DEVELOPMENT OF A LUMINESCENCE DATING DEVICE FOR *IN SITU* DATING OF GEOMORPHOLOGICAL FEATURES ON MARS. Regina Kalchgruber[1*], S.W.S. McKeever[1], M.W. Blair[1], S. Deo[1], D.K. Reust[2], S. Gupta[2] and B.N. Strecker[2], [1]Oklahoma State University, Department of Physics, 145 Physical Sciences II, Stillwater, OK 74078, USA, [2]Nomadics Inc., 1024 S. Innovation Way, Stillwater, OK 74074, USA, [*]email: rkalchg@okstate.edu

Introduction: The surface of Mars has been subject to eolian, fluvial, and periglacial activity. Unfortunately, establishing a chronology on Mars - e.g. for dunes, gullies, the north polar layers, and other surface features - is difficult. Consequently, techniques to quantify the ages of geomorphological processes on Mars have become an important area of research [1]. Among the techniques proposed is optically stimulated luminescence (OSL) dating, which is well established for age-dating sediments on Earth [2, 3]. We address some of the challenges associated with developing an OSL device for *in situ* dating of sediments on Mars. Results of experiments, using Martian simulant materials, as well as the design of an OSL instrument will be described.

OSL Dating Principles: OSL Dating is a "dosimetric" technique. The time elapsed since deposition of a sediment layer is determined from the radiation-dose accumulated in minerals since the last sunlight exposure, and the dose rate due to naturally occurring radioactive nuclides and cosmic radiation. Radiation exposure can be measured by stimulating the sample with light of one wavelength and monitoring the luminescence at another wavelength (OSL). The intensity of the OSL is a function of the absorbed natural radiation dose. If the rate of natural irradiation can be determined, then dividing absorbed dose by dose rate gives a radiation exposure age, i.e. the time elapsed since the last sunlight exposure.

Challenges on Mars: An *in situ* OSL dating method for Martian surface sediments requires new measurement techniques in order to deal with the multiple new challenges not usually found when using OSL to date terrestrial sediments. Among the many challenges are: (1) the use of polymineralic samples, without the benefit of chemical separation, (2) ambient temperatures that are significantly lower than on Earth and highly variable, (3) a solar spectrum that is different from that on Earth, (4) a dose rate that is significantly higher than on Earth and dominated by high energy charged particles from galactic cosmic rays; the dose rate varies with depth, (5) anomalous fading of the OSL signal …….among several other challenges.

Mineral composition. Using thermal emission data from the Mars Global Surveyor (MGS) Bandfield et al. [4] and Bandfield [5] identified areas on the Martian surface with mainly two different mineral compositions. The first one is composed of 65% plagioclase and 30 % clinopyroxene, and the second one of 45% plagioclase, only 10 % clinopyroxene and an additional 40 % potassium-rich glass. The plagioclase feldspars have calcium content of 30-70 % [6]. Based on these data we devised two mineral mixtures as surrogates for Martian sediments. The two mixtures are known as OSU-Mars-1 and OSU-Mars-2 and the compositions (in vol. %) are described in the following table:

	Mars 1	Mars 2
Andesine	22 %	15 %
Labradorite	22 %	15 %
Bytownite	22 %	15 %
Augite	15 %	5 %
Diopside	15 %	5 %
Hematite	5 %	5 %
Obsidian		40 %

Measurement of accumulated dose. We developed a measurement procedure for an in-situ luminescence dating device for Mars [7]. We suggest using a post-IR blue "single-aliquot regeneration" (SAR) procedure, with a 210 °C cutheat after the test dose and a 210 °C preheat for 10 s after the regeneration dose. Best results were obtained for IR stimulation (IRSL) at 60 °C, blue stimulation at 150 °C, and a test dose in the range of 15-20 % of the regeneration doses. The signal was integrated over the first 10 seconds; the background for subtraction was obtained from the last 5 seconds of stimulation. The post-IR blue procedure consumes more energy than an IRSL- or OSL-only procedure, but it results in two independent values for the equivalent dose. Furthermore, it was possible to measure higher doses with a greater accuracy. The accuracy for a 1600 Gy laboratory dose was 6.1 % using the IRSL signal and 4.0 % for OSL.

Low temperatures. As noted, ambient temperatures on Mars are significantly different (lower) than on Earth. OSU-Mars-1 and OSU-Mars 2 were irradiated at temperatures between room temperature (approximately 25 °C) and –100 °C, and the OSL was measured at various temperatures over the same temperature range. Dose recovery experiments were attempted using an SAR procedure. Several different combinations of irradiation and stimulation temperature were tried. The tests performed to date reveal that the dose recovery procedure is best performed at elevated temperatures compared with the temperatures of natural irradiation. Specifically, the OSL should not be performed at a temperature below the maximum temperature experienced by the sample in nature. This clearly places important design constraints upon a robotic experiment for in situ OSL dating on Mars.

Solar resetting. The entire premise of OSL dating is that the sediments to be dated were exposed to sufficient amounts of light at the time of deposition to erase any previously accumulated signal. In terrestrial applications, this “zeroing” of the signal is accomplished within a few minutes of exposure to sunlight [8], but the solar spectrum on Mars is different from that on Earth and may lead to different bleaching efficiencies.

Modelling of the Martian solar spectrum indicates that the visible part of the spectrum is less intense than that on Earth, but the UV portion of the spectrum (~200-300 nm) is more intense. As these differences in the solar spectrum may have profound consequences for OSL dating, we have simulated the Martian spectrum with a solar simulator and tested the bleaching characteristics of various feldspars. Both the OSL and the IRSL are bleached to 5-10% within 10 min, and the IRSL is fully bleached by 200 min.

Prototype design of the OSL instrument: Based on the results of lab-based experiments we can define the operational parameters required for an actual robotic device. Figure 1 shows the system block diagram; figure 2 shows our prototype OSL/IRSL chamber for Mars dating with X-ray source, IR and blue LEDs and two photo detectors (red and UV signal).

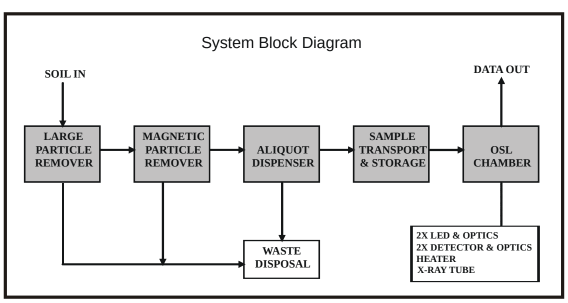

Figure 1

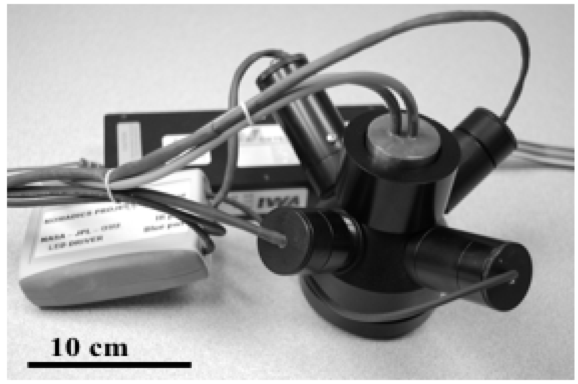

Figure 2

Summary and conclusion: OSL dose recovery experiments reveal a viable SAR procedure for polymineralic samples is possible. The SAR procedures indicate that OSL measurement at temperatures above the maximum temperature likely to be experienced by the samples during natural irradiation will yield successful equivalent dose determinations. We have also calculated the Mars solar spectrum using radiation transport codes and taking into account the atmosphere of Mars and atmospheric scattering, particularly due to suspended dust particles. The results indicate a more intense UV component than is found on Earth. Experiments with a Mars solar simulator indicate efficient bleaching of the OSL signals from the soil simulants, suggesting efficient zeroing of the OSL signal for solar-exposed sediments on Mars.

The next steps will be to refine and modify the design as required, to design the sample transport system, and to integrate it with the OSL module. Future experiments will concentrate on the radiation efficiency of cosmic rays at producing OSL in the simulant samples and potential corrections for, or experimental procedures to overcome, anomalous fading. The goal is a dating technique that can elucidate a wealth of knowledge about the recent geological and climatic activity on the Martian surface.

References: [1] Doran P. T. et al. (2004) *Earth Sci. Rev., 67*, 313-337. [2] McKeever S. W. S. et al. (2003) *Radiat. Meas., 37*, 527-534. [3] McKeever S. W. S. et al. (in press) *Radiat. Meas.* [4] Bandfield J. L. et al. (2000) *Science, 287*, 1626-1630. [5] Bandfield J.L. (2002) *JGR.*, 107, No E6, 10.1029/2001JE001510. [6] Milam K. A. et al. (2004) *JGR*, 109, No E04001, 10.1029/2003JE002097. [7] Kalchgruber R. et al. (in press) *Radiat. Meas.* [8] Aitken M. J. (1998) *An Introdcution to Optical Dating*, Oxford Science Publications, Oxford.