The ICDP BASE (Barberton Archean Surface Environments) project: exploring early Earth and distant habitability and life.

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Earth has been habitable (had a solid crust underneath surface liquid water) for 4.3 Ga. Life probably originated before 3.9 Ga, the age of LUCA (Last Universal Common Ancestor) estimated from molecular clocks, while the prokaryotic domains (Bacteria and Archaea) diversified before 3.4 and 3 billion years ago, respectively, based on undisputed traces of life preserved in the Archaean [1]. Complex cells (eukaryotes) appeared before 1.75 Ga, the age of the oldest eukaryotic microfossils, and multicellular algae and fungi diversified before 1 Ga [2]. These major evolutionary events occurred when the atmosphere was rich in methane and carbon dioxide but nearly devoid of oxygen during the Archean, or with low pO2 during most of the Proterozoic [3, 4]. So, although a diverse microbial biosphere flourished on the early habitable Earth, life detection would have been challenging for remote observers analyzing its oxygen-ozone-poor atmosphere, an example of false negative [5].

The 3.22 Ga Moodies Gp, Barberton Greenstone Belt (BGB), South Africa, represents a unique early Archaean record of marine-terrestrial transition. It is the oldest and best-preserved siliciclastic succession preserving coastal sediments, from marine deltaic to shallow-water, BIFs, intertidal deposits, terrestrial evaporites, paleosols, fluviatile gravel beds, and some lavas. Extensive silicified microbial mats have been reported in tidal sandstones and fluviatile conglomerates, and S, C- and N-isotopic signals were interpreted as evidence of diverse microbial metabolisms in terrestrial and marine settings [6]. Moodies shales and siltstones also preserve the oldest organic-walled microfossils reported in clay-rich shallow-water marine deposits [7]. However, the identity of both microbial mats and microfossils remains unknown, and hypotheses range between unknown extinct life to anaerobic prokaryotes to anoxygenic or oxygenic photosynthesizers and early eukaryotes.

In July 2022, the international ICDP project BASE (Barberton Archean Surface Environment) completed its drilling activities and retrieved 8 cores, each 280 - 450 m length, 3,200 m in total, in these sedimentary (and minor volcanic) units ~3,700m thick which have been deposited within 1 to 14 Ma. These drill cores provide access to unique and pristine archives of early terrestrial-marine ecosystems to explore Archean surface conditions and microbial biosphere. They also offer an opportunity to investigate the preservation of life traces and pseudosignatures in clay-rich environments analog to Noachian deposits on Mars, the focus of the ongoing and future missions NASA Perseverance, ESA Exomars, and NASA-ESA Mars Sample Return.

[1] EJ Javaux. *Nature*, **572**, 451-460 (2019).
[2] EJ Javaux, *in Encyclopedia of Astrobiology* 3rd ed. https://doi.org/10.1007/978-3-642-27833-4_538-4 (2021).
[3] TW Lyons, CW Diamond, NJ Planavsky, CT Reinhard, C Li. *Astrobiology*, **21,** 906-923 (2021)
[4] XM Liu, LC Kah, AH Knoll, H Cui, C Wang, A Bekker, RM Hazen. *Nature comm*, **12**, 351 (2021).
[5] CT Reinhard, SL Olson, EW Schwieterman, et al. *Astrobiology* **17,**287–297 (2017)
[6] Homann, M., Sansjofre, P., Van Zuilen, M., Heubeck, C., Gong, J., Killingsworth, B., Foster, I.S., Airo, A., Van Kranendonk, M.J., Ader, M., Lalonde, S.V.. *Nat. Geosci.* **11**, 665–671 (2018)
[7] EJ Javaux., CP Marshall, A Bekker. *Nature*, **463**, 934-938 (2010).