APPROACH FOR ACQUISITION OF ROCK CORES IN THE FIELD. K. Zacny[1], W. Cervantes[1], D. Kim[1], F. Rehnmark[1], B. Wei[1], N. A. Cabrol[2], [1]Honeybee Robotics, [2]SETI Institute Carl Sagan Center.

Introduction: Field geologists and astrobiologists need the ability to capture core samples for analysis. In the case of geologists, the core sample is required to be as intact as possible to allow analysis of stratigraphy and creating thin sections. For astrobiologists, the core needs to be free of any foreign contamination and, as such, the bit requires to be sterilized and core acquisition process needs to be sterile. Moreover, the core acquisition process needs to be simple and performed relatively fast. The hardware must be very robust and easily fixable in the field, if damaged.

Given all these requirements, we have developed a core acquisition system that can be deployed by geologists and astrobiologists in the field, on the surface or under water. The core bit was designed to capture 1 inch in diameter and 4-inch-long core.

The tools have been designed specifically for the SETI Institute NAI team (N.A. Cabrol, PI), and field tested in the Atacama in 2016 [1, 2]. Additional field opportunities presented themselves for testing different generations of these bits. The modified bits were used to capture samples of coral during the 2017 NEEMO tests. The bits have also been used to capture cores within the Hawai'i Volcanoes National Park as part of two PSTAR projects: BASALT: Biologic Analog Science Associated with Lava Terrains (Darlene Lim, PI) and SHyRE: Scientific Hybrid Reality Environments (Kelsey Young, PI).

Currently version 3 is being fabricated and will be tested in Atacama in the next field deployment.

These coring bit system are available to science community and can be requested from Honeybee.

The coring system includes five parts which are detailed below (Figure 1): 1. Auger Bit, 2. Core Breakoff Tube, and 3. Bit Adapter, 4. Hole Starter, and 5. Hammer Drill.

1. Auger Bit: The purpose of the auger bit is to cut the rock and move cuttings out of the hole. These cuttings can be retrieved at the surface and analyzed.

2. Core Breakoff & Release: To capture the core and retain it inside the coring bit, the core bit requires a core breakoff feature. We implemented the Honeybee Robotics' patented "eccentric tubes" method [3]. Here, the bit and the breakoff tube each have bores slightly offset from center by the same distance (**Figure 2**). During drilling, the two tubes are aligned. When core breakoff is desired, the breakoff tube is rotated relative to the bit. This pushes the core to one side, shearing it at the base and retaining it. Release is accomplished by returning the breakoff tube to the "open" position and orienting the drill so that the core drops out under its own weight. This technology has been implemented into the Mars2020 coring drill.

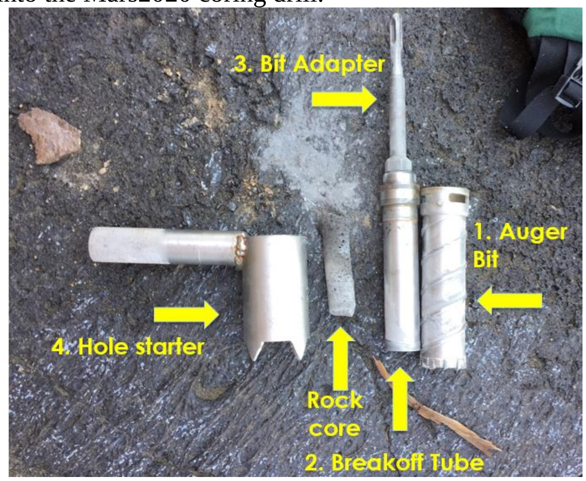

Figure 1. Coring bit assembly.

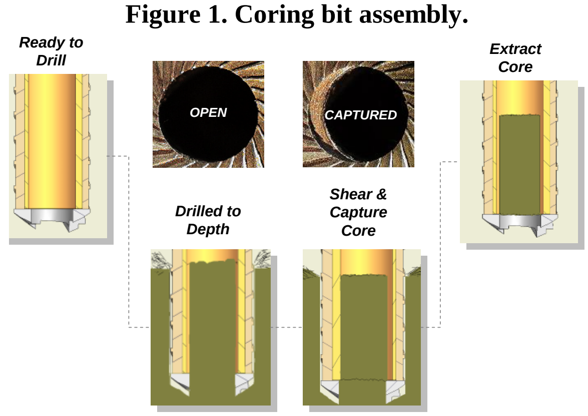

Figure 2. Honeybee Robotics patented "eccentric tubes" core breakoff approach.

3. Bit Adapter: The bit adapter is essentially a rod attached to the Breakoff Tube and the Hammer Dill. The adapter transfers drilling forces and hammer percussion from the drill to the bit.

4. Hole Starter: Full faced bits have center cutters that constrain the bit axially. Coring bits have peripheral cutters, which produces destabilizing forces causing the drill bit to "walk". Our hand-operated solution is the core bit stabilizer, used for the first few seconds of drilling until the coring bit cuts a few millimeter-deep groove, sufficient to center the coring bit.

5. Hammer Drill: we use off-the-shelf rotary-percussive cordless drills. The type of bit chuck determines how the Bit Adapter will look like. we utilizes Hilti 7A or similar for all tests, which uses SDS+ bits.

Testing: The testing was conducted in the Hawai'i Volcanoes National Park. Two types of formations have been samples: altered and unaltered fumarole materials, as well as young and old volcanic flaws. In each case approximately 20 core samples were extracted and bagged for analysis.

Drilling unaltered fumaroles took slightly longer than drilling altered fumaroles, however core retrieval was easier and faster because unaltered fumaroles were dry. Highly altered fumaroles, on the other hand, were hot (~ 50 °C) and wet a few centimeters below the top surface. As such, when exposed by the drilling action, the core would dry out and cement onto the inner tube. The solution to core extraction was to remove the Breakoff Tube and push the core out from the top. Other methods, such as thwacking against the Breakoff Tube with a screwdriver, was also effective. To allow easier core extraction, the next generation bit should have a low friction coating on the inside and larger slot along the Breakoff Tube to allow easy access and extraction of the core.

Figure 3. Core of altered fumarole from Mauna Ulu.

Drilling old and young lava flows offered opportunities to test various types of bits as shown in Figure 4. In particular, Bits A and B were commercial coring bit 1 inch in diameter, and 0.5 inch in diameter, respectively. Bit C was custom bit, 1 inch in diameter with large kerf. Bit D was custom bit, 1 inch in diameter with small kerf and 6 cutters. Bit E was custom bit 1 inch in diameter with small kerf and 10 cutters.

Overall, commercial bits penetrated rock much faster (approximately twice as fast) as custom bits. However, the core quality was significantly worst. Since commercial bits do not have core breakoff systems, if the core does not break during the coring operation, it must be somehow retrieved afterwards (normally a screwdriver is used to shear the core and forceps to pull core pieces out).

Custom bits produce much better core quality, they can capture core within the Breakoff Tube, and they also have a slot along the bit. The slot allows core investigation before it is ejected. Further, if a core adhers to the wall, a screwdriver can be inserted into the slot and used to push the core out.

Of the three custom bits, the Bit E performed best. It drilled fastest and also acquired the best quality cores.

Figure 4. Coring bits tested in lava flows and captured cores. From top to bottom: A, B, C, D, and E.

Next Steps: The 3rd version coring bit has been designed and is being manufactured. It will be tested in the Andes in 2018. The new coring will allow much faster in situ sterilization, core acquisition, and core ejection.

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References: [1] Cabrol et al., (2017). AbSciConf., [2] Rehnmark et al., (2017). AbSciConf., [3] Zacny et al., (2013), IEEE Aerospace Conf.