

# Dalradian rocks of the Loch Leven area - an excursion

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## Maps

Ordnance Survey, 1:50.000 sheet 41 (Ben Nevis) and sheet 49 (Oban and East Mull).

Geological Survey, one inch to one mile: 53 (Ben Nevis).

Fig.1 Geological map of the Loch Leven area showing the lithostratigraphy. Modified from sheet 53 (Ben Nevis) of the Geological Survey of Scotland.

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## Introduction

The object of this guide is the examination of the stratigraphy and structure of the Lower Dalradian "Ballachulish" Succession shown in Table 1 (see Bailey 1960). The rocks of the area are particularly rich in sedimentary structures which are an essential element in the erection of a stratigraphic succession in structurally complex areas (Bailey 1960, pp. 20-1). In this respect the excursions no more than complement the excellent descriptions given by Bailey (1960) in the Memoir for Sheet 53 of the Geological Survey of Scotland. The localities have also been chosen, however, to give an introduction to the structural techniques that have to be employed in such rocks in order that the three-dimensional geometry of the folds and their time-sequence may be understood.

## General geology

The distribution of the major lithostratigraphic formations is shown in the diagram, locally modified after Sheet 53 of the Geological Survey of Scotland. Bailey's (1934, 1960) view of the structure is exemplified by section AA of Sheet 53. In essence, Bailey envisaged three recumbent folds, the Appin Syncline, the Kinlochleven Anticline and the Ballachulish Syncline (highest) facing towards the north-west. The lower limbs of the two synclines have been considerably affected by tectonic sliding (the Fort William and Ballachulish Slides respectively) and the pile of recumbent folds have been deformed by a series of secondary antiforms and synforms (Bailey 1960, pp. 110-15).

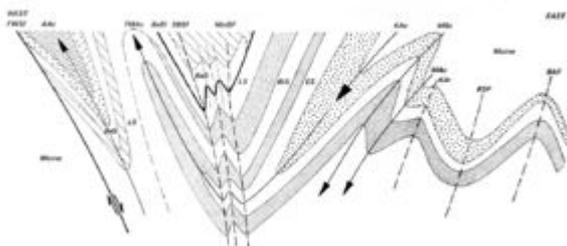
<b>Stratigraphy of the Loch Leven area</b>	
Cuil Bay	Slate Black slates or phyllites
Appin Phyllite	Grey semi-pelitic phyllites with psammitic ribs
Appin Limestone	Mostly creamy, dolomitic and sandy

Appin Quartzite	Upper part massive, white, gritty; lower part (Transition Series) striped quartzite and black slate
Ballachulish Slate	Black slate
Ballachulish Limestone	Grey, banded; lower part creamy
Leven Schist	Green-grey phyllite or schist
Glen Coe Quartzite	Grey, feldspathic
Binnein Schist	Dark grey schists with psammitic ribs
Binnein Quartzite	Pure white, often with rusty spots
Eilde Schist	Dark grey schists with psammitic ribs Eilde
Quartzite	Grey to white, feldspathic

The diagram shows the present authors' modified version of the structure based on the methods discussed below. The north-east trending recumbent folds are assigned to the  $F_1$  deformation, associated with an axial plane penetrative cleavage,  $S_1$ . These folds face up to the north-west in the west and in the east of the area. Between these there is a zone where the folds face down to the north-west occupying the common limb of a pair of secondary folds, the Stob Ban Synform in the north-west and the Kinlochleven Antiform in the south-east. The former fold opens to the south-west into the complex around Ballachulish (see Bailey 1960, chap. VI).



Geological map of the Loch Leven area showing the lithostratigraphy. Modified from sheet 53 (Ben Nevis) of the Geological Survey of Scotland.



Diagrammatic cross-section through the Moine and Dalradian rocks from Loch Linnhe (West) to the Blackwater Reservoir (East). Abbreviations as follows: FWSI Fort William Slide; Asc Appin Syncline; TMAC Tom Meadhoin Anticline; BaSc Ballachulish Syncline; SBSf Stob Bhan Synform; MnGF Mam na Gualainn Folds; BaSI Ballachulish Slide; KAc Kinlochleven Anticline; MSc Mamore Syncline; Kaf Kinlochleven

Antiform; MAC Mamore Anticline; BSf Blackwater Synform; BAF Blackwater Antiform.

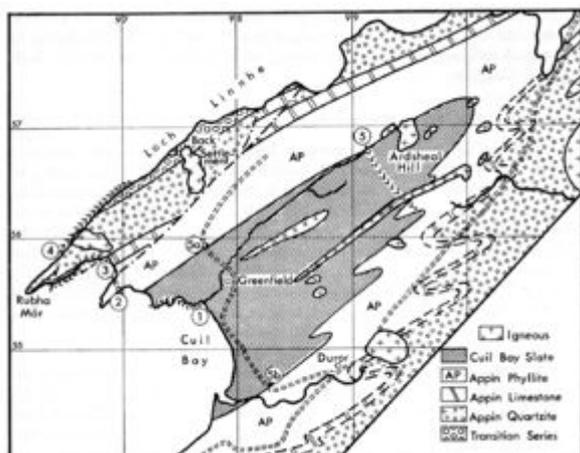
Five phases of deformation have been established in the east of the area (Treagus, 1974). The second phase is only of local importance and will not be considered further here.  $F_2$  (of this account) is responsible for the major secondary folds mentioned above; these folds trend NE. and are associated with an intense strain-slip cleavage ( $S_2$ ).  $F_3$  is responsible for the major deflection in strike of all previous structures across Loch Leven (the Loch Leven Antiform of Bailey (1960, p. 23);  $F_4$  is only locally associated with significant folding.  $F_3$  and  $F_4$  are both related to strain-slip cleavages, the former trending ENE. and the latter N-S.

## Excursion 1 : Ardsheal Peninsula

This excursion covers the upper five formations of the "Ballachulish" Succession. Sedimentary structures,  $S_1$  cleavage and  $F_1$  minor folds are used to demonstrate the presence of a major  $F_x$  syncline (the Appin Syncline). Locally  $F_2$  folds and  $S_2$  strain-slip cleavage are superimposed upon the  $F_1$  structure. For further details see Treagus and Treagus (1971) and for an alternative view see Bowes and Wright (1967, 1973).

Buses from Kinlochleven and Oban stop at the village of Duror, where cars may also be parked. The terrain is easy but there is much to be seen in some six miles walking and at least a full day should be allowed. From Duror Post Office (NM 990 549) follow the minor road along the south shore of Cuil Bay. Where the road turns sharply right to Greenfield Farm continue along the shore to the first outcrops.

### Locality 1: Cuil Bay (NM 976 554-973 554)



Geological map of the Ardsheal peninsula (Excursion 1, localities 1-5).

Slate is well exposed on four small peninsulas. Bedding generally dips SE. at a lower angle than the dominant  $S_1$  cleavage. Tight  $F_1$  minor folds can be seen plunging SW and verging NW with axial-planar  $S_1$ . On the second peninsula (below the fishing croft) bedding is at a high angle to  $S_1$  and graded bedding and load structures may be used to demonstrate upward-facing. These rocks are strongly affected by  $F_2$  folds which can be well seen, on the first peninsula, related to the NW dipping  $S_2$ . Elsewhere  $S_2$  can be seen cross-cutting  $F_1$  folds. On the fourth and largest peninsula strong kinking is associated with some dykes well exposed on the foreshore.

Walk across the bay to the next prominent peninsula.

### **Locality 2. Appin Phyllites (NM 969 555)**

Again the relationship of  $S_1$  to bedding together with way-up evidence (ripple-drift bedding, best seen on the north-west side of the peninsula) shows that the major syncline lies to the south-east. Good conjugate kink-bands. Walk across the next bay to the Rubha Mor peninsula.

### **Locality 3. (NM 968 558)**

Walk along the south-east side of this peninsula where the uppermost beds of the Appin Quartzite can be seen (cross-bedding and poor grading) to be locally inverted by  $F_2$  folding. To the south-west thin limestones and pelites are involved in tight minor  $F_1$  folds: note sense of vergence. Past the lime kiln, the Appin Limestone formation (including dolomite, pelite and psammite) is involved in a large  $F_1$  fold-pair, complicated by faulting; good younging, interesting fold morphology and cleavage relationships.

Cross the Appin Quartzite outcrops of the peninsula in a northerly direction to the shore of Loch Linnhe.

### **Locality 4. The Transition Group of the Appin Quartzite and igneous intrusions. (NM 964 559 to NM 971 565)**

The SE. dipping bedding exhibits a great variety of sedimentary structures, including slump folds, slump breccia, load structures, channelling and dykelets. Tight  $F_1$  folds plunge SW and verge NW with axial-planar  $S_1$ , locally folded by  $F_2$ . Other features include the dioritic intrusion at (NM 966 560) with marginal folding, NW. trending dolerite dykes and faults further north-east and the appinite and explosion-breccia at Back Settlement (NM 976 568).

The next exposures can be reached by crossing the Appin Quartzite in a south-east direction and climbing up to the path to Greenfield Farm. Then strike east to the burn and follow this almost to its head.

### **Locality 5. (NM 992 568 to NM 996 563)**

This traverse crosses the syncline from the north-west Appin Phyllite/Cuil Bay Slate boundary to that on the south-east limb.  $S_1$  dips steeply SE throughout whilst bedding, although involved in minor folds, turns through the synclinal hinge-zone. Ripple-drift bedding youngs upwards on  $S_1$ . Alternatively, the junction may be walked around the fold nose to the north-east, taking in the intrusion complex of Ardsheal Hill en route.

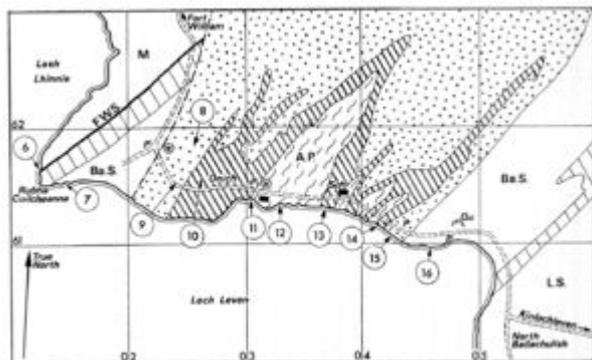
Return to Duror by following the phyllite/slate junction to the south-west (below a prominent wall), noting the development of strong  $F_2$  folding with NW. dipping  $S_2$  cleavage. A path may be joined at (NM 986 553) where it crosses a burn and which leads down to Cuil Bay.

Localities 5a and 5b: (NM 978 559 and 983 547) These localities provide an alternative to Locality 5 on the direct return route to Duror. Leave the shore exposures of Locality 4 and climb up to the path leading to Greenfield Farm. On and near the path the Appin Phyllite/Cuil Bay Slate junction can be located (NM 978 559). Confirm that the bedding/ $S_1$  relations indicate a syncline to the south-east. Follow the path back to the road to Duror. Just before the sharp bend to the left (NM 983 547) the same junction can again be located. The exposures of Cuil Bay Slate (in the fields and a private drive north of the road) are dominated by a strong strain-slip cleavage ( $S_2$ ). However, in the more

psammitic Appin Phyllite to the east (especially in a small cutting on the bend) the bedding/ $S_1$  relations can be clearly seen and indicate that this junction is on the south-east limb of the syncline.

The excursion may be extended profitably by examining several localities near the A828 to Ballachulish: the Appin Limestone and Quartzite on the south-east limb of the syncline may be seen at (NN 000 563) (in burn) and (NM008 567) (in quarry), respectively. The well-known Kentallenite and various dykes are seen on the shore at (NN 010 981) and the Ballachulish "Granite" and its contact metamorphism are seen near Kentallen Station (NN 013 584).

## Excursion 2. Onich Section



Geological map of the Onich section  
(Excursion 2, localities 6-16).

The object of this excursion is to examine the rocks lying in the core of the Appin Syncline along the north shore of Loch Leven, and to study their relationships with the Eilde Flags across the Fort William Slide. The excursion is centred on Onich, which may be reached by bus from Fort William or Kinlochleven, and involves about 8 km of walking over easy ground, mostly on the shore. Start from the main road opposite the United Free Church (NN 023 618) where cars may be parked. Follow the track leading to the shore past the entrance to Cuilcheanna House, and walk westwards to Rubha Cuilcheanna (NN 013 616).

### Locality 6. The Fort William Slide

The Fort William Slide is well-exposed on the NW coast of Rubha Cuilcheanna, separating Eilde Flags to the NW from Ballachulish Limestone to the SE. The party should walk along the NW coast for a short distance beyond a small rocky beach, to examine exposures of steeply-dipping Eilde Flags affected by steeply SW plunging  $F_2$  folds with dextral or NW vergence. Returning to the SW, along the shore, the Eilde Flags become increasingly flaggy as the slide is approached. Some thin quartzite bands are present. The slide itself is marked by the intrusion of a lamprophyre dyke along part of the contact with pale quartzose limestone to the SE. The exposures are found 60 m to the NE of the point at Rubha Cuilcheanna. These rocks are succeeded to the SE by two bands of quartzose schists (? Eilde Flags) separated by pale quartzose limestone, before the main mass of dark pelitic limestone is reached. The rocks are affected by steeply SW plunging  $F_2$  folds with dextral or NW vergence and by later kink-bands with a variety of attitudes.

### Locality 7. Ballachulish Slate

Return along the shore towards Onich to examine exposures of Ballachulish Slate to the west of the Boat-House (NN 015 616). The rocks are affected by an intense strain-slip cleavage which is axial planar to  $F_2$  folds, plunging steeply SW and verging NW. Lamprophyre dykes are displaced sinistrally by NE trending wrench faults.

## **Locality 8. Appin Quartzite**

Return to the main road, and ascend hill-side to the north-east of the United Free Church (NN 023 618). Exposures of gritty and pebbly Appin Quartzite show crossbedding which indicates that the beds young to the SE on the NW limb of the Appin Syncline.

## **Locality 9. Appin Quartzite**

Walk back to the main road along the track from Gleann Rìgh. Walk east along the main road to examine an exposure of Appin Quartzite at the bend (NN 024 615). Thin pelitic bands interbedded with quartzite show a slaty cleavage  $S_1$  which dips more steeply SE than bedding, indicating that the rocks lie on the NW. limb of the Appin Syncline.

## **Locality 10. Appin Limestone**

Leave the road at the last locality to examine exposures of dolomitic Appin Limestone on the hillside behind the village.

## **Locality 11. Appin Phyllites**

Return to the road and walk east past the Post Office to gain the shore opposite the Presbyterian Church (NN 030 614). Appin Phyllites on the NW. limb of the Appin Syncline young to the SE on the evidence of ripple-drift bedding. A slaty cleavage  $S_1$ , dipping more steeply SE than bedding, is axial planar to upward-facing  $F_1$  folds, plunging moderately SW. and verging NW. (Cars may be parked near the church.)

## **Locality 12. Dolomitic limestone in the core of the Appin Syncline**

Continue east along the shore past the Onich Hotel to reach a band of dolomitic limestone at the back of a small bay (NN 033 613). These rocks lie in the core of the Appin Syncline. This can be demonstrated using sedimentary structures such as grading (silty layers show sharp bases), channelling and ripple-drift bedding in the pelitic rocks on either side. The  $F_1$  structures change in vergence across the outcrop of the dolomitic limestone so that a slaty cleavage  $S_1$  dips SE at a lower angle than bedding on the SE limb.

## **Locality 13. Appin Phyllites**

Farther east along the shore, sedimentary structures, bedding-cleavage relationships and the vergence of minor  $F_1$  folds can be used to show that bands of dolomitic limestone are interbedded in the Appin Phyllites on the SE. limb of the Appin Syncline. The SE limb of the Appin Syncline extends as far east as the outcrop of a pink acid dyke, exposed on the shore near the school (NN 038 613). There, the  $F_1$  structures change in vergence to give a slaty cleavage  $S_2$  dipping more steeply SE than bedding.

## **Locality 14. Contact of the Appin Quartzite**

Continue east along the shore, noting that the  $F_1$  structures become progressively tighter and more intense as the contact with the Appin Quartzite is approached. Even so, it is possible to show from bedding-cleavage relations and the vergence of minor folds that the anticline of Locality 13 is flanked to the SE. by a syncline with its axial trace within 10 m of the contact of the Appin Quartzite at (NN 043 611). Quartzite beds exposed on the shore in front of the Creag Mhor Hotel show cross-

bedding younging to the SE on the NW. limb of this syncline. Although bands of dolomitic limestone are interbedded with the Appin Phyllites, the structure is such that a considerable part of the Appin Phyllites, and all the Appin Limestone, must be cut out by a slide at the contact of the Appin Quartzite.

### **Locality 15. Appin Quartzite**

The Appin Quartzite is well-exposed on the slight headland to the east of the last locality. Festoon cross-bedding shows the beds young to the NW. across the whole width of the outcrop. A slaty cleavage  $S_1$  dips SE at a lower angle than bedding, and faces upwards to the NW. (Cars may be parked at a quarry north of the road.)

### **Locality 16. Appin Quartzite flanked by Ballachulish Slates**

Exposures farther along the shore show that the Appin Quartzite is flanked to the east by the Ballachulish Slates. These are also exposed in a large quarry opposite a petrol station (NN 049 611). There, contact metamorphism associated with the Ballachulish Granite has resulted in pseudomorphs of pyrrhotite after pyrite, which weather freely to form holes. (Cars may be parked near the garage.) From this point, a return can be made along the main road to Onich.

## **Excursion 3: Callert Section**

The main object of this excursion is to examine exposures of the Ballachulish Slide on either side of the Stob Ban Synform, and to study the relationships of the  $F_1$  and  $F_2$  structures across this synform. The excursion is best started from North Ballachulish, served by bus from Fort William and Kinlochleven. Taking the road from North Ballachulish to Kinlochleven, a stop may be made near Altshellach House to examine exposures of Leven Schist in a quarry north of the road at (NN 059 603). Tight  $F_1$  folds plunging NE are affected by open  $F_2$  folds plunging SW and verging NW. (Parking is difficult). Continue east along the main road for 1.5 km to a roadside quarry near the Mausoleum (NN 073 598). Cars may be parked at the quarry.

### **Locality 17. Mausoleum Quartzite**



Geological map (after Roberts, 1976) of the area between Callert and Stob Bhan (inset), (Excursion 3-5, localities 17-27).

The quarry exposes a band of quartzite which is mapped as passing SE of the Tom Meadhoin quartzite. It is likely that this Mausoleum Quartzite represents the Glencoe Quartzite, while the Tom Meadhoin Quartzite represents the Binnein Quartzite, northwest of the Stob Ban Synform. Bailey (1960) records an observation of J.G.C. Anderson that cross-bedding in the Mausoleum Quartzite youngs SE. The road-side ditch at the NW end of the quarry exposes silty beds dipping steeply SE, cut by a slaty cleavage S<sub>1</sub> dipping steeply NW. Thin sections show that the F<sub>1</sub> structures face upwards on the evidence of ripple-drift bedding. Exposures along the roadside to the SE of the quarry show banded Leven Schists with thin silty bands which young to the SE on the evidence of graded bedding. These beds are cut at a slight angle by a slaty cleavage S<sub>1</sub> dipping more steeply SE than bedding. The F<sub>1</sub> structures face upwards.

### Locality 18. Mausoleum Quartzite

Leaving the road, the outcrop of the Mausoleum Quartzite can be followed SE. towards the shore opposite Eilean Choinneich (NN 074596). Small-scale cross-bedding is found in exposures near the loch side showing that the beds young to the SE.

### Locality 19. Garnetiferous Leven Schists and Ballachulish Limestone

Walk east across the outcrop of garnetiferous Leven Schists affected by abundant F<sub>2</sub> folds, plunging steeply SW. with dextral or NW vergence. These rocks are in tectonic contact with a thin remnant of Ballachulish Limestone across the line of the Ballachulish Slide, some 30 m west of the slight headland (NN 075 595). The Ballachulish Limestone is followed to the east by a narrow outcrop of black slates (the Ballachulish Slates) beyond which a thin band of impure quartzites and black slates, outcropping on the headland itself, represents the Appin Transition Group in the core of the Ballachulish Syncline. These rocks are succeeded to the east by a wide outcrop of Ballachulish

Slates.  $F_2$  folds plunge steeply SW. and overall show dextral or NW vergence.

## **Locality 20. Ballachulish Limestone and Ballachulish Slates**

Returning to the main road, continue east to reach the shore-section near Callert House at (NN 096 604). Cars can be parked some distance along the road to the west. The first exposures beyond the burn show pale quartzose limestone representing part of the Ballachulish Limestone on the upper limb of the Ballachulish Syncline. Minor  $F_2$  folds plunge SW at a shallow angle and verge SE, thereby supporting the Stob Ban Synform. These rocks are succeeded to the east by a narrow outcrop of Ballachulish Slates beyond which there is a transitional contact with a thin band of gritty quartzite, representing the Appin Quartzite in the core of the Ballachulish Syncline. This is flanked to the SE by a narrow band of impure quartzites and black slates, representing the Appin Transition Group. These rocks are in tectonic contact with greenish Leven Schists across the line of the Ballachulish Slide. The exposures of Appin Quartzite can easily be located as they form a slight headland marked by the foundations of a summer house.

## **Locality 21. Banded Leven Schists**

Continuing along the shore, there is a short gap in exposure beyond which banded Leven Schists are exposed at (NN 097 605).

These rocks are affected not only by  $F_2$  folds, plunging moderately SW. and verging SE, but also by  $F_1$  folds, plunging SW at a shallow angle and verging NW. Both sets of folds are well seen in an exposure formed by a low craig on the shore. The  $F_1$  folds face downwards to the NW on the stratigraphy. The contact of these rocks with the Glencoe Quartzite can be examined some 200 m farther to the east along the shore. Cross-bedding in the quartzite indicates that the beds young to the NW. From this point, the party may follow the line of the Ballachulish Slide uphill to the north-east around the hinge of the Mam na Gualainn Synform, an  $F_2$  fold exposed on the upper slopes of the hill so named. Thin remnants of Ballachulish Limestone may be located at two points along the line of the slide.

## **Excursion 4: Doire Ban and Tom Meadhain**

This excursion deals with the structural relationships of the Tom Meadhain Anticline which forms the nose of the Kinlochleven Anticline NW of the Stob Ban Synform. It involves walking 6 or 7 miles over rough ground. Doire Ban is best approached from the road which runs south from Fort William through Blarmachfoldach. The track through the Lairig Mhor to Kinlochleven is followed from Blar a'Chaoruinn (where cars may be parked) as far as the sheep-folds at the edge of the forestry wood (NN 101 648). Cross the Allt na Lairige Moire to gain the first exposures in the gully of a stream draining east from Doire Ban. Care should be taken if the river is in spate.

## **Locality 22. Ballachulish Slates/Leven Schists and their contact**

The burn exposes Ballachulish Slates in its lower course. Upstream the contact of these rocks with the Leven Schists across the line of the Ballachulish Slide can be located. There is a thin band of quartzite developed within the Leven Schists close to the slide.

## **Locality 23. Line of the Ballachulish Slide**

The line of the Ballachulish Slide, flanked to the SE by Ballachulish Slates and to the NW. by Leven Schists with a thin band of quartzite close to the slide, can be followed south-west across the hillside

around the hinges of two  $F_2$  folds. These folds plunge NE at a low angle, forming a synform to the NW and an antiform to the SE. They are complementary to the  $F_2$  folds developed on the SE. limb of the Stob Ban Synform. A thin remnant of Ballachulish Limestone, now in the form of calc-silicate, can be located on the NW. limb of the synform. Minor  $F_2$  folds are best seen where they affect the quartzite band between the synform and the antiform.

### **Locality 24. Tom Meadhoin Anticline**

Follow the thin band of quartzite south-west until the nose of the Tom Meadhoin Anticline is reached at (NN 095 637). This quartzite is separated from the Tom Meadhoin Quartzite by a banded series of impure quartzites and black slates. These rocks can be examined at a low craig immediately to the north of the Tom Meadhoin Quartzite. A slaty cleavage ( $S_1$ ) dips more steeply NW than bedding. Exposures farther downhill, at the nose of the Tom Meadhoin Anticline, show bedding dipping N or NE at a high angle to the slaty cleavage  $S_1$ . These bedding-cleavage relationships indicate that the Tom Meadhoin Anticline is an  $F_1$  fold. (This is confirmed by the observations made at locality 17.) The fold plunges NE at a moderately low angle.

### **Locality 25. Summit of Tom Meadhoin to North Ballachulish**

Continue south-west towards the summit of Tom Meadhoin (NN 086 622) across the quartzite outcrop, noting the cross-bedding which can be seen in nearly every exposure. The closure of the Tom Meadhoin Anticline, plunging SW at a moderately low angle, can be traced out SW of the Tom Meadhoin summit, starting on the SE limb and walking around the hinge to the NW limb. Abundant cross-bedding in the quartzite confirms that the fold is an upward-facing anticline. Although the Tom Meadhoin Quartzite lacks a cleavage which might be axial planar to this fold, exposures of banded Leven Schists at the head of a small burn draining north into the Allt Meurach show a slaty cleavage  $S_x$  dipping more steeply NW than bedding.

FIG. 5. Geological map (after Roberts, 1976) of the area between Callert and Stob Bhan (inset), (Excursion 3-5, localities 17-27).

From this point, the party may proceed towards North Ballachulish across the wide outcrop of the Leven Schists. Exposures of Ballachulish Limestone can be examined in the craigs west of Leac Mhor before descending to the main road at North Ballachulish. Alternatively, the party can examine the line of the Ballachulish Slide at the head of a burn draining north-east into the Allt na Lairige Moire, due east of the Tom Meadhoin summit at (NN 091 625). If time allows, the Fort William Slide can also be examined where it is exposed in the valley of the River Kiachnish at (NN 093 697). The exposures can be located with reference to a small stream which enters the river from the northeast. The interest of these exposures is that the rocks are practically unaffected by the  $F_2$  deformation so that the effects of the  $F_x$  deformation associated with the sliding can be better appreciated. The slide is marked by the contact of impure Ballachulish Limestone to the SE. with a narrow band of pelite and flaggy quartzite, beyond which the Eilde Flags are exposed to the NW. The exposures are only accessible if the river is relatively low.

## **Excursion 5: The Stob Ban Synform**

The object of this excursion is to examine the evidence that the Stob Ban Synform is an  $F_2$  fold which affects an earlier  $F_1$  fold as represented by the Ballachulish Syncline. It was this evidence which Bailey (1960) used as the foundation for his interpretation of the Ballachulish area as a whole. The excursion involves 4 or 5 miles of walking over rough ground and an ascent of some 2500 feet. It may be combined with the ascent of Stob Ban to provide a full day. Starting from Fort William,

follow the road up Glen Nevis as far as Archriabhach, where cars may be parked. The party should then walk south up the valley of the Allt a' Choire Dheirg to the junction of this river with the burn which drains the north-west corrie of Stob Ban. Following this burn upstream, the contact of the Mullach nan Coirean Granite can be located near the ruins of an old sheiling at (NN 148 664).

### **Locality 25. Pelitic hornfels in contact with the Mullach nan Coirean Granite and Ballachulish Syncline**

Dark pelitic hornfels is present in contact with the rocks of the Mullach nan Coirean Granite. These rocks are followed upstream to the SE by pale-green calc-silicate rocks representing the Ballachulish Limestone. These rocks are succeeded to the SE. by the Ballachulish Slates, exposed about halfway up the gorge below the corrie. These rocks are followed in turn by another band of pale-green calc-silicate rocks, representing the Ballachulish Limestone, beyond which the Leven Schists are exposed as a pelitic hornfels at the lip of the corrie. Throughout this section, abundant  $F_2$  folds with steeply dipping axial planes are developed, plunging SW and verging NW. The Ballachulish Slates occupy the core of the Ballachulish Syncline on the NW limb of the Stob Ban Synform, and are flanked by Ballachulish Limestone and Leven Schists, as successively older groups on the limbs of the Ballachulish Syncline.

### **Locality 26. SE limb of the Stob Ban Synform and core of Ballachulish Syncline**

The Leven Schists exposed at the corrie-lip are flanked to the SE by exactly the same sequence of rocks as seen to the NW. Pale-green calc-silicate rocks representing the Ballachulish Limestone are found midway along the NE shore of the lochan. They are followed to the SE. by Ballachulish Slates, exposed uphill to the NE. These rocks are succeeded by more pale green calc-silicate rocks, representing the Ballachulish Limestone, beyond which the Leven Schists are exposed as a pelitic hornfels. Throughout this section,  $F_2$  folds plunge SW and verge SE. The rocks lie on the SE limb of the Stob Ban Synform while the Ballachulish Slates outcrop in the core of the Ballachulish Syncline.

### **Locality 27. SE limb and closure of the Stob Ban Synform**

The rocks on the SE limb of the Stob Ban Synform can be traced uphill to the ridge running N. from the summit of Stob Ban. The closure of the Stob Ban Synform can be examined on the rather precipitous slopes of this ridge, facing east over Allt Coire a'Mhusgain. The outcrop of the Leven Schists forming the core of the synform terminates some 20 m below the crest of the ridge. Below this closure, the underlying groups can be traced from SE to NW round the hinge of the Stob Ban Synform. This is best done by following the thin band of Ballachulish Limestone which intervenes between the Ballachulish Slates and the Leven Schists on the upper limb of the Ballachulish Syncline. Care should be taken if the party is large. Once the reality of the Stob Ban Synform has been established, the party may follow the outcrop of the Ballachulish Slates on the NW limb of the Stob Ban Synform to locality 25, returning from there to Glen Nevis. Alternatively, a more direct return to Glen Nevis may be made down the ridge from locality 27, making sure to bear west towards the valley of Allt Choire a'Dheirg.

## **Excursion 6: Callert To Kinlochleven**



Geological map (after Treagus, 1974) of the Kinlochleven area (Excursion 6, localities 28-33).

This excursion is concerned with the stratigraphy and structure of the three quartzites and pelites that form the lower part of the "Ballachulish" succession. Two major structures can be demonstrated: a synform, which is the downwardfacing  $F_x$  Kinlochleven Anticline, and an antiform, the  $F_2$  Kinlochleven Antiform, which folds the inverted limb of the Anticline. The area particularly lends itself to the study of the superposition of deformation phases and the use of sedimentary structures in complexly deformed areas. For further details see Bailey (in Bailey and Maufe 1960, pp. 90- 110) and Treagus (1974).

The basic excursion (omitting the extensions to localities 30-33) may be accomplished in a day. Cars and coaches may be parked in several convenient lay-bys on the A82 and a bus service runs along the same road between Kinlochleven and Fort William. Low tide is of marginal advantage for some exposures.

### **Locality 28. Glen Coe Quartzite—Binnein Schist—Binnein Quartzite, upper limb of Kinlochleven Anticline**

Parking at quarry (NN 123 611) and lay-bys on both sides of road nearby. Both the shore and road-side exposures from (NN 120 610) to (NN 127 613) give an almost continuous section. The western-most exposure and the headland to the east exhibit typical impure Glen Coe Quartzite with abundant cross-bedding and locally slump structures, pebble beds and mud slithers. The beds can be seen to be involved in a large  $F_1$  fold pair, with axial-planar  $S_1$ , plunging steeply N. In pelitic beds a widely spaced strain-slip cleavage is developed related to the major  $F_4$  deflection of strike across Loch Leven.

To the east of the headland the quartzite grades transitionally into the Binnein Schist, which can be demonstrated, from small scale cross-bedding, to be older. These beds are dominated by a NE striking strain-slip cleavage,  $S_2$  and the related  $F_2$  minor folds. Garnet and white K-feldspar porphyroblasts are syn-tectonically related to this deformation. The glaciated exposures at the eastern end of the shore exposures show good examples of small-scale  $F_1$  closures folded by  $F_2$ ; in the road-side exposures above, the plunge of  $F_1$  can be seen to vary from steep to gentle to the N and the vergence indicates a synform to the east.

The eastern-most shore exposures and those of the road-side above provide a transition into Binnein Quartzite, which from cross-bedding can be demonstrated to be older.  $F_1$  folds in exposures above the road plunge steeply north and face down to the west. The synform to the east must be a downward-facing  $F_1$  anticline.

### **Locality 29. Binnein Quartzite—Eilde Schist, upper limb of Kinlochleven Anticline (NN 130 613 - NN 133 613)**

A lay-by is situated at the eastern end of the exposures. Start at western end of the shore section. The typical pure Binnein Quartzite exhibits westerly younging crossbedding and is involved in a large  $F_1$  fold-pair plunging N. Again, the vergence indicates a major synform to the east. Most of the

exposures of the shore section are on the short limb of this fold-pair and exhibit spectacular minor folding with axial planar  $S_2$ . Characteristic ellipsoidal iron-rich spots are elongated in  $S_1$ . Locally the first structures are deformed by the  $S_2$  strain-slip cleavage, crossing in its usual clockwise sense giving a steep intersection lineation.

At the eastern end of the section the quartzite grades into the Eilde Schists with smallscale graded silty bands (demonstrating that they are older) and sedimentary dykelets. The more pelitic beds to the east are dominated by  $F_2$ .

### **Locality 30. Eilde Schist—Eilde Quartzite, upper limb of Kinlochleven Anticline**

From the previous locality walk about 1.5 km east along the A82 until the first roadside exposures of Eilde Quartzite are reached (NN 146 618). Strike NE up the hillside keeping to the east of the small burn. The transitional beds of the Eilde Quartzite/Schist junction can be located at about 500 feet. Cross-bedding (demonstrating the quartzite is older),  $S_1$  and its steep N-plunging intersection with bedding can be seen in the quartzose beds; once again these relationships indicate that a major  $F_1$  downward-facing anticline still lies to the east. In the pelitic beds the wide strain-slip cleavages of  $S_3$  and  $S_4$  strike E-W and N-S respectively. The hinge of a large subsidiary fold to the Kinlochleven Anticline can be seen on the prominent quartzite face on the hillside above. The fold is a synform, but from the cross-bedding and the axial-planar  $S_1$  cleavage, it can be shown to be a downward-facing  $F_x$  anticline.

FIG. 6. Geological map (after Treagus, 1974) of the Kinlochleven area (Excursion 6, localities 28-33).

### **Locality 31 Binnein Schist—Binnein Quartzite—Eilde Schist, lower limb of the Kinlochleven Anticline.**

Start at lay-by (NN 161 621) opposite a small island and ascend hillside to the north, making for the smooth quartzite outcrops which overlie the schist of the lower ground. Careful observation will show that this junction is involved in tight  $F_1$  folds plunging at varying angles to the NE and cross-bedding demonstrates that the succession is right way up. The quartzite, with the characteristic rusty spots, is the Binnein and the vergence of the  $F_1$  folds show that we have passed across the downward-facing  $F_1$  anticline anticipated in localities 28-30.

If time permits, walk NW. across the dominantly south-west younging Binnein Quartzite to the Eilde Schist junction at (NN 162 625) (cf. Locality 29). Folding in the Eilde Schist is complex, but it is worth continuing NW. to the prominent junction with the Eilde Quartzite above at (NN 159 628). The first few tens of metres are strongly deformed but unambiguous cross-bedding soon shows that the quartzite is inverted. This junction is a slide which has completely removed the Eilde Quartzite on the lower limb of the Kinlochleven Anticline. Looking SE. from here towards the slopes of Garbh Bheinn on the south side of the loch, the Eilde Quartzite can be seen in the core of the synformal nose of the Kinlochleven Anticline; here it is greatly thinned, but not completely removed, on the lower limb. An interesting return route is made by walking NE. and locating the Binnein Quartzite/Schist junction that follows the bend in the Allt Nathrach (NN 166 628). The junction is involved in a large  $F_2$  fold and the transitional beds reveal excellent examples of small-scale interference patterns produced by  $F_1$  and  $F_2$ . Descend to the prominent knoll north of the Nathrach caravan site (NN 163 621). Here the banded Binnein Schist is dominated by micro-folding with an ENE. trending axial-planar cleavage. These exposures are at the hinge of the Loch Leven Antiform; the cleavage and folds related to this major  $F_3$  structure are intensely developed along its hinge zone.

## Locality 32. The F2 Kinlochleven Antiform

Park in Kinlochleven and walk west along the A82 on the south side of the river, branch right along the small road to the pier and pass through the dock gates. A quartzite/schist junction can be located where a small burn descends the cliff (NN 179 618). Note that the junction strikes SSE., rotated by the F3 Loch Leven Antiform and that the crossbedding youngs west towards the schist. This is the Binnein Quartzite/Schist junction on the eastern limb of the F1 Mamore Syncline, a subsidiary fold to the Kinlochleven Anticline.

Return eastwards through the Binnein Quartzite, note the NE-trending  $S_3$  cleavage in the pelitic beds. Near the dock gates small  $F_1$  folds can be seen; these folds support a downward-facing  $F_1$  Anticline to the east, the synformal hinge of which can be located along the old railway track outside the gates.  $F_1$  minor folds can be found again on the 'flat' limb; this is the Mamore Anticline, the other major subsidiary fold to the Kinlochleven Anticline. Exposures on the railway and road to the east show the development of more open, upright folds that clearly deform the  $F_1$  structures in pelitic beds and deform flattened spots in the quartzite. These are  $F_2$  folds related to the Kinlochleven Antiform.

Return to Kinlochleven via the old railway track; inversion of the quartzite can be demonstrated until an exposure of schist is reached where a small burn descends the hillside (NN 184 617); beyond this the quartzite dips steeply west and youngs in the same direction. The schist is the Binnein Schist in the core of the Kinlochleven Antiform. To demonstrate the relation of this structure to the strong  $S_2$  cleavage, it is necessary to climb the hillside south of Kinlochleven (NN 185 615) to the core of Binnein Schist or better still to ascend the prominent crag NE of the town (NN 195 624) where the Eilde Schist/Binnein Quartzite junction is affected by the antiform at a higher structural level.

## Locality 33. The eastern limb of the Kinlochleven Antiform

From Kinlochleven take the road eastwards on the south side of the river until the old bridge is reached at (NN 192 618). Exposures here and in the river show that the Binnein Quartzite/Schist junction to the east should now be located, either on the path to the north of the river or near the pipe-line on the south side. The penetrative cleavage in the semi-pelitic transitional beds looks like  $S_j$  and infers that the rocks face down to the west. Close examination, however, particularly of the more pelitic beds, will show that this cleavage is an intense development of the  $S_2$  strain-clip cleavage. By inference the  $F_1$  folds on this limb of the Kinlochleven Antiform must face upwards; although occasional  $F_1$  folds can be found in the Eilde Schist, lack of sedimentary structures in the critical exposures does not make this upward facing easy to demonstrate.

If time permits, a complete traverse of this limb of the Kinlochleven Antiform may be made by walking up the River Leven to the Moine junction at (NN 203 610). The vertical bedding is interrupted by a number of  $F_2$  major folds, but the relationship between bedding and  $S_2$  remains constant up to, and across, the Moine junction.

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Fig. 1 . Geological map of the Loch Leven area showing the lithostratigraphy. Modified from sheet 53 (Ben Nevis) 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.

FIG. 2. Diagrammatic cross-section through the Moine and Dalradian rocks from Loch Linnhe (West) to the Blackwater Reservoir (East). Abbreviations as follows: FWSI Fort William Slide; Asc Appin Syncline; TMAc Tom Meadhoin Anticline; BaSc Ballachulish Syncline; SBSf Stob Bhan Synform; MnGF Mam na Gualainn Folds; BaSI Ballachulish Slide; KAc Kinlochleven Anticline; MSc Mamore Syncline; KAf Kinlochleven Antiform; MAC Mamore Anticline; BSf Blackwater Synform; BAF Blackwater Antiform.

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