  folds can be examined on the shore immediately to the south of a modern house built on the seaward side of the road.

## Locality 11

Follow the B833 road as far north as the Ministry of Defence Establishment at Coulport [NS 209 873]. Cars can be parked where the road turns inland after running along the coast in front of the establishment. Cross a small stream and walk north-west along the coast to a boathouse. The Beinn Bheula Schists exposed to the north-west of this point include beds of schistose grit which are graded to show that the rocks have an inverted dip at a fairly steep angle to the SE. These exposures also afford good examples of  $B_{2a}$  structures in the form of well developed strain-bands.

## Locality 12

Return to the main A814 road at Garelochhead, and turn left towards Arrochar. After passing under the railway bridge at Whistlefield Station, turn left off the main road to the hamlet of Portincaple. Park at the roadside and descend a path towards the shore at [NS 230 933]. Exposures of schistose grit and quartzose mica-schists can be examined by walking south along the shore past a basalt dyke. Occasional examples of graded bedding in the schistose grits indicates that the rocks are inverted with a steep dip to the SE. The primary schistosity in these rocks is affected by the  $B_{2a}$  folding to give

a series of  $B_{2a}$  strain-bands plunging down-dip to the south and verging to the west. These structures are affected by secondary structures belonging to three phases of B2b folding. All these phases give rise to horizontal folds with Caledonoid trends. The earliest structures form a set of  $B_{2b}$  folds verging towards the SE. These structures are folded by a series of  $B_{2b}$  folds with their axial planes dipping NW at a moderate angle. These folds have foldlimbs which are alternately steeply-dipping and flat-lying. It is these folds which are congruent with the Ben Ledi Monoform linking the Highland Border Steep Belt to the south-east with the Cowal Flat Belt to the NW. The axial trace of this fold passes through Portincapple, so that the exposures being examined form part of the steep belt to the SE. Finally, a series of  $B_{2b}$  folds with vertical axial planes is superposed on all the earlier structures. All these secondary folds have strain-slip cleavages developed parallel to their axial planes. After examining these exposures, walk along the shore to the exposures north of Portincapple. Similar features are shown by these exposures except that, in passing across the axial trace of the Ben Ledi Monoform, the rocks tend to become flat lying. Graded bedding indicates that the rocks are inverted as part of the Loch Tay Inversion.

## **Excursion 2: The Dunoon Shore Section**

The geological features seen in this excursion along the western shores of Loch Long and the Firth of Clyde in the vicinity of Dunoon are similar to those already described for the excursion based on the Rosneath peninsula. In general, the exposures afforded by the Dunoon section are less satisfactory, particularly in relation to the lithological character of the Dunoon Phyllites and the structural relationships at the contact of these rocks with the Beinn Bheula Schists. However, the Dunoon section does give a somewhat clearer view of the structural relationships which exist between the Dunoon Phyllites and the Bullrock Greywacke. The first locality can be reached by taking the A815 road north from Dunoon, turning right along the A880 towards Ardentinn to a point 600 m north of Gairletter Point. Parking is rather difficult.

### **Locality 13**

The Beinn Bheula Schists are exposed on the shore immediately to the south of a retaining wall at [NS 193 853]. The rocks consist of schistose grits interbedded with quartzose mica-schists. They have a moderate dip to the SE. and are affected by a series of  $B_{2a}$  folds and strain-bands plunging moderately to the south and verging towards the west. The cleavage axial planar to these structures dips steeply towards the SE.

### **Locality 14**

Return towards Dunoon along the A880 to a point 500 m north of Blairmore Pier at [NS 194 822]. Exposures 40 m to the north of a slipway show two sets of  $B_{2a}$  structures in a series of schistose grits interbedded with more pelitic rocks. The first set of structures gives rise to  $B_{2a}$  folds plunging at a moderate angle to the SSW. and verging towards the WNW. A penetrative cleavage, developed axial planar to these folds, can be seen to affect an earlier cleavage parallel to bedding in the more pelitic beds. The penetrative cleavage developed in the schistose grits is affected by a second set of  $B_{2a}$  structures to form open strain-bands which plunge moderately towards the SSW. and verge towards the WNW.

### **Locality 15**

Continue towards Dunoon, taking the A815 road along the coast to Hunter's Quay [NS 185 791]. Exposures 100 m north of the pier show schistose pebbly grits with inverted graded bedding dipping moderately to the SE. These beds are cut by a plane of grain flattening which dips SE. at a steeper angle than bedding. These structures, therefore, face downwards to the SE. Walking along the shore, good examples of  $B_{2a}$  strain-bands can be seen immediately to the south of the pier. These structures plunge moderately towards the SW. and verge towards the NW. A fibrous mineral lineation, plunging moderately to the SE., is developed as the stretching direction on the cleavage axial planar to the  $B_{2a}$  structures. Continue south along the shore, noting that the beds become more pelitic in character until a band of purple slate marks the contact of the Beinn Bheula Schists with the Dunoon Phyllites at a point 200 m south of Hunter's Quay. Schistose grits exposed near a boathouse 100 m south of the contact show right-way-up graded bedding which dips moderately to the south.

## Locality 16

Follow the A815 through Dunoon to a point on the coast at Bethania House [NS 167 756]. Parking is rather difficult. Schistose pebbly grits are exposed on the shore near a boathouse. Graded bedding indicates that these rocks have an inverted dip at a moderate angle to the SSE. Similar features are shown by another horizon of schistose pebbly grits, exposed 100 m to the south along the shore. Exposures immediately to the south at the foot of a retaining wall show dark blue slates with silty bands affected by intense  $B_{2a}$  folding. The limbs of these folds are commonly attenuated to a greater or lesser extent as the result of shearing, giving rise in extreme cases to completely isolated fold-hinges. These folds plunge moderately towards the south while their axial planes are defined by an intense and penetrative strain-slip cleavage dipping moderately to the SE. Ripple-drift bedding in some silty layers shows that these  $B_{2a}$  structures face downwards to the SE. in this cleavage.

## Locality 17

Regain the road and walk south past Bullwood to examine exposures of the Bullrock Greywacke on the shore at [NS 166 745]. Graded bedding is developed in schistose pebbly grits 100 m to the south of the first exposures, indicating that the rocks dip right-way-up at a moderate angle to the SE. These beds are cut by a plane of grain flattening dipping SE. at a lower angle than bedding. The intersection of this cleavage with bedding has a Caledonoid trend, so that these structures face downwards at a moderate angle to the SE. Locality 18

Follow the A815 through Innellan to a point 400 m to the east of Toward Quay at [NS 115 678]. Cars can be parked at the road-side. Pebbly grits interbedded with slates are exposed on the shore. The pebbly grits form graded beds with complex lobate bases. These beds are right-way-up, dipping moderately towards the south. A slaty cleavage in the pelitic layers dips moderately towards the SSW. at a shallower angle than bedding. The intersection of this cleavage with bedding plunges at a low angle towards the SW. The  $B_1$  structures face downwards to the SE. in the plane of the slaty cleavage.

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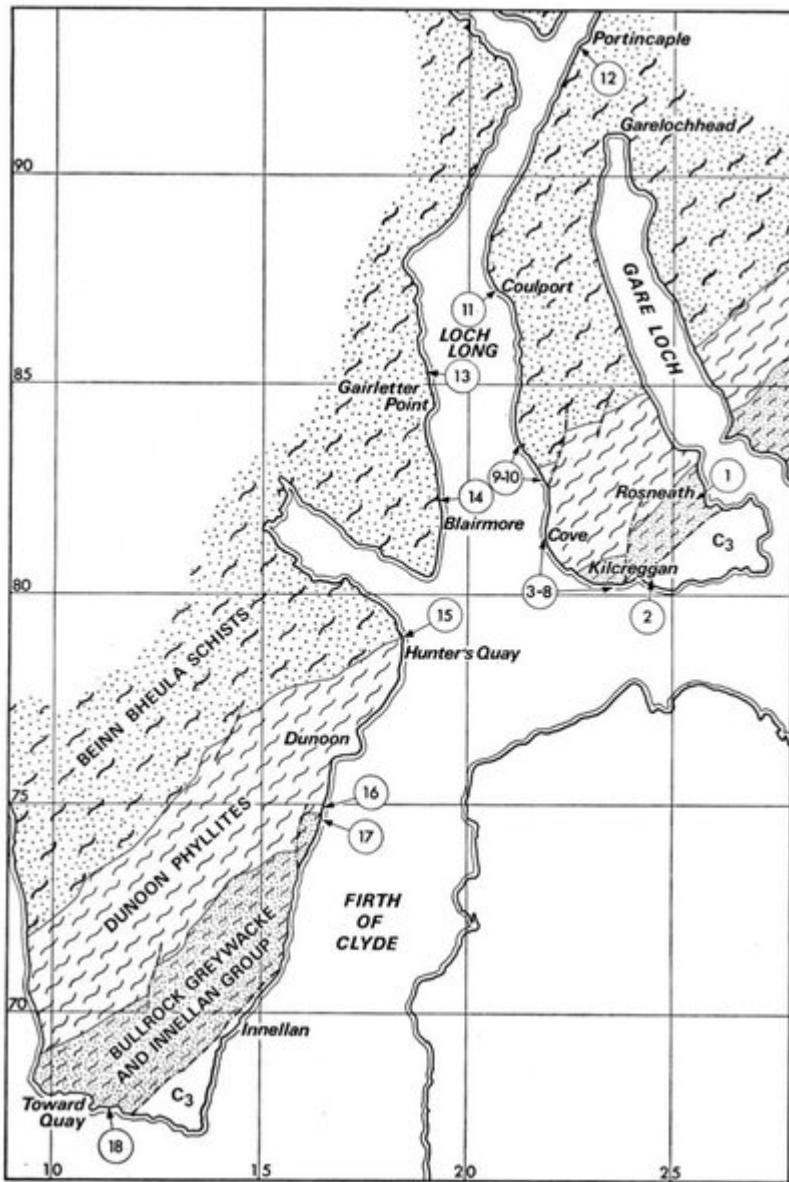
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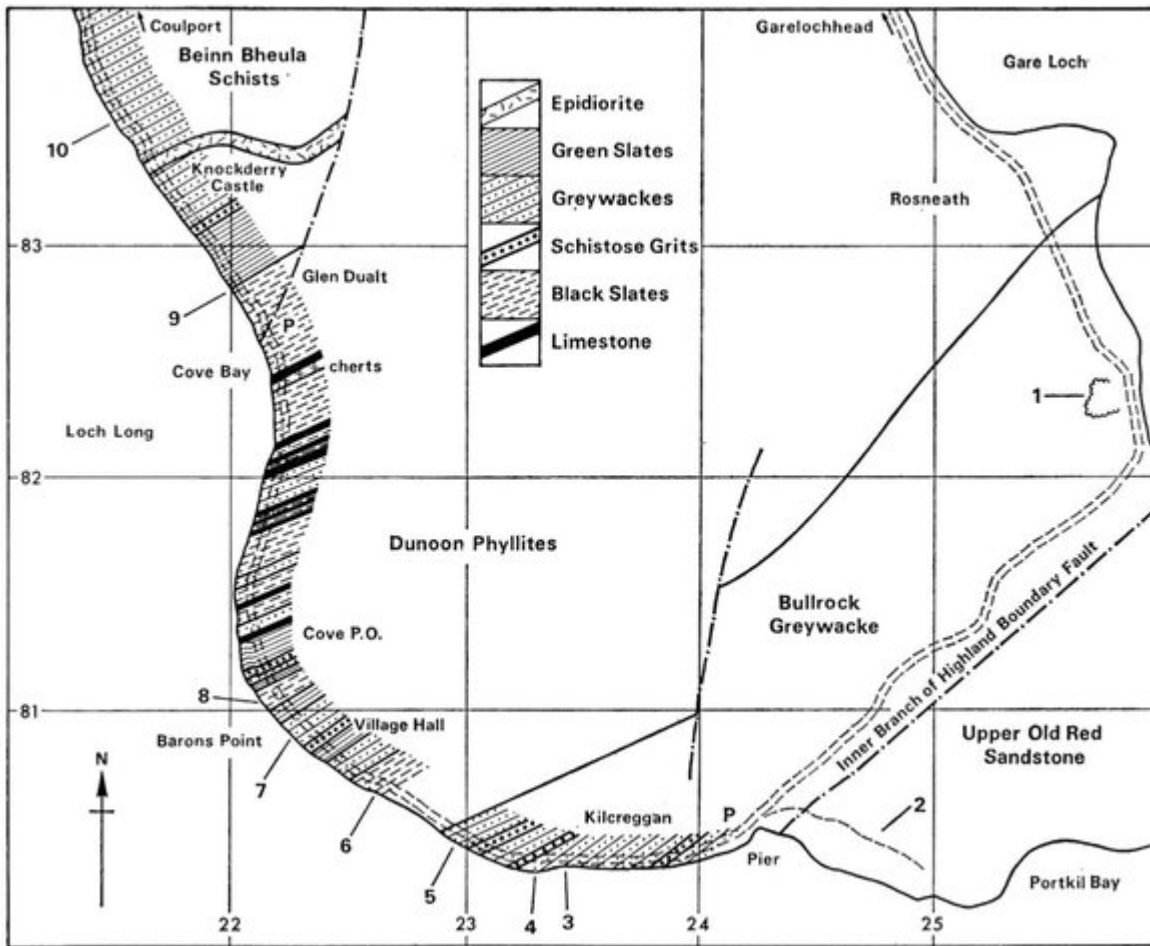
## Figures

(Figure 1) Geological map of Rosneath and south-east Cowal (after sheets 29 (Rothesay) and 30 (Glasgow) of the Geological Survey of Scotland). See (Figure 1) of the introductory guide for the axial traces of the major folds recognized in this area.

(Figure 2) Geological map (after Roberts 1966) of the southern end of the Rosneath Peninsula showing the various lithologies developed within the Beinn Bheula Schists, the Dunoon Phyllites and the Bullrock Greywacke.

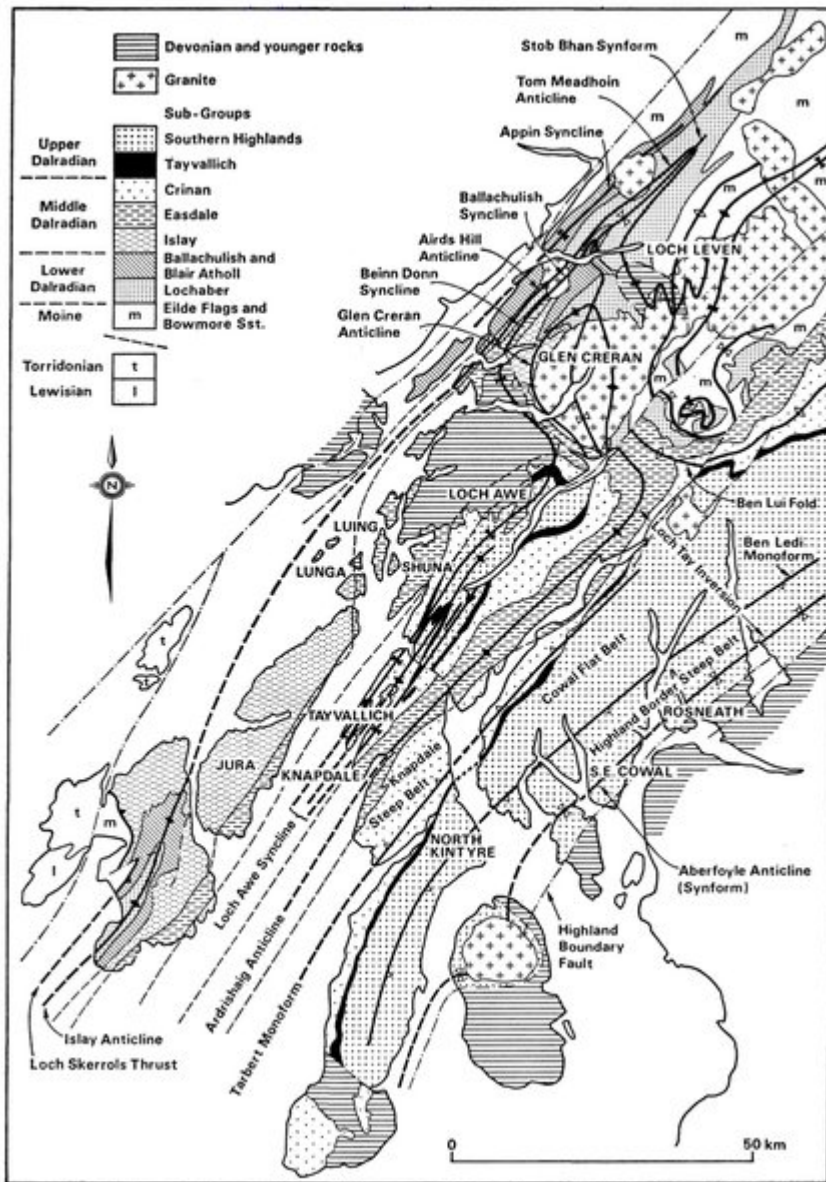


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(Figure 2) Geological map (after Roberts 1966) of the southern end of the Rosneath Peninsula showing the various lithologies developed within the Beinn Bheula Schists, the Dunoon Phyllites and the Bullrock Greywacke.





(Figure 1) Simplified geological map of the Dalradian rocks in the South-west Highlands of Scotland, showing the axial traces of the major folds according to Roberts and Treagus (1977). Place-names in capitals give the locations of the various field-areas covered by this series of excursion guides. Note that the stratigraphic units correspond to the various sub-groups as given in (Table 1).jpg