

LIFE DETECTION AND CHARACTERIZATION OF SUBSURFACE ICE AND BRINE IN THE MCMURDO DRY VALLEYS USING AN ULTRASONIC GOPHER: A NASA ASTEP PROJECT. P. T.

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Introduction: Evidence for the presence of ice and fluids near the surface of Mars in both the distant and recent past is growing with each new mission to the Planet. One explanation for fluids forming spring-like features on Mars is the discharge of subsurface brines. Brines offer potential refugia for extant Martian life, and near surface ice could preserve a record of past life on the planet. Proven techniques to get underground to sample these environments, and get below the disruptive influence of the surface oxidant and radiation regime, will be critical for future astrobiology missions to Mars. Our Astrobiology for Science and Technology for Exploring Planets (ASTEP) project has the goal to develop and test a novel ultrasonic corer in a Mars analog environment, the McMurdo Dry valleys, Antarctica, and to detect and describe life in a previously unstudied extreme ecosystem; Lake Vida (Fig. 1), an ice-sealed lake.



Figure 1: Landsat image of the dry valleys region showing location of Lake Vida. The image is centered at 77.5oS 162oE.

Ice-Sealed Lakes: Lakes in the McMurdo Dry Valleys of East Antarctica have long been studied as extreme environments and potential analogs of purported Martian lakes of the past [e.g. 1, 2]. Commonly studied dry valley lakes have a 2 to 6 m perennial ice

cover and 20 to 60 m water column beneath. These lakes also have a range of salinities from fresh to hypersaline, and all allow sufficient sunlight to pass through the ice for photosynthesis to occur in the water column and benthos.

A few lakes in the dry valleys have been largely unstudied until recently because they were believed to be frozen to their beds. One of these lakes (Lake Vida) is also one of the two largest lakes in the dry valleys. Using a combination of ground-penetrating radar and ice coring techniques we have established that Lake Vida comprises a NaCl brine with a salinity seven times sea water and temperature constantly below -10°C lies beneath ~ 20 m of ice that is at least 2,800 radiocarbon years old [3]. Microbial mats occur throughout the ice column and are viable upon thawing. Sediment layers in the ice effectively block incoming solar radiation (Fig. 2).

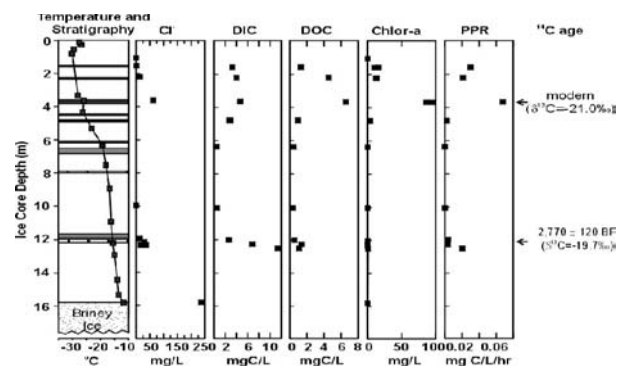


Figure 2: Physical and chemical properties of Lake Vida ice core taken in October 1996. Black horizons on the stratigraphy plot represent sediment layers, gray horizons are sandy ice, and vertically banded horizons contain microbial mat. The temperature profile shown was taken at the time of ice extraction.

Ultrasonic Gopher: Planetary sampling using conventional drilling and coring techniques is limited by the need for high axial force necessitating the use of heavy rovers or anchoring mechanisms. A novel ultrasonic/sonic driller/corer (USDC) mechanism [4] was developed that overcomes these and other limitations

of conventional techniques. The novel element of the USDC is the free-mass that operates as a frequency transformer converting 20 KHz ultrasonic waves to a 60-1000 Hz sonic hammering action (percussion) that is applied onto the drilling/coring bit. The USDC actuator consists of a stack of piezoelectric ceramics with a backing material that focuses the emission of the acoustic energy forward, and a horn that amplifies the displacements generated by the stack. The tip of the ultrasonic horn impacts the free-mass creating a sonic resonance between the horn and the bit.

The USDC has been demonstrated to drill rocks that range in hardness from hard granite and basalt to soft sandstone and tuff. This novel drill is capable of high-speed drilling (2 to 20 mm/Watt·hr for a 2.85mm diameter bit) in basalt and Bishop Tuff using low axial preload (<10 N) and low average power (<5 W). The USDC mechanism has also demonstrated feasibility for deep drilling. The Ultrasonic-Gopher (Fig. 3a) can potentially be used to reach great depths and large diameters (3 and 4.5 cm have been demonstrated) using a low mass rover. Generally, the bit creates a borehole that is larger than the drill bit outer diameter and it also creates a core that is smaller in diameter than the inner diameter of the coring bit. This reduces the chances of bit jamming where hole integrity is maintained, and it eases in the extraction of the core from the bit. Current models suggest that the USDC performance does not change significantly with changes in ambient gravity.



Figure 3: a) Ultrasonic-Gopher and extracted limestone core, b) Recent prototype of ice gopher. Ice chisel bit on the left and actuator on the right.

“Ice Gopher”: Ice below 16 m depth in Lake Vida and the brine body have never been sampled directly due to logistical constraints. We are building an ultrasonic “ice gopher” (Fig. 3b) to make in situ ecosystem measurements, and acquire samples to be fur-

ther analyzed. Early versions of the “ice gopher” suggest that coring through ice may prove a bigger challenge than coring through rock. A large part of our efforts in the early stages of development are focused on the problems of chip handling and ice melt during drilling, both of which can create significant potential for getting the instrument stuck during the mission.

Our field plan is to use the gopher to core through the Lake Vida ice cover, cycling in and out of the hole to retrieve ice cores along the way. The gopher will sample brine as it goes and the brine will be collected at the ice surface under clean and sterile conditions. Using the gopher we will address two main hypotheses

H1. Microbial communities within the brine (include brine pockets in the deep ice) and benthic sediments are currently viable, active and affect the present-day geochemistry of the lake.

H2. The ice, water column and benthos of deeply frozen lakes contain geochemical signatures of past microbiological activity.

Conclusions: Lake Vida provides the unique opportunity to investigate lake ecosystems on the edge of existence to determine what conditions may lead to the eventually complete freezing of a lake and the subsequent development/evolution of microbial communities and geochemical signatures. The combined hypersaline, aphotic, atmospherically isolated and cold conditions in Lake Vida make it potentially among the most extreme aquatic environments on Earth. These conditions were likely to have been present during the last stages of purported lakes on Mars near the end of its water-rich past. Our drilling program will provide useful insight into the challenges of drilling through cold dirt and ice with a low power and light weight instrument to retrieve samples for life detection.

References: [1] McKay C. P. et al. (1985) *Nature*, 313, 561-562. [2] Doran P. T. et al. (1998) *JGR*, 103(E3), 28481-28493. [3] Doran P. T. et al. (2003) *PNAS* 100, 26-31. and Author C. D. (1997) *JGR*, 90, 1151-1154. [4] Bar-Cohen Y. et al. (2001) “Ultrasonic/Sonic Driller/Corer (USDC) With Integrated Sensors,” U.S. Patent filed.