Residential Excursion to KNAPDALE:

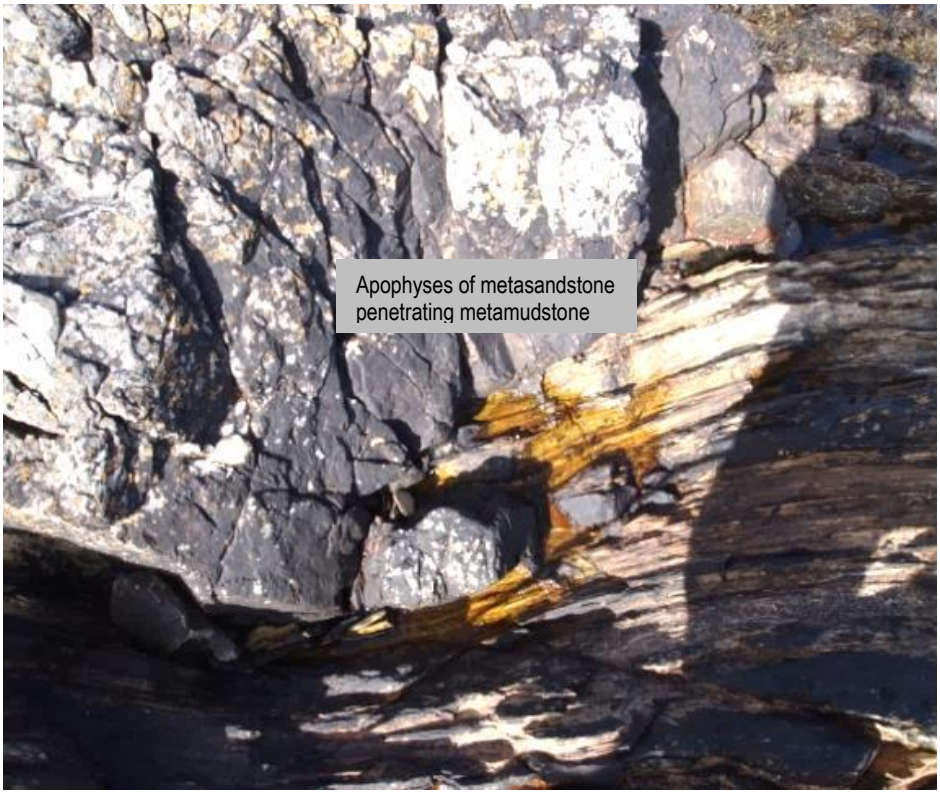
Saturday 16th - Monday 18th April 2016
Leaders: Iain Allison & Roger Anderton Participants 20
Reports by: David Webster, Seonaid Leishman, Bill Gray

Saturday 16th April 2016
Report by David Webster

The entourage left the Stag Hotel in Lochgilphead in a fleet of cars. First stop was at Kilmory Chapel where Roger gave us a tour of the building stones and grave slabs inside. The geological interest was centred around the use of slabs of green schistose metabasite (which used to be called epidiorite) for lintels and the carved grave slabs. He noted that the use of the metabasite for building was supplanted by easier to work Carboniferous sandstone around 1840 so any building with green lintels would be older than that. However the main aim of the day was to make a traverse through part of the Late Neoproterozoic Dalradian succession, here comprising the Ardrishaig Phyllites and the overlying Crinan Grit Formations in the Kilmory Bay syncline. But before we got the see these rocks we had a brief stop to look at the coastal geomorphology.

Locality 1 [NR 70062 74200] Once on the coastal section Roger pointed out a 50m wide rock platform just above present sea level and a 10m high backing cliff. The same platform is found throughout this part of western Scotland and it is now believed that both the platform and the cliff were cut quite rapidly (maybe in 500 years) by intense periglacial freeze/thaw weathering during a brief cold spell at the time of the Loch Lomond Readvance about 11-10ka. This so-called 'Main Rock Platform' is slightly tilted by subsequent isostatic uplift, here it is a few metres above sea level whereas it is +13m near Oban to the NE and disappears below sea-level further SW in Islay.

Locality 2 [NR 70011 74038] At the small sandy bay called Port Ban we were asked to examine the sedimentary section in the Ardrishaig Phyllite Formation and discuss our findings. The main features here were an abrupt planar contact (striking about N30 and dipping quite steeply NW) between laminated metamudstones with thin fine-grained metasandstones and a much thicker more massive metasandstone. The latter appeared to be about 3-4m thick and was overlain by more laminated brown and grey metamudstones, however, the top contact caused much puzzlement as it appeared to suddenly stop when traced laterally away from the centre of the locality and end abruptly at more sandstones. The overlying sequence of metamudstones was about 50-80 m or so thick, was quite deformed in many places and appeared to contain a number of discontinuous 'pods' of metasandstone maybe 2-5m thick and 10-20m in length.

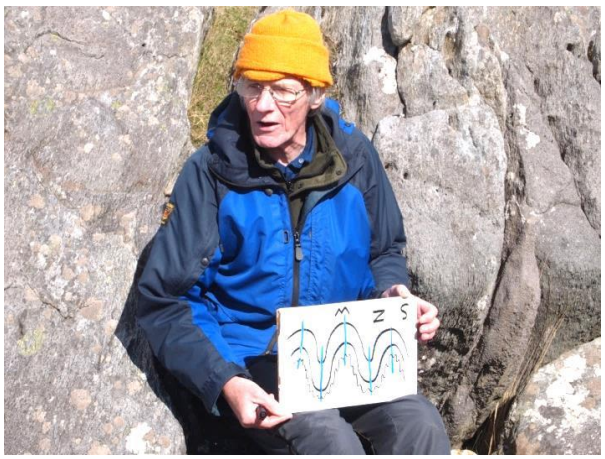


There were a number of necks of sandstone that appeared to connect the various sand bodies and on careful examination it could be seen that the base of the 'pods' were irregular, there were several examples of sandstone apophyses and - although shaped like a channel feature – it was better interpreted as an intrusive feature. Roger went on to explain that wet sand can behave like a fluid and can be injected into surrounding sediments in a similar way to igneous rocks. He thus interprets this sequence as a gigantic injection structure with all the pods connected by a series of feeder dykes from the main basal sandstone layer, which is now much thinned. He envisages the original sand body to be sand-bar comprised of quite well sorted sand which was buried by about 80-100m of mud and then fluidized by a major shock such as an earthquake which caused the liquid sand to inject rapidly upwards and outwards to form a series of interconnected dykes and irregular sill-like bodies in the overlying mudstone sequence.

Locality 3 [NR 70041 74340] We walked N for about 300m towards the sands of Kilmory Bay and on the S side of the bay came across an extensive area of interbedded metasandstones and metamudstones. The former were about 0.5 – 2m in thickness, f-m grained and showed some grading but were mostly quite featureless. They have been interpreted as turbidites and assigned to the Crinan Grit Formation. They represent much deeper water sedimentation, probably fault controlled. It is conceivable that the fault which produced the earthquake that caused all the dyke

injection at Locality 1 was an active syn-depositional fault that was one of a series that resulted in the rapid basin deepening. The main feature of the locality was, however, some spectacular folding with a wavelength of several metres with some smaller-scale parasitic folding. The folds were generally markedly non-cylindrical and mainly plunged quite steeply NE. Ian explained that thicker more competent layers tend to buckle with a long wavelength and thinner interbedded less competent layers in the same area exhibit much shorter wavelength buckling. Ian drew a useful diagram for us which showed how bedding and cleavage are related in these types of folds and further explained that if the bedding and cleavage on a fold limb was 'Z'-shaped then the axial plane of an anticline was likely to be to the observers right and if 'S'-shaped the anticline axis should be to the left. In the fold hinge the pattern would more likely be 'M' or 'W'-shaped as the cleavage became more axial planar. Many good examples of these shapes and configurations were found and we ended the stay at this locality with Ian leading a 'conga-line' along a 2m wide folded turbidite!

Ben examining one of the folds



Iain explaining the meaning of M, Z and S

Leading the conga line over a folded sandstone bed!

Locality 4 [NR 69683 74653] to [NR 69728 75128] We crossed the sandy bay (going over several fold axes forming the Kilmory Bay syncline) and for the next 500 m or so stopped in several places along the rock platform to examine the mainly SE dipping Crinan Grits on the NE limb of the Kilmory Bay syncline. Some more small-scale folds were encountered with spaced cleavage in the sandstones and tighter closer cleavage in the more mud-rich layers. Some interesting carbonate concretions were also found, mainly interpreted to be formed relatively soon after burial but some [NR 69673 74887] appeared to be synmetamorphic and demonstrating that the carbonate-rich metamorphic fluid must have flowed parallel to cleavage in the direction of maximum permeability.

These are quite common locally and have been mistaken for pre-historic ‘ring’ markings.

A 3m thick brown fine-grained unit which was sub-vertical and NE-SW trending was encountered [NR 69678 74994]. It had a persistent strike-parallel foliation and an apparent carbonate weathering appearance which was more intense along NW side. The central and SE parts had a more-spaced foliation and contained white crystals with the appearance of feldspar phenocrysts. It was thought to be an altered metabasite sill with its base on the more foliated side. Studies of these sills locally has revealed that the original pyroxene+plagioclase mineralogy was altered to amphibole + epidote + chlorite + albite during greenschist metamorphism and that in the parts of the sills (mainly the base) more exposed to infiltrating hot metamorphic fluids the amphibole and epidote were further broken down into quartz, calcite and more chlorite. The abundant chlorite is causing the foliation and the metamorphic calcite is weathering out. It is possible that the white feldspar crystals are albite porphyroblasts cored by remnant original igneous phenocrysts of more calcic plagioclase.

Locality 5 [NR 69778 75423] Another spectacular section in steeply dipping Crinan Grits.

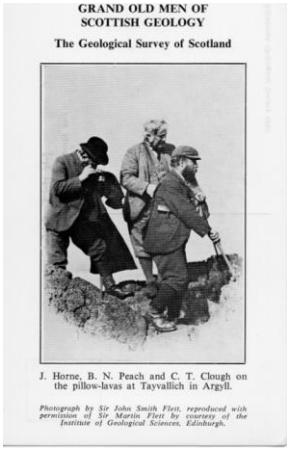
Locality 5: Channelised turbidites in the Crinan Grits

Here the metasandstones are much more conglomeratic and after careful examination we could see that several of the beds thickened along strike and that a channel-like base could be observed. The conglomeratic parts of the beds were better developed towards the axis of the channel body which was probably about 5-6m deep and typical of submarine fan systems like this one.

We then walked up and over the hill eastwards back to Kilmory and hence back to Lochgilphead where later that evening we all squeezed into the Smiddy Bistro for a fantastic meal and a well-earned drink or three.

Sunday 17th April 2016
Report by Seonaid Leishman

Kiells Peninsula


GRAND OLD MEN OF SCOTTISH GEOLOGY

The Geological Survey of Scotland

J. Horne, B. N. Peach and C. T. Clough on the pillow-lavas at Tayvallich in Argyll.

Photograph by Sir John Smith Flett, reproduced with permission of Sir Martin Flett by courtesy of the Institute of Geological Sciences, Edinburgh.

Today the plan is to study the top stratigraphical section of the Tayvallich subgroup exposed on the Tayvallich peninsula. It was on the west coast (An Aird) that Peach made the historic and important discovery of volcanics with pillow lavas when mapping for the Geological Survey in 1911.

Not only did these metabasites establish the sequence of the Argyll Group, but eventually assisted with dating the Dalradian. Throughout North Knapdale the metabasites and Crinan Grits form the higher ground.

We park in a small limestone quarry on the road alongside Linne Mhuirich where the rare grassland allows farming and settlements. At Barrahormid Farm (NR 716 838) we walk up the track heading for the western coast line and Port nan Clach Cruin. Just as we pass through a steep sided narrow passage in the top of one of the ridges of high ground, the farmer approaches and says he does not want such a big group on his land because of lambing. After some debate we reluctantly agree and return back to the road.

The change of plan is not a problem. Rubha na Cille at the southernmost tip of the Peninsula is full of interest. It lies on the steeply dipping/vertical NW limb of the Tayvallich syncline and contains historic geological exposures…., carved stones in the ancient Keills chapel…..evidence of sea floor spreading…. and the much debated Loch na Cille Boulder Bed. We are spoiled for choice.

Iain's diagrammatic Excursion Handout clearly identifies the different episodes of crustal stretching and thinning associated with opening of the Iapetus Ocean. The molten magma sometimes formed sills by hydraulic jacking up of soft sediment not yet lithified. This magma therefore never reached the surface. With mild metamorphism this became the Knapdale metabasite.

Having parked near Keilmore Chapel (NR 693 806) we walk south to the Main Rock Platform and start on the eastern shore of Rubha na Cille. By continuing SSW along strike we will be in the core and going up stratigraphy towards the nose of the syncline (To the west we will go down stratigraphy)

The first locality (NR 690 842) is black organic-rich micritic metalimestone with clear carious solution weathering. The gravel, sand and mud grains are clues to the origin of the sediment. The micrite pebbles are squashed and rotated perpendicular to the strain caused by shortening and extension. Some undeformed clasts indicate the original size of matrix grains.

Next stop is the famous Rhu na Cille 'boulder bed' (NR 687 799). The Scottish Journal of Geology Guide to the Dalradian Rocks of the South-west Highlands (published 1977) notes that the Survey suggested its origin as tectonic crushing or a conglomeratic mud-flow. Later proposals included dacite**,** porphorytic lava flow, hyaloclastic breccia or even tillite. The volcanics are accurately dated at 595-601 Ma. which does not match any tillite date. Roger intends to persuade us that …..

i) the total sequence fines up from volcano-clastic to ash to pillows.
ii) the feldspar crystals in this bed are important diagnostics. If they are fragmented they must have been *injected* at one stage.
iii) The 'boulder bed' is re-worked volcanic debris. It post-dates the actual volcanics so formed from material eroded *from* volcanics and washed in as ash or 'crystal tuff'. It is therefore a sediment.
iv) varied size of clasts could mean a moving flow in a delta.

At NR 688 799 kink folds are beautifully exposed in a sequence of metamudstones. Iain explains they are caused by buckling of one layer with a strong planar fabric in order to achieve shortening. Why only on this part of this layer? Local pressure means slippage and de-

coupling of the other layers to allow shortening of the cleavage fabric. The shortening could have come from an igneous intrusion, evidence being a local lens-shaped (basaltic?) unit.

Kink Folds

Finally we arrive at the Pillows on the west coast of Rubha na Cille (NR 686 798)
I should explain here that on this trip we are being galvanised by a group of generous geologists! Not only Iain and Roger, but Brian Bell our past President, and Con Gillen lately of Edinburgh University. The debates and discussions are many and it is not possible to attend to them all!

Pillow with epidote

In the pillow field (we work out way- up because of their shape. The pillows have a curved top, a flatter base and sag into depressions giving a younging direction to the ESE. This confirms that the peninsula is on the NW limb of the Tayvallich syncline. Some show pillow rind – quenched glass (palagonite) – which also fills cavities. We find some good crystals of epidote exhibiting the typical pistachio green colour. Whereupon Iain produces a bag of nuts for us to munch! Epidote could be related to spilitic metasomatism (interaction with seawater resulting in Ca-plagioclase changing to albite and releasing Ca).

There is then a discussion between Roger and Brian (who have their heads <u>on</u> the pillows…). Was the eruption on the sea bed and into water OR injected into unconsolidated sediments – perhaps due to tectonics. Are we seeing hyaloclastite or peperite?

Heads down!

And the conclusion? Context is everything!

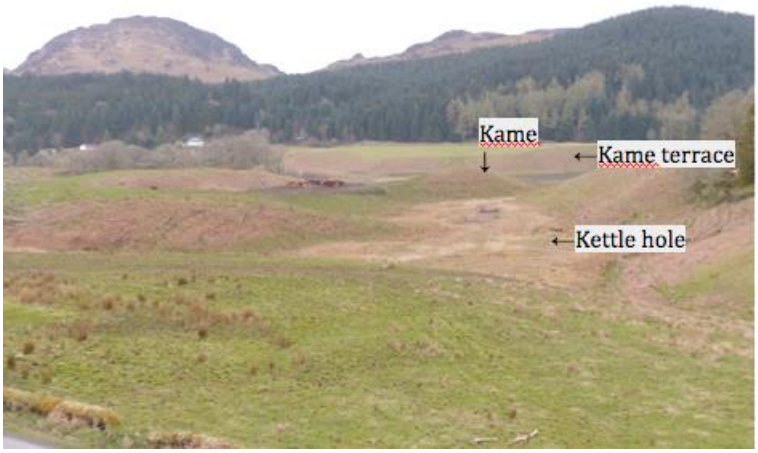
It has been cold and wet most of the day so we make our way to the shelter of the chapel at Keillmore via the peri-glacial Sea Stacks on the Main Rock Platform which had been a skerry at the time of the Loch Lomond Readvance 12 kya.

Monday 18th April 2016

Report by Bill Gray

Today saw a marked change in both our meteorological and geologic circumstances. In contrast to yesterday's cold and wet weather, we now enjoyed bright sunshine, albeit with a fresh west wind. Our geologic focus moved forward by 600 million years, from the Argyll group of the Dalradian to the late Pleistocene of the Quaternary. We had the privilege of spending our last morning doing a tour around several of the prime Quaternary localities in the Kilmartin area under the expert guidance of Roger Anderton.

We travelled between the various localities by car, using as few cars as possible. Our first stop was on the B840 just east of the village of Ford (grid reference NM 878 038). From a rise to the south of the road we had a marvellous panoramic view of kame and kettle topography, formed at around 12 ka, near the end of the last glacial of the Pleistocene (the Devensian).



Kame and kettle topography near Ford. *Bill Gray*

This locality is just to the west of the nose of Loch Awe, and we were again in the Loch Awe Syncline. We were near the terminus of the glacier that had filled Loch Awe, and the landforms that we saw were created as this glacier retreated. Roger described how, during the advance of the glacier, the direction of the ice flow was determined by the topography of the land surface. Of particular note was a kame terrace, a collapse structure formed from the moraine deposited against the sloping country rock at the margin of the ice sheet. This moraine collapsed when the ice that had formerly supported it melted. The kame and kettle moraine in this area is around 1 km thick. We now drove back westwards along the B840 to our next locality, passing some more kames and kettle holes, the latter now occupied by lochans, on our left (south). The second locality (NM 863 017) was a fluvial terrace adjacent to a minor road at Glennan, 2.5 km to the southwest of the first locality. We looked north to another kame and kettle vista, dominated by a lochan in the largest of the kettle holes. This point marked the southern extremity of the Loch Awe glacier, and the end of the kame and kettle topography. We were now introduced to the concept of a sandur, which is an Icelandic term for a glacial outwash plain. A sandur is formed beyond the terminal moraine of a glacier by sheets of sand and gravel carried by the meltwater pouring from the receding glacier. The land to our left, all the way southwest to the sea, was basically a huge sandur. If sea level falls, rivers cut down through a sandur to form lower terraces. However, if the sea level rises, everything is filled in and terraces are obliterated. We would see evidence for progressively lower terraces later at Kilmartin. At the present stop we also visited a gravel bed beside a stream, which displayed ripple marks at the bottom and cross-bedding at the top. This bed was possibly formed when outwash from the retreating glacier filled a void beside the ice.

The view to the south from the car park at Kilmartin. The high terrace can be seen to the left, while the middle and lowest terraces are to the right. (The lowest has a cairn on it.) The flat area in the centre of the picture is the modern flood plain. *Bill Gray*

Our next stop was at the car park beside the museum at Kilmartin (NR 835 988), a further 3.5 km to the southwest. This is situated on the topmost of three terraces that were formed from glacial outwash towards the end of the Pleistocene. From here we had a glorious view to the southwest down Kilmartin Valley. This top terrace is a legacy of the sand and gravel sandur that originally filled the whole valley. The lower terraces were formed when the sea level fell in stages as the result of the isostatic rebound at the end of the Pleistocene. From our vantage point we could see both of the lower terraces and the present day flood plain below. The terraces slope by 5 m/ km towards the southwest, becoming horizontal at their southwest ends, which correspond to where

the sandur plain reached sea level. The sand and gravel washed out from the valley as the lower terraces were formed were dumped downstream to create the extensive area of raised bog that now forms the Moine Mhor SSSI. The terraces were formed over a period spanning two millennia. The high terrace was formed at around 14 ka, when sea level was 36 m above the present level, and the lowest terrace was formed at 12 ka, when sea level was 9 m above the present level. The kame and kettle topography that we saw earlier and the main rock platform were also formed at this time.

The high terrace can be seen to the left, while the middle and lowest terraces are to the right. (The lowest has a cairn on it.) The flat area in the centre of the picture is the modern flood plain.
Bill Gray

We now started making tracks back to Lochgilphead, but made three short stops on our way. The first was at Poltalloch (NR 816 966), where we had a brief look at a shingle ridge on the top terrace. The second was in Moine Mhor, where we had a brief chance to absorb the atmosphere of this special area before going on across the 13 m post-glacial raised beach, which was formed between 8 ka and 6 ka, to our final stop (NR 840 944). Here we stood on the raised beach, with the main rock platform (formed at 12 ka) 2 m below our feet, and looked across the A816 at a rock cliff formed at the same time as the rock platform.
We now returned to the Stag Hotel to join our cars for the journey home, full of the joys of spring and enthusiasm for the Dalradian, the Quaternary and the Knapdale area in general