The Mars Environmental Compatibility Assessment (MECA) Abrasion Tool.

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The Mars Environmental Compatibility Assessment (MECA) experiment [1], an instrument suite to be flown on Mars Surveyor 2001, will include a tool for doing simple mineralogical scratch and streak tests on particles from the Martian regolith. The Abrasion Tool will be applied to particles that adhere themselves to highly polished substrates of various hardnesses. Granular soil components will be subjected to a compressive force of about 3 N using a leaf spring. The spring will be applied with a paraffin actuator capable of a 0.76 mm throw to achieve a maximum displacement of about 7.5 mm at the tip of the tool. The pressure per grain will be dependent on the grain size, the number of grains that adhere to the substrate and the number of grains in compression. The pressure per particle is expected to be on the order of 100 MPa - 1 GPa. The MECA sample wheel containing the substrates will be rotated after the particles are placed in compression to produce scratches or pits.

A primary goal of the Abrasion Tool is to identify quartz (Mohs' hardness = 7) using substrates of varying hardnesses. Quartz is considered hazardous to future human explorers of Mars because it can cause silicosis of the lungs if it is of respirable size. It is also hazardous to machinery, structures, and space suits because of its ability to abrade and scratch surfaces. Since large quantities of minerals harder than quartz are not expected, any scratches produced on polished quartz substrates might be reasonably attributed to quartz particles (Figure 1), although there may be minerals such as impact metamorphic diamond in the soils. Careful calibration of the tool will be necessary to ensure that grains are not overloaded; for example, a steel ball pressed into glass will produce a Hertzian fracture, even though it is softer than glass. Other minerals, such as magnetite (Mohs' hardness = 6.5) have been shown to scratch glass ceramics such as Zerodur (Mohs' hardness = 6.5) (Figure 2). Thus, minerals can be differentiated: note that regardless of the mineral species, if any particle is harder than 6.5 it will certainly be an interesting discovery for both planetary geology and human exploration concerns.

The scratches will be identified using the 6X optical microscope and profiled with the atomic force microscope included in the MECA instrument suite. Analysis of the scratch morphology will yield evidence concerning the shape of the particle responsible for producing each scratch. For example, angular grains should leave vertical cracks with microconchoidal lateral chipping [2], while rounded grains might leave chatter marks, or nested partial Hertzian cracks [3]. Particle shape can thus be inferred from these indentation modes, as well as material hardness. In addition, particle size information may also be available if pits caused by rolling particles can be identified. Converse to scratching, the minerals may be crushed at their contact points, and be smeared onto the target substrates to leave what geologists refer to as "streaks". These are cold-welded trails of mineral material that have structure and color indicative of mineral composition. The AFM will determine the morphology of these streaks, while the microscope will ascertain the color. On the harder substrates, we might expect streaking to dominate; on the softer substrates, scratching may dominate. Progressions of material interactions across the substrate selection will be a valuable source of data for mineral discrimination. It should also be noted that many minerals have coatings (such as iron oxides), and these will have to be differentiated from the host mineral grains; laboratory tests will establish the effects of such coatings on the scratch results. Finally, we note that the microscope will provide corroborative data regarding likely mineral species by grain shapes, fracture patterns, surface textures, color, and UV fluorescence reactions.

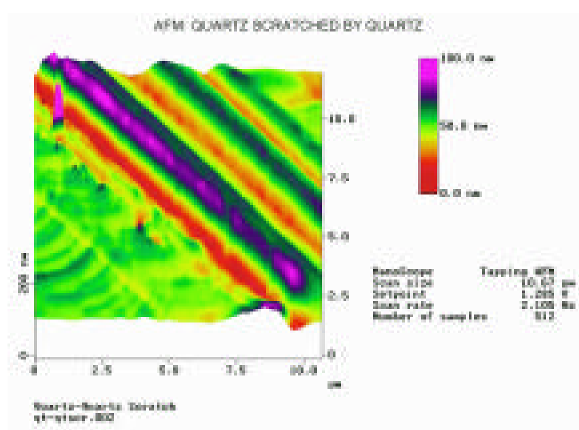

Figure 1. Atomic force microscope image of a scratch on a flat quartz surface produced by an angular quartz fragment.

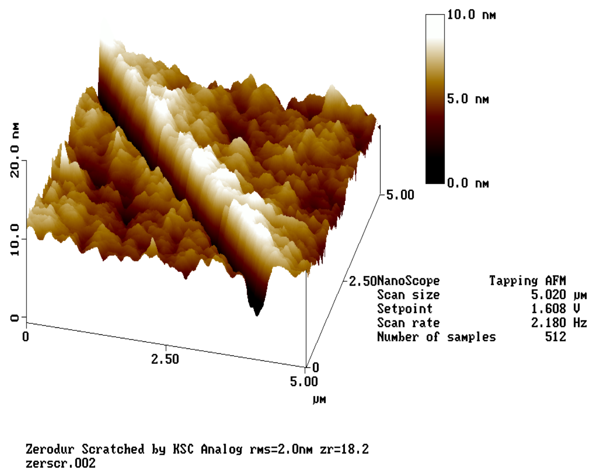

Figure 2. Atomic force microscope image of a scratch produced by abrading highly polished Zerodur (glass ceramic) with the standard JSC Martian soil simulant, JSC Mars-1 [4]. The scratch is attributed to magnetite which is a relatively large fraction of the simulant.

References: [1] http://mars.jpl.nasa.gov/2001/lander/MECA/ (1999) *MECA Public Home Page*, [2] Lawn, B., et al. (1993) *Fracture of Brittle Solids* (Cambridge University Press, Cambridge), [3] Marshal J. R., et al. (1987) *Clastic Particles* (Nostrand Rhienhold, New York). [4] Allen, C. C., et al. (1998) *LPSC XXIX*.