**LUMINESCENCE DATING OF MARTIAN POLAR DEPOSITS: CONCEPTS AND PRELIMINARY MEASUREMENTS USING MARTIAN SOIL ANALOGS.** K. Lepper[1], C. K. Kuhns[2], S. W. S. McKeever[3] and D. W. G. Sears[4]; [1]Environmental Science Program / Department of Physics, lepper@okstate.edu; [2]Department of Chemical Engineering; [3]Department of Physics, u1759aa@okstate.edu. [1,2,3]Mailing address: Department of Physics, 145 Physical Sciences Bldg., Oklahoma State University, Stillwater, OK 74078; [4]Cosmochemistry Group, Dept. of Chemistry and Biochemistry, University of Arkansas, Fayetteville, AR 72701. dsears@comp.uark.edu.

**Introduction:** Martian polar deposits have the potential to reveal a wealth of information about the evolution of Mars' climate and surface environment. However, 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." At that same conference Lepper and McKeever [2] proposed development of luminescence dating as a remote *in-situ* technique for absolute dating of silicate mineral grains incorporated in polar deposits. Clifford et al. [1] have also acknowledged that luminescence dating is more practical from cost, engineering, and logistical perspectives than other isotope-based methods proposed for *in-situ* dating on Mars.

We report here the results of ongoing experiments with terrestrial analogs of martian surface materials to establish a broad fundamental knowledge base from which robust dating procedures for robotic missions may be developed. This broad knowledge base will also be critical in determining the engineering requirements of remote *in-situ* luminescence dating equipment intended for use on Mars.

**Background:**

*Geologic Clocks and Luminescence Properties.* A successful geologic clock is based on three fundamental concepts; (i) the existence of a measurable property that changes (ii) at a stable, predicable rate over an appropriate time scale and (iii) has a means of distinguishing intervals. When evaluating the luminescence properties of sediments the above concepts translate into; (i) the luminescence signal should increase with absorbed radiation dose, (ii) the signal should be stable under natural and experimental conditions, and (iii) the signal should be depleted ("zeroed") while the mineral grains are transported.

*General Principles of Luminescence Dating.* 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 leading to accumulation of a "trapped" electron population. 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 deposition of the mineral grains. Experimentally, thermal or optical stimulation can be employed to liberate trapped charge and thus produce 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.

The event dated by luminescence techniques is the last exposure of the sediment grains to sunlight (i.e. a luminescence age is effectively a depositional age). Solar radiation, particularly UV radiation, optically stimulates and removes pre-existing trapped charge accumulated prior to burial and efficiently resets the luminescence clock. Eolian sediments are generally well dispersed when transported, so their exposure to solar radiation is high, making them prime candidates for accurate luminescence dating [3]. Because a luminescence date is a depositional age and eolian sediments are optimal, the technique is uniquely suited to address questions of chronostratigraphy and climate evolution as recorded in the polar deposits on Mars.

*Historical perspective on luminescence dating.* Luminescence dating is a well-established terrestrial absolute dating technique that has been applied to terrestrial geologic research for over 20 years and even longer in archeological research [4]. Recent advances in equipment design [5] and experimental techniques [6,7] have made it possible to preform fundamental luminescence dating measurement from less than 1 mg of sediment [8]. The success of these advances paves the way for the automation and miniaturization that will be required for robotic dating experiments on Mars.

**Investigations of the Luminescence Properties of the Mars Soil Simulant JSC Mars-1:** We have previously reported our preliminary characterization of the fundamental luminescence properties of the JSC Mars-1 soil simulant [9]. The results indicated that the **bulk** sample has a wide dynamic radiation dose response range, with no unusual or prohibitive signal instabilities, and is susceptible to solar resetting. These three properties form a stable base for future investigation of the material's utility for luminescence dating.

However, objections to JSC Mars-1 have been raised [10]. First, the grain size distribution of eolian surface sediments on Mars, **as inferred** from Viking Lander data and Pathfinder airborne particulate data, is dominated by grains that are less than 10 microns in diameter (fine silt and clay fractions) [10]. The dominant grain size fraction in JSC Mars-1 is, however, medium sand (250-450 microns) [11]. The second principle objection to JSC Mars-1 is based on differences in composition [10]. From available geochemical data for martian soils, JSC Mars-1 appears to be deficient in sulfur and chlorine and enhanced in plagioclase feldspar [12]. Allen has repeatedly addressed these concerns and maintains that, "JSC Mars-1…is a reasonable approximation for martian mineralogy, chemistry, grain-size distribution, and magnetic properties in as far as we actually know those parameters for the planet [10]."

Despite the objections, JSC Mars-1 remains a valid and widely recognized Mars soil simulant. However, to address the objections to the simulant in the context of our own research we have characterized the luminescence signal response (TL and OSL) to applied radiation and the luminescence signal stability for various grain-size fractions isolated from JSC Mars-1. We found that all grain size fractions analyzed exhibit signal growth with applied radiation. We have also undertaken the production of aggregate sediment particles using clay and silt fractions from JSC Mars-1 cemented by calcium sulfate and sodium chloride. The fundamental luminescence properties of these simulant aggregates will also be characterized and the results discussed in this presentation.

**Potential *in situ* OSL dating platforms:** We envision the development of DS2-like "chrono-probes" or a deck-mounted luminescence dating module suitable for deployment by lander or rover on the surface of Mars. The essential elements of either system would include a sample collection device, a sample chamber, an optical stimulation source (IR laser or green LEDs with filters and lenses), a light sensor (photodiode) and an irradiation source (e.g. a low level Sr-90 beta source). Many of these components have already been engineered in the soil water detection experiment aboard the DS2 Mars microprobes and in the MECA microscopy station on the Mars Polar Lander (Table 1).

Also needed is a mechanism for determining the background radiation dose rate in the sample location. To do this we propose the use of a OSL dosimeter probe such as carbon-doped sapphire [13] or silica glass doped with rare earth elements [14]. After exposure of the OSL dosimeter in the martian soil for a suitable period, the signal can be read via stimulation with the same light source used for dating measurements. This type of dosimeter can be calibrated prior to launch and maintain its calibration integrity during transit.

Table 1. Components required for an *in-situ* luminescence dating experiment compared to components engineered for experiments on previous missions.

| Required for a Luminescence Dating Exp. | Available in **DS2** - Water Detection Exp. | Available in **MECA** microscopy station* |
|---|---|---|
| sample collection | soil auger | robotic arm* |
| sample chamber | single sample cup | Multi-sample turntable |
| optical source | IR laser | LEDs |
| light sensor | photodiode | CCD camera |
| irradiation source | none | none |

*aboard Mars Polar Lander

**Summary:** Luminescence dating is uniquely suited to assist in the task of deciphering the depositional history, chronostratigraphy, and climate evolution recorded in the martian polar deposits. We discuss in this presentation the requirements for an *in-situ* robotic luminescence dating module and the results of preliminary laboratory tests on martian soil analogs. The results point toward the realistic potential for the development of luminescence dating as a valuable tool for absolute dating of the eolian sediments incorporated in the martian polar deposits.

**References:**

[1] Clifford S.M. et al. (2000) *Icarus*, in press. [2] Lepper K. and McKeever S.W.S. (1998) LPI Contibution No. 953. [3] Berger G.W. (1990) *J. Geophys. Res*, 95(B8), 12375-12397. [4] Aitken M.J. (1985) Thermoluminescence Dating. [5] Bøtter-Jensen L. and Duller G. (1992) *Nucl. Tracks and Radiat. Meas*, 20(4), 549-553. [6] Duller G. (1994) *Quat. Sci. Rev*, 13, 149 156. [7] Duller G. (1995) *Radiat. Meas*, 24(3): 217-226. [8] Lepper K. et al. (in review) *J. Geophys. Res*. [9] Lepper K. and McKeever S.W.S. (2000) *Icarus*. in press. [10] Hargraves R.B. et al., with reply by Allen (1999) *EOS*, 80(15), 168-169 [11] Allen C. et al. (1998) *EOS*, 79(34), 404. [12] Morris R. *Pers. comm.* [13] Bøtter-Jensen L. and McKeever S.W.S. (1996) *Radiation Protection Dosimetry*, 65, 273-280. [14] Justus, B. et al. (1997) *Radiation Protection Dosimetry*, 74, 151-154.