An exciting new project at Somerset Earth Science Centre

by Simon Carpenter

I have recently started volunteering at Somerset Earth Science Centre www.earthsciencecentre.org.uk, to help them repurpose an old geological collection formerly belonging to Kingswood School, Bath. This is an exciting opportunity to examine an important historic collection, containing some exceptional fossils and minerals, many found over a century ago.

Kingswood School, Bath was founded in 1748 by John Wesley, who with his brother Charles, started the Methodist movement in the Church of England.

Sir Arthur Dixon (1867- 1955), an accomplished mathematician and Fellow of the Royal Society as well as a former pupil of the school, donated a substantial geological collection to Kingswood School. His collection, as well as many other fossils and minerals added by former pupils and staff, were used by generations of children studying GCSE and A level geology. With the introduction of the National Curriculum in the late 1980s, a steady decline in the teaching of geology in schools began. These collections, once an important teaching and learning resource, were now no longer needed and often abandoned. Some like the Kingswood School Collection were rescued early on, before serious neglect took hold, but many other teaching collections faced a much bleaker future and were simply discarded.

The Kingswood School Collection is an important, relatively intact, early example of a school fossil and mineral reference collection. It includes many fine examples of invertebrates and some vertebrate fossils. These were collected at a time when there were many more active quarries to collect from, with fewer access restrictions and without the intensity of fossil collecting we see today.

The collection is also associated with a number of prominent and famous geologists including William Jocelyn Arkell (1904 – 1958) who was regarded as the leading authority on the Jurassic Period during the middle part of the 20th century and was friends with Alfred Barrett Sackett (1895 – 1977), the headmaster of Kingswood School between 1928 – 1959. Towards the end of Arkell's short life he had been working on Bathonian ammonites discovered during the excavation of a new hockey pitch on land below Kingswood School.

Somerset Earth Science Centre is rescuing as much of the collection as possible to repurpose it as a reference collection for the Centre, with some of the more interesting and important fossils and minerals put on display for visitors. An immediate priority has been the careful cleaning of fossils, the rescue of specimen labels and tackling conservation issues such as pyrite decay. At the time of writing, only about 20% of the fossil collection has been processed. The Centre have approached the Russell Society to help sort through the minerals.

It has been immensely satisfying to see this old collection rescued and revitalized and a real delight to handle so many fascinating fossils. I hope to bring you updates as the project progresses.

Fig. 1: provided by Adel Avery Adel Avery, Centre Manager and Simon Carpenter with some of the Kingswood School collection

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Life forms in the Torridonian Group of North West Scotland

By Phil Burge

Introduction

As discussed in the first Newsletter of the Society in April 2020, my undergraduate mapping exercise was completed in an area around Diabaig and Upper Diabaig, north of Loch Torridon. I still have the map and write up and, as I still have an interest in the area, the time spent in this area must have had a deep and lasting impact, as I expect each undergraduate geologist experiences. As such, my newsfeed occasionally throws interesting research on the geology of the North West Highlands, one of which described a possible billion year old holozoan with differentiated multicellularity (Strother et al 2021).

The consensus view is that all the Torridonian Group was deposited in fluvial/lacustrine/playa type environments. The finding of multicellular structures in a non-marine environment of this age revises our understanding of the evolution of multicellular life and holozoans.

Torridonian Supergroup Stratigraphy

The North West Highlands have a particular and impressive geography with high hills and mountains of Torridonian age lying uncomformably on Palaeoproterozoic Lewisian gneiss. The Torridonian Supergroup comprises the Stoer, Sleat and Torridon groups (Fig. 1).

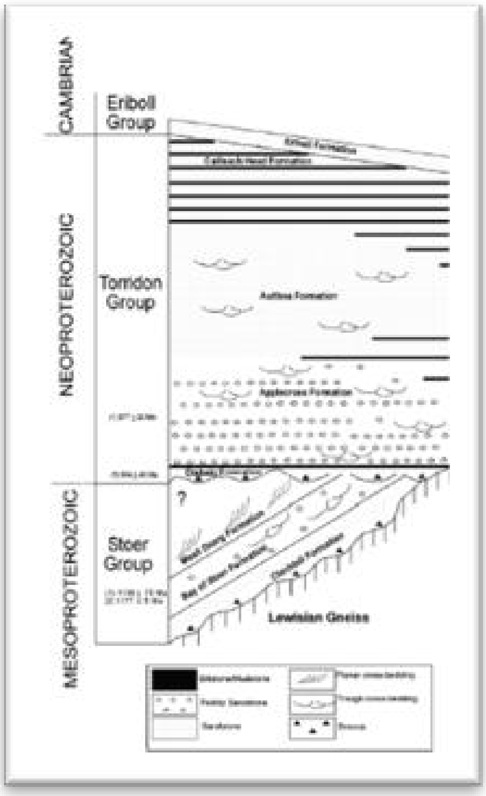

Fig. 1: Generalised Stratigraphy of Torridonian Supergroup (from Callow et al 2011)

The basal Stoer Group comprises the Clachtoll, Bay of Stoer and Meall Dearg Formations of red mudstone, siltstone and sandstone. The Bay of Stoer Formation includes the Stac Fada Member, a possible meteorite injector blanket dated at 1177+/-55Ma (Parnell et al). The Sleat Group found on Skye is believed to be contemporaneous with the Torridon Group. The Torridon Group is made up of mudstone, conglomerate, and sandstone, about 200 million years younger than the Stoer Group. The Group consists of the Diabaig, Applecross, Aultbea and Cailleach Head Formations.

In the area of my mapping exercise and of interest in the debate on life forms in the Torridonian, the Lewisian is unconformably overlain with Torridonian mudstone, sandstone and conglomerate/breccia of the Diabaig and Applecross Formations.

Evidence for Non-Marine Facies

There is some controversy as to the evidence for palaesols and weathered surfaces at the unconformity between the Lewisian and the Torridonian. On the one hand geochemistry such as oxidation of iron in biotite and magnetite, points to a weathered surface where thin layers of hydrothermal dolomite within 1m of the unconformity resulting from retrograde metamorphosis of illite and smectite has been interpreted as pedogenic. The stratigraphy strongly suggests that the Lewisian was sub aerially exposed.

The Clachtoll Formation of the Stoer Group largely composed of Lewisian clasts, was deposited in deep cut valleys. The basal conglomerates grade upwards into interbeds of conglomerate and red sandstone with trough cross bedding interpreted as valley confined alluvial fan deposits. Muddy and desiccated sandstones may have been deposited in a terrestrial mudflat environment.

The Stac Fada Formation has now been interpreted as a single event density current resulting from a meteorite impact.

The Meall Dearg Formation consists of planar cross bedded sandstone interpreted as being deposited as alluvial transverse bar deposits.

The Torridonian Group overlies the Stoer Group uncomformably with a gap of 130 – 200 million years. The lower Diabaig Formation comprises conglomerates with clasts of gneiss, and clasts of sandstone and grey shale deposited in valley-confined alluvial fans. Higher energy shorelines facies outcrop at Shieldaig on the southern shore of Loch Torridon with muddier shoreline facies at Loch Diabaig. Geochemical analysis of the grey shale suggests deposition in a non-marine environment (Stewart et al 1979). Sedimentary structures indicate deposition in shallow water with periodic subaerial exposure e.g., short wavelength symmetrical wave ripples.

The boundary of the Diabaig and Applecross Formations is probably conformable. The depositional environment is terrestrial fluvial to with channel deposits showing trough and ripple crossbedding in sandstones, planar cross bedded gravels and gravel sheets. Commonly seen are soft sediment deformation structures. A neptunian dyke was observed in my mapping area.

Stewart (2002) considered the differences between the Applecross and Aultbea Formations as being “mere facies”, the Aultbea Formation missing pebbles. Microfossils have been reported in a thin grey shale at the base of the Aultbea formation interpreted as non-marine (Zhang 1982).

Emphasis on the Diabaig Formation

The Diabaig Formation has been of special interest in the search for microfossils starting with Peach’s work published in 1907 and continued by many eminent geologists including Selley, Stewart, Brasier and Strother. It is worth looking in more detail at the Diabaig Formation and facies of a few exposed locations.

Shieldaig South – At the base red coarse normally-graded, sandstone and conglomerate of Lewisian gneiss are overlain with medium coarse, cross-laminated red sandstone fining-upwards into fine-grained sandstone and red mudstone. Short wavelength wave ripples and subaerial desiccation cracks are common with synaeresis cracks in some horizons, indicating alternating subaerial and subaqueous conditions. The Shieldaig rocks are courser than other Diabaig Formation localities indicating higher energy in a more proximal deposition. No phosphate nodules or microfossils have been found in this location.

Shieldaig North – Here, fine grained sandstone and siltstone are found with gently dipping bedding planes. Short wavelength wave ripples with multiple generations of desiccation cracks indicate shallow water deposition with periodic exposure. There are abundant phosphate lenses at the top of the section. The facies here is more distal than Shieldaig south, i.e., farther from the sediment source with lower rates of deposition (finer grain size and phosphate).

Diabaig – The Diabaig Formation is clearly seen on the foreshore of Lower Diabaig, first mapped by Peach (1907 and then me in 1975). A succession of fine-grained grey to black mudstone and siltstone alternate at the millimetre scale. Desiccation is very common. These desiccated layers are overlain by thin sandstone beds with short wavelength wave ripples. Authigenic phosphate occurs as nodules, thin laminae and linings of desiccation cracks.

Brasier et al (2016) concluded that it would indeed be controversial to reinterpret the environment of deposition of the Torridon Group as anything other than terrestrial/lacustrine but that doesn't stop some researchers from trying!

Not So Non-Marine

From geochemical analysis the Poll a Mhuilt Member of the Stoer Group has been interpreted as being fluvio-lacustrine deposits, more oxygenated and nutrient-rich than marine environments making them preferable for early eukaryote evolution. Some of the evidence for a lacustrine environment has been contested by researchers (Stewart and Parker 1979 and Stewart 2002). Detailed analysis of the Poll a Mhuilt Member shows the following sequence from oldest to youngest.

The Poll A Mhuilt Member consists largely of red beds showing channels and trough cross bedding, desiccation cracks and flat laminated to ripple cross bedding all indicative and consistent with a fluvial-lacustrine environment. Within this Member can be found thin beds (>50cm) of fine to medium sandstone and calcareous grey shale showing wave ripples, herring bone cross-lamination, flaser and lenticular bedding, reactivation surfaces and evaporite pseudomorphs after gypsum. The features within this 3-30m thick layer show evidence of marine tidal flats. Geochemical analysis shows $^{87}Sr/^{86}Sr$ ratios indicative of marine environments (Steuken et al 2017).

The significance of this reinterpretation is with regard to the origin of eukaryotes within the lower Torridonian sequence. This we now discuss.

Proterozoic Terrestrial Lifeforms

The widespread evolution of life on land occurred in the Late Cambrian to Ordovician, although actinobacteria and cyanobacteria could have emerged on land as much as 3 billion years ago. Some cyanobacteria are only known from freshwater environments.

Archean microbialites (formed through mats of prokaryotic cyanobacteria) are found in sediments 1.5 billion years older than the Stoer/Diabaig formations. That Torridonian lakes and land surfaces were colonized by microbial mats should not be surprising. Stromatolites have been reported from the Stoer Group, though possibly of an abiotic genesis. Some sedimentary structures indicative of windswept sediments forming ripples, were locally bound by microbial mats (Prave 2002).

Microbial mats (biofilms) can be identified from wrinkle structures, pustules, sand chip, shrinkage cracks and lineations, otherwise known as microbially induced sedimentary structures (MISS). Structures like this have been reported in the Torridonian since Peach in 1907 and variously interpreted as abiogenic. Since 2002 these structures have been related to the effects of microbial mats (Fig. 2-4).

Fig. 2: Reticulate structures forming on planar bedding surfaces and ripple horizons. Scale bar 5 cm (from Callow et al 2011)

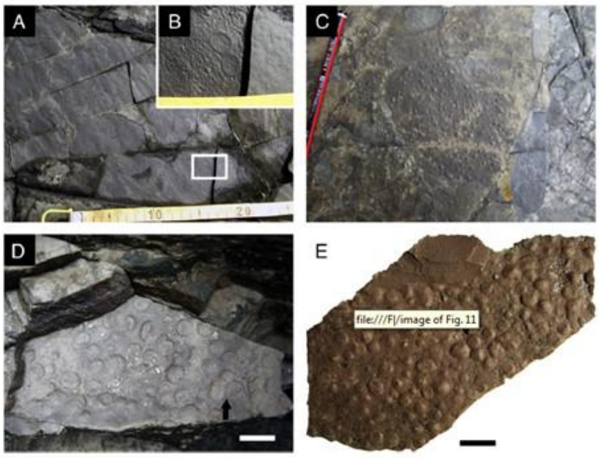

Fig. 3: Discoidal features from bedding planes (A, B) comparable with Aspidella terranovica. C,D, E pimple structures due to gas domes during decomposition of microbial mat (from Callow et al 2011)

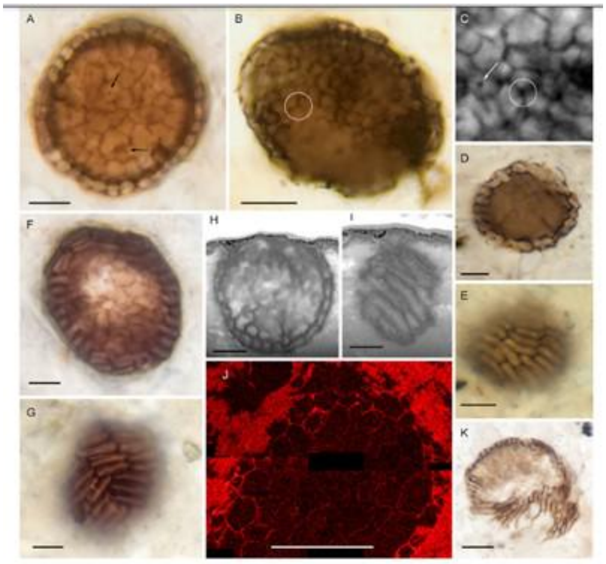

Fig. 4: Bicellum brasieri from thin sections of Diabaig Formation, Lower Diabaig location. Scale bar A-J 5 micron, otherwise 10 micron (from Strother et al 2021)

Studies beginning in the early 1980's found evidence of a range microfossils including: single celled sphaeromorphs and other eukaryotic forms, multi-walled and colonial forms, organisms with complex morphologies. Examples include *Leisphaeridia* and *Lophosphaeridium*, the latter showing cysts encased in thin-walled vesicles interpreted as original vegetative cell walls – evidence of eukaryotic organisms living in these Torridonian lakes.

The best preservation of these microfossils occurs in phosphatic nodules within the Diabaig Group. Cell membranes and cell contents are well preserved. Explanations of phosphogenesis include a biotic origin within microbial mats for instance, the result of seasonal anoxic conditions in the deeper lake environment or the breakdown of seasonal microbial blooms. The phosphates in the Diabaig Group are found in green sands and mud suggesting a reducing environment.

This brings us back to the first paper cited in the introduction to this article. A new organism *Bicellus brasieri* has been identified within Diabaig phosphate nodules (Fig. 4). Bicellus consist of a solid, spherical ball of tightly packed roughly spherical shaped cells surrounded by elongate cells. Some examples appear to show the development from a spheroidal cluster to one showing the elongate outer cells. There is an absence of cell walls suggesting that these cells did not originate from algae but are more consistent with a holozoan origin. The simple cell differentiation and morphogenic processes are similar to those of present-day metazoans. It is then concluded that *Bicellum* shows that differentiation and morphogenesis occurred in freshwater protists as much as a billion years ago.

Summary

The evidence is clear that the Torridonian Group formations were laid down in terrestrial, freshwater lacustrine environments. Microbial mats and microfossils showing eukaryotic characteristics are found in facies ranging in depth and exposure above the water line. The further examination of these, perhaps unique Torridonian rocks may suggest a revised view on the evolution of eukaryotes on land.

Built from the oldest metamorphic and sedimentary rocks in Britain, the North West Highlands are among the most scenic and well worth a staycation. While the resources available to a mid 1970's undergraduate geologists undertaking a mapping exercise were somewhat limited in comparison to today's generation of geology students and not capable of coming close to consider or identify holozoan genesis within the studied rocks, the experience lingers and still engages. The advantage of newsfeeds ensures a continuing source of new material to entertain and enlarge upon these youthful experiences. I am also pleased to record that it was due to suggestions by my sedminentology lecturer and field trip leader Sandy Stewart and my tutor Roland Goldring at Reading University that the work on Torridonian microfossils began.

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Machair – a gaze across deep time

by Charles Hiscock

In 1788, the eminent pioneering Scots geologist James Hutton made one of the most profound statements in the history of geology. He wrote "we see no vestige of a beginning, no prospect of an end". He had visited the localities in Scotland that are now famous sites, Hutton's Unconformity on Arran, at Jedbergh and elsewhere, culminating in his visit to Siccar Point in 1788. From his observations he recognised the huge passage of time in the formation of the earth, "deep time" as he called it. He is justly called the "Father of Geology".

I was standing on the sand dunes looking out over the beach and sea at Seilebost on the west coast of the Isle of Harris. In front of me, the beach was a very pale creamy colour, bright and glistening in the sunshine while the sea was a brilliant turquoise blue, graduating at the shallows from a pale hue to a deep, intense blue away from the shore (Fig. 1). Gentle wavelets broke