

Residential Excursion to Ben Lawers Synform and Ben Lui Fold

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Saturday 5th October 2013

Participants 20

Leaders: Dr. John Mendum (BGS) and Dr. Graham Leslie (BGS)

Report by *Ben Browne*

About twenty members both of The Geological Society of Glasgow and of The Open University Geological Society gathered at the car park at the head of Glen Ogle (NN558283). We were to be privileged to be led by Dr. John Mendrum and Dr. Graham Leslie both of the BGS over some ground covered by the forthcoming Killin Sheet of the BGS geological map of which they brought proof copies, having also previously distributed by email a comprehensive guide to our intended excursion. It was with regret that we learned that this might be the last such sheet to be printed by the BGS.

Objectives were explained. First to recognize the lithology of the three main stratigraphic units of the Argyll Group to be seen, viz:-Loch Tay Limestone, Ben Lui Schist, Ben Lawers Schist. Secondly to identify their way up by their stratigraphic sequence, lithological markers of their way up being rare due to metamorphism. Thirdly to understand the large scale folding of the Tay Nap, the Ben Lawers Synform (anticline) and the Ben Lui Fold and fourthly to consider the nature of the unconformity observed in Glen Lyon where much of the lower Argyll and upper Appin Group are missing above the right way up Grampian Group. For this unconformity previously described as the Iltay Boundary Slide we were to be offered a new interpretation as a primary stratigraphic unconformity.

Firstly we were given a graphic demonstration of the geometry of the large scale overturned Tay Nap and the secondary folds of the Ben Lawers Synform and of the Ben Lui Fold using the brilliant model of a folded length of carpet in which the way up indicators, pile is top, were far more obvious than in the rocks to be examined.

John Mendum demonstrates the folding of the inverted limb of the Tay Nap. Note the pile side, the young side, of the carpet is down except where he holds the Ben Lui Fold in his left hand and the lower limb of this fold, held by his fingers, is right way up. This fold youngs to his right, to the SSE, along its axial plane i.e. it faces SSE. The Ben Lawers synform is beneath his right elbow where the carpet sags. It is older in its core, so it is an anticline.



We were at that point in the Loch Tay Limestone of the inverted lower limb of the Tay Nap at the northern limit of its flat belt.

We followed the burn immediately behind the car park up hill to the east examining rocks mainly where well exposed below a series of waterfalls. At the first significant fall was a good exposure of typical prominently folded dark grey Loch Tay Limestone with striking calcareous weathering complicated by an injected sheet of red felsite and cut up by faulting. Further up the burn, past the power cables, was a massive amphibolite. The presence of this basic volcanic rock, common in the Loch Tay Limestone, was taken as an indicator of an extensional regime related to, the opening of the Iapetus Ocean. Proceeding structurally up the burn, but stratigraphically down the sequence, we encountered more pelitic bands and less limestone then at the first high fall we found a garnetiferous schist with muscovite and biotite having come through a transitional sequence from the Loch Tay Limestone into The Ben Lui Schist which we were informed was only a little older than the underlying limestone.

The next stop was at a recently reopened quarry on the left 500m up the minor road from north Loch Tayside towards Bridge of Balgie at NN621368. Three large boulders carefully placed at the start of a forest road illustrate the

local lithologies. One is of Loch Tay Limestone in which the quarry is excavated. One is of amphibolite, a metagabbro, found within the Loch Tay Limestone and in all probability responsible for the distinct horizontal ridges seen from that spot to run along the braes above the south shore of Loch Tay. The third was of garnetiferous Ben Lui Schist which we would be crossing next in proceeding up hill to the summit pass by Lochan nan Lairige. Examining the rock in the quarry it was found to dip NNW towards the Ben Lawers Synform to the north. We were encouraged to examine the fold hinges which being the least deformed zones stand the best chance of showing crenulation of a preserved former fabric. I must return to this task and persevere.

Further up the road just past the dam we pulled off left onto a short track at NN601394 leading down to the shore of Lochan nan Lairige. From here it was possible to appreciate the larger scale structure in the east slopes of Meall nan Tarmachan forming a steep hillside falling down to the western shore of the loch. The high central ground was formed of Ben Lawers Schist which despite being softer than the Ben Lui Schist is less jointed and so tends to form the higher ground but of rounded hills.

To the south could be seen the Ben Lui Schist dipping north and to the north the Ben Lui Schist dipping south thus defining the Ben Lawers Synform (anticline). The foreshore gave a close up view of the complex highly folded and varied lithology of the Ben Lawers Schist. It is dominantly calcareous semi elite with abundant amphibolite. The generations of folds are interpreted as recording the staged collision of irregular continental margins and of island arcs between 470 and 450Ma that is the Caledonian Orogeny.

A stop about two thirds of the way along the lochside road gave another good view of the slopes above the western shore topped by crags with clear vertical cleavage traces representing the hinge zone of the synform and the south dipping bedding in the lower crags to their north to be examined at the next stop.

At the north end of the loch we parked at NN595412 on a track leading down to the water. From the head of the loch we followed a fence up to the NW to a stile then left over irregular rising ground SW towards the face of the crags overlooking the northern end of the loch. The ground was formed at first of garnetiferous Ben Lui Schist first encountered in a loose block then in outcrop where quartzites were found interleaved with the schist. Further up to the SW good decimeter sized folds were found but the only convincing way up indicator was graded bedding but in a recently fallen block. However it became evident that the lithology was becoming progressively more heterogeneous with thinly bedded quartzite, garnet mica schist and calcareous schist with thin hornblende schist units. We were passing through a graded transition from the Ben Lui Schist to the Ben Lawers Schist first examined on the SE shore but now at a higher structural level on the northern limb of the synform.

We concluded the first day well pleased that we had achieved the first of our objectives in recognizing the three principle lithologies, the way up subject to a given stratigraphy, and the structure of one of the major secondary folds, the Ben Lawers Synform.

Day 2
Sunday 6 October 2013
Report by *Con Gillen*

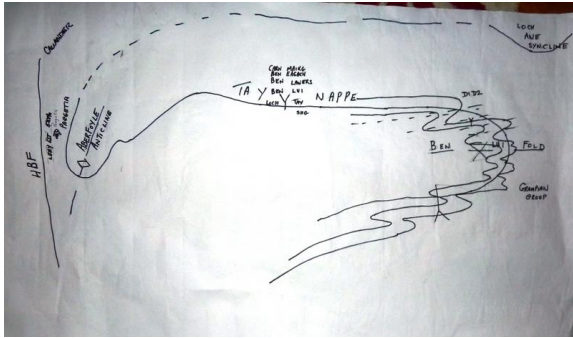
Day two started well, quite bright, cool breeze, high mist. After gathering, we went in convoy past yesterday's final stops at Lochan na Lairige and on down towards Glen Lyon. At our first stop in the Allt Bail a'Mhuilinn stream, beneath the impressive corrie in the Tarmachan Ridge, we were presented with fine outcrops of the Loch Tay Limestone, vertical, with two early fold phases, and easily recognised by its dark blue colour and coarse sugary texture.

Standing on the Loch Tay limestone



Upstream, we noted one of the amphibolites frequently associated with the Loch Tay Limestone, usually near the top of the succession and related to the 600 million-year-old Tayvallich Volcanic Formation, an important time-marker in

Dalradian geology. Also, we saw the transition beds (towards the Ben Lui Schist) of semi-pelites with garnets. The introduction to the day was a most instructive résumé of yesterday's geology.



Graham's drawing of the structures of the inverted limb of the Tay Nappe in this area of the Ben Lawers Synform and Ben Lui fold.

Emboldened and encouraged, we headed down valley to see something completely different: Grampian Group quartz-rich psammites with large muscovite flakes, right-way-up and dipping beneath the Loch Tay Limestone, and on the lower limb of the Ben Lui synform. We could easily see the evidence (in the pleasantly warm sunshine): original sedimentary slump folds, somewhat flattened and tightened up.

A lovely drive then followed, taking us into Glen Lyon, resplendent in autumn colours, peaceful and truly magical. In the bed of the River Lyon, beneath the slopes of Meall Ghaordaidh, with a nice example of a hanging valley, we found ourselves in Southern Highland Group rocks (garnet–biotite–hornblende schist or 'greenbeds' of possible volcanoclastic origin), in the hinge zone of the Ben Lui fold. On the hillside, these rocks are overlain by the Ben Lui Schists, separated by Loch Tay Limestone, recognised by the associated amphibolites which allow the structural repetitions to be traced easily.

Lunch beckoned. Our chosen spot was at the Giorra dam on Loch an Daimh. Having had our sandwiches, we went down to the lochside by the dam to have a look at the pale-weathering quartz-rich Glen Spean Subgroup, at the top of the Grampian Group (the lowest Dalradian group). Here we saw good convincing examples of slumping and cross-bedding, proving right-way-up. From the dam, we could see the target for the afternoon: a long walk along the lochside track to a prominent waterfall on the north shore (there was a boat, but we thought better of taking it and went on foot instead). On the way down, our civil engineering members pondered on the reasons for the dry spill way and empty stream bed: it seemed that entry and exit points were all in underground tunnels.

As we followed the track to the waterfall, a sudden short sharp shower of drizzle sprang up and took us by surprise. We had now gone up into the Lochaber Subgroup at the base of the Appin Group (above Grampian Group) – these are tightly folded and laminated semi-pelites (mica-rich) with hornblende schists. Some of the folds are really spectacular, with clear evidence of foliation being refolded, and with garnets in fold cores, all very photogenic.



Searching for garnets in Lochaber Subgroup

Excited, we carried on to the eagerly-awaited key locality at the waterfall. And it was a most unusual surprise: great jumbled blocks of quartz-rich rocks in a mass of more schistose material (Ben Lawers Schist).

This looked like a slump formation, possibly some sort of basal unconformity. . There was no evidence of high strain that would indicate a tectonic junction. Here, Ballachulish, Blair Atholl and Islay subgroups are all missing from the succession. After considerable discussion and debate here and at the lochside, it was concluded that the junction (Leven Schist against Ben Lawers Schist) represents onlap, a type of unconformity related to transgression, and not a result of shearing. The relationship is well seen on the new BGS 1:50k map of the area, and appears not to have been much commented upon in the past.

Disrupted blocks in a possible intra-Dalradian unconformity or slump



Ben Lawers and Ben Lui schists across Loch an Daimh, with fine corrie (looking south from the unconformity)

We then retraced our steps to the dam to collect our vehicles. At this point, Graham had to leave for work-related reasons, so we thanked both our leaders warmly for an extremely interesting, challenging and fulfilling two days, and for sharing the unpublished revised maps of the area. Those of us staying on until Monday then headed back to Killin for dinner (with copious helpings of peas, and tales of sailors' feet for some reason).

Day 3
Mon 7th Oct
Report by *M.Donnelly*

We said farewell to those of the group who were heading home, and nine of us, with leader John Mendum, drove along to the bridge over the River Dochart in Killin, and the Falls of Dochart which were in full flow and giving a spectacular display.



We hung over the wall admiring them and taking pictures. The rocks are part of the Southern Highland Group of the Dalradian; psammites with a lot of pelitic material, they were flaggy, mainly flat-lying, and dipping a little, approximately to the north. We went through an opening in the perimeter wall and made our way down onto them – not an easy task as they were soaking wet and more than a *little* slippery. They contained muscovite, biotite, and some garnets indicating lower amphibolite grade – higher than most of the Southern Highland Group which is usually of greenschist facies. There were also crenulations related to the Ben Lawers Syncline. The deformation is stronger here than in Glen Ogle but less than at Ben Lawers, and is Syn/Post D1 – D2.

There were numerous pot holes; these are post glacial and were gouged out by the current and loose rocks. We slithered around, some more than most, looking for ‘way up’ indicators with little success.....until we were on our way back onto the road when an eagle eye spotted an appropriate section showing clearly that the stratigraphy was, as hoped, upside down. Our leader explained that, near Bovain Farm in Glen Dochart, there had been a glacial lake which had broken through a terminal moraine dam; the vast torrent of water had eroded the landscape, and made a path for the waterfall.

Back in the cars we set off up the Auchlyne road along the north side of Glen Dochart where there were abundant glacial features – it was a typical flat bottomed U-shaped valley, with numerous moraine mounds and erratics. At our first stop we looked at the very full and very fast river, and the hillside, to determine the controls on the width and speed of river. Our next stop was beyond and west of the terminal moraine which had blocked the valley and produced the glacial lake at the end of the Loch Lomond Readvance.

This moraine was simply huge, and stretched the width of the valley; the river had finally broken through and found its present course. Again in the surrounding landscape, there were abundant glacial features, mostly moraine mounds, while to the west was an enormous flat expanse – the floor of the lake, now mostly farmland. We drove around this and stopped at the head of the lake, to view the huge extent of the lake from this different perspective.



Our leader pointed out Corrycharmaig just opposite at the top of a **big** hill...I was relieved that we had decided not to investigate this!! However, we had only a few minutes here in this single track road, as other traffic soon piled up behind us and we were forced to move on. We headed for Glen Ogle, where a couple more folk dropped out, and our depleted group set off for Loch Katrine.

We drove to the Trossachs Pier car park and climbed a few metres up to the crags at the south end, NN 4957 0710, where there were alternating psammites and pelites, with beds dipping fairly steeply, and an obvious cleavage dipping more steeply, both to the northwest. It was difficult to find good examples of graded bedding but we were able to satisfy ourselves that the beds were inverted. Looking more closely, we realised that there was a second cleavage

and set of axial fold planes, sub-parallel to bedding. Locally, open to tight northwest-verging minor F2 folds had deformed S1, and an associated secondary S2 spaced cleavage, whose spacing ranged from c. 5mm to several centimetres, had developed. These outcrops had originally been turbidites; the coarser, quartz-rich arenite beds and the finer more argillaceous ones were suitably contrasted by the varying intensity and style of both S1 and S2. The rocks belonged to lowest stratigraphical part of the Ben Ledi Grit Formation; the more dominant effects are D2 as this occurred at deeper structural levels.

We then walked to the loch and the road alongside it, where a selection of road cuts traverse stratigraphically downwards from the Ben Ledi Grit Formation through the thicker beds of the more arenaceous Creag Innich Sandstone Formation, with gritty to conglomeratic horizons, and into the Loch Katrine Volcaniclastic Formation. Our first stop was just past the kiosk where psammites of the Ben Ledi Grit Formation dipped steeply north-northwest, and we could examine S1 and F2 / S2 relationships. About a hundred metres further on, we were led from the road into a wooded area where there were two or three *huge* boulders lying on the grass - each about the size of a caravan. We came to a particular one - about 3 metres high and 5 metres in diameter. It had the same lithologies and bedding/cleavage relationships as the previous outcrops, but we were urged to walk around it.....when we realised that it was the complete nose of a fold!! Very impressive!! Unfortunately the lack of space among the trees and the poor light did not permit a photograph which would do justice to this enormous 'lump of mountain'! We were, however, able to examine in detail the axial planes, lineations and various features therein.

We continued along the lochside, stopping at each road cut; some were excellent, with good geological information, while others were not, because of their attitude and/or state of weathering. In the gritty, thickly bedded arenites of the Creag Innich Sandstone Formation, bedding, S1 and S2 were clear, as well as good examples of S1 folded by F2. Around (NN 4950 0765), we found obvious bedding, dipping gently to the north-northeast in interbedded thin pelites and coarse-grained arenites, with S1 orientated at a high angle to bedding. We were clearly in an F1 fold hinge at this point, although there was some superimposed D2 deformation, and minor F2 folding with cleavage development. Structurally all these outcrops, near and around Loch Katrine, lie to the south-east of the hinge zone of the Ben Vane Synform, on the common limb between the hinge zones of the latter and the Ben Ledi Antiform. The beds are generally inverted, but if corrected for the Downbend they would form part of a 'right way up' fold limb facing south-east within the overall hinge zone of the Tay Nappe.

We turned east away from the loch for a little way, through the woods near the Glen Finlas Reservoir outlet, and came to a former quarry whose face exposed typical volcaniclastic arenites ('Green Beds') of the Loch Katrine Volcaniclastic Formation. I was delighted as I had been looking out for 'Green Beds' for most of the weekend!! The rocks were massive with a distinct, soft bluish green-grey colour due to their significant chlorite and epidote content. They also contained beautiful pyrite crystals. Although we could identify bedding, evidence for the S1 and S2 cleavages was noticeably absent. The presence of these volcaniclastic rocks indicate a deepening of the basin, thinning of the crust and the early attempts of the Iapetus to open.

We had had a wonderful day; we returned to the cars and thanked John profusely for his time and expertise, and for all the information that he had imparted throughout the weekend, before saying our 'goodbyes' and heading for home.