
2 The Dalradian rocks of Knapdale and North Kintyre

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Maps

Ordnance Survey, 1:50.000, sheet 55 (Lochgilphead) and sheet 62 (North Kintyre).

Geological Survey, one inch to one mile: 28 (Jura) and 29 (Rothesay).

Introduction

The area under consideration lies 50 km south of Oban and 80 km west of Glasgow, in the South-west Highlands of Scotland. It is limited by the shores of Loch Fyne to the east and by the deeply indented coast-line of the Sound of Jura to the west. The inland exposures are poor. However, the rocks are well-exposed on the smooth glaciated surfaces which form the shores of Loch Fyne and on the raised beaches which form the coastlines of Loch Sween and Loch Caolisport along the Sound of Jura.

General geology

The Dalradian rocks found in Knapdale and North Kintyre form a stratigraphic sequence extending upwards from the Ardrishaig Phyllites to the Beinn Bheula Schists. The Ardrishaig Phyllites are formed by greenish phyllites, often interbedded with minor amounts of limestone and fine-grained quartzite. They are succeeded by the Crinan Grits as a group of pebbly quartzites characterized by graded bedding. A transitional group of calcareous phyllites, fine-grained quartzites and pebbly quartzites is found in some places as the Ardnoe Beds between the Ardrishaig Phyllites and the Crinan Grits. The Crinan Grits are affected in Knapdale by a major fold known as the Kilmory Bay Syncline. This fold is flanked to the north-west by the Loch Sween Anticline and the Tayvallich Syncline. Together, these folds form the compound Loch Awe Syncline in south-west Argyll. The Ardrishaig Phyllites are exposed on the south-eastern limb of the Kilmory Bay Syncline where they occupy the core of a major fold known as the Ardrishaig Anticline. This fold forms the anticlinal root of the Tay Nappe. Its axial trace corresponds to the north-western limit of the Loch Tay Inversion.

The Crinan Grits are repeated as the Erins Quartzite on the south-eastern limb of the Ardrishaig Anticline. This formation is similar to the Crinan Grits except that it contains a greater proportion of fine-grained quartzite. The Erins Quartzite is followed to the south-east by a group of quartzose mica-schists known as the Stonefield Schists. These rocks are succeeded in turn by the Loch Tay Limestone. This horizon forms the boundary between the Middle and Upper Dalradian. The sequence continues with the Glen Sluan Schists and the Beinn Bheula Schists, separated from one another by the distinctive horizon of the Green Beds. The first two groups are formed by schistose grits, quartzose mica-schists and albite-schists, representing a metamorphosed series of greywackes and shales. The Green Beds are characterized by pelitic rocks, rich in chlorite and epidote, which are interbedded with schistose grits. Their distinctive character is thought to be caused by the incorporation of basic volcanic detritus into more normal sediment. The Middle Dalradian rocks are intruded by a large number of basic sills which are now in the form of epidiorite sheets. This intrusive activity is associated with the eruption of the basic Tayvallich Pillow Lavas which followed the deposition of the Tayvallich (= Loch Tay) Limestone.

The structure of the Dalradian rocks developed largely in response to three episodes of deformation. These episodes can be referred to the B_1 , B_{2a} and B_{2b} phases in the regional deformation history. The B_2 deformation resulted in a slaty cleavage axial planar to folds of bedding. The vergence of these folds, and the relationship of the slaty cleavage to bedding can be used to show that major folds such as the Kilmory Bay Syncline are B_1 structures,

The B_{2a} deformation appears to be a "symmetry-constant continuation" of the B_1 deformation in that the B_1 and B_{2a} structures have the same vergence and facing in those areas where they are found together. The B_{2a} structures are best

developed on the southeastern limb of the Ardrishaig Anticline where they form an intense strain-slip cleavage axial-planar to folds of bedding and slaty cleavage. These structures are typically developed as wide zones of monoclinial B_{2a} folds. These folds verge, overall, towards the north-west. This would support the interpretation of the Ardrishaig Anticline as a probable B_1 structure, if the B_{2a} folding is a symmetry constant continuation of the B_1 folding.

The B_1 and B_{2a} structures represent the primary deformation in Knapdale and North Kintyre. Both sets of structures are associated with the development of major folds such as the Kilmory Bay Syncline and the Ardrishaig Anticline which control the structural disposition of the Dalradian rocks. These structures were developed in response to a penetrative deformation which resulted in the stretching or extension of the rock-mass in a north-westerly or south-easterly direction. Accordingly, a fibrous mineral lineation, known as the stretching-direction, is commonly seen pitching steeply on the Caledonoid cleavage planes. Rock fragments, detrital quartz and feldspar grains, pyrite blebs, phenocrysts and pressure shadows are all elongated parallel to the stretching-direction.

The B_1 and B_{2a} folds commonly occur in the form of oblique folds with their axes lying at an angle to the stretching direction which is developed on the cleavage parallel to their axial planes. Some folds have axes which are strongly curved within their axial planes. The B_1 and B_{2a} folds developed in the northwest of the present area have axes which are dispersed within their axial planes to form two maxima, pitching respectively towards the north-east and the south-west, at approximately 45° to the regional stretching direction. Farther towards the southeast, the B_{2a} folds within the Loch Tay Inversion have a north-south trend oblique to the north-west-south-east trend of the stretching direction.

There is a gradual increase in the intensity of the primary deformation from the Loch Awe Syncline south-eastwards into the Loch Tay Inversion.

The B_{2b} folding represents the secondary deformation which is superposed on the earlier phases of primary deformation. There is only one phase of B_{2b} folding of any importance to affect the rocks of Knapdale and North Kintyre. It gives rise to a strain-slip cleavage axial planar to folds of bedding and the primary cleavages. The B_{2b} structures form conjugate sets in the north-west of the present area. However, one set of these structures becomes suppressed towards the south-east, leaving a single strain-slip cleavage dipping at a moderate angle towards the SE. This cleavage is axial planar to horizontal folds with Caledonoid trends. These folds are developed between an area in the northwest known as the Knapdale Steep Belt, where upright primary structures face steeply upwards, and an area in the south-east known as the Cowal Flat Belt, where recumbent primary structures face horizontally towards the SE. The B_{2b} structures are congruent with the monoclinial fold linking the Knapdale Steep Belt to the north-west with the Cowal Flat Belt to the south-east, known as the Tarbert Monoform. It forms part of the Cowal Antiform in South-west Argyll, and has the effect of inverting the rocks on the south-eastern limb of the Ardrishaig Anticline, giving rise to the Loch Tay Inversion as the lower limb of the anticlinal Tay Nappe.

The metamorphic history of the Dalradian rocks in Knapdale and North Kintyre is relatively simple. The primary deformation is associated with a low-grade metamorphism resulting in the development of the primary cleavages. Only this low-grade metamorphism affects the rocks in the north-west of the present area where slates and phyllites belong to the chlorite zone. Towards the south-east, however, a later phase of regional metamorphism has resulted in the growth of biotite and garnet, subsequent to the B_{2a} deformation. This was associated with the development of albite schists in rocks of an appropriate composition. Accordingly, schists belonging to the biotite and garnet zones are found in the south-east of the present area.

Excursion 1 : The Kilmory Bay Syncline

The object of this excursion is the study of the sedimentary and structural features shown by the Crinan Grits, exposed in the core of the Kilmory Bay Syncline, and by the Ardrishaig Phyllites, on the south-eastern limb of this major fold. The Kilmory Bay Syncline is a major B_1 fold which forms part of the compound Loch Awe Syncline in south-west Argyll. Exposures around Kilmory Bay show that it is itself a compound fold formed by two synclines separated from one another by an anticline. These folds plunge at a moderate angle to the NNE. while their axial planes dip at a steep angle to the NW. Ubiquitous examples of graded bedding and other sedimentary structures in the Crinan Grits indicate that all these folds face upwards in the slaty cleavage developed parallel to their axial planes.

Kilmory Bay is reached by the narrow single-track road which runs down the southeast side of Loch Sween. Park at the hair-pin bend [NR 702 753] above Kilmory village, and follow a wall which descends west-north-west to the coast at [NR 697 756].

Locality 1

The Crinan Grits are exposed as massive beds of pebbly quartzite on the shore near the end of the wall. Bedding is vertical with a NNE. strike. Graded bedding shows that the rocks young to the ESE. Cross-bedding is occasionally developed in the pebbly beds. A plane of grain flattening represents the slaty cleavage in these rocks. It dips steeply to the NW., giving rise to an intersection with bedding which plunges at a moderate angle to the NE. All these relationships indicate that these rocks lie on the north-west limb of the Kilmory Bay Syncline. Traced along the strike to the south-south-west, the beds become affected by B_1 folds, plunging at a moderate angle to the NNE. and verging towards the NW.

Locality 2

Continue south-south-west along the coast to [NR 696 749] where the beds start to swing around the hinge of the syncline forming the north-westerly fold in the compound Kilmory Bay Syncline. Farther along the coast from this point, beds of pebbly quartzite are exposed, dipping moderately towards the NNE. in the hinge of this syncline. Graded bedding indicates that the rocks are right-way-up. The beds of pebbly quartzite are cut by a plane of grain flattening, dipping steeply towards the NW. at right angles to the bedding. These pebbly quartzites are interbedded with thin layers of dark slate showing complex sedimentary structures. The slaty cleavage in these slate bands dips steeply towards the NW., while its intersection with bedding plunges moderately towards the NNE.

Locality 3

From the jetty [NR 696 747] opposite Eilean a'Chapuill a bed of coarse pebbly quartzite can be traced inland along the cliffs forming the back of a raised beach. The bed changes from a coarse pebbly quartzite to a conglomerate containing pebbles of blue and white quartz, feldspar and dolomite. Its base is markedly lobate, possibly as a result of load-casting.

Locality 4

The beds underlying this conglomerate horizon form the upper part of the Ardnòe Group as a series of fine-grained quartzites, limestones and slates. These rocks are well-exposed on the low headland [NR 696 746] to the west of Kilmory Bay. The beds are affected by a series of spectacular B_1 folds plunging at a moderate angle to the NNE. A slaty cleavage in the pelitic rocks is developed axial planar to these folds. On the headland, these folds have neutral vergence in the hinge of the northwesterly syncline while towards Kilmory Bay, these folds start to verge towards the southeast on the southeastern limb of this syncline. There is a corresponding change in the overall strike of the beds.

Locality 5

Walk across the sands of Kilmory Bay to the first exposures at [NR 700 745], where beds of gritty quartzite are exposed, dipping vertically and striking NNE. Graded bedding indicates that these beds young towards the ESE. They are cut by a slaty cleavage dipping steeply towards the NW. The intersection of this cleavage with bedding plunges at a moderate angle towards the NNE. These relationships indicate that these beds lie on the north-western limb of the south-easterly syncline forming the compound Kilmory Bay Syncline. The hinge of the anticline intervening between this syncline and the northwesterly syncline, already visited, is hidden beneath the sands of Kilmory Bay.

Locality 6

Continue south across exposures of slates and impure schistose quartzites to reach a series of fine-grained quartzites, limestones and slates in the core of the south-easterly syncline at [NR 700 744]. These beds are thought to be equivalent to the upper part of the Ardnòe Group. They are affected by a very spectacular series of B_1 folds, plunging at low or

moderate angles to the NNE. A slaty cleavage, dipping steeply towards the NW. parallel to the axial planes of these folds, is developed in the more pelitic rocks. If the tide is low, the lowest bed of fine-grained quartzite can be traced with scarcely a break from northwest to southeast across a complex series of B_1 folds in the core of the major syncline.

Locality 7

The slates seen between localities 5 and 6 reappear on the south-eastern limb of the syncline to form the valley of the stream which enters the sea half-way between Kilmory Bay and Port Ban. Beyond the mouth of this stream, a series of schistose pebbly quartzites is exposed to form a slight headland at [NR 699 741]. The bedding of these rocks dips moderately towards the north. A plane of grain flattening, dipping steeply towards the NW., represents the slaty cleavage in these rocks. The intersection of this cleavage with bedding plunges at a moderate angle towards the NNE. The exposures around the headland show that the beds are right-way-up on the basis of graded bedding and large-scale cross-bedding which affects the upper parts of the graded beds. Traced towards Port Ban, these pebbly quartzites become much coarser towards their base, so that some beds are conglomeratic. These exposures have an historical interest in that the presence of graded bedding in these conglomeratic beds was used by the Geological Survey to infer that the Crinan Grits were younger than the Ardrishaig Phyllites exposed to the southeast at Port Ban. The base of the Crinan Grits is marked by a thick bed of massive finegrained quartzite which is exposed on the north-west side of Port Ban [NR 700 740]. A limestone or dolomite breccia is locally developed along the base of this bed.

Locality 8

The Ardrishaig Phyllites are exposed as a series of fine-grained quartzites interbedded with a greater proportion of pelitic rock on the southeast side of Port Ban [NR 700 740]. These quartzites are intensely folded, giving rise to B_1 folds which plunge NE. and SW. at moderate angles. If the tide is low, individual folds can be seen to have curved axes which change in plunge from NE. to SW. The slaty cleavage affecting the more pelitic rocks dips steeply towards the NW., parallel to the axial planes of these folds. A fibrous mineral lineation is commonly developed as the stretching-direction parallel to elongate pyrite blebs on these planes of slaty cleavage.

Locality 9

The various lithologies present in the Ardrishaig Phyllites, and the structures affecting these rocks, can be examined in walking SW. from Port Ban to Carraig na h-Acairsaid [NR 697 736]. There are, however, no exposures of particular interest along this part of the coast.

Locality 10

Continue south-west along the coast to a point opposite Eilean Naomhachd at [NR 696 732]. The original character of the Ardrishaig Phyllites, in contact with a thick epidiorite sill to the south-east, is clearly preserved from the effects of the B_1 deformation.

Ripple-drift bedding in the less pelitic layers shows that these beds young towards the SE. A thin sheet of epidiorite can be seen cutting across the bedding of the Ardrishaig Phyllites if the tide is low, while the epidiorite to the SE. appears to show columnar jointing.

Locality 11

The Ardrishaig Phyllites, which are exposed at the back of a small bay some 100 m to the south of the last *locality*, are cut by a series of sedimentary *dykes of fine-grained* and rather impure quartzite. These dykes vary up to 25 cm in width, and trend ENE.- WSW. at an angle to the bedding of the Ardrishaig Phyllites. The exposures immediately to the south-east show groove and flute casts developed on the soles of fine-grained quartzite beds. These structures plunge *steeply* towards the SW., *and appear to indicate* currents flowing from the NW. They are associated with ripple marks and ripple-drift bedding. These exposures are limited to the SE. by another epidiorite sill.

Locality 12

Exposures of fine-grained quartzites on the north-west side of Port an Aomaidh [NR 697 728] show B_1 folds with curved axes, while a limestone breccia can be seen in a series of inland exposures 100 m to the south-east of this bay.

Locality 13

Continuing south towards the Point of Knap, spectacular B_1 folds are developed in a series of fine-grained quartzite beds interbedded with slates on the headland [NR 697 725] between Port an Aomaidh and Port an t'Salainn. These folds mostly plunge towards the NE. at a moderately steep angle.

Locality 14

The exposures of Ardrishaig Phyllites to the south of Port an t'Salainn at [NR 698 723] show a series of thin quartzose beds interbedded with slates. These layers are buckled to form long trains of B_1 folds plunging at a moderate angle to the NE. and verging towards the SE. A slaty cleavage axial planar to these folds is developed in the intervening slates. Immediately to the south-east, and close to the contact of an epidiorite sill, silty beds show ripple-drift bedding affected by a series of minor B_1 folds. These structures face upwards in relation to the ripple-drift bedding.

After examining the epidiorite sills forming the Point of Knap, the party can return to the road at Kilmory village.

The excursion involves 6–7 km of walking over ground which is rather rough along some parts of the coast.

Excursion 2: The Loch Tay Inversion and the Tarbert Monoform

The object of this excursion is to examine the Middle and Upper Dalradian rocks which form part of the Loch Tay Inversion to the south-east of the Ardrishaig Anticline. These rocks are affected not only by the B_{2a} folding but also by the B_{2b} folding associated with the development of the Tarbert Monoform linking the Knapdale Steep Belt to the north-west with the Cowal Flat Belt to the south-east.

The party should follow the narrow single-track road (B8024) from its junction with the main road (A83) from Tarbert to Ardrishaig to reach the south-eastern coast of Loch Caolisport. Note that this road is restricted in use to vehicles carrying less than 16 persons. Cars should be parked north of Port Cill Maluaig at [NR 723 701] where the road turns inland after following the coast south of Ormsary.

Locality 15

Walk south along the coast to examine a wide zone of monoclinial B_{2a} folding affecting the Ardrishaig Phyllites on the SE. limb of the Ardrishaig Anticline. The rocks consist of fine-grained quartzites interbedded with a considerable amount of phyllite. The B_{2a} folds affecting the quartzites have axial planes which are defined by an intense strain-slip cleavage in the phyllites. This cleavage dips at a moderately steep angle towards the NW. The B_{2a} folds plunge overall at a moderate angle to the NE. However, some folds have axes which are strongly curved within their axial planes. Good examples of curved foldaxes are seen to the south-west of a thin basalt dyke at [NR 717 697]. Continue as far southwest as a point 50 m to the north-east of the small beach at Port Mhoirich [NR 716 696]. Careful search of an area of reddened rocks is required to find a series of B_1 folds affected by a series of B_{2a} folds. The exposures are located on the raised beach some 10 m from its seaward edge. Since the structural relationships shown by these exposures have not been observed elsewhere in Knapdale, visitors are asked to refrain from hammering. The party should return along the coast to the road, noting that the B_{2a} folds verge overall to the NW. even although minor folds developed on the limbs of the major folds may verge to the SE.

Locality 16

Return along the B8024 to the main road (A83) from Tarbert to Ardrishaig. Turn right and follow the main road for 3 km towards Tarbert. Park at [NR 857 788] where a strip of old road is present at a bend in the new road. The rocks exposed on the slight headland below the road are typical representatives of the Erins Quartzite. They are affected by two episodes of folding. The earlier B_{2a} folds have a north-south trend characteristic of the Loch Tay Inversion. Their axial planes are defined by a strain-slip cleavage on which the stretching direction is locally developed as a fibrous mineral lineation with a NW.-SE. trend. Although they are rather complex, the B_{2a} folds exposed on the headland verge towards the NW. The later B_{2b} folds are seen to be superposed on the B_{2a} folds in the exposures formed by the small bay to the south-east of the headland. These B_{2b} folds plunge at a low angle to the NE., while their axial planes dip at a moderate angle to the SE. A coarse strain-slip cleavage is developed parallel to their axial planes. These folds verge to the SE., giving rise to steeply-dipping long limbs and flat-lying short limbs. Such attitudes are characteristic of the Knapdale Steep Belt to the north-west and the Cowal Flat Belt to the south-east, respectively. Continue south along the main road past the entrance of Stonefield Hotel to the roadside lodge at [NR 866 704]. Park in a lay-by and walk north along the private road through Forestry Commission land to the coast at South Bay [NR 868 713].

Locality 17

The first exposure encountered on the coast to the south of the isthmus connecting Barmore Island to the mainland are formed by quartzose mica-schists and schistose grits belonging to the Stonefield Schists. The bedding is vertical with a NE. strike. One bed of schistose grit, exposed at the very start of the section, is graded indicating that the rocks young to the SE.

Locality 18

The Stonefield Schists are followed immediately to the south-east by the Loch Tay Limestone with a steep or vertical dip to the NW. The limestone is rather quartzose in some layers, and is interbedded with a certain amount of dark pelitic schist. Some layers show grading from a quartzose base to a calcareous top, indicating that the beds have an inverted dip to the NW. A limestone breccia, in which highly deformed fragments are flattened in a plane parallel to bedding, and stretched in a steep NW.-SE. direction, is developed towards the south-east margin of the limestone. Quartzose layers in the limestone commonly show a pinch-and-swell structure, while the more pelitic horizons are affected by the folding to a slight extent.

Locality 19

The Glen Sluan Schists are exposed immediately to the south of the Loch Tay Limestone at [NR 868 710]. These rocks consist mostly of quartzose mica-schists interbedded with some schistose grit. Albite is commonly developed as conspicuous porphyroblasts in the more pelitic layers. The first exposures of schistose grit are found some 100 m to the south of the Loch Tay Limestone.

Locality 20

Continue south along a very rocky coast-line to examine the first band of Green Beds exposed 50 m beyond a wall which reaches the coast at a small indentation opposite the south end of Barmore Island. B_{2a} folds are developed in the schists immediately to the south of this Green Bed horizon. These folds plunge at a moderate angle to the NE. and verge towards the NW.

Locality 21

Continue south to reach a slight headland at [NR 869 707] marked by a wire fence on its SE. side. At the fence, an earlier set of B_{2b} structures is developed as strain-bands with SE. vergence. These structures are affected by the later set of B_{2D} folds congruent with the Tarbert Monoform. These folds which plunge at a low angle to the NE. and verge towards the SE., give rise to alternate steeply-dipping and flat-lying limbs. Schistose grits, exposed on a small stack 30 m south of the fence, show graded bedding which indicates very clearly that the beds have an inverted dip to the NW.

Locality 22

The B_{2b} folds affecting the Green Beds along this part of the coast line start to plunge moderately towards the NNE. from a point 200 m south of the last locality, at the back of a slight bay. These folds have axial planes dipping moderately to the E., long limbs dipping steeply to the NW. and short limbs dipping moderately to the NE. Geometrical considerations indicate that the layering affected by these folds had originally a steep NW. dip, now characteristic of the Knapdale Steep Belt. This zone of plunging B_{2b} folds continues as far south as a point on the coast opposite Sgeir Port a 'Ghuail at [NR 873 699].

Locality 23

The Green Beds are well exposed within this zone of plunging B_{2b} folds to the south of the last locality. They form massive rocks, rich in chlorite and epidote, in which the bedding is defined by alternate coarse and fine layers. These rocks are interbedded with schistose grits and quartzose mica-schists of a more normal character. Graded bedding is seen in exposures of schistose grit to the north of the mouth of a small stream which enters the sea at [NR 872 702]. Some beds, dipping towards the NW., are inverted while others are right-way-up.

The party should return to the main road by walking up the valley of the small stream mentioned in the last paragraph. This part of the excursion involves 3–4 km of walking over ground which is very rough along the coast.

The party should then follow the main road into Tarbert, turning left along the harbour to reach the end of the A8015 at the old pier. Cars may be parked at the road-end. Walk 150 m south-east along the coast across two small bays to reach locality 24.

Locality 24

The Beinn Bheula Schists are well exposed as a series of schistose grits and quartzose mica-schists on the north of Mealdarroch Point at [NR 883 684]. Although the rocks are highly deformed, graded bedding is sufficiently well-preserved in one band of schistose grit to show that the beds have an inverted dip to the NW. These rocks are affected by horizontal B_{2b} folds with a NE.-SW. trend. The axial planes of these folds are defined by a coarse strain-slip cleavage which crenulates the primary cleavages developed more or less parallel to bedding. The B_{2b} folds have axial planes dipping moderately towards the SE., and *fold* limbs which are alternately steep-dipping and flat-lying. Traced towards the SE. from this locality, the flat-lying limbs of these folds expand at the expense of the steeply-dipping limbs, and the rocks pass from the core of the Tarbert Monoform into the Cowal Flat Belt. It can be noted that the B_{2b} folding affecting the rocks already examined results in local flat belts within which the bedding is completely inverted.

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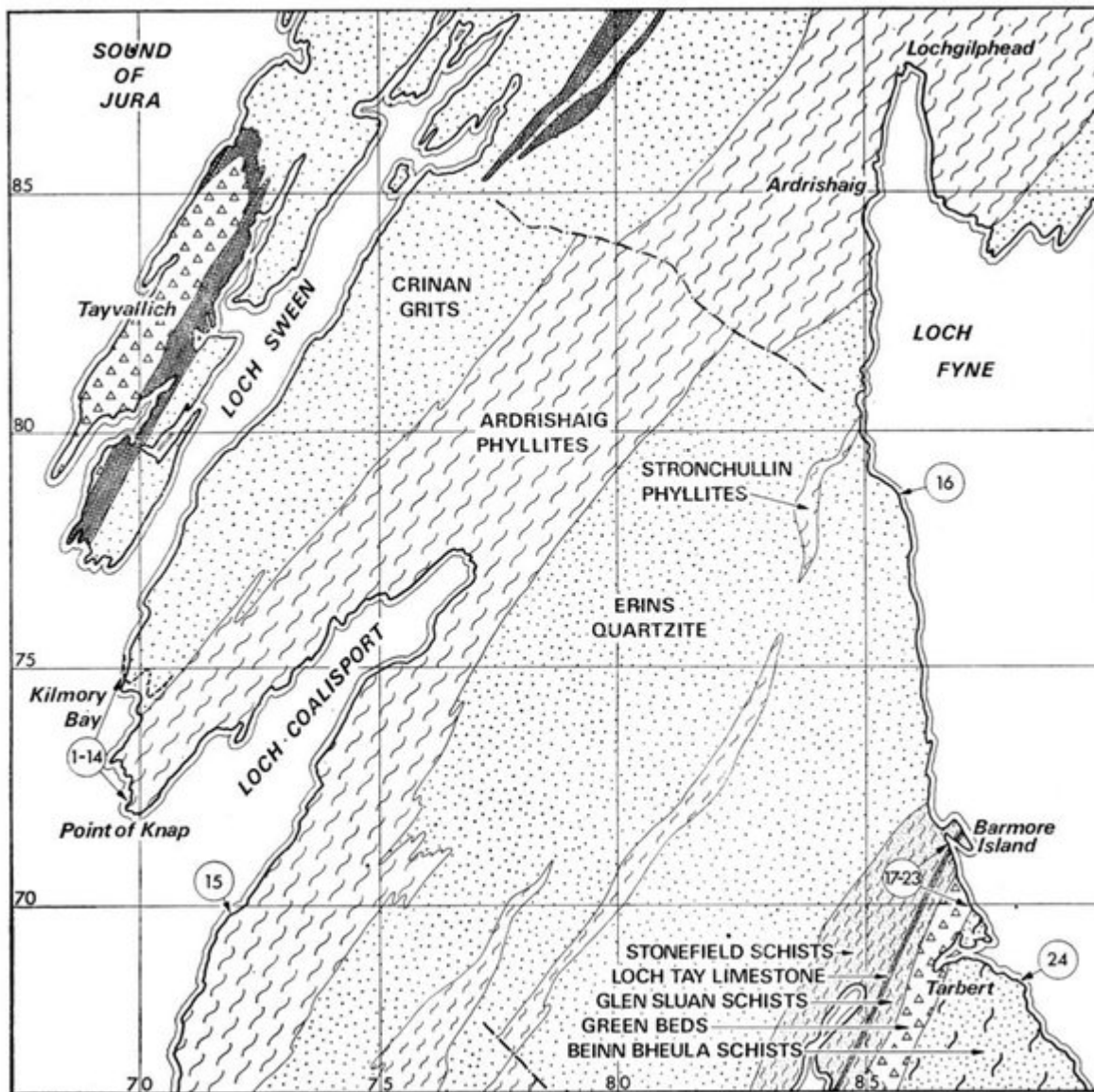
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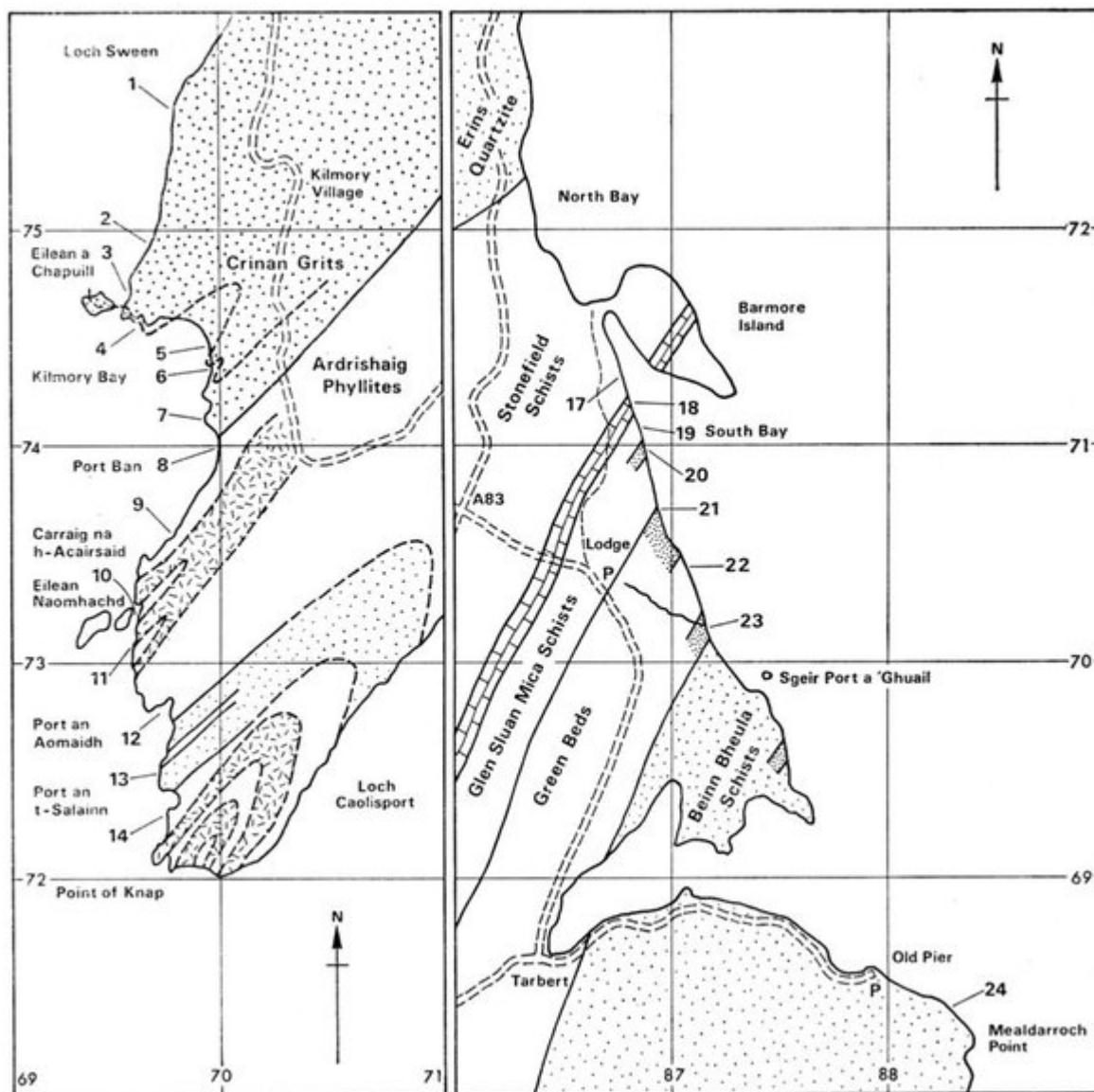
Figures

(Figure 1) Geological map of Knapdale and North Kintyre (after sheets 28 (Jura) and 29 (Rothesay) 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) Left: Geological map of the section between Kilmory Bay and the Point of Knap (Excursion 1, localities 1–14). Right: Geological map of the section between Barmore Island and Tarbert (Excursion 2, localities 17–24).



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