

Zach ADAM
Lewis and Clark Fund for Exploration and Research
Awarded May, 2011

Characterizing the Mesoproterozoic Microfossil Record of the Belt Supergroup, Montana

PROJECT REPORT

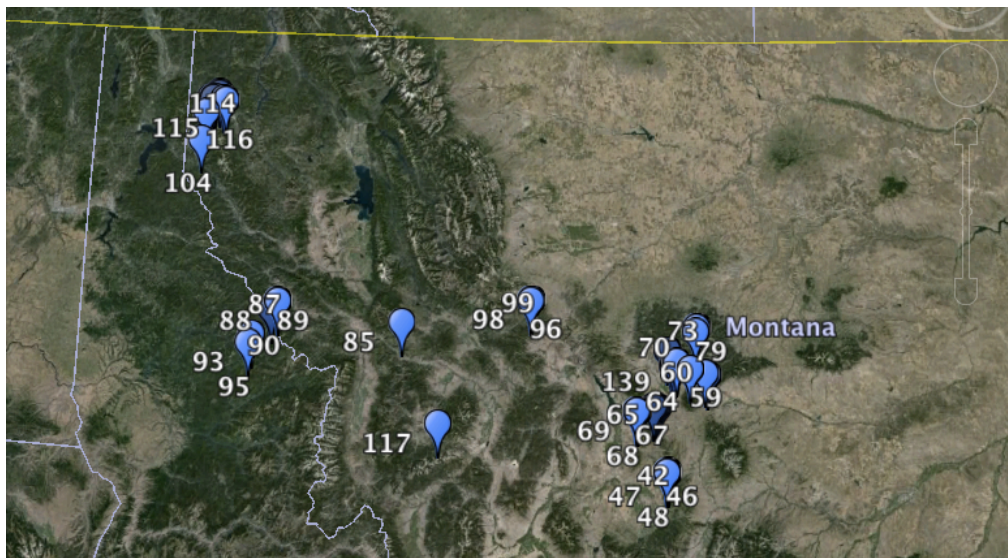
EXECUTIVE SUMMARY

The field travel and exploration activities that were conducted throughout the Belt Supergroup of Montana with support from the American Philosophical Society (APS) and the NASA Astrobiology Institute (NAI) were a substantial success. In my grant proposal, I outlined an ambitious survey of Belt outcrops and core samples from all around western Montana, to be conducted over the 2011-2012 years. The purpose of this survey was to locate new fossil deposits over 1.4 billion years old (Ga) that would provide critical information about the earliest evolution of eukaryotes on Earth. These data, in turn, may be used to form hypotheses about the frequency and distribution of common complex life on planets found outside of our solar system. By the end of the APS/NAI-funded survey, over 200 outcrops from throughout the Belt had been visited over the course of 5 trips, covering at least 4800 driven miles over a total of 27 days in the field, and with microfossil survey samples collected from at least 100 different layers of the Belt Supergroup. The survey, which was conducted until late fall of 2012, yielded diverse microfossil assemblages within layers scattered throughout the upper Greyson Shale and lower Chamberlain Shale, along with numerous assemblages containing microfossil fragments and partial remains. The diverse assemblage deposits are found in the Lower Belt and are some of the oldest deposits from the Belt Supergroup, with estimated ages ranging from about 1.45-1.47 Ga. Prior to this survey, the Belt Supergroup had yielded only simple spherical microfossils that lacked distinct morphological features; the discovery of diverse assemblages in the Belt represents the opening of a new window into early eukaryotic life in the Mesoproterozoic. With help from the APS and NAI, the Belt Supergroup assemblage is now known to contain what is perhaps the most diverse of fossil collections worldwide of similar age (e.g., compared to the Roper Group of Australia or the Ruyang Group of China), with multiple layers yielding *Valeria*, *Tappania*, *Gemmulooides*, *Dictyosphaera* and striated tubes in addition to a variety of anomalous forms that have yet to be characterized or observed in rocks of this age. Field activities have also yielded an abundance of microfossil-containing rocks that may now be studied using state-of-the-art analytical techniques to extract stable isotope, molecular biomarker and micrometer-scale morphology and chemical composition data. Manuscripts based on these findings are currently being written and will be submitted over the next 3-4 months, and the newly discovered fossils will be the subject and focus of nearly my entire PhD thesis effort.

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ACTIVITY SUMMARY

The original proposal baselined 6 trips to and from Great Falls, MT as the basis of the field work to be conducted throughout the Belt Supergroup. The first two trips to the Helena Embayment in the summer of 2011 were restricted to the area between Great Falls and Bozeman. Information gathered during these initial trips redirected my attention to four potential sources of microfossil-bearing rocks: (a) microfossils that had been recovered from greenschist-facies rocks in the vicinity of Libby, MT (Kidder and Awramik, 1990), (b) outcrops along Rogers Pass containing an abundance of biogenic molar tooth structures and stromatolites (e.g., Furniss *et al.*, 1998), (c) outcrops along a ridgeline near Sandpoint, ID with algal biostrome layers (Timothy Hayes, USGS, pers. comm.) and (d) drillcore that had been extracted from all members of the Helena Embayment being stored in a warehouse at Fort Missoula in Missoula, MT (Don Winston and Jerry Zieg, pers. comm.). After a preliminary survey of rocks in the White Sulphur Springs, MT area had been conducted during these initial two trips, a broader reconnaissance survey of the primary axis of the Belt (generally ranging from Libby, MT to the area south of Missoula, MT) was conducted. Survey activities in the summer of 2011 throughout the Helena Embayment were coordinated with Eva Stueeken (University of Washington) and Nicholas Butterfield (University of Cambridge). To access backcountry areas with biogenic structures near Sandpoint, a 4 wheel drive vehicle was rented. Free or reduced rate campsites were used whenever possible, but lodging at commercial campsites and one night at a hotel was also arranged throughout the survey. After the primary axis survey was made, the samples collected were analyzed for microfossil content and evaluated to direct remaining survey activity trips. Microfossils and microfossil fragments were recovered from outcrops throughout the entire Belt Supergroup, but the highest-quality fossils were found in outcrop samples from the Chamberlain Shale and Greyson Shale in the vicinity of White Sulphur Springs, MT and in drillcore samples from the Chamberlain Shale recovered from the Fort Missoula core warehouse. For the remainder of the survey, two trips were made to/from the outcrops in the area near White Sulphur Springs, MT, focusing on the outcrops where the highest-quality fossil specimens had been found.



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Figure 1. Location of all outcrops from which microfossil samples were collected during the APS/NAI-funded survey. Image generated using Google Earth.

KEY SURVEY RESULTS AND SIGNIFICANCE

This comprehensive survey of the Belt Supergroup achieved or surpassed all objectives set forth in the original proposal. With financial support from APS/NAI, I was able to survey over 200 outcrops spanning almost the entire extent of Belt Supergroup exposures. Specifically:

- New fossiliferous layers that had never been described before were found in the Greyson Shale and Chamberlain Shale units of the Lower Belt. The fossils include typical Mesoproterozoic specimens such as *Tappania*, *Dictyosphaera*, *Satka* and striated tubes that establish that the fossils are not likely to be younger contaminants, and these fossils were found with other fossils that have never before been reported from rocks of this age.
 - Significance: There are only a handful of sites worldwide that possess fossils of this age. By collecting a mix of known and novel specimens, the Belt microbiota may be used to compare and contrast paleoenvironmental settings of the original depositional basins, and may also be used to make new inferences about the relative complexity and lifestyles of the original organisms.
- Iterative recovery of rare and morphological complex specimens has allowed the reconstruction of partial life cycles of the original organisms. It is possible that these will become the oldest eukaryotic life cycles known from the fossil record.
 - Significance: Life cycle characteristics are critical for resolving taxonomic affinity, which in turn is critical for incorporating the fossils into molecular clock analyses and for speculating about the ancestral state of existing crown lineages. Exploring how, when and why the earliest eukaryotes evolved is one of the most active areas of astrobiology and paleobiology research today. There are few sources of data from this time period, and there are severe limitations on the extent to which modern organisms may be used to inform us about the timing and nature of ancestral organism states. Although fossil evidence is extremely limited, it is nevertheless essential for understanding past macroevolutionary processes, and for extrapolation to form hypotheses concerning the predominance of complex life on extrasolar planets.
- The Belt Supergroup is now one of the most accessible Mesoproterozoic fossil deposit for researchers based in North America.
 - Significance: Fossiliferous rocks of similar age are found elsewhere in the world (e.g., the Roper Group of Australia or the Ruyang Group of China), but exploring these relatively isolated sites is time-consuming and expensive. The discovery of these rocks in North America opens up new opportunities to undertake iterative studies of the new fossils and to investigate new analytical techniques that may be applied and extended back into the Mesoproterozoic. Such studies would likely be impossible or impractical with samples collected from other localities worldwide, as in many cases testing new analytical techniques requires statistically significant numbers of fossils that are destroyed during the analysis process. The Belt Supergroup microbiota may not only help us to understand the timing and

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morphological characteristics of the earliest eukaryotes, but the rocks hosting the fossils may also serve as a valuable benchmark for the development and application of new instrumentation suites that may be sent to look for signs of ancient life on other planets, such as Mars.