INSTRUMENTATION FOR *IN-SITU* LUMINESCENCE DATING OF MARTIAN SEDIMENTS

K.J. McKeever[1], S.W.S McKeever[1], M. Blair[1], M. Leuschen[2], D. Reust[2] 1.Arkansas-Oklahoma Center for Space and Planetary Sciences, Stillwater, OK 74078 2. Nomadics Inc. Stillwater, OK 74076

Introduction and Background: Current chronology methods for Mars use crater counting to date the Martian surface and thus have only been able to make estimates of the surface age [1]. New techniques, now used on Earth to date surface sediments, could be employed on the Martian surface. Using a process known as the Optically Stimulated Luminescence Single Aliquot Regeneration (OSL SAR), more accurate dating of the surface of Mars may prove possible. Optically Stimulated Luminescence (OSL) dating determines the last time the sediment was exposed to light by evaluating the dose of radiation absorbed since the last sunlight exposure. From a separate determination of the dose rate, one can determine the age of the sediment in question using the relationship Age=dose/dose rate [2]. Also, the technique can be used to determine if the sediment was deposited by wind or water (See Figure 1) [1].

The system proposed would be completely automated and would allow *in-situ* dating; this has never been done before, even on Earth. OSL dating of Martian sediments would require a robotic instrument for *in-situ* measurements. The information obtained could help to determine Mars' geologic history, especially if it can be developed to date sediments trapped in the polar ice caps and would help to provide a "Rosetta Stone" of sorts for Mars' history.

Fig 1. A valley on Mars, created by water. But some of the surrounding features could have been created by wind.

Challenges Faced: The average temperature on Mars is much lower than on Earth. It can reach to as low as –130°C during the Martian winter [3]. This presents many problems. Materials and devices that would work for such an instrument on Earth, may not work on Mars. Many plastics for instance, cannot take the very cold temperatures. They become very brittle and have different expansion coefficients. The radiation Mars receives is also quite different from that of Earth. This also presents a problem as many materials are affected by radiation, especially by the higher levels they would receive on Mars. The Solar Particle Emission (SPE) radiation is a lot higher and so is the Galactic Cosmic Ray (GCR) radiation. This is partly due to Mars' lack of a thick atmosphere as on Earth and different gravitational and magnetic fields than those of Earth [3].

Before a material can be chosen, the background radiation of Mars would have to be determined. The samples must also be protected from optical bleaching. To be useful, the samples must be unexposed to light. If they are exposed, they become bleached and the "clock" is reset [1]. The signal from the samples must also be corrected for fading [4]. Methods to do this have yet to be developed. Also, there is a very wide range of possible minerals that may be contained in the sediments on Mars. So far, the SAR process has only been developed for quartz and work is being done to make it useable for feldspar. In addition, some work has been done on Mars soil simulants [1].

Equipment and Materials: There are several components required for the instrument. It needs to have a detector to detect the light emitted from the sample. It also needs to have an irradiation system; the sample is repeatedly given different doses of radiation in order to calibrate the OSL and determine its absorbed radiation dose [2]. There must also be some form of sample delivery system such as a hopper and sample cup. The instrument may also contain a Thermoluminescence system (TL) and possibly an Electron Spin Resonance (ESR) system developed at the Jet Propulsion Labs. Currently, however, plans only call for the OSL system. The equipment used must all be space hardy. The OSL will need a stimulation source such as an LED or a laser that can survive the Martian environment. Similarly, the light detection system, either a photomultiplier tube, a PIN Photodiode or an Avalanche Photodiode, must work in such harsh conditions. The irradiation system, such as an x-ray tube or a radioisotope must also be able to work in extreme conditions. Currently, plans call for the x-ray tube.

The materials used for the instrument must also be considered, as previously mentioned. Metals, plastics and carbon fiber are all being considered. See Table 1. Since the instrument needs to be lightweight, it is important that the materials used have a low density. Everything must be able to resist the cold temperatures and the radiation environment. If the ESR system is used, the static charge that builds up from movement must be very low and, in addition, components made out of non-magnetic material, i.e. something else other than metal, are preferred.

System	Component	Material
Irradiation source	Moxtek 40kVp	-
	"Bullit" x-ray system	-
Light source	Nichia LEDs	InGaN
light detector	Hamamatsu PMT	bialkali cathode
	Hamamatsu APD	Si
	Hamamatsu PIN diode	Si
Turntable	-	Delrin or PTFE
OSL holder	-	Delrin or Al
X-ray holder	-	Delrin or Al
Hopper	-	Al
Box	-	Al

Table 1. Possible materials for the different components.

Design Process: The first step in the design process was to narrow down the possible materials for consideration of the components. The short list thus far consists of Polytetrafluorethylene, a plastic sometimes know as Teflon®; Delrin®, another low density plastic; aluminum and carbon fiber. Components such as LEDs and lasers are currently being researched.

There were two main ideas for the design of the instrument. One idea is a belt system, employing a thin belt of about 5mm width. The ESR cavity size would restrict the size of the belt, were it to be added to the project. The other idea consists of a turntable. Both ideas were considered and it was decided that a preliminary design of a turntable system should be devised. From this design, a to-scale model was constructed from foam board, Styrofoam and cardboard. See Fig 2.

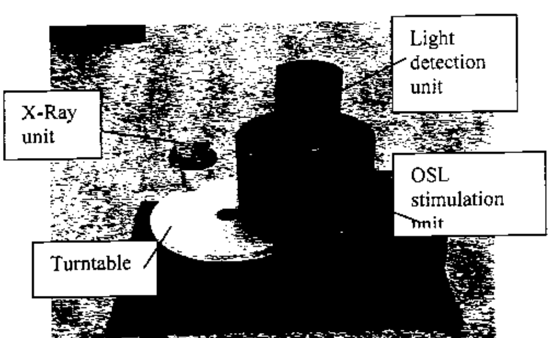

Fig 2. Side view of the model of the Optical Dating Instrument (ODIN).

The system sits inside a light tight box. A hole in the top of the box allows the sediment to be introduced via a hopper. The sediment is then filtered down to 300 micron size grains. A small sample, about 5 to 10 milligrams, is then delivered to the sample cups, one by one. The cups sit on a turntable that rotates between the OSL and x-ray tube. The sample goes back and forth between the two until enough readings have been taken to determine the age of the sediment. The current preliminary design allows for the entire system to fit in an 18.9 cm high, 21cm wide and 29cm long box. The volume inside the box is 10.5 x 10^3 cubic centimeters. The size of the x-ray tube and the base of the OSL system, which are already determined, helped in calculating the size of the whole system. The size of the hopper is debatable. It currently has a radius of 37.5cm and is 136cm tall. A smaller hopper will probably be used. The OSL, x-ray tube and hopper sit just above the surface of the turntable. See Figure 3. The entire system would probably weigh about 15 pounds.

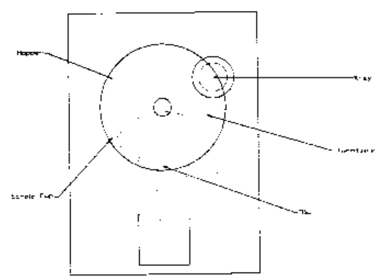

Fig 3. Top view of the preliminary design of the instrument as described.

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References: [1] Concepts and Approaches to In-Situ Luminescence Dating of Martian Sediments. S.W.S McKeever et al. Radiat. Meas. (submitted, 2002). [2] Quartz OSL: Effects of Thermal Treatment and Their Relevance to Laboratory Dating Procedures Wintle A.G. and Murray A.S. Radiat. Meas. **32,** 387-400 (2000). [3]Mars Fact Sheet: http://nssdc.gsfc.nasa.gov/planetary/factsheet/marsfact.htm. [4] *A soluition to Anomalous Fading and Age Shortfalls in Optical Dating of Feldspar Minerals.* Lamothe, M and Auclair, M. Earth and Planetary Science Letters, **171,** 319-323 (1999).