Subsurface Ice and Brine Sampling Using an Ultrasonic/Sonic Gopher for Life Detection and Characterization in the McMurdo Dry Valleys

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With each new mission to the Planet Mars, there is growing evidence for ice and fluids near the surface. 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. Under a NASA Astrobiology for Science and Technology for Exploring Planets (ASTEP) task a novel ultrasonic/sonic gopher is being developed to operate in a Mars analog environment. This field analogue is the McMurdo Dry valleys, Antarctica, where efforts are being made to detect and describe life in a previously unstudied extreme ecosystem; Lake Vida, an ice-sealed lake.

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 was developed that overcomes these and other limitations of conventional techniques. The USDC consists of three loosely coupled elements including a piezoceramic based actuator, free-mass and a bit. The free-mass is the novel element of the USDC and it operates as a frequency transformer converting 20 KHz ultrasonic waves that are generated by the actuator to a 60-1000 Hz sonic hammering action. This hammering action is applied onto the drilling/coring bit. The actuator has a horn that amplifies the induced displacements and its tip impacts the free-mass causing it to hop in 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). 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 and it eases in the extraction of the core from the bit. Current analytical models suggest that the USDC performance does not change significantly with changes in ambient gravity. The USDC mechanism was modified to form the Ultrasonic/Sonic Gopher and it has been demonstrated for feasibility to perform deep drilling. This gopher was made in 3 and 4.5 cm diameter models and it has the potential to core ice and to operate from a low mass rover.

Ice below 16-m depth in Lake Vida and the brine body have never been sampled directly due to logistical constraints. The ultrasonic/sonic "ice gopher" that is being developed is designed to make in-situ ecosystem measurements, and acquire samples for further analysis. Coring ice with the USDC suggests that it is a greater challenge than coring through rock. A large part of our current efforts is focused on the problems of ice chip handling and potential ice melt during drilling, both of which can create significant potential for jamming the gopher during the mission. An analytical model is being developed to optimize the design of the gopher with emphasis on the thermal issues, drilling rate, power requirements and the electromechanical behavior of the gopher.

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.