FIELD TESTING OF THE ICEBREAKER MARS DRILL IN THE ANTARCTIC. G. Paulsen[1], K. Zacny[1], C. McKay[2], B. Glass[2], M. Szczesiak[1], J. Craft[1], C. Santoro[1], J. Shasho[1], A. Davila[2], M. Marinova[2], W. Pollard[3], A. Jackson[4], [1]Honeybee Robotics, 398 W. Washington Ave, Suite 200, Pasadena, CA 91103, zacny@honeybeerobotics.com, [2]NASA Ames Research Center, Moffett Field, CA, [3]McGill University, Montreal, Canada, [4]Texas Tech University, Lubbock, TX.

Introduction: The 2008 Mars Phoenix lander used a scoop with a high-speed drill (called rasp) to penetrate less than a centimeter into the ice surface at the Martian North Pole [1]. The next step in the exploration of the martian subsurface is to drill at least two orders of magnitude deeper and deliver samples to a suite of instruments for analysis.

To enable this next step we have been developing a one meter class drill, called the IceBreaker [2, 3]. The drill consists of a rotary-percussive drill head, a sampling auger with a bit at the end, a Z-stage for advancing the auger into the ground, and a sampling station for moving the augered ice shavings or soil cuttings into a sample cup.

In November/December of 2010, the IceBreaker drill was tested in the University Valley (within the Beacon Valley region of the Antarctic Dry Valleys). University Valley is a good analog to the Northern Polar Regions of Mars because a layer of dry soil lies on top of either ice-cemented ground or massive ice (depending on the location within the valley) [4, 5]. That is exactly what the 2008 Phoenix mission discovered on Mars.

Drilling 1 meter in Ice-Cemented Ground: The first set of tests included drilling into ~ 20 cm of dry soil followed by 80 cm of ice-cemented ground, that is to a depth of 100 cm. The IceBreaker drill was placed outside of a science tent (our Mars-analog site), while control system with the drill operator was inside the tent (control room on earth) – as shown in Figure 1. This was done in order to demonstrate remote operation of the drill. We also followed protocols used to operate the Rock Abrasion Tool on Mars Exploration Rovers and in particular, we issued only three different commands: 'seek', 'drill', and 'sample'. The drilling protocol was designed to allow for collecting samples in 10 cm intervals. The tasks for the person outside of the tent was to change out sample bags and take pictures (these tasks will be automated in the future). The exact drilling location was S77°51.891', E160°48.029', and the elevation was 1709 m.

During the drilling process, the bit temperature was continuously monitored by a temperature sensor embedded inside a bit. The bit temperature was one of the most important drilling telemetry since it indicated whether the subsurface ice within the soil matrix was reaching the melting point. The drilling algorithm was constructed in such a way as to either slow down or stop the drilling operation altogether if the temperature was reaching 0° C. Note that the algorithm developed for Mars drilling would limit that temperature to a temperature less than 0° C to account for possible presence of freezing point depressors within the ice-soil mixture (e.g. perchlorate).

A single test that included drilling to 1 meter depth and collecting samples in 10 cm intervals took a few hours (Figure 2). The majority of the time was spent pulling the drill out of the hole after drilling the 10 cm interval. This was required in order to deposit the sample into a cup or a sample bag and to clean the auger surface using a passive brush to minimize cross-contamination.

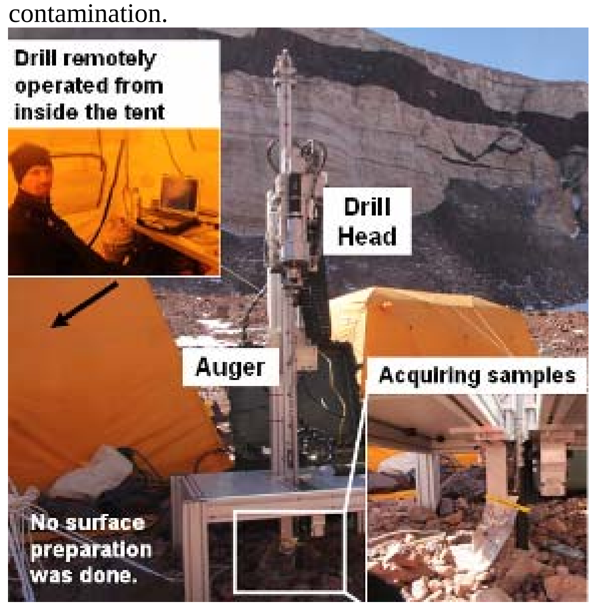

Figure 1. The IceBreaker drill in the University Valley, Antarctica was used to drill 1 meter in ice-cemented ground and collecting drilled cuttings into dedicated sample bags.

During the drilling process, the average power was approximately 70 Watt, the Weight on Bit, WOB (i.e. the force the bit was pushing against the ground) was < 70 Newton, and the penetration rate was ~1.12 m/hr. We refer to this drilling mode as 1-1-100-100 that is 1 meter in 1 hour with less than 100 Watt of power and 100 Newton Weight on Bit. The electrical energy required to perform drilling and sampling was less than 100 Whr (the drilling energy itself was 63 Whr). The bit temperature never exceeded -5 °C (the ground temperature was -19 °C).

These tests have shown that drilling on Mars, in ice cemented ground with limited power, energy and Weight on Bit, and collecting samples in discrete depth intervals is possible within the given mass, power, and energy levels of a Phoenix-size lander and within the duration of a Phoenix-like mission.

Figure 2. Samples were collected in 10 cm intervals using autonomous sampling system (only replacing of bags after each 10 cm interval was not automated).

Drilling 2.5 meter in Massive-Ice: Our second drilling location was massive ice with small to boulder-size rocks on top as shown in Figure 3. The exact location was S77° 51.950', E 160° 48.418', while the elevation was 1724 m. Although the goal was to drill to 1 meter only, after reaching the 1 meter depth in just over an hour, we decided to proceed to a depth of 2.5 meters. Drilling to 2.5 meter depth took ~2.5 hrs (at a penetration rate of ~1 m/hr). The average power at a depth of 2.5 m was 120 Watt, and the Weight on Bit was < 100 Newton. Drill electrical energy to 2.5 m was < 300 Whr. During the test, the maximum bit temperature was -10 °C (the ground temp. was -24 °C).

The ice cuttings were initially collected in 10 cm depth intervals (to a total depth of 100 cm). After 100 cm depth, the ice cuttings were collected in two depth intervals: 100-180 cm and 180-250cm. These ice chips contained numerous ice crystals as large as 0.25 inch in size (Figure 4). This shows that drilling action does not necessarily crush all the ice.

Teleoperation from California: As part of the education and public outreach, and to demonstrate the ease of controlling the drill, the IceBreaker drill was teleoperated by a group of 5th graders from the Valley View School in Pleasanton, California [6]. During that time, the IceBreaker drill was placed in McMurdo station, outside of the Crary building. This particular location enabled easy access to the internet. During approximately one hour, students drilled to a depth of ~20 cm and acquired samples.

Figure 3. Drilling 2.5 meter in massive ice in the University Valley (the Beacon Valley region of Antarctica.)

Figure 4. Ice cuttings contained single ice crystals as large as 0.25 inch.

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