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Identifying early Earth microfossils in unsilicified sediments

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The search for life on the early Earth or beyond Earth requires the definition of biosignatures, or "indices of life". These traditionally include fossil molecules, isotopic fractionations, biosedimentary structures and morphological fossils interpreted as remnants of life preserved in rocks. This research focuses on traces of life preserved in unsilicified siliciclastic sediments. Indeed, these deposits preserve well sedimentary structures indicative of past aqueous environments and organic matter, including the original organic walls of microscopic organisms. They also do not form in hydrothermal conditions which may be source of abiotic organics. At our knowledge, the only reported occurrence of microfossils preserved in unsilicified Archean sediments is a population of large organic-walled vesicles discovered in shales and siltstones of the 3.2 Ga Moodies Group, South Africa. (Javaux et al, Nature 2010). These have been interpreted as microfossils based on petrographic and geochemical evidence for their endogenicity and syngeneity, their carbonaceous composition, cellular morphology and ultrastructure, occurrence in populations, taphonomic features of soft wall deformation, and the geological context plausible for life, as well as lack of abiotic explanation falsifying a biological origin.

Demonstrating that carbonaceous objects from Archaean rocks are truly old and truly biological is the subject of considerable debate. Abiotic processes are known to produce organics and isotopic signatures similar to life. Spheroidal pseudofossils may form as self-assembling vesicles from abiotic CM, e.g. in prebiotic chemistry experiments (Shoztak et al, 2001), from meteoritic lipids (Deamer et al, 2006), or hydrothermal fluids (Akashi et al, 1996); by artifact of maceration; by migration of abiotic or biotic CM along microfractures (VanZuilen et al, 2007) or along mineral casts (Brasier et al, 2005), or around silica spheres formed in silica-saturated water (Jones and Renaut, 2007) or inside gaz bubbles (Brasier et al, 2009; Bengston et al., 2010); or as mobile hydrocarbon microspheres (Wanger et al, 2012). However, these processes cannot explain the formation of large recalcitrant (acid-resistant) hollow vesicles flattened in 2D parallel to bedding, with structurally preserved organic walls, and occurring in shallow-water shales. They do not occur in the right geological conditions, or do not produce the right taphonomy nor structurally preserved morphology; or the right chemistry (acid resistant kerogen, not bitumen); or the right size range and unimodal size distribution. Therefore the carbonaceous microstructures are interpreted as organic-walled microfossils of unknown biological origin (the definition of acritarchs, which may of prokaryotic or eukaryotic origin). In our study, ultrastructural analyzes by transmission electron microscopy provided a crucial test to evidence that large organic-walled vesicles from the 3.2 Ga Moodies Group were true microfossils and not just large kerogen particles (Javaux et al, 2010). This discovery showed that fine-grained siliciclastic window is an interesting target, not only for the proterozoic record, but also for archean paleobiology. Such study also suggests that aqueous fine-grained silicilastic or clay deposits from the Noachian on Mars should be high priority astrobiological targets.

To improve the Archean record, siliciclastic sedimentary rocks from new cores recovered through the ICDP Barberton "peering into the cradle of life" will be investigated for discovering and characterizing traces of life (organics, microfossils, microbial mat structures) and their paleohabitat and preservation conditions. Analytical approaches will include in situ study by petrography, organics extraction, optical and electronic microscopy, Raman and FTIR microspectroscopy, pyrolysis, datings, stable isotope analyzes, and a range of redox proxies, in collaboration with partners from the ICDP Barberton project, the ERC ELiTE project, and the Belspo IAP PLANET TOPERS project.