OPTICAL DATING OF MARTIAN EOLIAN SEDIMENTS BY ROBOTIC SPACECRAFT. Derek W. G. Sears[1], Kenneth Lepper[2], and Stephen W. S. McKeever[3]. Arkansas-Oklahoma Center for Space and Planetary Science, [1]Cosmochemistry Group, Dept. of Chemistry and Biochemistry, University of Arkansas, Fayetteville, AR 72701. Dsears@comp.uark.edu. [2]Environmental Science Program / Dept. of Physics, 145 Physical Sciences Bldg., Oklahoma State University, Stillwater, OK 74078. Lepper@okstate.edu [3]Dept. of Physics, 145 Physical Sciences Bldg., Oklahoma State University, Stillwater, OK 74078. u1759aa@okstate.edu.

Introduction: The Martian polar ice caps record a wealth of information about the past history and climate of Mars, but as pointed out by Clifford *et al.* in the summary of the *First International Conference on Mars Polar Science and Exploration* [1], "The single greatest obstacle to unlocking and interpreting the geologic and climatic record preserved at the [martian] poles is the need for absolute dating." Stratification in the polar caps arises, at least in part, from the incorporation of eolian material into the ice [2], and dune fields near the poles indicate eolian transport is an important surfical process in this region of Mars [3]. Eolian materials are ideally suited for sediment dating using luminescence methods. Luminescence dating techniques have been used successfully to make absolute age determinations for numerous terrestrial Quaternary eolian deposits. Clifford *et al.* [1] also concluded that cost, simplicity and potential for minaturization make luminescence dating more feasible than isotopic methods for *in situ* dating by robotic landers. In fact, the water detection equipment of the Deep Space 2 microprobes and the MECA on the Mars Polar Lander contain components similar to those required for luminescence dating.

Theoretical Considerations. Over geologic time, ionizing radiation from the decay of naturally occurring radioisotopes and from cosmic rays liberates charge carriers (electrons and holes) within silicate mineral grains. The charge carriers can subsequently become localized at crystal defects and are thus accumulated at these "electron traps". Recombination of the charge carriers results in photon emission, *i.e.* luminescence. The intensity of luminescence produced is proportional to the number of trapped charges, and thereby the time elapsed since trapping began. Experimentally, thermal or optical stimulation can be employed to liberate trapped charge producing thermoluminescence (TL) or optically stimulated luminescence (OSL), respectively. The response of the luminescence signal to ionizing radiation and the local ionizing radiation dose rate of the deposit must also be determined.

For successful application to dating, (i) the luminescence signal should increase monotonically with absorbed radiation dose, (ii) once promoted to traps, the electrons should remain trapped and not find ways of returning to the ground state, in other words the signal should be stable, and (iii) the signal should be essentially zero when the sediments are deposited so that the method actually determines the time interval since a physically significant event occured, namely the deposition of the grains.

The range of the method depends on mineralogy and local dose rates, but is typically ~1ka BP to ~150ka BP. Pore water in terrestrial sediments attenuates the external radiation dose which has the effect of extending the this accessible age range. The attenuation effect of the water ice and carbon dioxide ice of the Martian ice caps and the local ionizing radiation dose rates are unknown but amenable to laboratory experiments.

Reviews of the development of luminescence dating, and detailed discussions of procedures and limitations can be found in the references [4,5]. We have been exploring these questions and investigating the potential of luminescence dating for use on robotic Mars landers. Here we describe some of our results.

Characteristics of Martian Eolian Sediments. Data from the Pathfinder mission indicates that surface materials on Mars are similar to terrestrial basalts and andesites [6]. The primary components of such rocks are pyroxene, calcic plagioclase, and biotite, but spectroscopy of the martian surface suggests the presence of significant amounts of poorly crystalline iron-oxides and clay minerals, reflecting the importance of chemical weathering of surface deposits [7]. In this case, secondary quartz would also be expected in the suface sediments [8]. The morphological similarity between terrestrial and Martian dunes suggests that martian dunes are composed of sand-sized grains [2]. Eolian material incorporated in the polar ice caps is poorly determined at present, but is believed to be sand and smaller particles [3].

Preliminary investigations of the Luminescence Properties of the Mars Soil Simulant JSC Mars-1. We have conducted a preliminary characterization of the fundamental luminescence properties of the JSC Mars-1 soil simulant. The results indicate that the bulk sample has a wide dynamic radiation dose response range (Fig. 1), with no unusual or prohibitive signal instabilities, and is susceptible to solar resetting (Fig. 2) [9]. These three properties form a stable base for future investigation of the material's utility for luminescence dating. Further research on JSC Mars-1, other terrestrial analogs and, perhaps, Martian materials is needed to develop luminescence dating procedures and protocols for remote application to Martian samples.

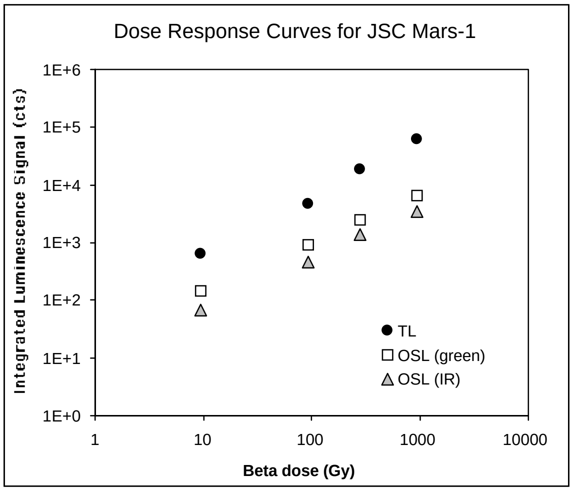

Fig. 1. Luminescence response to radiation dose for JSC Mars-1 soil simulant. Measurable dose response range exceeds that of terrestrial materials commonly used for luminescence dating.

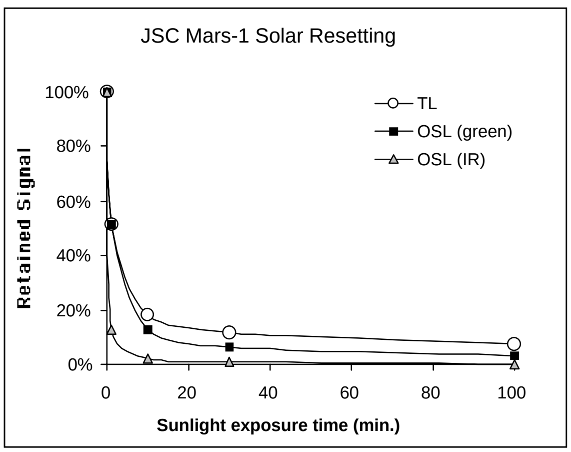

Fig. 2. Solar resetting curves for JSC Mars-1, shown as the percentage of luminescence signal retained after timed exposures to sunlight, exhibit responses typical of terrestrial materials commonly used for luminescence dating.

An *in situ* OSL dating experiment. We envision the development of DS2-like "dating-probes" or a deck-mounted luminescence dating module suitable for deployment by lander or rover on the surface of Mars. The essential elements of this system would include a sample collection device (similar to the soil auger aboard DS2), a sample chamber, an optical stimulation source (IR laser with filters and lenses), a light sensor (photodiode) and an irradiation source (*e.g.* a low level

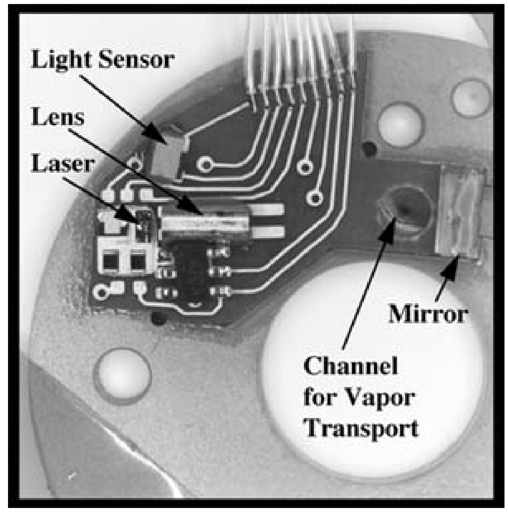

Fig. 3. Water determination apparatus on the DS-2 is very similar to that required for optical dating.

^{90}Sr β source). Many of these components already exist in the soil water detection experiment currently aboard the DS2 Mars microprobes (Fig. 3) and the MECA microscopy station on the Mars Polar Lander.

Also needed is a mechanism for determining the background radiation dose rate in the sample location. To do this we propose use of an OSL dosimeter probe consisting of, for example, carbon-doped sapphire [10] or silica glass doped with rare earth elements [11]. After exposure of the OSL dosimeter in the martian soil for a suitable period, the OSL signal can be read via stimulation with the IR laser.

With the components of such a system in place on a suitable platform (*i.e.* microprobe, lander, rover), a full OSL dating protocol could be carried out using procedures predetermined from laboratory experiments here on Earth. Data from the experiment would be transmitted to Earth where the age calculations would be performed. As an added bonus of this system, the OSL dosimeter will record the low-LET (<15keV μm^{-1}) dose absorbed during transit from Earth to Mars. Reading the OSL dosimeter upon arrival at Mars will reset the signal for *in situ* dosimetry and, at the same time, yield the Earth-Mars low-LET transit dose.

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