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Organo-mineral imprints in fossil cyanobacterial mats of an Antarctic lake

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Lacustrine microbial mats in Antarctic ice-free oases are considered to be modern analogues of early microbial ecosystems because they are dominated by cyanobacteria that need to cope with elevated UV radiation during summer by producing protective compounds such as UV-screening pigments. These microbial consortia offer a unique opportunity to (i) identify biogeochemical signatures to study the fossil record of microorganisms, and (ii) better understand their imprint mineral record.

We studied sediment cores from a meromictic brackish-water lake, Kobachi Ike, Skarvsnes Peninsula, Lützow Holm Bay, East Antarctica, where primary production is dominated by photosynthetic benthic communities. The faintly to finely laminated (stromatolitic) sediments include variable amounts of organic-rich laminae, micritic carbonate, clays and silicate sand.

We studied the microstructure and chemistry of organo-mineral associations in a suite of sediments ranging in age from several tens to ca. 3500 years. We examined Os- and U-stained polished resin-embedded sediments in a scanning electron microscope (SEM). We imaged photosynthetic pigments of microorganisms in fluorescence by confocal laser scanning microscopy (CLSM). We analyzed organic matter chemistry in demineralized sediments and cultured cyanobacteria using Fourier-Transform Infrared (FTIR) spectromicroscopy. Molecular analyses of fossil cyanobacterial DNA were performed using Denaturating Gradient Gel Electrophoresis of partial 16S rRNA genes and sequencing.

SEM revealed an intimate association between nanostructured Ca-carbonate peloids, fossil cell clusters resembling colonies of unicellular coccoid cyanobacteria, and cell-like imprints preserved in nanocarbonates. Diffuse organic matter (kerogen or EPS) is associated with nanoclays to form a laminae-building network around the carbonates. These organo-mineral microstructures strongly resemble those of the 2.7 Gyrs old Tumbiana stromatolites. CLSM imaging and fossil DNA analyses indicated that unicellular cyanobacteria dominate the microfossil assemblage. In addition, demineralization separated relatively few sheaths of filamentous cyanobacteria, dark brown or colorless to light brown. The dark sheaths showed FTIR fingerprints of scytonemin, a class of cyanobacterial UV-screening pigments that is not detected in other organic phases. In these lacustrine sediments, cyanobacterial microfossils may thus survive diagenesis for thousands of years and preserve molecular signatures (including pigments) in situ. Delicate mineral imprints, empty or encapsulating microfossils, may provide additional signatures of microorganisms in ancient sediments.