Ross ANDERSON
Lewis and Clark Fund for Exploration and Field Research in Astrobiology
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Preservational Controls on Neoproterozoic-Cambrian (1000 MA–485 MA) Eukaryotic Fossil Diversity in the Zavkhan Terrane of Southwestern Mongolia

PROJECT REPORT

The aim of this project was to assess the preservational controls on eukaryotic fossil diversity in Neoproterozoic (1000-541 Ma) rocks of the Zavkhan terrane, southwestern Mongolia. Over the past few decades paleontologists have documented a diversification event among early eukaryotes within this Neoproterozoic record set in the dramatic environmental context of global glaciations, carbon cycle perturbation, and continental reconfiguration [1, 2]. Yet our knowledge of the preservational processes (taphonomy) which create this early eukaryotic fossil record remains very sparse. Consequently our ability to understand this diversification event and any temporal correlations between it and environmental change are compromised.

In the Phanerozoic Eon microfossil eukaryotes form significant accumulations of sedimentary rocks due to their mineralized skeleton – for example, the White Cliffs of Dover, England which are composed of Cretaceous cocolithophorid algae [2]. However in the Proterozoic Eon, before the advent of biomineralization, we rely on the rare preservation of organisms with no mineralized parts to understand diversity. Clay minerals are thought to play an important role in organic fossil taphonomy. Clay minerals may precipitate in situ onto organic tissue and encase it, or bind to degradative enzymes slowing the rate of organism decay [3, 4].

A pilot study (figure 1) investigated microfossil taphonomy during the crucial time period between Cryogenian ice ages, a period noted for its paucity of early eukaryotic microfossils, possibly linked to biologically unfavorable environments. Carbonate rocks exposed in the Zavkhan terrane, southwestern Mongolia, yielded microfossil eukaryotes that were distributed stratigraphically coincident with changes in clay mineralogy – fossils were present when the clay mineral was berthierine and absent when the clay was kaolinite.

To explore the nature of this relationship and any role of clay minerals in the fossil preservation, I conducted fieldwork in the region around the town of Altai, Mongolia from June 1 – June 17, 2014. The fieldwork centered on three principal camps Ulaanbulag, Khongor, and Taishir (figure 2). The samples collected from these localities will be used to build a high-resolution combined stratigraphic record of clay mineral distribution and microfossil diversity. Clay minerals will be analyzed using bulk rock X-ray diffraction while fossils will be documented in petrographic thin-section and macerated sample. An understanding of the taphonomy of these fossils will enable us to resolve the roles of extinction/origination versus changing preservation conditions, providing a more rigorous explanation of the factors controlling diversity through time.

In total 335 samples were collected and transported back to Yale University for laboratory analysis.

Ulaanbulag – (46.707497°N, 96.040644°E)

Two days were spent at Ulaanbulag, which provided access to Khunker Gorge. Here the exposure comprises rocks from the ~800 Ma Zavkhan volcanics through Ediacaran strata. The first day was spent familiarizing myself with the stratigraphy. Some samples were collected from Ediacaran strata that contained early diagenetic cherts as cherts are a common repository for organic microfossils. These samples were collected to prospect for evidence of a eukaryotic organic microfossil record. We also found possible Ediacaran biomineralizing forms *Cloudina* and *Namacalathus*. If authenticated these would provide a temporal constraint on the strata and be the first fossils of this type to be found in Mongolia, increasing the known paleogeographic distribution of these organisms. However the focus of our time in Ulanbulag was to obtain a stratigraphic suite of samples at ~20 cm resolution through cap carbonate rocks in the crucial inter-glacial interval above the older Cryogenian glaciation (Sturtian glaciation ~720-655 Ma). This suite of samples will complement others collected in 2013, improving the geographic distribution of my samples across the basin.

Khongor – (46.660805°N, 96.263125°E)

At Khongor the Cryogenian stratigraphy is well exposed including both Sturtian and Marinoan equivalent diamictites and cap carbonates. My investigation focused on the same interval sampled at Ulaanbulag. Samples were taken at ~30-50 cm intervals through ~100 m of stratigraphy from the top of the Sturtian equivalent cap carbonate through interbedded shale, marl, and carbonate facies. Locally I also sampled early diagenetic cherts. This sample suite covers a range of facies deposited at similar times, providing a basis for comparing and testing how facies affect preservation. The shale and marl facies likely also have higher clay content making measurement of clay mineralogy easier.

Of particular note was a ~20 m interval of black shale directly above the Sturtian equivalent cap carbonate. Black shales can provide radiometric age constraints using the Rhenium-Osmium system [5] and important environmental information through the analysis of trace elements such as Molybdenum [6]. They are also known to be a common repository of some of the best preserved organic microfossils [7]. In addition to these post-Sturtian shales, I collected some shale samples from horizons directly below the Marinoan equivalent diamictite.

On our final day at Khongor we focused efforts on the Ediacaran carbonate strata. Some microfossils have been found by our colleagues in these rocks, which look similar to Cryogenian examples. I sampled these horizons to understand the stratigraphic extent of microfossil occurrences and to investigate whether pre-Marinoan forms survived into post-

Marinoan oceans. Early diagenetic cherts from time equivalent horizons were sampled for comparison.

Taishir – (46.691504°N, 96.583625°E)

The location of our final camp, Taishir, allowed me to return to my 2013 field site. One question I must ask of clay data from this study is whether the clays are of primary origin or are they the product of geological events that occurred subsequent to deposition. If the latter is the case it is unlikely that the clays played a role in fossil preservation. At Taishir there is a Permian intrusive body. The contact metamorphism associated with its emplacement could have affected some of the clay mineralogy. To test this I took a suite of samples at Taishir through the same interval as at Khongor and Ulaanbulag, i.e., through the strata immediately above the Sturtian equivalent cap carbonate. However I did so at multiple times at different geographic distances from the Permian body. These suites will be analyzed for clay mineral assemblages. If the clay mineral assemblages change as the intrusive body is approached it would suggest that those farthest away were not effected by the metamorphism and can be assumed to be primary. However if all the clay assemblages are the same regardless of geographic distance from the body it may indicate that they have been overprinted and this factor will need to be considered in interpreting the results of the study.

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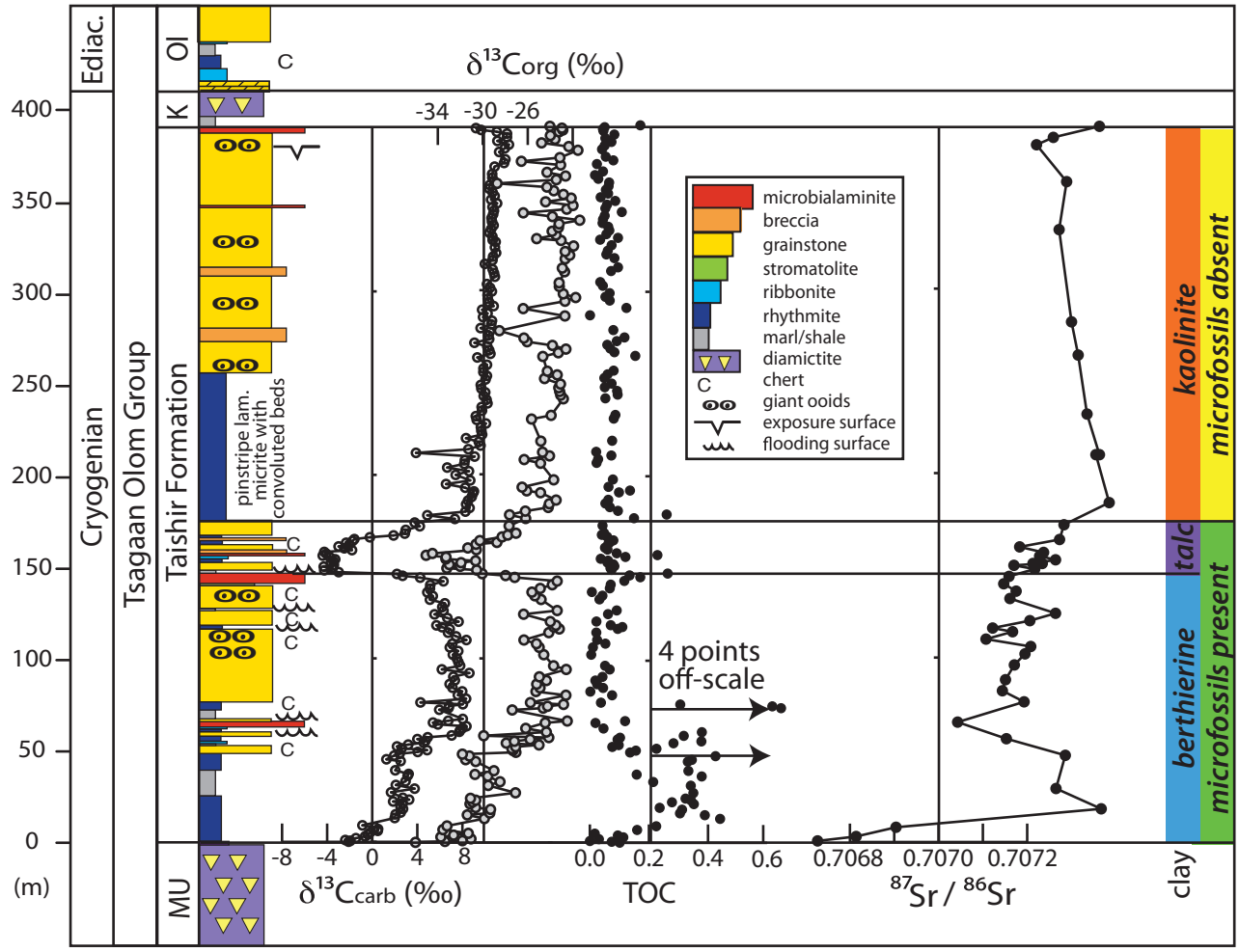

Figure 1 Generalized stratigraphy between the Sturtian (MU) and Marinoan (K) ice ages of the Tsagaan Olom Group, Mongolia. Preliminary results of microfossil abundance and clay mineral assemblages plotted in the context of environmental change as indicated by sedimentary facies; carbonate carbon, organic carbon, and strontium isotopes; and percentage total organic carbon (TOC). Isotopic measurements supplied by the lab of F. A. Macdonald at Harvard. The Taishir Formation is the primary focus of this project as it allows sequences apparently barren of fossils to be compared with those where fossils are preserved in the same locality.

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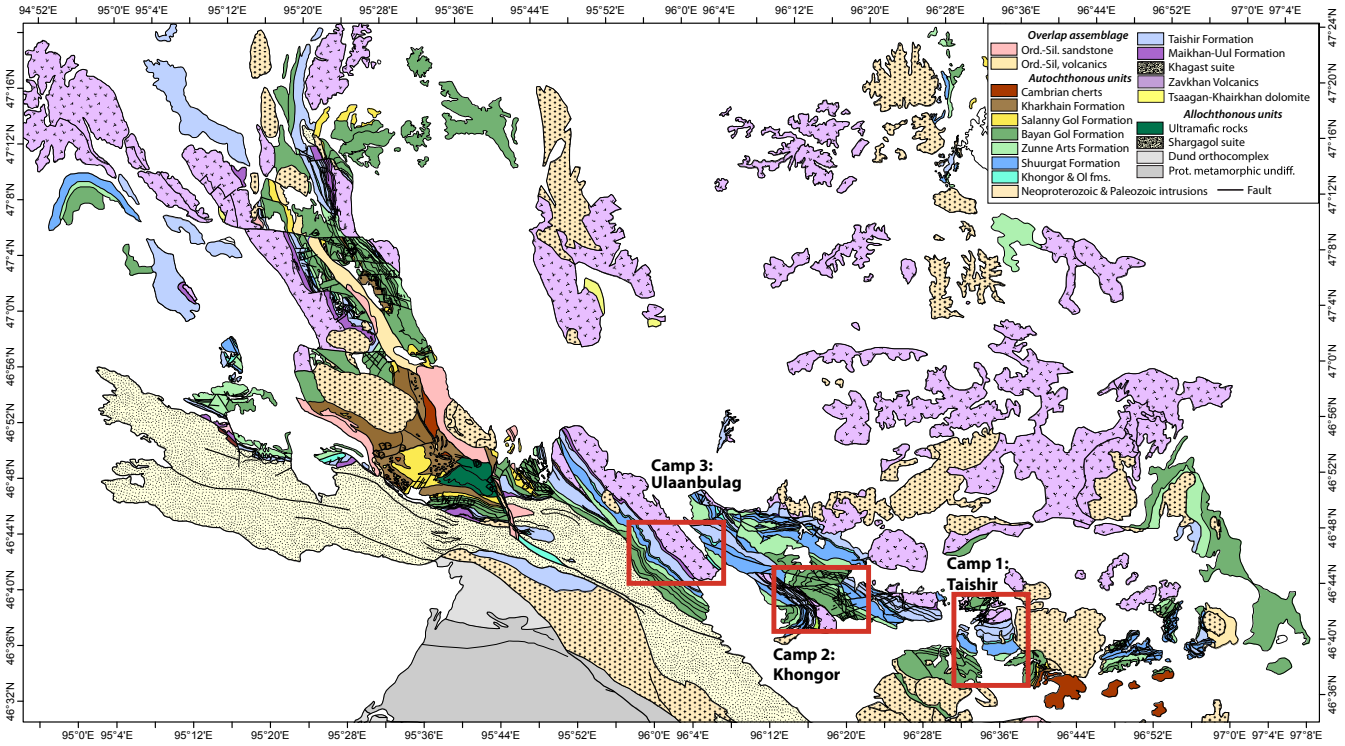

Figure 2 Geological map of the Zavkhan terrane, southwestern Mongolia. The three camps visited in 2014 are shown.

Figure 3 Left: Ulanbulag camp. **Right:** Sturtian equivalent Maikhan Ul diamicitie (bottom) overlain by the Taishir cap carbonate at Taishir camp showing transition form a ice-house to hot-house environment.

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