MICROSCOPY OF ANALOGS FOR MARTIAN DUST AND SOIL. M. A. Anderson, W. T. Pike and C. M. Weitz, Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena CA 91109.

Introduction The upcoming Mars 2001 lander will carry an atomic force microscope (AFM) as part of the Mars Environmental Compatibility Assessment (MECA) payload. By operating in a tapping mode, the AFM is capable of sub-nanometer resolution in three dimensions and can distinguish between substances of different compositions by employing phase-contrast imaging. Phase imaging is an extension of tapping-mode AFM that provides nanometer-scale information about surface composition not revealed in the topography. Phase imaging maps the phase of the cantilever oscillation during the tapping mode scan, hence detecting variations in composition, adhesion, friction, and viscoelasticity. Because phase imaging highlights edges and is not affected by large-scale height differences, it provides for clearer observation of fine features, such as grain edges, which can be obscured by rough topography. To prepare for the Mars 01 mission, we are testing the AFM on a lunar soil and terrestrial basaltic glasses to determine the AFM's ability to define particle shapes and sizes and grain-surface textures. The test materials include the Apollo 17 soil 79221, which is a mixture of agglutinates, impact and volcanic beads, and mare and highland rock and mineral fragments (fig. 1). The majority of the

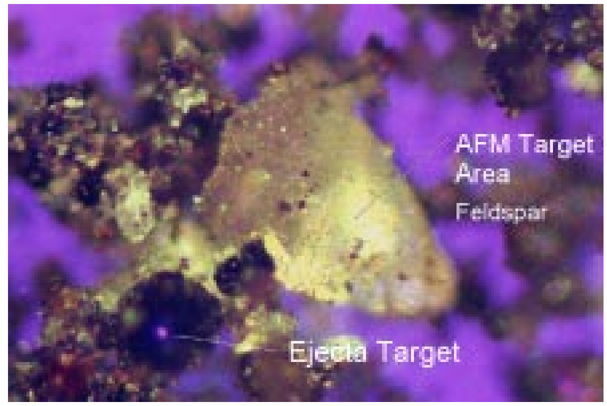

Figure 1: Optical microscope image of lunar sample

lunar soil particles are less than 100 microns in size, comparable to the sizes estimated for Martian dust [1]. The terrestrial samples are millimeter size basaltic glasses collected on Black Pointe at Mono Lake, just north of the Long Valley caldera in California. The basaltic glass formed by a phreatomagmatic eruption 13,000 years ago beneath a glacier that covered the Mono Lake region. Because basaltic glass formed by reworking of pyroclastic deposits may represent a

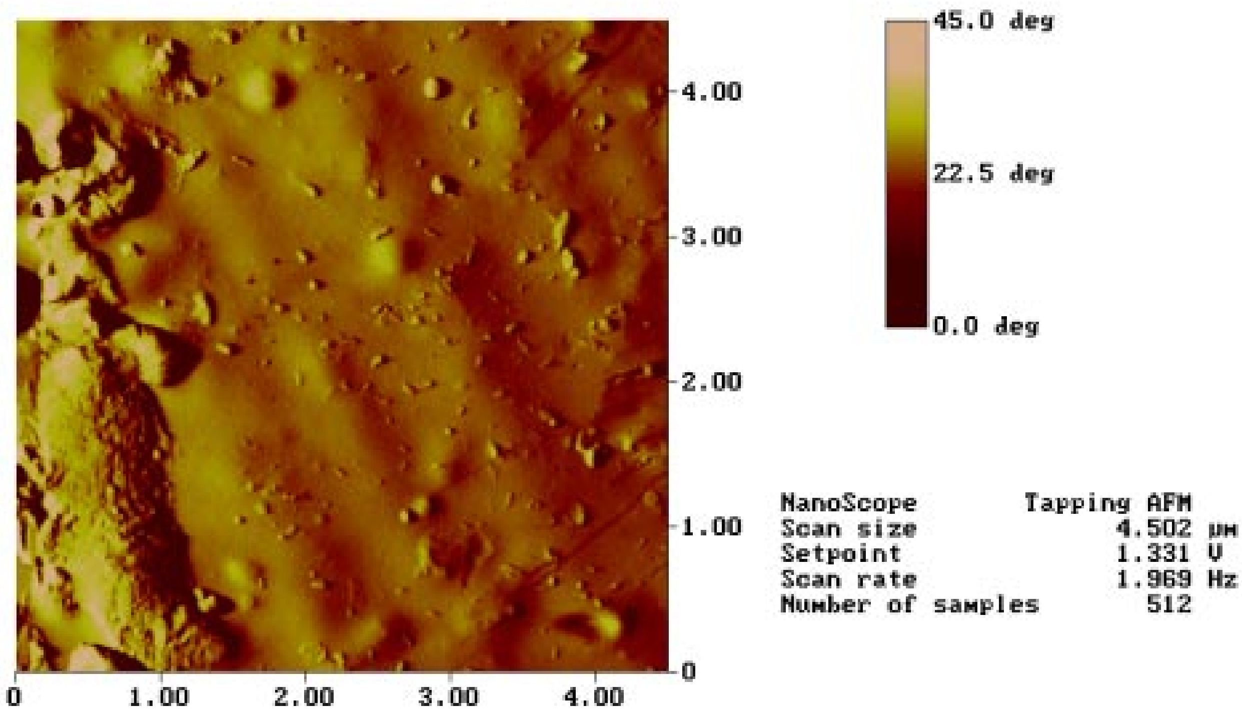

Figure 2: AFM image of lunar feldspar with small particles

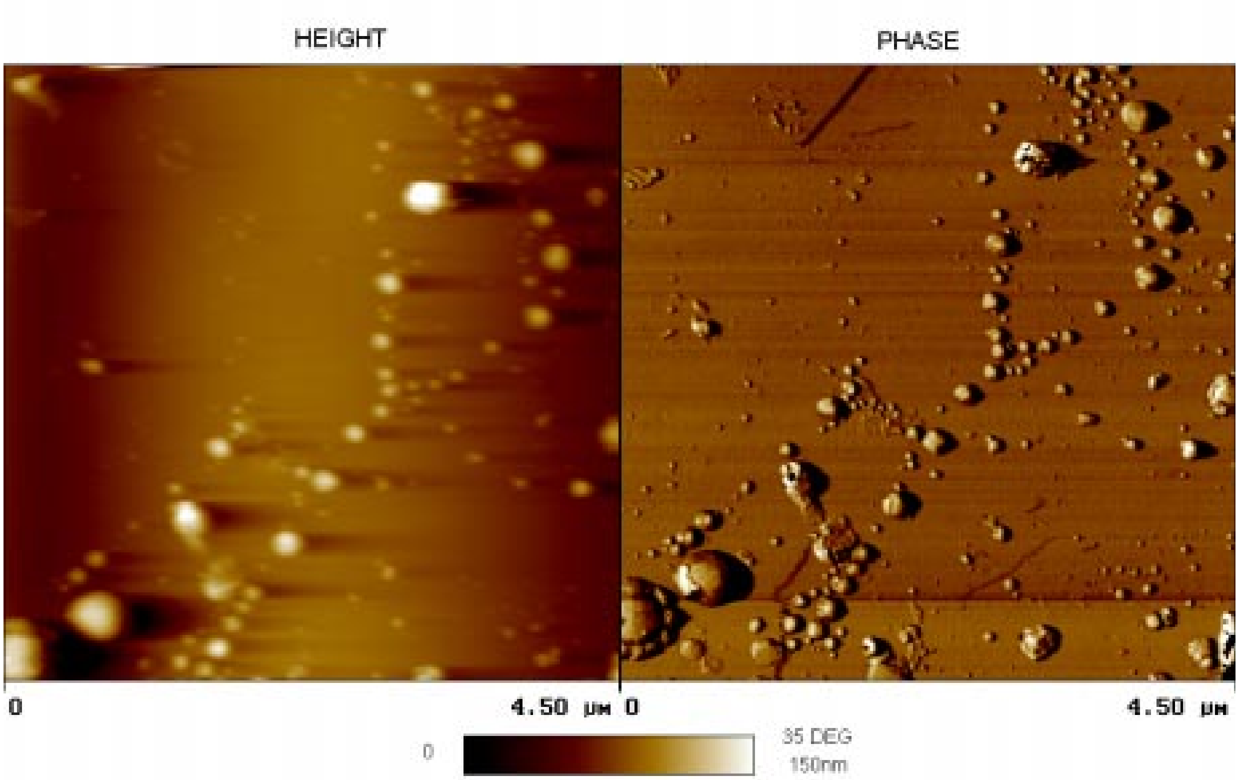

Figure 3: AFM of spherical ejecta in lunar soil

likely source for Martian dunes [2], these basaltic glass samples represent plausible analogs to the types of particles that may be studied in sand dunes by the 01 lander and rover. We have used the AFM to examine several different soil particles at various resolutions. The instrument has demonstrated the ability to identify parallel ridges characteristic of twinning on a 150-micron plagioclase feldspar particle (Figure 2). Extremely small (10-100 nanometer) adhering particles are visible on the surface of the feldspar grain, and appear elongate with smooth surfaces. Phase contrast imaging of the nanometer particles shows several compositions to be present. When the AFM was applied to a 100-micron glass spherule, it was possible to define an extremely smooth surface. Also visible on the surface of the glass spherule were chains of 100-nanometer-and-smaller impact melt droplets (fig. 3)

AFM imaging: In tapping-mode AFM, the cantilever is excited into resonance with a piezoelectric driver. The oscillation amplitude is used as a feedback signal to measure topographic variations of the sample. In phase imaging, the phase lag of the cantilever oscillation, relative to the signal sent to the cantilever's piezo driver, is simultaneously monitored. The phase lag is very sensitive to variations in material properties such as hardness, adhesion and viscoelasticity. Phase-imaging applications relevant to Mars soil include the ability to map different components in composite materials, and differentiating regions of high and low surface adhesion or hardness. Since phase imaging is an extension of tapping mode it can image loosely bound samples. The resolution of phase imaging is comparable to the full resolution of tapping mode AFM.

Conclusions: For the 2001 Mars mission, the AFM is intended to define the size and shape distributions of soil particles, in combination with the MECA optical microscope system and images from a camera on a robot arm. These three data sets will provide a means of assessing potentially hazardous soil and dust properties. The study that we have conducted on the lunar and terrestrial soils now suggests that the MECA experiment will be able to define grain transport and weathering processes. For example, it should be possible to determine if Martian grains have been subjected to aeolian or water transport, volcanic activity, impact melting processes or in-situ weathering. Additionally, textural maturity could be assessed (via freshness and form of fracture patterns and grain shapes) [Marshall reference].Thus, the AFM has the potential to shed new light on Martian surface processes by adding the submicroscopic dimension to planetary investigations.

References: [1] Rover Team (1997), Science, 278, 1765-1768,

[2] Edgett and Lancaster (1993), J. Arid Env., 25, 271-297