Phosphorites as a universal indicator for life? A 2.4 Ga case study from the Turee Creek Group in Western Australia

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Introduction: While life leaves behind many signs of its existence, many of these signals are also lost over time due to environmental and geological factors. Minerals are useful deep-time signals of life because of their preservation potential, for example, pyrite preserving microfossils in the c. 3.5 Ga Dresser formation (Baumgartner et al., 2019). Diagenesis and metamorphism are processes that can, however, erase or overprint primary mineral-microbe signals and complicate our interpretation of Earth analogues.

Phosphorites are sedimentary deposits composed of phosphate minerals, which are generally associated with multiple microbial signals (energy, by-product and preserver: Papineau, 2010). Yet, both biological and abiological mechanisms have been attributed to phosphorite formation (see Papineau, 2010; Pufahl and Groat, 2017; Yang et al. 2021). In Ediacaran-aged deposits, textural (the presence of microfossils) and chemical (the presence of Fe-oxides) data have been used to differentiate these formation mechanisms (Yang et al. 2021), but whether these mechanisms are universal to older phosphorite deposits (e.g., Papineau, 2010; Soares et al., 2019) is unknown.

Case study: In order to better understand the usefulness of this type of deposit as a potential universal indicator of life on terrestrial planets, we investigated the origins of an ancient phosphorite deposit on Earth. During the Great Oxidation Event (GOE), 2.4 billion years ago, a shallow water phosphorite was deposited in what is now termed the Turee Creek Group (TCG), in Western Australia. The ancient phosphorite has low thermal maturity (229-261°C; Soares, 2021); it has been affected by diagenesis and only low-grade, burial metamorphism, which means its preservation potential is relatively high. Thus, the TCG phosphorite can act as a test of whether biological-specific signals are retained in the deep-time rock record.

Results. Three distinct types of textures containing phosphate minerals were recognized in petrography, including microbial sediments, peloids and micron-sized grains within branching organic structures (Soares et al., 2019; Soares, 2021). The microbial sediments are texturally associated with life, while the peloids and sub-micron grains have more ambiguous origins. Here we aim to compare the trace element, trace metal and U-Pb isotopic signals from each of these three textures to signals from a younger deposit (i.e., see Yang et al., 2021), to determine whether these ancient phosphate minerals retain common biological-specific signals despite being subject to long-term Earth processes that can overprint and degrade primary signals.

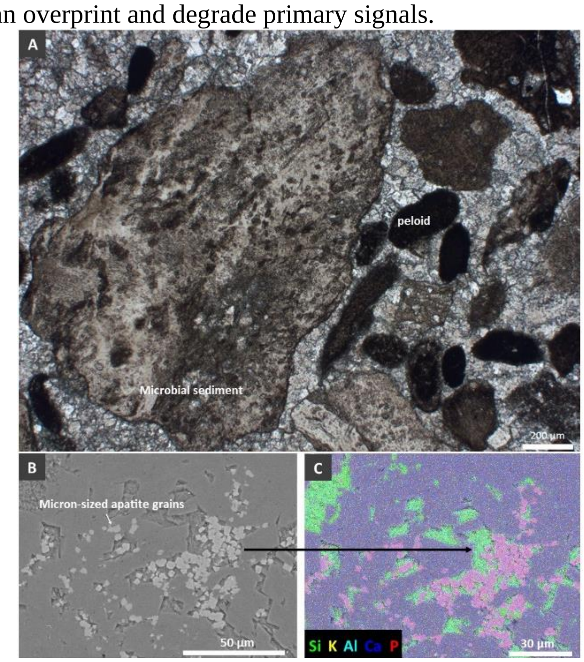

Figure 1. A) Petrographic image of microbial sediment (larger fragments) and peloids, in plane polarized light, described in Soares et al. (2019). Apatite and phosphate minerals are light brown, darker brown peloids also contain organic matter. B and C) are BSE and EDS images modified from Fig. 4.13 in Soares (2021) illustrating the micron-sized apatite grains (pink in RHS image) within branching organic structures.

Implications: Biologic signals are commonly associated with phosphate minerals within phosphorites but is it unknown whether this association extends into deep-time. By studying the mineralization and preservation of an ancient phosphorite deposit, we can assess the potential of such deposits as universal indicators of life. This research will also improve our understanding of potential phosphate mineral-rich deposits in our solar system.

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