Quaternary Newsletter
Reports: Meetings
QRA Quaternary Research Association

QRA FIELD MEETING: THE QUATERNARY OF WESTER ROSS 18TH–21ST MAY 2023

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Introduction

The QRA Field Meeting was held between 18th and 21st May 2023 in Wester Ross and based in Ullapool and was led by **Colin Ballantyne**. The meeting's aims were to: consider the evidence for the Wester Ross Readvance (WRR); reassess Loch Lomond Stadial glacial landsystems, focussing specifically on the potential signatures of former surging glaciers; investigate the periglacial and aeolian sediments and landforms of An Teallach; and to review the record of sea-level change in the region. The group assembled at the Macphail Centre on the evening of the 18th of May for initial introductions and finalisation of logistics and to hear introductory presentations on the various field meeting themes by **Colin Ballantyne, Doug Benn, Tom Bradwell** and **Alistair Dawson**.

Day one Friday 19th May

Excursions 1 and 2 ran concurrently and participants selected their preference.

Excursion 1

A small group of QRA members joined **Colin Ballantyne** on a 14 km trek around An Teallach. The name translates as 'the forge', because of the way it catches the clouds coming in from the sea. The mountain had been catching our interest too, as we had been able to see its distinctive peaks for most of the journey up from Inverness.

Starting from the Corrie Hallie car park the group walked up valley and encountered Cambrian Quartzite. This white, blocky lithology is an important feature of the area, as it hugely contrasts with the underlying Torridonian sandstone, and the quartzite escarpment also governs the route of small valley glaciers that flowed from corries on the eastern face of An Teallach. Continuing west up towards a prominent terminal moraine we encountered a number of striations, excellently preserved on the quartzite, and indicative of local ice flowing northeast. There were also other textbook indicators of glacial erosion in the form of roches moutonnées, whalebacks and chattermarks.

Figure 1. Group photo *taken by Andy Russell* (Newcastle).

Figure 2. Colin Ballantyne points out features of interest on the way to An Teallach *(photo by Andy Russell)*.

Approaching the eastern face of Glas Mheall Liath, we were able to see that the top 200 m of the peak was made up of the lighter coloured quartzite rocks, while the lower potions were red Torridonian sandstone. The contact between the two lithologies is obscured by a mantle of quartzite mass-movement deposits up to half a metre thick. The terminal moraine when we arrived already had some other visitors, some deer, who were also presumably impressed by its steep distal face over 20 m high.

Pausing briefly on the moraine crest to catch our breath and take some photos of the Moine Thrust, we carried on northwards to Coire a' Mhuillin. On the way we encountered some more, smaller moraines, probably fed by rockfall inputs from a failure scar on the NE face of Glas Mheall Mòr. Coire a' Mhuillin when we arrived was striking, the most distinctive feature was the large terminal moraine that crossed the entire valley. Just as striking were the lack of any other clear glacial features: the valley sides were mantled in relict and active scree slopes, there was no well-developed cirque and the ground down valley of the moraine was covered in a thin, patchy layer of till.

After a quick lunch on the moraine, we climbed quickly up and out of the valley, starting to transition onto the high plateau. Before we reached the plateau an area of weakly-stratified, poorly sorted sands grabbed our attention. Colin revealed that these were the high-altitude niveo-aeolian sands that he had introduced the previous evening. These has been dated with OSL to have formed during the Holocene, with a notable peak in sedimentation rates during the height of the Little Ice Age (Ballantyne and Morrocco, 2006).

Onto the plateau at c. 750 m altitude, we were rewarded by spectacular views to the north and west of Little Loch Broom and the Summer Isles. Closer at hand we could see into Coire Mòr An Teallach, and smaller adjacent valleys. The plateau itself was composed of low-relief blockfield, interspersed by summit tors. Thinking that this was a classic periglacial landscape, we were amazed to have presented to us an extensive area of Cambrian quartzite erratics, forming a sharp boundary with the Torridonian sandstone plateau, indicating that active ice had over-ridden the plateau. The final surprise for us was walking off the plateau and over laterally extensive steps in the blockfield with grassy risers: turf-bank terraces. These were created by downslope debris creep, with vegetation possibly developing in the shelter of the terraces.

Descending north from the plateau via Garbh Coire Beag we encountered terminal moraines from local Younger Dryas glaciers cutting-across lateral moraines from ice that occupied Little Loch Broom during the Wester Ross re-advance. Despite the impressive work dating moraine chronologies in the area, it was

Figure 3. The group view the quartzite erratic belt at 720 m on An Teallach *(Photo by Colin Ballantyne)*.

apparent that a great deal more remained to be done. By this stage of the day the steep slopes were starting to affect the company, with knees, backs and legs complaining, even amongst the younger members. Our attention remained captivated though, the Airdeasaidh waterfalls being a final sight reminding us that tired legs were a price worth paying.

Excursion 2

The focus of this excursion was to view glacial landsystems associated with the Loch Lomond Readvance (LLR), especially the evidence for possible former glacier surges and was led by **Doug Benn**. The first stop was at the key Lateglacial site of Loch Droma, on opportunistic find by Kirk and Godwin (1963) made possible by the construction of a dam in 1958. Overlying the local till at this site was a sequence of sands and silts, the latter appearing rhythmically bedded (possibly varved) and sub-divided into three sub-units based on organic content and/or colour. Comparison of the pollen from the silts with other Scottish Lateglacial sites suggested that this was a Lateglacial (Windermere) Interstade deposit, tentatively supported by a radiocarbon age of 12.8 ^{14}C yrs BP which is likely affected by hard water error (cf. Pennington *et al.* 1972). A Lateglacial age for the deposits is critical to the debate on whether or not this area remained ice free through the Lateglacial Interstade, a subject touched upon by **Tom Bradwell**, who highlighted that the antiquity of the previous work at the site and the problematic radiocarbon age should prompt a re-appraisal. The issue of the stratigraphy now being covered by the dam prompted a number of coring specialists (and indeed non-specialists) in the group to seriously consider a re-visit with a boat/raft and coring equipment!

Immediately over the interfluve lay our next site, the unusual moraine of Loch a' Gharbhrain. The broad, multi-ridged moraine fronts a loch on the floor of the trough that drains the southwest sector of the Beinn Dearg massif. Not only is this the largest Loch Lomond Readvance end moraine in Wester Ross, it also constitutes one of the very few glacitectonic hill-hole pairs related to the readvance in Scotland. Such landforms have been proposed as diagnostic of surging snouts but at only one other site in Scotland, the Lake of Menteith, has a hill-hole pair been used to infer Loch Lomond Stade surging (Evans and Wilson 2006). **Doug Benn** pointed out that further surge diagnostic features, possible zig-zag eskers or crevasse infills, lie up valley from Loch Gharbhrain. He also predicted that further examples of similar surge landsystems will likely be recognised in the Loch Lomond Readvance record, largely because Scotland lies within the regional climatic envelope for surging activity (Benn 2021). **Dave Evans** then expanded on the long-rehearsed debate on the surge diagnostic nature of large thrust moraines, a notion that has previously been questioned because of their occurrence in front of Canadian high Arctic, cold based glaciers as well as surging glaciers; the recent acknowledgement that the high Arctic glaciers can

Figure 4. The 'hill-hole pair' of Loch Gharbhrain *(Photo by Colin Ballantyne).*

also surge has rekindled the surge diagnostic status of proglacial thrust masses. This led on to discussions about the energy and/or glacier velocity needed to construct such moraines and the potential for patchy permafrost to weaken proglacial materials and thereby facilitate thrust mass construction. **Doug Benn** outlined some examples from Svalbard, where the glacier foreland is in a weakened state due to high hydrological pressures imparted by surge lobes.

The third stop of the day was the Strath Vaich end moraine and associated outwash terraces. **Doug Benn** pointed out a prominent series of lateral moraines and meltwater channels, which record the early stages of recession of the Loch Lomond Readvance glacier in this valley. Also prominent inside the outermost moraine is an area of mounds and kettle holes indicative of stagnation. Outside the moraine is a fine example of terraced proglacial outwash with two major levels, typical of areas lying distal to Loch Lomond Readvance limits. A further, higher terrace with a slightly undulatory surface lies inside the limit and has been incised by lateral meltwater channels. This prompted a brief scratch around in the surface materials, convincing the group that till overlies the terrace and hence it likely predates the Loch Lomond Readvance.

Next was an iconic glacial geomorphological site that everyone was eagerly anticipating - the celebrated "hummocky moraine" of Coire a' Cheud Chnoc (the 'Valley of a Hundred Hills'). After taking lunch at the car park and well known viewpoint for the moraine, we crossed the river and followed the path to the Ling Hut and into the hummocks. **Doug Benn** explained that although these hummocks appear chaotic on the ground, they have long been recognised as displaying linearity and containing flutings (Hodgson 1986; Wilson & Evans 2000). The group wandered through the hummocks to arrive at a suitable overview and there debate the origins of the various mounds and ridges. Discussions led by **Doug Benn** and **Dave Evans** centred on the occurrence of arcuate ridges superimposed by flutings (interpreted as overridden latero-frontal moraines) and more sinuous forms that likely represent the fragmented remnants of englacial eskers and kames whose construction was directed in many areas by crevasses, for which there are excellent modern analogues evolving today in Iceland. Doug again raised the possibility of surging during the Loch Lomond Stade, which would be entirely consistent with the overriding and streamlining of pre-existing recessional moraines at this site. This concept was to be re-visited at the next stop of the day.

After retracing our steps it was a short drive to the head of Loch Torridon and some excellent stratigraphic exposures through the Thraill moraine, the terminal

Figure 5. The group listening to Doug Benn amongst the hummocks at Coire a' Cheud Chnoc *(Photo by Dave Evans)*.

moraine of the Loch Lomond Readvance glacier that flowed out from the cirques of the Beinn Damh Forest to the south. This glacier split into two lobes due to its divergence around the upland of Seana Mheallen, the northeast lobe forming the Coire a' Cheud Chnoc and the northwest lobe extending to the head of Loch Torridon to construct the Thraill Moraine. The stratigraphy clearly demonstrates that the moraine is composed of heavily folded and thrust sequences of stratified sands and gravels, which **Doug Benn** proposed to be a glacitectonic thrust mass and hence further evidence of surging during the Loch Lomond Stade. Aided by some keen diggers, **Dave Evans** pointed out some specific structures that were clearly diagnostic of proglacial thrust mass construction.

Day 2 Saturday 20th May

Excursion 3

This excursion followed the coastline of Wester Ross southward from Little Loch Broom. It focused on coastal landforms (high rock platforms, Lateglacial raised shorelines and Holocene raised beaches), and outlined the evidence linking former sea level to the Wester Ross Readvance.

Our first stop was a view over Little Loch Broom at Dundonnell. **Alistair Dawson** discussed past changes in sea level around this area and the relationships between the Wester Ross Readvance limits and the fluctuations in sea level. Shoreline altitudes of the Main Wester Ross shorelines for inner Little Loch Broom range from ~19 m to ~24 m. Alistair also pointed out a terrace which declines northwards from ~23.0 m OD to 15.5 m OD and is interpreted as outwash merging into a raised shoreline. Discussions centred on the uplift rates in this area and the style of deglaciation. We then travelled a short distance along the road to another viewpoint over Little Loch Broom, where **Tom Bradwell** presented the group with an impressive map of the onshore and offshore Quaternary geology of Little Loch Broom, constructed by the BGS using multibeam surveys and cores using the James Cook research ship. Tom highlighted the numerous inset moraines on the seabed and explained their evolution as related to the grounding lines of the former glacier occupying the loch. Discussions turned to the distinct differences in moraine occurrence and density between offshore and onshore locations in the area, with Tom illustrating that it was difficult to pinpoint exactly which seafloor moraine equated to the prominent, single onshore Wester Ross Readvance moraine. **Colin Ballantyne** outlined the different morphologies of the landforms on the hillslopes south of Loch Broom, proposing that Wester Ross Readvance moraines were overridden by a Loch Lomond Readvance glacier. Some deliberations, led by Colin and Tom, on the exact ages of these features then ensued based upon the interpretation of cosmogenic dates reported by Bradwell *et al.* (2008).

Figure 6. Dave Evans cleaning off a section of the Thraill moraine outcrop. *(Photo by Ailsa Guild)*

At our next stop, Gruinard Bay, Alistair Dawson talked the group through the local sea level history illustrated by an excellent view over an incised and terraced marine limit raised delta displaying two main levels. The highest level of 19m OD records the sea level at the time of the Wester Ross Readvance, evidenced by the connection of the gravel fan that feeds the delta surface to a moraine limit some 3 km up valley. The lower level records the subsequent Holocene marine limit. Alistair provided an overview of glacioisostatic adjustments in relation ice sheet retreat and highlighted that fact that many shorelines lying immediately outside the Wester Ross Readvance limit, unlike this example, record sea level prior to the readvance. Additionally, negligible falls in marine limit altitude directly inside the readvance limit indicate that very little rebound took place and hence that the readvance was short lived.

Figure 7. Tom Bradwell showing the group an impressive map of the on and offshore Quaternary geology of Little Loch Broom constructed by the BGS *(Photo by Ailsa Guild).*

Figure 8. View over Gruinard Bay showing the marine limit delta of Wester Ross Readvance age trimmed by a lower Holocene marine bench *(Photo by Dave Evans)*

Our fourth site was Druim Breac and the Aultbea moraine, which represents the eastern margin of the lobe of ice that occupied Loch Ewe at the time of the Wester Ross Readvance. The moraine is composed of sandstone boulders and there are indications of buried ice being present in some locations. Continuing discussions from the earlier site in Little Loch Broom, the age of the readvance and its cause were reviewed. An age range of ~15.4 – ~15.8 ka is indicated by different calibrations of the cosmogenic dates from the moraine. **Colin Ballantyne** led the discussion on the cause of the readvance, which is thought to be related to regional climatic forcing. Whether at the younger or older end of the age range, this may relate to cooling trends identified in the NGRIP ice core record, with an older age coinciding with Heinrich Event H-1. Further discussions then ensued about the possible occurrences of ice sheet marginal readvance at this time in other areas of Scotland, with various locations being proposed by the group.

At the next stop, Poolewe, **Alistair Dawson** talked about some prominent gravel terraces that were deposited during glacier retreat from the Wester Ross Readvance limit. The highest terrace is 1.3 km long and up to 500 m wide and terminates 2 km inland from the coast at 25 m OD where the former ice margin is thought to have been located, at the NW of Loch Maree. From here, proglacial streams aggraded outwash deposits to a marine terrace at 10.8 m OD. This ice-contact outwash fan and marine terrace lie up to 17 km inside the readvance limit, which is associated with a marine limit of 19 m OD. This indicates a fall in relative sea level of 8 m over 17 km and it is uncertain whether or not Loch Maree was inundated by marine waters during ice recession. It was this question that was then debated by the group, with further plans of boat/raft-based coring being contemplated for the future.

While coring isolation basins was fresh in the minds of the group, the next stop at Badachro delivered some interesting results of such endeavours (Simms *et al.* 2022). The group were treated to direct access to cores extracted from the Loch Bad na h-Achlaise isolation basin by **Louise Best**, **Alex Simms** and **Jen Taylor**. The important transition from marine to non-marine deposits was demonstrated using the extracted cores and much discussion was generated around the radiocarbon age of this transition of 15.9 cal ^{14}C ka, placing seal level at that time at 11.3 m OD. As the site also lies inside the Wester Ross Readvance

Figure 9. Sediment cores taken by Louise Best, Alex Simms and Jen Taylor at Loch Bad na h-Achlaise isolation basin *(Photo by Ailsa Guild)*

limit in Loch Gairloch, it provides also an important minimum age on ice recession from that limit and further indicates that the readvance took place at the older end of the range of cosmogenic ages discussed at the Aultbea Moraine stop earlier in the day. After further discussions on the implications of lithological changes in the core for specific erosional and depositional events in the basin since deglaciation, the group continued along to the end of the road at Redpoint. Here **Alistair Dawson** talked the group through an excellent example of a partially drift covered marine rock platform and cliff. This initiated a critical discussion on the production and age of the high rock platform and cliff more generally. This platform example lies at 23.5 m OD and is mantled by Lateglacial marine gravels. Similar examples of Lateglacial sea level modification of the rock platform exist elsewhere in western Scotland, but many are also mantled with till indicating that the cutting of the platform and cliff predate at least the last glaciation. Also available for the group to briefly peruse at this site were dunes containing Holocene peats dating back to 8.2 cal ^{14}C ka and overlying podsols in glacifluvial deposits.

Our penultimate stop of the day was at Loch Maree, whose implications in terms of ice sheet retreat and related sea level events were introduced earlier in the day at Poolewe. Lake sediments here have been cored by Birks (1972) and revealed a basal layer of laminated silts overlain by a Holocene sequence. This site lies outwith the limit of the Loch Lomond Readvance, but no Lateglacial sequence is present. Ensuing discussions related to this lack of Lateglacial deposits and the notion that the loch could have been occupied by the sea immediately after deglaciation.

The final stop of the day was at the spectacular debris flows and slope-foot debris cones of Glen Docherty. Here **Alastair Curry** outlined the research he had carried out on Holocene debris-cone stratigraphy, based in part on radiocarbon dating and pollen analysis of buried organic soils intercalated within the debris-flow deposits Curry (2000). This evidence suggests that the timing of debris-flow events reflects exceptional rainstorms of random periodicity and is unrelated to longer-term climate shifts or anthropogenic effects such as deforestation or burning.

Day 3 Sunday 21st May.

Excursion 4

This half-day excursion started with a visit to the spectacular Achnasheen delta terraces and lake shorelines, which were created in an ice-dammed

Figure 10. Doug Benn explaining the Achnasheen delta terraces, which are visible in the background *(Photo by Dave Evans)*.

lake, most likely during the Loch Lomond Readvance, although Brian Sissons in his comprehensive study of the landforms provided no firm impression of exact age. **Doug Benn** highlighted that the two upper delta surfaces, although now separated by river incision, may have once been laterally continuous. Lower terraces record progradation of sediments into a lowering lake level. Both upper delta terraces terminate upvalley at steep ice contact slopes, indicative of sediment progradation directly from the former glacier margin. Doug presented the results of his exhaustive sedimentological research at the site (Benn 1989a, 1992), including overviews of the deposits representative of bottomset and foreset beds and indicative of Gilbert-type delta formation. Doug also detailed the nature of the evidence for ice-contact sedimentation directly into the lake in a temporary road cut to the east of the main delta terraces. Although now generally regarded as of Loch Lomond Stade age, the deltas have never been dated and so discussions moved on inevitably to the various solutions to this problem, most specifically the applications of OSL dating. Fittingly, a public display board in the railway station car park uses modified versions of Doug's diagrams to explain the landforms visible to the visiting tourist, although the group were glad to have the man himself and his originals on site!

The second stop of the day was an overview of Loch Clair, where Pennington *et al.* (1972) reported on 16 piston cores that revealed laminated sands and silts overlain by muds containing a full Holocene pollen sequence. Importantly, no Lateglacial deposits were present in any of the stratigraphies. **Colin Ballantyne** outlined that the limit of the Loch Lomond Readvance in this area is not well defined. Sissons (1977) and Robinson (1977) depicted Loch Clair as lying outside the readvance limit, but it has been implied by others that much of the adjacent terrain was covered by ice during the Loch Lomond Stade. Indeed, lateral moraines that descend westwards along the slopes adjacent to the loch indicate that it was covered by ice during the stade, with the glacier snout terminating near the head of the loch in Glen Torridon. **Colin Ballantyne** suggested that the basal sands and silts in the loch were probably deposited as the ice retreated from the loch basin. For those interested in the details of the Holocene vegetational history of Loch Clair, and indeed other key pollen sites and Lateglacial stratigraphies around Wester Ross, Mike Walker and John Lowe have compiled a comprehensive overview in the Field Guide, together with a fitting tribute to the work of Winifred Pennington.

Our next site was a spectacular viewpoint over Loch Torridon, spoiled only partly by some low-lying cloud that frustratingly for this view burned off as the day progressed. From here we could see Beinn Alligin and **Colin Ballantyne** pointed out the area of knock-and-lochan terrain on Lewisian gneiss west of the mountain. At this site discussions were had regarding a tidal water terminating glacier and its lateral moraine. Colin also discussed the Beinn Alligin rock avalanche, which is the largest postglacial rock avalanche in Scotland, with runout debris extending ~1.25 km along the adjacent valley floor. Cosmogenic

10Be exposure dating of the runout debris indicates that the rock avalanche occurred at ~4.4 ka (Ballantyne and Stone, 2004). Discussions then focussed on the cause of the landside and whether there have been other similar-magnitude rock avalanches during the Lateglacial period in the area.

The next stop was overlooking the lower Srath a' Bhàthaich valley, which contains an unusually complex assemblage of recessional moraines, hummocky moraine and transverse ridges, prompting **Doug Benn** to raise further the question of former surging glaciers in the Scottish landscape during the Loch Lomond Stade. **Colin Ballantyne** presented the work of Robinson (1977, 1987), highlighting specifically the occurrence of classic pollen stratigraphies diagnostic of Loch Lomond Stade "inside" and "outside sites"; inside the prominent end moraine of the landform assemblage, a core at Druim Dubh contains only Holocene sediments, whereas outside the moraine at Glasscnock there is a Lateglacial sequence.

From Srath a' Bhàthaich we drove on to the spectacular mountain and fjord scenery of Coire nan Arr for final stop of the trip, focussing on a section through the lateral moraine that marks the limit of the Loch Lomond Readvance in this valley. For **Doug Benn** this was a return to his PhD stomping grounds and some reminiscences on his development of the concept of within-valley asymmetry of lateral moraines (Benn 1989b). Erratics in the section show that the glacier had reworked debris previously deposited by the last ice sheet, and large angular boulders inside the moraine provide evidence of rockslide runout onto the former Coire nan Arr glacier.

At this last stop, the trip was drawn to a close by **Dave Roberts** who thanked Colin, Doug and the rest of the field presentation and guide writing team for putting together a wonderful trip and to Colin in particular for compiling and editing a superb field guide. We were then treated to an unusual ceremony for a field meeting when **Simon Lewis** stepped forward to present the James Croll Medal to **Colin Ballantyne**, an award richly deserved for a career of seminal and inspirational research in mountain geomorphology. Colin gave a short speech thanking everybody who he has been lucky enough to collaborate with over the years and provided some words of wisdom to early career researchers that collaboration is the key to success. The comprehensive, richly illustrated and beautifully produced Wester Ross field guide (Ballantyne 2023) is certainly testament to that!

Figure 11. Simon Lewis presenting the James Croll Medal to Colin Ballantyne *(Photo by Ailsa Guild)*.

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