14. *The BALLACHULISH FOLD near the HEAD of LOCH CRERAN*
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[PLATE XLV—GEOLOGICAL MAP.]

THE main features of the tectonics of the Loch Creran district have already been delineated in a paper dealing with a more extended region, and published in 1910 by the Geological Society of London.¹ The results of this earlier work, brought up to date, are epitomized in the map (p. 322), which will serve as an index of the relations of the district to neighbouring portions of Argyllshire and Inverness-shire.

The original mapping of lower Glen Creran was carried out by Mr. H. Kynaston and the late Mr. J. S. Grant Wilson. Before preparing the paper just cited, I visited the district on two or three occasions, once accompanying Mr. C. T. Clough, and at another time Mr. H. B. Maufe. Various alterations in the mapping were made as a result of these traverses, and it was found that the more essential structural features were readily determinable in the light of evidence furnished by the country to the north-east. At the same time, it was apparent from the first that anything like detailed knowledge could only be attained as a result of systematic re-examination, involving a considerable expenditure of time. A favourable opportunity for further work arose officially during the past season, when observations were made which seem worthy of record as an illustration of the complexity locally recognizable in the Highland Schists.

Two main difficulties are encountered in the field: there are many slides (fold-faults), so many, in fact, that the original stratigraphical sequence has to be accepted from neighbouring districts; there is also intense contact-alteration, extending for about a mile and three-quarters from the Cruachan Granite, and masking original differences in certain of the rock-groups.

The following is the stratigraphical sequence; but, whether it should be read upwards or downwards, is uncertain:—

9. Eilde Flags and (according to Mr. R. G. Carruthers) other groups.
8. Glen Coe Quartzite.
- 7'. Banded Series. } Leven Schists.
7. Pelitic Schists. }
6. Ballachulish Limestone.
5. Ballachulish Slates (black).

¹ E. B. Bailey, 'Requombent Folds in the Schists of the Scottish Highlands' Q. J. G. S. vol. lxvi, p. 586.

Map and section illustrating the tectonic structure of parts of Argyllshire and Inverness-shire.

	Lavas		Groups 1-6 of the table in the text, included in the Appin, Aonach Beag, and Ballachulish Cores.
	Granite		Groups 7-9 where they structurally overlie the Ballachulish Core.
	Faults		Groups 7-9 where they structurally intervene between the Ballachulish and Appin Cores.
			Groups 7-9 where they structurally underlie the Appin Core.

- 4'. Striped Series (where separated). } Appin Quartzite.
4. Pebbly Quartzite. }
3 & 2. Appin Limestones (3) and Appin Phyllites (2).
1. Cuil Bay Slates.¹

When they are mapped out in detail, it is found that Groups 2 to 6, taken together, have a continuous curving outcrop in the neighbourhood of Loch Creran, and that this outcrop separates an internal area of pelitic Leven Schists from an external area of much more quartzose banded rocks—also Leven Schists, but belonging to a different division of this group. The explanation of this has already been given, and is based upon the reading of sections at Loch Leven, Glen Coe, and Glen Etive, north and east of the district now described. It may be summarized as follows:—

The schists of this region are disposed in a great recumbent fold—the Ballachulish Fold—of which Groups 2 to 6 are taken as constituting the core—the Ballachulish Core. The pelitic Leven Schists of the interior outcrop overlie the Ballachulish Core, while the banded Leven Schists of the exterior outcrop underlie the same. The absence of a belt of pelitic Leven Schists immediately below the Ballachulish Core, corresponding to that above, is due to the presence of the Ballachulish Slide—a powerful fold-fault at the base of the Ballachulish Core. We must not, however, leave out of account an original difference of facies of the Leven Schists above and below the Ballachulish Core in the Loch Creran district: in the upper structural layer the Leven Schists are divisible into an immensely thick pelitic group, and a comparatively insignificant banded series; in the lower layer the pelitic group is still evidently thick, but the Banded Series seems to have swollen greatly at its expense, and now, so far at least as outcrop is concerned, is predominant. The banded part of the upper layer, and the pelitic part of the lower layer, it may be mentioned, both lie beyond the limits of the map (Pl. XLV).

Another fact determined on outside evidence is that the Ballachulish Fold gapes towards the north-west, and closes towards the south-east.

Two phenomena strikingly illustrated by the local evidence are:—

(i) The complexity of the slides affecting the Ballachulish Core, and the correlated quite exceptional occurrence of more groups towards the close of the fold, south-east of the River Creran, than towards the gape, north-west of the same.

(ii) The intense secondary refolding of the Ballachulish Fold, and the resultant sinuous outcrop of the Ballachulish Core.

These two phenomena will now be dealt with a little more in detail.

¹ Groups (1) & (9) do not occur in the Loch Creran district (Pl. XLV), but are met with in the wider region included in the index-map (p. 322). The uncertainty in regard to Group 9 does not affect the present district. Mr. Carruthers has given good reason for suspecting that various mica-schists, quartzites, and flags, which I have regarded as repetitions of the Leven Schists, Glen Coe Quartzite, and Eilde Flags, respectively, are stratigraphically distinct. A résumé of Mr. Carruthers's position has been published in the 'Summary of Progress for 1912' Mem. Geol. Surv. 1913, p. 52.

(1) The Slides.—Much the most important slide is the Ballachulish Slide, which has been traced for many miles through neighbouring districts. Locally, this slide has two branches, and such is the case where it crosses the northern margin of the map. Between the two branches at this point, there occur thick representatives of the Ballachulish Limestone (6) and Slates (5). It is well known that the Ballachulish Limestone, when intact, is roughly divisible into a dark-grey, or black, comparatively pure limestone, next the Ballachulish Slates, and a pale-grey, or cream-coloured, highly-impure calcareous division, next the Leven Schists. Of these two parts, only the pure black Limestone is preserved between the two branches of the Ballachulish Slide: the impure portion is cut out by the western, or lower, branch of the slide, which, as already stated, also eliminates the pelitic division of the Leven Schists (7). East of the eastern, or upper, branch of the Ballachulish Slide, occurs a folded complex of Appin Quartzite (4), Appin Limestone (3), and Appin Phyllites (2).

South of the stream which flows past the Post Office, only the lower branch of the Ballachulish Slide has been traced. Its effect is generally to bring the black Ballachulish Slates (5) into direct contact with the banded Leven Schists (7). Locally, as at the road beside Loch Creran, a thin band of dark Ballachulish Limestone (6) is interposed between the two.

On crossing Loch Creran, one can recognize at first only a single branch of the Ballachulish Slide. It brings Appin Quartzite (4) with sometimes a thin marginal layer of calc-silicate-hornfels, probably Appin Limestone (3), against banded Leven Schists (7).

A mile farther on there is a return to the conditions met with at the northern margin of the map. The Ballachulish Slide is double, and includes between its two branches black pure limestone and hornfelsed black slates, belonging respectively to the Ballachulish Limestone (6) and Slates (5). The two branches of the slide have been traced eastwards, until terminated by a powerful fault, which displaces their outcrop to Allt Buidhe. Both branches are found here, including between them an important belt of Ballachulish Limestone. This latter is, in places, black and still a limestone or marble; but elsewhere, especially where it turns northwards up hill from Allt Buidhe, it occurs as a thick mass of pale-greenish calc-silicate-hornfels, the baked representative of the impure calcareous division which normally separates the black limestone from the Leven Schists. The mapping of the two branches of the slide is only approximate in the vicinity of the stream, owing to the considerable cover of morainic material thereabouts. It is known, moreover, that in the more westerly exposures both Ballachulish Limestone and Appin Limestone occur, the former well seen immediately south of the stream, the latter actually in the bed of the same. The upper branch of the slide should, therefore, be drawn at this point in the middle

of what is now, for convenience, shown as a single limestone outcrop. As a result, the mapping on the two sides of the fault would be brought into closer agreement than at present. A revision, effected on these lines, would probably also indicate a less dentate outcrop for the slides, but the difference would merely involve changes of local import. The limestone (calc-silicate-hornfels, with some dark marble) in the eastern outcrops, exposed on the slopes north of Allt Buidhe, certainly belongs wholly to the Ballachulish Group.

After being obliterated for a little by the Cruachan Granite, the Ballachulish Slide reappears as a single structure. It swings round sharply to the west for a space, and its course is somewhat ill defined—owing to the difficulty of determining an exact line separating the contact-altered Striped Series (4') from the Banded Series (7'). The difficulty is not nearly so marked, however, as would have been the case nearer Loch Creran, for the Leven Schists at this point, although banded with quartzose ribs, are in large measure pelitic grey mica-schists, already indicating an approach to the facies of the group as developed in the structural layer overlying the Ballachulish Core. Beyond this westward turn, the Ballachulish Slide is very easily traced, as it separates Ballachulish Slates (5) from the comparatively pelitic Banded Series (7'). For a short distance, a thickness of some 40 feet of calc-silicate-hornfels, representing part of the Ballachulish Limestone (6), separates the two.

Before reaching the granite margin, on the slopes of Glen Ure, the Ballachulish Slates fail, and the Ballachulish Limestone of the upper limb of the great fold comes directly into contact with the Banded Series on the south.

A point of very considerable importance is the occurrence of pebbly Glen Coe Quartzite (8) in association with the banded Leven Schists (7') which occur here between the Ballachulish Slide and the Cruachan Granite. In the typical region the Glen Coe Quartzite is fine-grained; in the exposures now considered it is coarsely pebbly, with large grains of quartz and felspar. In this feature it resembles the Appin Quartzite (4); but, even so, there can be no possibility of mistaking the two rocks, for the Glen Coe Quartzite is interbanded with grey semipelitic material, towards its margins especially, and is linked inseparably with the banded Leven Schists—nor is it a case of mere mechanical intermingling, for many of the semipelitic beds carry quartz- and felspar-pebbles. It is interesting to recall that in Glen Strae, on the other side of the Cruachan Granite, a similar pebbly quartzite, in what is believed to be the same structural position with relation to the Ballachulish Slide, has already been assigned to the Glen Coe horizon.¹

Only one other slide need be mentioned specially in this summary. It has been known for some years to extend about 5 miles north

¹ E. B. Bailey & M. Macgregor 'The Glen Orchy Anticline' Q. J. G. S. vol. lxxviii (1912) p. 172.

of the district here described to Sgòrr a' Choise, near Ballachulish, and on this account may be termed the Sgòrr a' Choise Slide. In its northern extension it almost constantly lies some little way within the Ballachulish Core; but, for a short distance east of Allt Coire Mulrooney, it constitutes the actual boundary of the core bringing Ballachulish Slates (5) into contact with Leven Schists (7). South of Allt Coire Mulrooney, the Ballachulish Slates disappear on the north-west side of the slide, while the pale highly-impure portion of the Ballachulish Limestone is prominently developed on the south-east side. For a distance of over a mile south-west from Allt Coire Mulrooney, greatly thinned-out representatives of the Appin Quartzite (4) and Limestone (3) persist on the north-west side of the Sgòrr a' Choise Slide. The limestone is well exposed in Easan Diblidh, and in the burn at Fasnacloich; the quartzite is seen both here and in intermediate exposures. South-east of the Fasnacloich burn, the quartzite and limestone both fail, but a belt of Appin Phyllites (2) still continues, until it tapers out, half a mile farther on, in the heart of Ballachulish Slates (5). At this point the Sgòrr a' Choise Slide and the upper branch of the Ballachulish Slide run together, and are no longer traceable.

A glance at the map will show that the Ballachulish and the Sgòrr a' Choise Slides are complementary. Both cut out a considerable thickness of rock, the one in the lower, the other in the upper limb of the Ballachulish Fold. Where the Appin Phyllites (2) are bounded on each side by Ballachulish Slates (5), it is a fair presumption that the missing Appin Limestone (3) and Appin Quartzite (4) have been squeezed out to find a resting-place somewhere nearer the close of the fold. Even where the Ballachulish Slates are continuous, owing to the Sgòrr a' Choise Slide meeting the upper branch of the Ballachulish Slide, it seems necessary to suppose that an unknown amount of rock has been squeezed through the slates, and that these have come together again, effectually concealing the passage. It is in this manner that we can most readily account for the presence of Appin Quartzite, Limestones, and Phyllites in the outcrop of the Ballachulish Core west of the River Creran.

Two further observations may be recorded. By far the greater part of the Ballachulish Limestone of the upper limb of the Ballachulish Fold consists, in this district, of pale highly-impure calcareous schist (calc-silicate-hornfels east of the River Creran). This suggests that a branch of the Sgòrr a' Choise Slide may continue at or near the base of the limestone outcrop, cutting out the black pure portion which one expects to encounter next the Ballachulish Slates.

The other point is the occurrence of a narrow phyllitic outcrop, extending south from near the Post Office, for about three-quarters of a mile, in the heart of Ballachulish Limestone. It probably is merely a non-calcareous band interstratified in the limestone series, but it must be admitted that its characters recall those of some parts of the Appin Phyllites—a very heterogeneous group.

(2) The Refolding.—The secondary folding to which the Ballachulish Core has been subjected after its development is well illustrated in the sinuous outcrop of the core as shown on the map (Pl. XLV). Where the strike of the beds runs north-east and south-west, the dips are normally very steep and directed north-westwards. Even where the strike runs east and west, and the dips give an indication of the pitch of the secondary folding, they are still generally very high, and are directed more often towards the south than the north—the exact opposite of what might be expected. The pitch of the secondary folding is not, however, a very clearly-defined phenomenon, for there is a sudden swirl in the strike of the folding in the upper part of Allt Buidhe. All that can be said is that the secondary folding is very compressed, and of isoclinal type; and that the local evidence furnishes no clue as to which is the upper, and which the lower, side of the Ballachulish Core—a point which has been determined quite definitely, however, in neighbouring districts.

A feature of the geology noted already in previous publications¹ may be restated here. Between the River Creran and the Cruachan Granite, there are great numbers of small intrusions of basic igneous rock in the condition of hornblende-schist. They are distributed impartially on the two sides of the Ballachulish Slide, so that they must be of later date than the movement along this slide. Their metamorphic condition, however, shows that they have been affected by powerful movements; thus it seems probable that they antedate the secondary movements dealt with above.

EXPLANATION OF PLATE XLV.

Geological map of the country around the head of Loch Creran, on the scale of 2 inches to the mile, or 1:31,680.

¹ E. B. Bailey & M. Macgregor, Q. J. G. S. vol. lxxviii (1912) p. 178.