**CALCITE CRYSTALS AND CONCRETIONS IN MODERN CONICAL STROMATOLITES FROM LAKE UNTERSEE, EAST ANTARCTICA.** D. Schumann[1], D. T. Andersen[2], M. Kunzmann[1], S. K. Sears[3], H. Vali[1,3], [1]Department of Earth and Planetary Sciences, McGill University, 3450 University Street, Montréal, Québec, Canada, H3A 0E8, dirk.schumann@mail.mcgill.ca, [2]Carl Sagan Center for the Study of Life in the Universe, SETI Institute, 189 Bernardo Ave. Mountain View, CA 94043, USA, [3]Facility for Electron Microscopy Research, McGill University, 3640 University Street, Montréal, Québec, Canada, H3A 0C7

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**Introduction:** Understanding processes of bioalteration and biomineralization in modern and ancient terrestrial environments, particularly in cold and permafrost conditions is critical to recognizing biosignatures and how they may be used in the search for extinct and extant life in both terrestrial and extraterrestrial rocks.

Lake Untersee, the largest and deepest (>160 m) freshwater lake in East Antarctica, is considered an analog for the polar regions of Mars as well as the icy moons of Jupiter and Saturn. The lake has a perennial ice cover and a water column that is well mixed and supersaturated with dissolved oxygen with the exception of a small anoxic basin in the southwestern part. The water in the oxic basin is highly alkaline (pH 10.3 - 10.8) with a constant temperature of ~0.6ºC [1]. Dissolved inorganic carbon (DIC) is exceptionally low in the oxidized part of the lake [1]. The lake sediments of the anoxic basin contain some of the highest concentrations of methane of any natural body of water on Earth [2]. The lake floor is covered with photosynthetic microbial mat communities at depths of at least 100 m [1]. These mats are composed of filamentous cyanophytes that form both small, cm-scale cuspate pinnacles and conical stromatolites that rise up to 50 cm above the lake floor [1] (Fig. 1). The conical stromatolites are characterized by alternating laminae of organic material and sediments containing silt- and clay-sized material. The sediments enter the lake as glacial flour through subglacial melting and are deposited on the microbial mats. As the conical stromatolites are not found in any other modern environments they may be an analog for the growth of some of the oldest well described Archean stromatolites [1]. The objective of this study is to characterize the mineralogy of these mats and to investigate the calcite crystals and concretions that occur within the sediment layers by using electron microscopy and ascertain the role of biological activity in the process of mineralization.

**Methods:** Samples of conical stromatolites where collected from the floor of Lake Untersee as outlined in [1]. XRD, TEM, and SEM as well as carbon and oxygen isotope analyses were used to characterize the mineralogy, micro-texture, geochemistry of the sediments of the mats as well as the calcite crystals and concretions that were found within the sediments.

**Results and Discussion:** XRD, SEM- and TEM-EDS analyses indicate that the predominant minerals in the sediment lamina of the conical stromalites are plagioclase, potassium feldspar, quartz, mica, pyroxene-minerals, calcite, and smectite-group minerals. The detrital, silt-sized mineral and rock fragments are embedded in a matrix consisting of clay-minerals and extracellular polymeric substances (EPS). The matrix of the sediment laminae is pierced by microbial borings that are filled with EPS. Calcite occurs in some lamina as both single crystals and aggregates up to 2 mm long and as concretions of irregular shape up to 1 cm long (Fig. 2A, B). The calcite concretions, which have an envelope of EPS, are found in the upper portions of the microbial mat while the crystals appear to be restricted to the lower parts of the mat. The calcite concretions show signs of dissolution and are intersected by microbial borings that are different from those in the sediment laminae (Fig 3 A, B). The microbial borings in the concretions are characterized by a layer of calcite that precipitated on the walls of the tubules (Fig 3A, B).

The $\delta^{18}O$ (PDB) and the $\delta^{13}C$ (PDB) values for the calcite concretions range from -39.53 to -34.97‰ ($\delta^{18}O$ SMOW -5.15 and -9.83‰) and from -3.41 to -5.55‰, respectively. The $\delta^{18}O$ (PDB) data of the calcite crystals cluster between -36.74 and -37.17‰ ($\delta^{18}O$ SMOW -6.96 and -7.41‰). The $\delta^{13}C$ (PDB) values of the crystals range from -4.51 to -6.09‰. The lake water has a $\delta^{18}O$ (VSNOW) value of -35.05‰ [3]. This data, as well as the shape and growth orientation of the crystals and concretions in the sediment laminae, suggest an authigenic origin within the microbial mats.

The lake water has a high $Ca^{2+}$ concentration, but is depleted in $CO_2$ [1]. The precipitation of the concretions and crystals within the mats suggests the source of $CO_2$ ($CO_3^{2-}$) was from within the mats. Concretions precipitated in the upper part of the microbial mats in pockets within the sediment laminae that contained sufficient $CO_3^{2-}$ to form calcite. The source of the $CO_2$ ($CO_3^{2-}$) was likely from microbial activity and/or the decomposition of organic matter. Concretions may have dissolved in the lower parts of the mats and calcite crystals precipitated from solutions in the pores. The microbial borings observed in the calcite concretions are likely the result of cyanobacteria. It is know from various examples that microbial phototrophes, especially cyanobacteria, are responsible for borings in many carbonate substrates [4], [5].

Figure 1: Conical microbial mats from Lake Untersee [1].

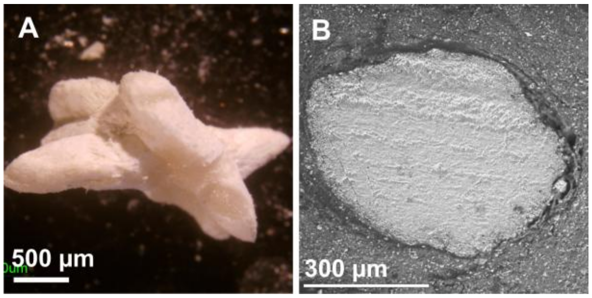


Figure 2: (A) Light microscope image showing an aggregate of calcite crystals grown within the sediment layer of a microbial mat. (B) SEM backscattered electron (BSE) image of a calcite concretion embedded in the sediment layer of a microbial mat.

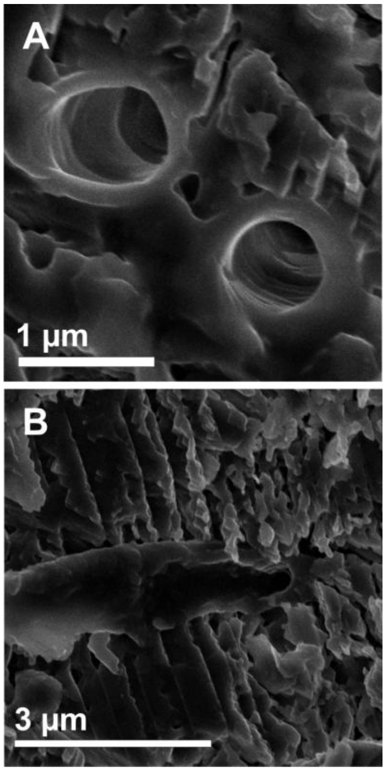


Figure 3: Representative SEM images of microbal borings. (A) Microbial borings in a calcite concretion. Note the rim of newly precipitated calcite around the inner wall of the tubules. (B) Microbial boring in a calcite concretion with mineralized walls. The tubule protrudes from the strongly altered surface of the concretion.

**References:**

[1] Andersen D. T. et al. (2011) *Geobiology, 32*, A74. [2] Wand U. et al. (2006) *Limnol. Oceanogr., 51*, 1180–1194. [3] Hermichen W. D. et al. (1985) *Nature*, 315, 131-133. [4] Garcia-Pichel F. (2006) *Sediment. Geol.*, 185, 205-213. [5] Garcia-Pichel F. et al. (2010) *PNAS*, 107, 21749-21754.