CONTROL ID: 1499052 **TITLE:** Sources of Sulfate Found in Mounds and Lakes at the Lewis Cliffs Ice Tongue, Transantarctic
Mountains, Antarctica and Inferred Sub-glacial Microbial Environments

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ABSTRACT BODY: Massive but highly localized Na-sulfate mounds (mirabilite, $Na2SO4.10H2O$) have been found at the terminal moraine of the Lewis Cliffs Ice Tongue (LCIT), Antarctica. δ34S and δ18O values of LCIT mirabilite range from +48.8 to +49.3‰ (CDT), and -16.6 to -17.1‰ (V-SMOW), respectively, while Δ17O average -0.37‰ (V-SMOW). LCIT mirabilite mounds are isotopically different from other mirabilite mounds found in coastal regions of Antarctica, which have isotope values close to seawater compositions. δ18O and Δ17O values suggest the incorporation of isotopically light glacial water. Data point to initial sulfate formation in an anoxic water body, either as a stratified anoxic deep lake on the surface, a sub-glacial water reservoir, or a sub-glacial lake. Several surface lakes of varying size are also present within this region of the LCIT, and in some cases are adjacent to the mirabilite mounds. O and D isotope compositions of surface lakes confirm they are derived from a mixture of glacial ice and snow that underwent moderate evaporation. δ18O and δD (V-SMOW) values of snow, ice, and lake water range from -64.2 to -29.7‰, and -456.0 to -231.7‰, respectively. However, the isotope chemistry of these surface lakes is extremely different from the mounds. Dissolved SO4-2 δ34S and δ18O values range from +12.0 to +20.0‰ and -12.8 to -22.2‰ (the most negative δ18O of terrestrial sulfate ever reported), respectively, with sulfate Δ17O ranging from +0.93 to 2.24‰. Ion chromatography data show that lake water is fresh to brackish in origin, with TDS less than 1500 ppm, and sulfate concentration less than 431 ppm. Isotope and chemical data suggest that these lakes are unlikely the source of the mirabilite mounds. We suggest that lake water sulfate is potentially composed of a mixture of atmospheric sulfate and minor components of sulfate of weathering origin, much like the sulfate in the polar plateau soils of the McMurdo Dry Valleys. A simple model explains mirabilite mound formation at the LCIT. Sulfur redox processes could occur sub-glacially as a result of liquid-water-based glacial conditions (Alpine style glacier), most likely formed by pressure melting of overlying ice (Aharon, GCA, 52, 2321-2331). We suggest that the aqueous base of the LCIT contains dissolved SO42- and is anoxic where sulfate reduction to H2S, HS-, or native sulfur takes place. Sulfide is removed by either precipitation as sulfide minerals or by escape of H2S (neither of which have been observed). Mirabilite precipitation is likely the result of evaporation or freezing of sulfate-rich brines as they reach the surface where they manifest themselves as mounds. Pressure from the overlying ice contributing to a pressure-melting scenario that creates the sub-glacial aqueous environment also contributes to the mechanism of upward transport of the sulfate-rich fluids. Further evidence to support this upward transport model comes from the nature of ice motion at the LCIT. Cassidy et al (Meteoritics, 27, 490-525, 1992) pointed out that it is the vertical ice motion in this area that creates the meteorite-stranding surface that could also account for upward transport of sulfate-rich fluids. Alternatively, mirabilite was deposited in a similar condition as present-day coastal Antarctica when the LCIT was wetter and warmer.