Progress on the Development of a Thin Section Sample Preparation Device for Space Exploration. C. Dreyer[1], K. Zacny[2], J. Skok[1], J. Steele[1], G. Paulsen[2], M. Szczesiak[2], M. Nakagawa[1], J. Schwendeman[1], [1]Colorado School of Mines (cdreyer@mines.edu), [2]Honeybee Robotics Spacecraft Mechanisms Corporation, New York, NY, (zacny@honeybeerobotics.com).

Introduction: Petrographic thin sections are used to identify minerals and their structural aspects (cleavage, fractures, mineral zoning) rock microtextures that indicate the mode of formation of the rock (igneous, metamorphic, sedimentary). A thin section, along with chemical analytical data for a rock on the Moon, Mars, other planetary body, an asteroid, or comet would remove much ambiguity from interpreting the geology of the sampled site. Use of a polarized light microscope with a thin section would enable mineral identification. While use of an unpolarized light microscopy would enable some textural, structural, and mineral identification.

A petrographic thin section is a sample mounted on a glass slide and then ground to approximately 30 µm in thickness and subsequently polished with a fine abrasive. The 30-micron thickness is chosen because most common minerals (e.g. silicates) are transparent at that thickness, while a few minerals (e.g. ilmenite, spinel, sulfides) are opaque. A petrologist handy with the petrographic microscope can rapidly identify minerals from the interference colors related to birefringence. The art of thin section preparation is in the skill of the preparer judging the thickness of the slice from polarized light transmission and judging the adequacy of the surface finish.

We present here progress by research groups at the Colorado School of Mines and Honeybee Robotics toward the development of an automated rock thin section device for space exploration. We are developing methods for rough cutting, epoxy/slide application, and grinding/polishing to finished thin section, in addition to an examination of rock finish requirements work.

Rough Cutter: The process of preparing a thin section begins with the downsizing of a selected rock specimen from it's original size and shape to a tablet 50 x 20 x 5 mm. This process is called rough cutting and requires the manipulation (alignment) of the specimen along three orthongonal planes. While most traditional petrographic thin section systems use cut-off saws with embedded diamond, we are exploring the use of diamond embedded wire saws because they require less energy, reduce over-cutting waste (kerf), produce less dust, have the capability to cut in multiple directions (e.g., produce orthogonal cuts without rock repositioning), and for reduced system weight and volume.

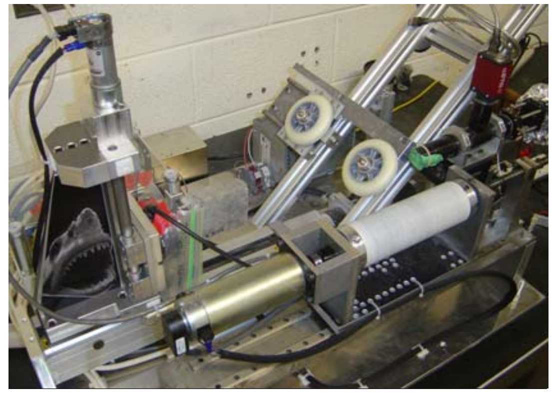

Figure 1: Picture of Rough Cutter prototype

The prototype system is shown in Fig. 1. The current configuration is a capstan design with the wire wound onto the capstan for storage, and the wire is spooled off the capstan through guide pulleys and past the rock before being rewound onto the other end of the capstan. This approach requires an oscillatory motion profile and good control of the kinematic behavior of the wire motion since impact loading of the wire has been shown to be the major mode of wire failure. The wire trajectory nominally follows a trapezoidal velocity profile, as shown in Fig. 2. Testing of wire performance, wear rate, specific energy used, as well as viability of different configurations have been conducted.

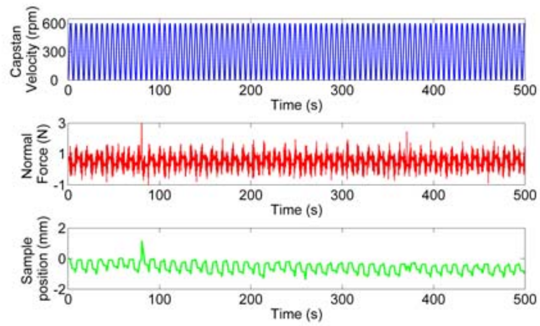

Figure 2: Rough cutter control data. Capstan radial velocity (revolutions per minute), applied force normal to wire, and sample position.

GRITS: The prototype system is shown in Fig. 3. This system is comprised of three stations. These are (from right to left) the grinding/polishing station, thickness measurement station, and surface finish measurement station. The laptop with a control software enabling autonomous operation is shown to the far right. The prototype system is designed so that the grind station can be oriented to grind with either a cup or straight type grinding wheel. The tablet holder is mounted to a load cell to provide information on the force with which the wheel is pressing against the rock and in turn the grind pressure. The load cell is mounted to a precision linear lift stage with a resolution of 0.2 microns. Finally, this stage is mounted to an X stage for tablet transfer between the stations and to enable oscillatory motion (backforth) during the grinding process.

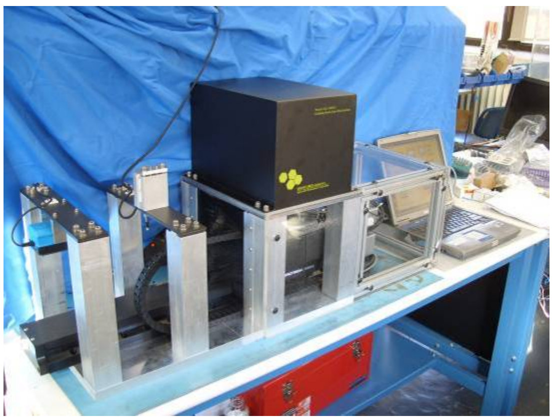

Figure 3: Picture of GRITS autonomous grinder/polisher prototype.

The GRITS system has successfully completed in autonomously grinding a tablet to a thickness of ~33 microns and to a surface finish that is adequate for petrographic analysis using a polarizing microscope. In Fig. 4 micrographs of an Anorthrosite sample are shown. The images on the left, Fig. 4a and 4c, were produced by the GRITS system under automated grinding. The images on the right, Fig. 4b and 4d, were produced using tradiational preparation by a skilled petrographer. The GRITS prepared thin section has increased pitting on some minerals and grinding marks can also be seen. The tradiationlly prepared thin section is clearly superior to the GRITS prepared thin section shown in Fig. 4, but the GRITS prepared thin section was deemed adequate for petrographic analysis by a petrographic expert.

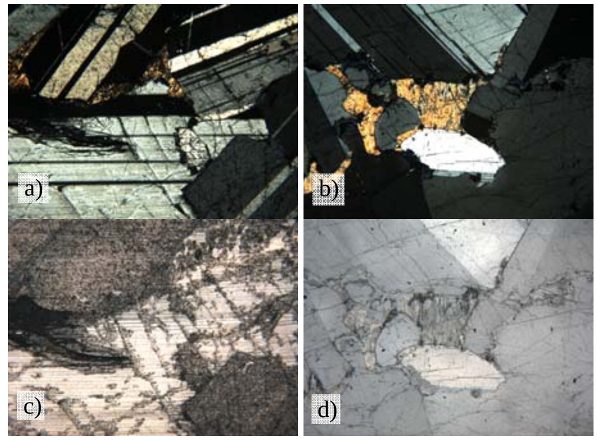

Figure 4: A thin section of an Anorthrosite sample (MSFC/USGS, ref 1) under cross polarizers (top: a and b) and reflected light (bottom: c and d) as produced by the GRITS system (left: a and c) and by traditional preparation (right: b and d).

Conclusions: The development of an automated rock thin section device for space exploration is a challenging endeavor. Thin section preparation in terrestrial labs is typically performed by human operators with many years of experience learned by trial and error. We are researching several all of the component step for thin section preparation. To this end we have constructed prototype systems for studies for the autonomous rough cutting and grinding/polishing of analog samples.

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References: [1] Rickman D., et al., (2006) *Space Resources Roundtable VIII*, Abstract #1037.