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## Chapter 8 Metamorphic rocks Lochaber and Appin (Resume)

A brief summary will now be given of the results which have been set forth in some detail in chapters iv to vii concerning the schists on the south-east side of Loch Linnhe (see also Bailey 1910, 1934a, 1938).

### Stratigraphy

The following stratigraphical sequence has been established, with the youngest placed top. Internal age relations have been furnished by current-bedding in four quartzite members. Acknowledgment of invaluable assistance from Carruthers, Vogt, Buckstaff, Rove and Tanton has been made in chapter 2 and more fully in (Bailey 1930, 1934a).

0. Lismore Limestone (dark-grey) — youngest of the list
1. Cuil Bay Slates (black)
2. Appin Phyllites (with large proportion of flaggy quartzite)
3. Appin Limestone (dolomitic, cream-coloured, pink, etc.)
4. Appin Quartzite (massive gritty-4 where separated)
4. Appin Quartzite (striped transition zone-4' where separated)
5. Ballachulish Slates (black)
6. Ballachulish Limestone (youngest part, dark-grey and pure; middle, calcareous schist; oldest, cream-coloured)
7. Leven Schists (grey with banded edge against 8)
8. Glen Coe Quartzite (fine-grained)
9. Binnein Schists (grey)
10. Binnein Quartzite (fine-grained)
11. Eilde Schists (grey)
12. Eilde Quartzite (fine-grained)
13. Eilde Flags (psammitic Moine type of Scots geologists — quartzo-felspathic with micas) — *oldest of the list*

The propriety of introducing the Lismore Limestone of Shuna [NM 920 490] into the above list has been debated on p. 41. As regards thicknesses, the Appin Limestone, apart from interbedded phyllite and quartzite, may not be much more than 100 feet. All the other formations appear to be considerably thicker, with the Appin Quartzite, if we take its two parts together, 1000 feet, and the Leven Schists and Eilde Flags, each 2000 feet or more.

The listed formations seem to be linked seriatim by passage zones to form a continuous whole.

Facies is wonderfully constant, except that the Leven Schists in their outcrop reaching south-west from the Ballachulish Pluton are in large measure inter-banded with quartzitic beds and dark pelitic seams.

### Metamorphism

Metamorphism increases in an easterly direction, ranging from a grade in which biotite is inconspicuous or absent to one in which garnet is prominently developed. It also increases downwards as shown at faulted juxtapositions in Glen Coe and at Ben Nevis.

## Recumbent folds

For a broad appreciation of the structure of the district it is convenient to adopt an arbitrary grouping of its formations into two major stratigraphical units. The younger of these consists of Ballachulish Limestone (6) and all younger formations; the older consists of Leven Schists (7) and all older formations. The outcrops of the younger unit are shown in black in (Figure 17); those of the older unit are dotted with a density corresponding with structural position.

The two stratigraphical units are interfolded in great recumbent folds; and it is pleasant to recall that the first step towards recognition of large-scale recumbent folding in the district was taken by Maufe in 1905 (pp. 19, 87 — a discussion of structural terms is given in chapter 3). Among these recumbent folds, synclines can be distinguished from anticlines through their cores consisting of relatively young formations. Three main recumbent synclines have been given proper names, to wit, the Appin, Aonach Beag and Ballachulish Synclines. All three gape towards the north-west and close towards the south-east.

It has been found convenient in dealing with these synclines to define and name their cores with an arbitrary stratigraphical limitation. Thus the terms Appin, Aonach Beag and Ballachulish Cores (when used as proper names in this memoir) stand for the cores of the Appin, Aonach Beag and Ballachulish Synclines, in so far as these cores consist of Ballachulish Limestone and younger formations. On this understanding the black band running between the Ben Nevis Pluton and Appin in the map of (Figure 17) represents the outcrop of the Appin Core; the thick black lines about Aonach Beag represent the outcrop of the Aonach Beag Core; and the complicated black belt that divides near Ballachulish represents the outcrop of the Ballachulish Core.

The Appin Core is the lowest of the three. In section it is shown in (Figure 17) between Loch Linnhe and Loch Leven. The Aonach Beag Core seems to be a minor affair in an intermediate position. According to this view it does not come to earth along the line of section in (Figure 17), but finishes in the air as a digitation or finger-like projection a little below the Ballachulish Core — a slightly different alternative is discussed on p. 47. The Ballachulish Core, the highest of the three, is shown in the (Figure 17) section as going underground in Meall Mòr, south of Loch Leven, to reappear in the recumbent fold of Achnacon [NN 119 566] (p. 78) and in the Windows of Etive [NN 160 510]. This last exposure does not mark its eastern limit, since it has been recognised again in Coire an Easain [NN 250 496] (p. 82). The distance from the west margin of the outcrop of the Ballachulish Core, north of Loch Leven, to Coire an Easain [NN 250 496] is 13 miles measured south-east across the usual strike of folding; and for twelve miles of this, Ballachulish Limestone underlies Leven Schists, older than itself.

The stratigraphical-structural convention adopted above in relation to core-rocks leaves the Leven Schists and all older formations as envelope-rocks. In (Figure 17) these envelope-rocks are dotted, densely if they underlie the Appin Core, more openly if they intervene between the Appin and Ballachulish Cores, and more openly still if they overlie the Ballachulish Core.

The map of (Figure 17) thus depicts the Ballachulish Core as bent into a great basin (pitch-depression) which may be called after Glen Creran (it is loosely styled the Glen Creran Syncline instead of Synform in the accompanying section). The most striking evidence of this basin, which the map by itself affords, is the glimpse one gets of the eastward underground continuation of the Ballachulish Core, revealed in the Windows of Etive [NN 160 510]. In the field there is plenty of parallel evidence. Here we need only recall how the outcrop of the Ballachulish Core terminates to the north-west on the Stob Bàn ridge, midway between Loch Leven and Ben Nevis, where it is seen to lie along the axis of a secondary (that is later) synform, the narrowed representative of the Glen Creran Pitch-Depression (p. 47).

The envelope rocks between the Appin and Ballachulish Recumbent Synclines are disposed in a recumbent anticlinal complex, closing to the north-west and gaping to the south-east. In the Loch Leven district the outstanding feature is the Kinlochleven Recumbent Anticline with its core of Eilde Quartzite (12) extending to Am Bodach and Garbh Bheinn

((Figure 14), p. 94). Its inverted limb gives us the Kinlochleven Inversion, reaching fully 4 miles across strike and abundantly demonstrated by upside-down current-bedding. The Kinlochleven Inversion may be interpreted as belonging, not only to the lower limb of the Kinlochleven Anticline, but also to the upper limb of the Appin Syncline, and thus supplies good evidence for essential recumbency of the latter. Otherwise the essential recumbency of the Appin Syncline is mainly inferred from the close analogy which this fold bears to the Ballachulish Syncline, the great horizontal extent of which is abundantly clear.

The fate of the Kinlochleven Inversion, when traced north-east past Meall a' Bfairich, and the relation between the Kinlochleven and the Stob Inversion at a lower structural level cannot be fully appreciated on evidence within Sheet 53 (p. 110).

## Slides

When attention is given to the map (Sheet 53) and the sections ((Figure 7), (Figure 14), pp. 48, 94), it is seen that the limbs of various recumbent folds are, in many instances, reduced by slides. Some of these slides are situated in the lower limbs of recumbent anticlines, and thus correspond with the thrusts so familiar in descriptions of mountain tectonics all over the world. To this category belongs the Sgòrr a' Choise Slide, S■ of (Figure 7); but, strange to say, the two most important slides of the district, the Fort William Slide of (Figure 14) and the Ballachulish Slide, B.S. of (Figure 7), both lie in the lower limbs of recumbent synclines, and are therefore lags. Necessarily associated with this predominance of lags is a quite unusual tendency for reversed successions to escape much of the thinning that has affected nearby unreversed successions. Contrast, for instance, the two representatives of the Leven Schists (7), thick above, and thin below the Ballachulish Limestone (6) as exposed in the Windows of Etive [NN 160 510] ((Figure 7), G, H). Still another peculiarity of the local geology is the regularity of the thinning affected along the slides. In the North-West Highlands thrusting has often produced a jumble of formations with *Schuppen Struktur* between a main thrust mass and its foundation. Here, however, such thinned-out remnants as persist along slides are almost always in correct stratigraphical sequence. Finally, the sliding is not, at any rate in all cases, accompanied by mylonisation and retrograde metamorphism. It probably occurred at a temperature that allowed of concurrent recrystallisation.

## Inversions

The very extensive inversions of Sheet 53 invite comment. It is difficult to suppose that inversions, miles in cross-strike extent, have developed as a result of wholesale rotation from the normal position, through the vertical, to the inverted position. It seems much more likely that these great inversions have been accomplished piecemeal, like the fore and aft inversion of the "track" of an advancing military "tank". In a paper entitled "Eddies in Mountain Structure" (Bailey 1938), it has been pointed out that this type of inversion might be expected to be coupled with development of extensive lags. The subject is very difficult, and is likely to be more fully understood when comparable structural associations have been identified and studied in other chains of folded mountains.

## Secondary folds

An obvious feature of the sections illustrating the structure of Sheet 53 is that earlier-formed, recumbent folds and slides have suffered in places extensive corrugation of isoclinal type. Secondary, meaning relatively late, synforms are conspicuous in Aonach Beag [NN 197 714], Stob Bàn [NN 146 654], Callert [NN 092 604] and Glen Creran [NN 030 480] (Figure 6)–(Figure 9). When these secondary folds started their existence the recumbent folds they affected had, very likely, already ceased to develop; but there is no reason to suppose that this marked a general sequence of events: recumbent folding may still have been in operation even close at hand.

The secondary synform of Stob Bàn and the two secondary synforms which unite with it west of Mam na Gualainn [NN 116 625] strike and pitch south-west. They produce detailed deflections of strike in the various formations, but they leave the general grain of the country running north-east — south-west. When, however, the augmented Stob Bàn Synform swells to give the great Glen Creran Pitch-Depression south of Loch Leven, the outcrops between Bridge of Coe [NN 104 589] and Kinlochleven and between Stob Mhic Mhartuin [NN 207 575] and Càrn Ghleann are swung through a right angle carrying their early foliation with them. Recumbent folding was probably continuing at the time this deflection was

developed, for otherwise it is difficult to account for the recumbent fold marked by the limestone core above Allt na Muidhe [NN 110 550] reaching south-west from Glen Coe at Achnacon [NN 119 566] to Meall Lighiche [NN 093 528].

## Secondary metamorphism

Metamorphism connected with the secondary Aonach Beag Synform has left its mark in conspicuous strain-slip cleavage seen for instance in the Glen Nevis gorge (p. 24). It also seems likely that the metamorphism of many small intrusions of the Glen Creran district is connected with the secondary Glen Creran Synform. These schistose rocks, judging from their field distribution (p. 69), must have been intruded after movement along the Ballachulish Slide had come to an end.

## Addendum

After this chapter had been written a paper by Weiss and McIntyre has shown the need for further explanation — see p. 22. E. B. B.

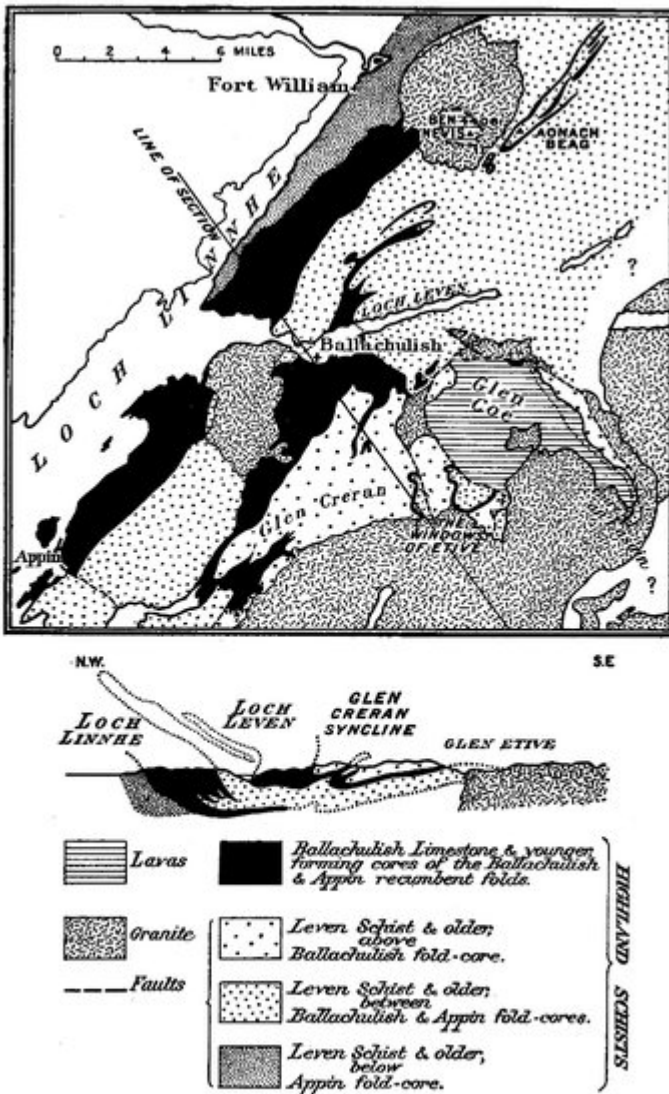


FIG. 17. Map and Section showing the structure of the Highland Schists and the positions of the cauldron-subsidences of Glen Coe and Ben Nevis

(Figure 17) Map and Section showing the structure of the Highland Schists and the positions of the cauldron-subsidences of Glen Coe and Ben Nevis.

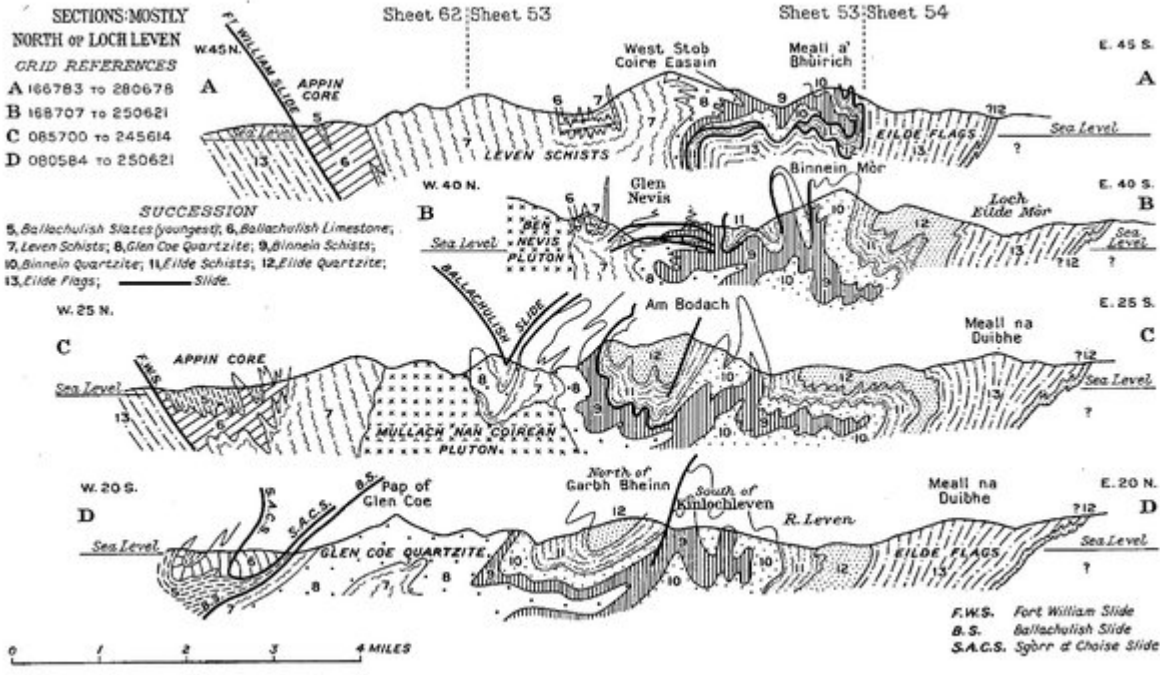


FIG. 14. Sections: mostly north of Loch Leven

(Figure 14) Sections: mostly north of Loch Leven A [NN 166 783] to [NN 280 678]; B [NN 168 707] to [NN 250 621]; C [NN 085 700] to [NN 245 614]; D [NN 080 584] to [NN 250 621].

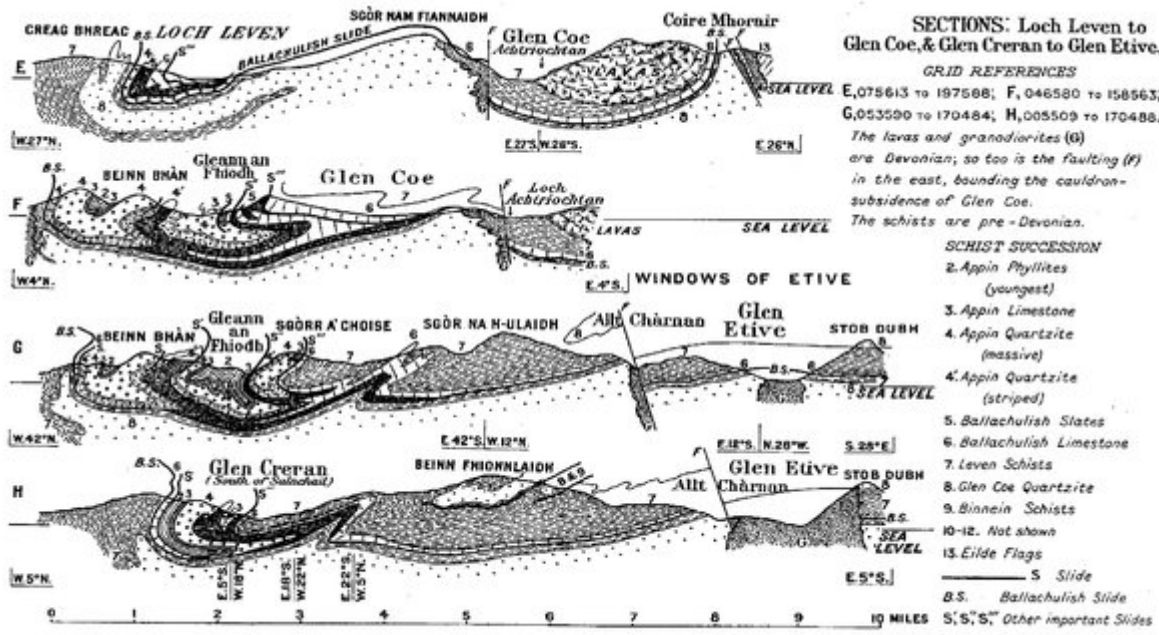


FIG. 7. Sections: Loch Leven to Glen Coe, and Glen Creran to Glen Etive

(Figure 7) Sections: Loch Leven to Glen Coe, and Glen Creran to Glen Etive. E, [NN 075 613] to [NN 197 588]; F, [NN 046 580] to [NN 158 563]; G, [NN 053 590] to [NN 170 484]; H, [NN 005 509] to [NN 170 488].

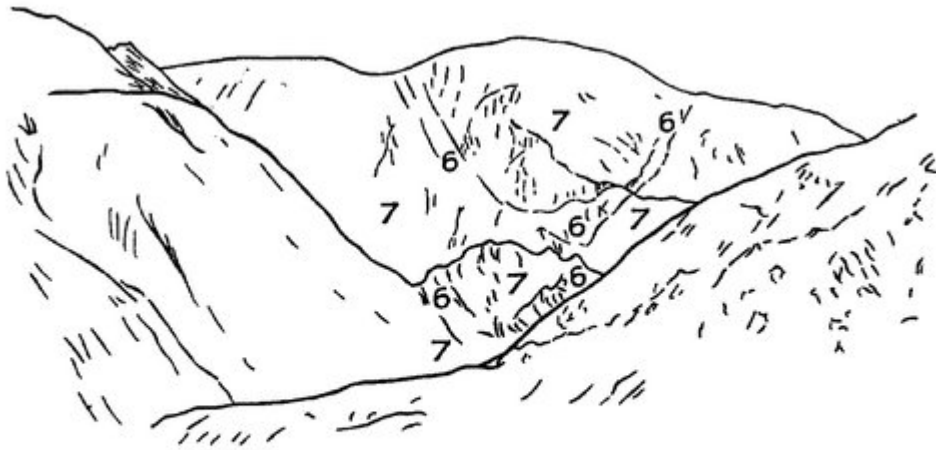


FIG. 6. View up Glen Nevis from Stob Bàn of Aonach Beag Synform

The Aonach Beag Core of Ballachulish Limestone (6), with Leven Schists (7) above and below, is refolded into a synform well seen in Aonach Beag (4060 ft) and also in Meall Cumhann in the middle distance

(Figure 6) View up Glen Nevis from Stob Bàn of Aonach Beag Synform. The Aonach Beag Core of Ballachulish Limestone (6), with Leven Schists (7) above and below, is refolded into a synform well seen in Aonach Beag (4060 ft) and also in Meall Cumhann [NN 178 697] in the middle distance.

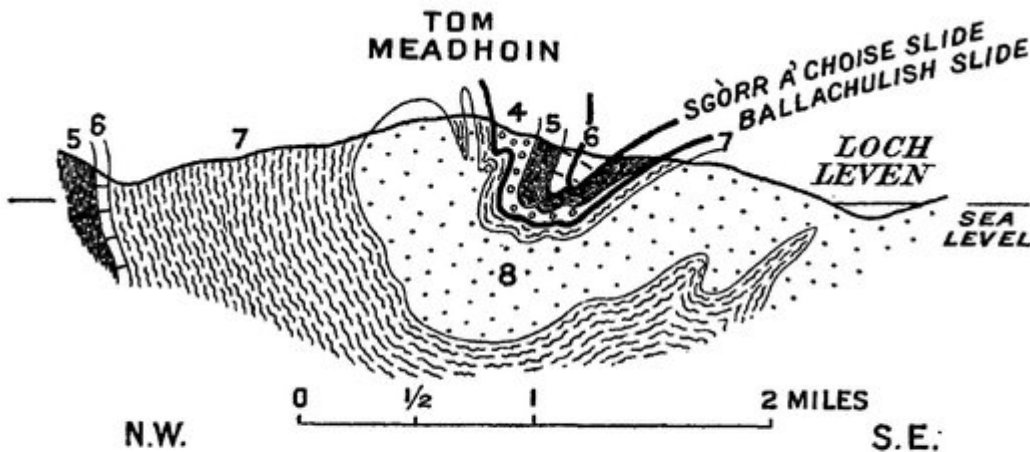


FIG. 9. Section across Fig. 8 showing the relation of the Ballachulish Slide to the Tom Meadhoin Antiform

4, Appin Quartzite (youngest); 5, Ballachulish Slates; 6, Ballachulish Limestone; 7, Leven Schists; 8, Glen Coe Quartzite

(Figure 9) Section across (Figure 8) showing the relation of the Ballachulish Slide to the Tom Meadhoin Antiform 4, Appin Quartzite (youngest); 5, Ballachulish Slates; 6, Ballachulish Limestone; 7, Leven Schists; 8, Glen Coe Quartzite.