IN-SITU GEOCHRONOLOGY FOR MARTIAN DUNES: A REVIEW OF OPTICAL DATING CONCEPTS AND EXPERIMENTS WITH ANALOG MATERIALS. K. Lepper. Optical Dating and Dosimetry Laboratory, Department of Geosciences, North Dakota State University, 218 Stevens Hall, Fargo, ND, 58105; ken.lepper@ndsu.edu.

Introduction: Eolian dunes are a direct geomorphic expression of the dynamic interaction between the atmosphere and the lithosphere of planets. The timing, frequency and spatial extent of dune mobility reflect changing climatic conditions. However, one of the greatest challenges to deciphering the record of climate variability on Mars will be the need for absolute dating techniques, particularly those techniques applicable to the timeframes and materials involved in Mars surface processes [1]. Lepper and McKeever [2-4] have proposed developing optical dating (a.k.a. OSL), an established terrestrial Quaternary dating method based on principles of solid-state physics, for remote *in-situ* application to Martian sediments. Eolian transport provides the optimal conditions for successful optical dating and the technique has been used successfully to make absolute age determinations for numerous terrestrial eolian deposits (reviewed in [5, 6]).

The MER rovers and the orbital instruments OMEGA and CRISM have identified sulfate minerals as important constituents of Mars surface deposits. Orbital observations also suggest that sulfates may be concentrated by eolian processes and may occur as primary components of dunes (Fig. 1). The goals of this presentation are to introduce optical dating to the community of planetary scientists that are conducting research on dunes and to review nearly a decade of OSL experimental work with terrestrial analogs of Mars surface sediments focusing on our recent work with sulfate minerals.

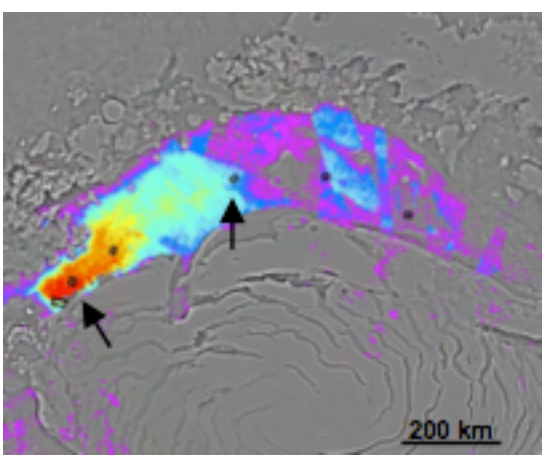

Fig. 1. Image of Mars' Northern Polar ice cap and adjacent erg. OMEGA 1.9 μm spectral mapping data overlain on the sand deposits. Red indicates highest concentrations of sulfates grading to purple (from [7]).

Methodological Background: Over geologic time, ionizing radiation from the decay of naturally occurring radioisotopes and from cosmic rays liberates charge carriers (electrons and holes) within 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 and relaxation results in photon emission, i.e. luminescence. The intensity of luminescence produced is proportional to the amount of trapped charge, and thereby to the radiation dose absorbed by the mineral grains since deposition at the sampled site. A determination of the ionizing radiation dose rate at the sample location allows the age of the deposit to be determined (from *Age = Absorbed Dose / Dose Rate*). Experimentally, optical excitation is used to initiate the measurement process which gives rise to the method's name - optically stimulated luminescence (OSL) dating or, simply, optical dating.

Methods and Samples: We have examined the fundamental optical dating properties of (i) radiation dose response, (ii) measurement induced sensitivity change (MISC) and (iii) signal fading for a variety analog materials including:

- the soil simulant JSC Mars-1 [3,8]
- evaporated mixtures of JSC Mars-1 and geologic salts [9]
- natural and synthetic gypsum as well as synthetic anhydrite [10-13]
- synthetic thenardite [14]
- synthetic kieserite and hexahydrite [10,13,15]

using blue light or infrared stimulation and monitoring the resultant luminescence in the UV or blue region (blue monitoring with infrared stimulation only). Other research groups have conducted similar studies on pyroxenes [16,17] mixtures of plagioclase feldspars [16], and mafic rocks [17,18].

Synopsis of Sulfate Experimental Results:

Calcium Sulfates [10-13]. The OSL measurements made on natural and synthetic gypsum as well as synthetic anhydrite indicated OSL dose response in all stimulation and monitoring combinations used. Signal stability (MISC and fading) varied considerably among the samples and stimulation methods. Anhydrite exhibited a high degree of signal instability with fading ranging from 23 to 40% per decade. An important exception, however, were the results from natural gypsum, including a sample from White Sands National Monument, which yielded stable signal characteristics

and large saturation doses (~3000 to ~4500 Gy) when utilizing the infrared stimulation and UV signal measurement configuration.

Singhvi and others [19,20] have directly dated sand dunes at White Sands, New Mexico with OSL methods, but found small amounts of quartz incorporated in the dunes to give more precise results than measurements made on the gypsum grains. Although developmental work may be needed, it appears that gypsum may have the potential to serve as an OSL geochronometer on Mars.

Sodium Sulfates [14]. Our measurements of unannealed dopant-free thenardite (Na_2SO_4) indicated UV phosphorescence following beta irradiation and both infrared and blue stimulated UV luminescence. However, all of these luminescence signals were highly unstable over short time scales (fading at a rate of up to 70% per decade) suggesting that natural unheated thenardite is an unlikely candidate for an in-situ OSL dating.

Magnesium Sulfates [10,13,15]. We have also carried out preliminary optical dating characterizations on kieserite ($MgSO_4 \bullet 1H_2O$) and hexahydrite ($MgSO_4 \bullet 6H_2O$). These magnesium sulfates did not exhibit phosphorescence or infrared stimulated luminescence, but they did show blue stimulated OSL response with saturation doses of ~3000 Gy and ~600 Gy for kieserite and hexahydrite, respectively. The signal stability characteristics of the magnesium sulfates exhibited similarities to both quartz (MISC) and feldspars (fading), which warrant more detailed examinations.

Summary: Based on our current data and interpretations of the optical dating properties of sulfates, their presence as trace or minor components in Martian eolian deposits will need to be considered when developing *in-situ* dating protocols, however, they should not preclude the application of optical dating to silicates in Martian dunes. Moreover, our characterizations suggest that gypsum may have the potential to be dated directly using OSL techniques. Certainly, more detailed examinations of the optical dating properties of calcium and magnesium sulfates are warranted. With proper development and deployment strategies optical dating holds the potential to help establish a geochronology for Martian eolian activity and, by extension, a geochronology for important aspects of climate change in the latest Amazonian epoch on Mars.

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