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. Nakagawa[1], J. Schwendeman[1], E. Carroll[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. The use of a polarized light microscope would allow optical characteristics of minerals and their identification and, to some extent, mineral composition. However, unpolarized light microscopy can enable some textural, structural, and mineral identification to be made.

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 was 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 and the adequacy of the surface finish.

We present here progress by research groups at the Colorado School of Mines and Honeybee Robotics on progress toward 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. Here we report progress on rock surface finish requirements, rough cutting and Grinding/Polishing (GRITS).

Surface Finish Requirements: As part of the research effort we have examined the surface finished produced by polishing with different diamond grits. Samples of anorthrosite, hartsburgite, and norite acquired from the USGS and MSFC [1] have been examined, in addition to "saddleback" basalt used in MMS[1]. Fig. 1 shows reflected light micrographs of a norite sample at 100x magnification. The large particle size polishing pads produce a rougher surface finish with more pitting. The variation in pitting on the 9 μm particle finish actually reveals different crystals not easily visible with the finer polished. An evalation by a skilled thin section profession concludes that the 3 μm particle finish would be adequate for use in a petrographic microscope, while some of crystals of the 6 μm particle finish would be adequate and fewer of the 9 μm particle finish. Average surface roughness was determined with an optical profilometer to be 0.2 μm or less for all adequately polished areas.

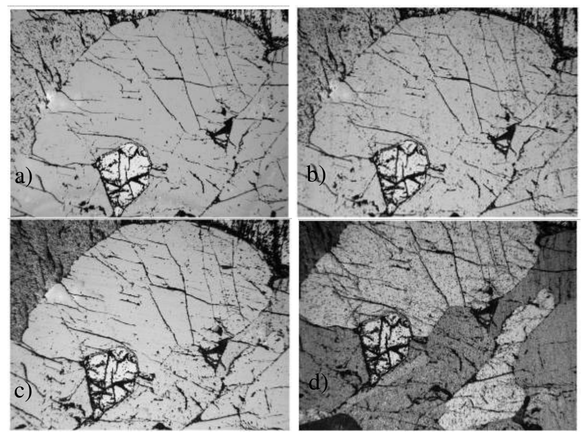

Figure 1: Reflected light micrographs of norite sample after polishing with diamond lapping pads of a) 1, b) 3, c) 6, and d) 9 micron particle size.

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 traditional petrographic techniques use cut-off saws with embedded diamond, we have chosen to explore the

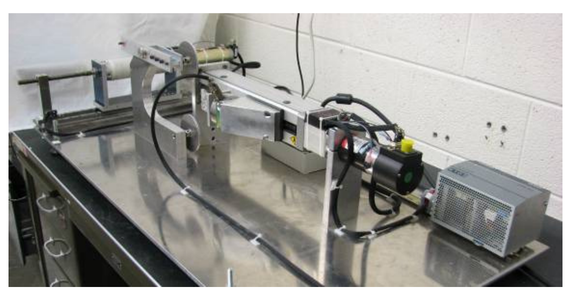

Figure 2: Picture of Rough Cutter prototype.

design and use of diamond embedded wire saws due to their lighter weight and their ability to be positioned in more dexterous cutting configurations. The prototype system is shown in Fig. 2.

Control of contact force and pull (traction) force are important factors and work is currently focused on tuning the control to obtain repeatable and reliable cutting performance. In addtion to closed-loop motion control of the capstan, force control of the linear stage that advances the specimen is required. Cuts of parallel faces have been completed and design of rotary stage to allow cutting of orthogonal faces is underway. Initial cutting results are promising. At 5 N average force applied and 114.3 meter/minute average (linear) wire velocity, a cut on a 12 mm thick piece of rock with a 51 mm depth of cut was completed in approximately 21 minutes or runtime. With an estimated kerf width of 0.3 mm the total volume of material removed for this cut was approximately 1.3 cm3.

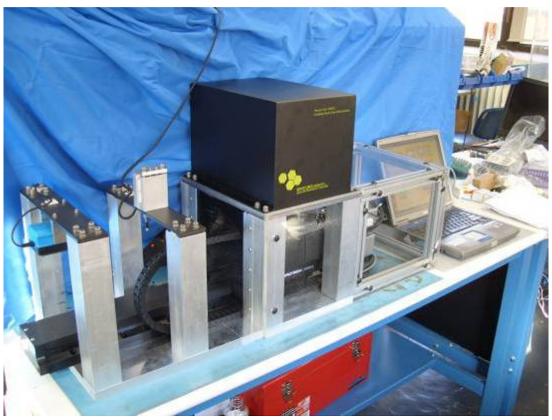

Figure 3: Picture of GRITS autonomous grinder/polisher prototype.

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 ontrol software anabling 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 to enable oscillatory motion (backforth) during the grinding process.

At the time this abstract was written, the GRITS system had just completed the grinding process on it's first rock tablet. It was successful in autonomously grinding a tablet to a thickness of ~33 microns. Further analysis of the tablet must be performed to determine the average relative thickness of the rock. The surface finish, Ra, was measured to be 0.3 microns. In the follow on work, this ground tablet will be examined under a polarized microscope by a thin section expert to evaluate the quality of the grind. An image of the ground tablet is shown in Fig. 4.

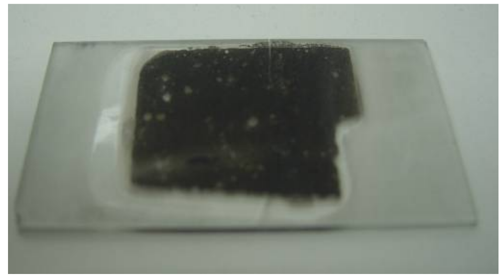

Figure 4: Rock sample ground by the GRITS autonomous grinder/polisher prototype.

Conclusions: The development of a 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 contructed prototype sytems for studies for the autonomous rough cutting and grinding/polishing of analog samples.

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