Ashley MANNING-BERG
Lewis and Clark for Exploration and Field Research in Astrobiology Grant

Project Report

Preservation of Proterozoic Microbial Mats

Early diagenetic, peritidal chert deposits are common in Meso- to Neoproterozoic carbonate strata (Maliva and Siever, 1989; Maliva et al., 2005). These deposits have the potential to inform our understanding of early Earth processes because they commonly record textural evidence of precursor minerals and display exceptional preservation of microbial elements (Knoll, 1985; Perry Jr and Lefticariu, 2007). Although well-preserved morphologies cannot provide information regarding the microbial processes, lipid biomarkers, extracted from the organic matter can provide information regarding plaeoenvironmental conditions (Brocks and Summons, 2003) and the microbial metabolisms that were active at the time of preservation. Geochemical characterization of organic matter preserved in ancient rocks is fundamental to our ability to recognize preserved organic matter within extraterrestrial samples (Des Marais et al., 2008).

The Angmaat Formation (Turner, 2009), Bylot Supergroup, records late Mesoproterozoic carbonate strata deposited within an evaporative microbial flat (Kah and Knoll, 1996). Early diagenetic silicification records microbial growth and decomposition across a range of peritidal environments from more restricted and exposed supratidal zones to more persistently submerged, subtidal zones. Chert in the Angmaat Formation records four distinct microfossil assemblages (Knoll et al., 2013) that are preserved across a range of taphonomic states, from pristine mats that are interpreted to have silicified during active growth, to highly degraded and compacted mats that represent preservation during later stages of biological decomposition. These samples provide a unique opportunity to investigate to what extent samples with well-preserved microfossil morphologies preserve organic geochemical signals.

Chert samples collected during a 1993-1994 field season were used for initial taphonomic assessment and preliminary geochemistry. The taphonomic assessment has proven complicated; these chert samples preserve complex microbial mats with spatially discrete regions that show different preservation. Our understanding of microscale mat morphology within these samples is being prepared for publication. Although we were limited by the quantity of rock available from this previous field season, we were able to get interesting preliminary results. The samples selected for analyses have $\delta^{13}C_{kerogen}$ values between -23.1 and -29.8‰, which are typical values for microorganisms (Wacey, 2009). The average $\delta^{13}C_{kerogen}$ values for mat fabrics gets heavier as the preservation of the mat changed, which might represent the heterotrophic breakdown of primary photosynthetic organic matter.

Preliminary gas chromatography mass spectrometry (GC-MS) was also performed on the limited sample size available (3-5 mg of powdered sample). Hopanes and steranes were observed in each sample and were absent in the blank. Petrographic evidence for the red alga *Bangiomorpha* (Butterfield, 2000) supports the presence of eukaryotic steranes in these samples. An even-over-odd carbon preference, typical for marine organisms in a hypersaline carbonate environment (Peters et al., 2007) was observed in the long chain *n*-alkanes (nC_{24}-nC_{35}) of each of the samples (Fig. 1). Preservation of the distinctive carbon preference suggests thermal alteration of the organic matter has been minimal. Despite the small sample size used in these preliminary analyses, the Angmaat Formation chert samples suggest that they are capable of preserving biomolecules.

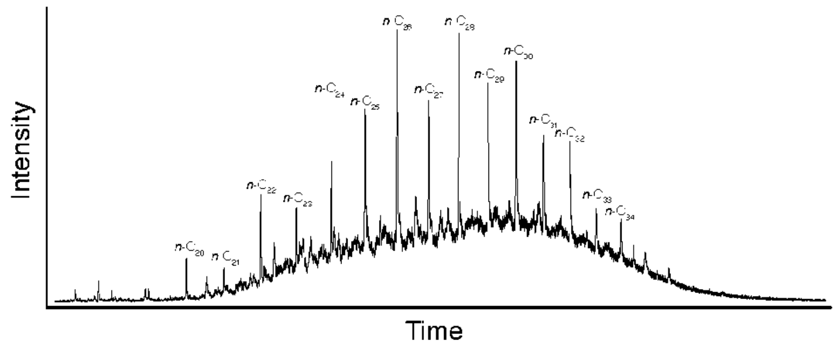

Figure 1. A typical chromatograph from the sample suite collected in 1993-1994. The alkanes show an even-over-odd carbon preference.

The funding provided by the Lewis and Clark Astrobiology Grant was applied to a July 2017 field season to collect more chert from the Angmaat Formation. The new samples provide both more material to perform geochemical analyses, and a wider range of mesoscopic textures, which may provide a greater range of fabrics. We established camp (72.2006°, -79.5815°) near a lake between the two inlets of White Bay (Fig. 2). This location was central to the outcrops we wanted to visit. Most of the outcrop localities were places that my advisor had been previously, including the localities called East White Bay (72.2172° to 72.1932°, -79.5008° to -79.5411°), and White Bay (72.2217° to 72.2333°, -79.6756° to -79.6714°); and a couple of the locations were new, including North Lake (72.2153° to 72.2226°, -79.5422° to -79.5312°) and West White Bay (72.2583° to 72.2649°, -79.7755° to -79.7803°). Chert within the Angmaat Formation commonly occurs as beds and nodules that follow primary bedding planes (Fig. 3 a-b). Later diagenetic chert (Fig. 3 c-d) is also present in these samples. Bedded chert comprises most of the samples collected on this trip that will be used for geochemical analyses. Unlike the late diagenetic chert, the bedded chert samples preserve microbial mat fabrics. Some samples of diagenetic chert nodules were also collected for comparison to the bedded chert.

After returning from the field, I traveled to the NASA Jet Propulsion Laboratory to work in their astrobiogeochemistry lab. All of the new samples have been cataloged and 12 have been cut and made into thin sections. Most of the new thin sections contain microfossils and mat fabrics. GigaPan mosaics will be taken of each of the new thin sections and can be used in the taphonomic assessment with the first sample suite. My collaborators and I are in the process of ensuring that we have a clean procedural blank for each step in our process, including cutting, powdering, and extracting the samples. Once we know that we have clean blanks we will start preparing the samples for GC-MS analyses to confirm the presence of steranes. If confirmed, these would be among the oldest steranes preserved (French et al., 2015; Brocks et al., 2017). Some of the powdered sample from these new samples will also be analyzed with elemental analyzer-isotope ratio mass spectrometry to get carbon isotope values. These new values will be used to determine if the pattern seen in the first suite of samples is significant.

References:

Brocks, J. J., Jarrett, A. J. M., Sirantoine, E., Hallmann, C., Hoshino, Y., and Liyanage, T., 2017, The rise of algae in Cryogenian oceans and the emergence of animals: Nature, v. 548, no. 7669, p. 578-581.

Brocks, J. J., and Summons, R. E., 2003, 8.03 - Sedimentary Hydrocarbons, Biomarkers for Early Life, *in* Turekian, H. D. H. K., ed., Treatise on Geochemistry: Oxford, Pergamon, p. 63-115.

Des Marais, D. J., Nuth III, J. A., Allamandola, L. J., Boss, A. P., Farmer, J. D., Hoehler, T. M., Jakosky, B. M., Meadows, V. S., Pohorille, A., and Runnegar, B., 2008, The NASA astrobiology roadmap: Astrobiology, v. 8, no. 4, p. 715-730.

French, K. L., Hallmann, C., Hope, J. M., Schoon, P. L., Zumberge, J. A., Hoshino, Y., Peters, C. A., George, S. C., Love, G. D., Brocks, J. J., Buick, R., and Summons, R. E., 2015, Reappraisal of hydrocarbon biomarkers in Archean rocks: Proceedings of the National Academy of Sciences, v. 112, no. 19, p. 5915-5920.

Kah, L. C., and Knoll, A. H., 1996, Microbenthic distribution of Proterozoic tidal flats: Environmental and taphonomic considerations: Geology, v. 24, no. 1, p. 79-82.

Knoll, A. H., 1985, Exceptional Preservation of Photosynthetic Organisms in Silicified Carbonates and Silicified Peats: Philosophical Transactions of the Royal Society B: Biological Sciences, v. 311, no. 1148, p. 111-122.

Knoll, A. H., Wörndle, S., and Kah, L. C., 2013, Covariance of microfossil assemblages and microbialite textures across an upper Mesoproterozoic carbonate platform: Palaios, v. 28, no. 7, p. 453-470.

Maliva, R. G., Knoll, A. H., and Simonson, B. M., 2005, Secular change in the Precambrian silica cycle: Insights from chert petrology: Geological Society of America Bulletin, v. 117, no. 7-8, p. 835-845.

Maliva, R. G., and Siever, R., 1989, Nodular Chert Formation in Carbonate Rocks: The Journal of Geology, v. 97, no. 4, p. 421-433.

Perry Jr, E. C., and Lefticariu, L., 2007, Formation and Geochemistry of Precambrian Cherts *in* Holland, H. D., Turekian, Karl K., ed., Treatise on Geochemistry: Oxford, Pergamon, p. 1-21.

Peters, K., Walters, C., and Moldowan, J., 2007, The biomarker guide: Volume 2, Biomarkers and isotopes in petroleum systems and earth history, Cambridge University Press.

Turner, E. C., 2009, Mesoproterozoic carbonate systems in the Borden Basin, Nunavut: Canadian Journal of Earth Sciences, v. 46, no. 12, p. 915-938.

Wacey, D., 2009, Techniques for Investigating Early Life on Earth, Early Life on Earth: A Practical Guide, Spinger Netherlands, p. 87 - 123.

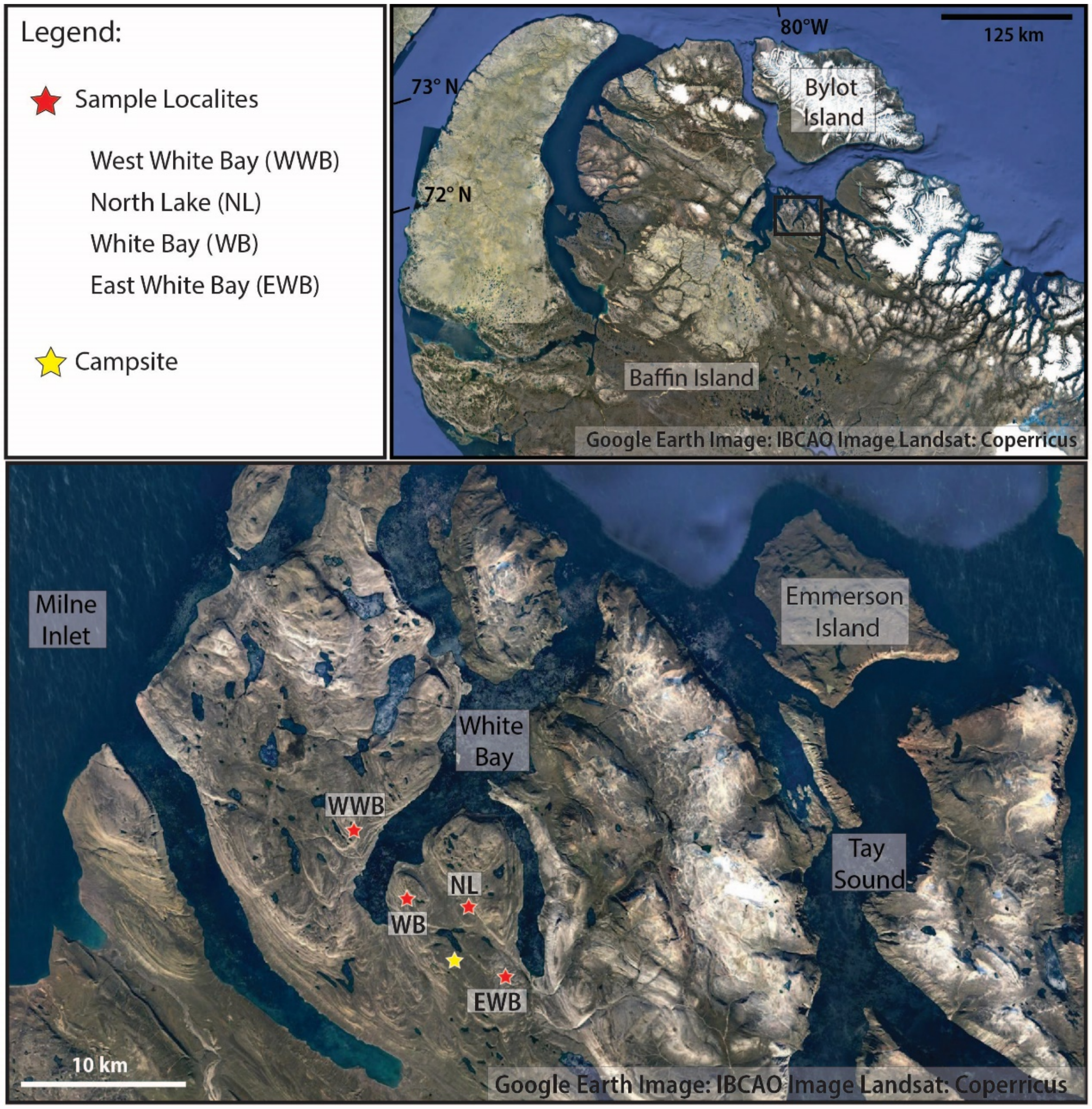

Figure 2. Field localities and campsite location near White Bay on Baffin Island. Imagery is from Google Earth Image: IBCAO Image Landsat: Coperricus.

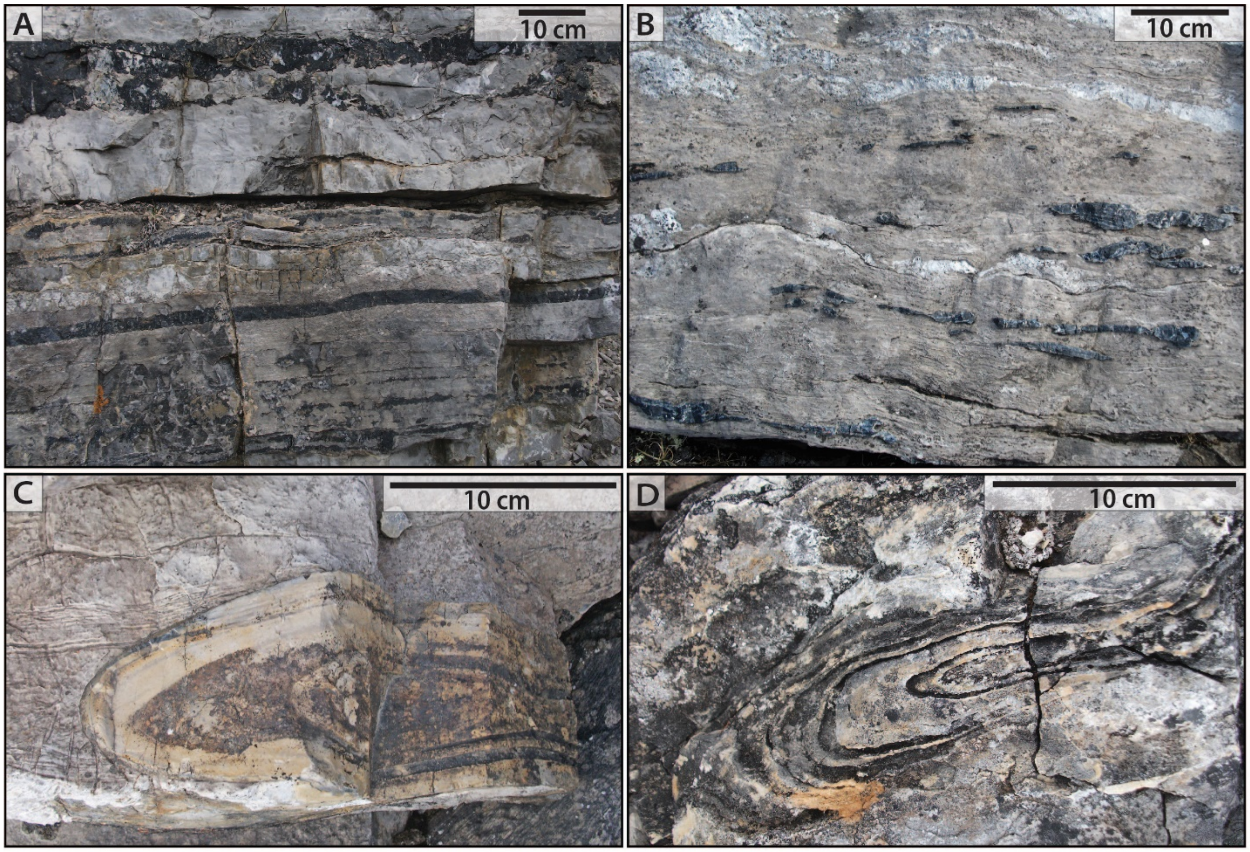

Figure 3. Chert occurrences in the Angmaat Formation. (A) Early diagenetic chert occurs as beds (B) and nodules within the carbonate strata. Late diagenetic chert occurs as nodules (C and D), and ranges in color from buff to light gray (C) or dark gray (D) in color.