OPTICAL DATING PROPERTIES OF CALCIUM AND MAGNESIUM SULFATES: IMPORTANT COMPONENTS OF MARS SURFACE SEDIMENTS. V. O'Connor[1,2] and K. Lepper[1], [1]Department of Geosciences, North Dakota State University, 218 Stevens Hall, Fargo, ND 58105. [2]Environmental & Conservation Sciences Program, North Dakota State University, 218 Stevens Hall, Fargo, ND 58105, vanessa.oconnor@ndsu.edu; ken.lepper@ndsu.edu.

Introduction: Extensive research on Mars conducted by the Mars Exploration Rovers (MERs), along with the past and present international efforts involving probes and remote sensing techniques including OMEGA and CRISM have determined that sulfates play a significant role in the surface sediments. Optical dating or OSL is an established terrestrial dosimetric dating technique that has been proposed for use on Mars [1,2]. On Earth optical dating is applied almost exclusively to silicates, however, surface sediments on Mars will be composed of a mixture of various minerals. Therefore, in order to adapt optical dating for Mars the fundamental OSL properties of sulfate minerals must be examined and documented.

Gypsum ($CaSO_4 \cdot 2H_2O$) is one of the most stable and abundant sulfate minerals on Earth, and current research suggests that gypsum, anhydrite ($CaSO_4$), jarosite ($KFe_3(SO_4)_2(OH)_6$), and various Mg-sulfates ($MgSO_4 \cdot xH_2O$) are present on the surface of Mars [3]. In this study, adapted single-aliquot regenerative-dose (SAR) experimental procedures [4,5] have been used to characterize the radiation dose response and signal stability of two natural gypsum samples formed in different environments, as well as those of synthetic gypsum, synthetic anhydrite, synthetic hexahydrite ($MgSO_4 \cdot 6H_2O$), and synthetic kieserite ($MgSO_4 \cdot H_2O$).

Methods: The fundamental optical dating properties examined in this study include measurement induced sensitivity change (MISC), fading, and radiation dose response. The measurements were conducted on a natural gypsum sample from White Sands National Monument (WSG), a natural gypsum sample which is a secondary precipitate mineral from the Pierre Shale Formation (PSG), synthetic gypsum (SGP), synthetic anhydrite (ANH), synthetic hexahydrite (HEX), and synthetic kieserite (SKS). An adapted SAR procedure was applied to the experiments which utilizes test dose corrections without heat treatments to prevent alteration of the hydrated sulfates [4,5]. The typical preheat temperature range for OSL measurements using SAR is between 160°C and 260°C, which can induce chemical instability, crystallographic phase changes, or structural changes within these minerals as they are dehydrated. The properties were evaluated using a Risø DA-15 automated system equipped with a Sr^{90}/Y^{90} ß-radiation source, and a type 9235 QA photomultiplier tube (PMT). The PMT was fitted with apertures ranging from 1/16 in. to 1/2 in. for samples that produced the highest signal levels, and with optical filters for three different stimulation/monitoring combinations. These stimulation/monitoring combinations were: BOSL/UV, IRSL/UV, and IRSL/Blue, where stimulation in visible blue-light is 475 ± 25 nm (BOSL), and infrared is 830 ± 10 nm (IRSL). Signal monitoring was in the ultraviolet (Hoya U-340 filter), or in the visible blue-light range (Schott BG-39 plus Kopp 7-59). Previous work on kieserite suggests that Mg-sulfates do not respond to stimulation in the infrared [6], so the optical dating properties of synthetic hexahydrite and kieserite were only examined using the BOSL/UV stimulation/monitoring method.

Results: The results are summarized in the table below and in the figures on the following page.

I.D.	Stimulation/ Monitoring	A	B	Est. Sat. (Gy)	Fading (% per Decade)
SGP	BOSL / UV	37.37	4.63×10^{-3}	1255	6.50
SGP	IRSL / UV	41.49	1.73×10^{-3}	3357	5.50
SGP	IRSL / Blue	62.11	1.16×10^{-3}	5027	-5.00
WSG	BOSL / UV	30.10	5.93×10^{-3}	979	9.50
WSG	IRSL / UV	59.06	1.30×10^{-3}	4462	-1.00
WSG	IRSL / Blue	64.48	1.04×10^{-3}	5567	10.50
PSG	BOSL / UV	43.06	3.36×10^{-3}	1729	14.50
PSG	IRSL / UV	35.83	1.90×10^{-3}	3057	-0.50
PSG	IRSL / Blue	71.13	9.79×10^{-4}	5932	6.50
ANH	BOSL / UV	23.29	8.34×10^{-3}	696	23.00
ANH	IRSL / UV	10.61	3.52×10^{-3}	1650	40.50
ANH	IRSL / Blue	10.24	3.63×10^{-3}	1602	35.50
HEX	BOSL / UV	8.29	9.25×10^{-3}	628	14.00
SKS	BOSL / UV	32.06	1.98×10^{-3}	2927	10.00

Table 1. The tabulated results for saturation dose, estimated at 99.7% of signal saturation, and fading. The saturation dose and the coefficients A and B were determined by fitting the model equation: $y = A[1 - e^{(-Bx)}]$ to the data sets, and assuming $y = 0.997A$. Sample I.D. is explained in the text of the "Methods" section.

Discussion: The MISC data indicate sensitivity change for both the Ca- and Mg-sulfates in all three stimulation/monitoring combinations, however, the adapted SAR procedure adequately corrects for the sensitivity changes observed (Fig. 1). Gypsum exhibits a range of fading from 0–14.5% per decade, anhydrite exhibits the widest range and fades up to 40.5% per decade, and hexahydrite and kieserite fade at 14% and 10% per decade, respectively (e.g.: Fig. 2). Gypsum was the only sulfate examined with unusual fading results where short-term fading occurs until ~300s before the signal stabilizes. The IRSL/UV measurements on the two natural gypsum samples produced the results most closely resembling an "ideal dosimeter."

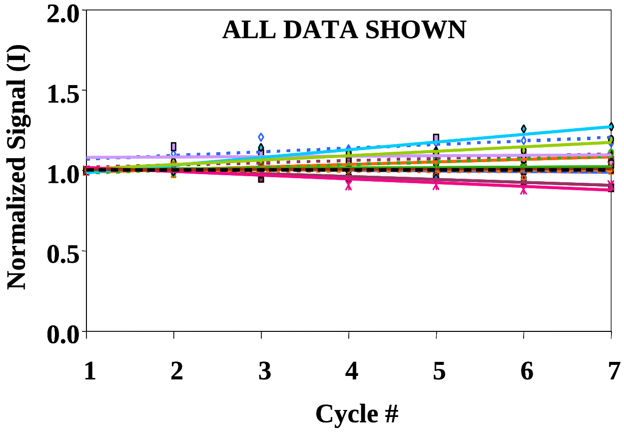

Fig. 1. The normalized average MISC measurements of the calcium and magnesium sulfates in all three stimulation/monitoring combinations: BOSL/UV, IRSL/UV, and IRSL/Blue. The black dashed line at *I* = 1.0 represents the trend of an "ideal dosimeter."

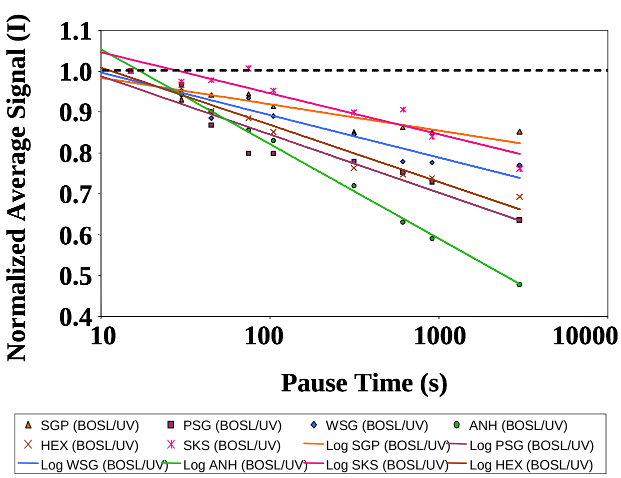

Fig. 2. Normalized average fading results for all samples using BOSL stimulation and UV monitoring. The black dashed line is representative of an "ideal dosimeter" signal which exhibits no fading over time. All fading results are outlined in Table 1.

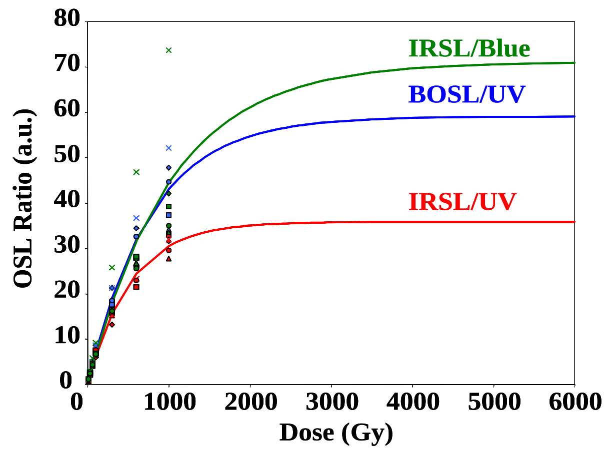

Fig. 3. Dose response curves collected in all three stimulation/monitoring combinations for the natural Pierre Shale gypsum. The complete saturation dose data set is outlined in Table 1.

Conclusions: The adapted SAR procedure was successfully applied to the sulfate samples examined and was used to document fundamental optical dating properties of Ca- and Mg-sulfates. Though signal stability and saturation doses varied among the samples, the natural gypsum samples exhibited stable signal properties and relatively high saturations doses (~4500 to ~6000 Gy) using the IRSL stimulation and UV monitoring combination. The results suggest that gypsum could potentially be used as geochronometric materials on the surface of Mars. These OSL properties will need to be considered in developing protocols for in-situ optical dating experiments.

Future Work: Since jarosite is also a significant sulfate mineral found on Mars, the basic optical dating properties of synthetic jarosite are also being examined with an emphasis on the role of Fe within the mineral and of its influence on the OSL results. Since the optical dating characteristics of jarosite have not previously been studied, little is known about the distribution of defects or traps for this mineral.

Acknowledgements: This work is supported by the NASA Mars Fundamental Research Program, grant # NNX06AB24G. WSG and permission for use was provided by David Bustos of White Sand National Monument. SKS was synthesized and provided by Steve Chipera of Los Alamos National Laboratory.

References: [1] Lepper, K. & McKeever, S.W.S. (2002) *Icarus, 144,* 295-301. [2] McKeever, S.W.S. et al. (2005) *Rad. Meas., 37,* 527-534. [3] Squyres, S.W., et al. (2004) *Science, 306,* 1709-1714. [4] Wintle, A. G. & Murray, A. S. (2000) *Rad. Meas., 32,* 57-73. [5] Wintle, A. G. & Murray, A. S. (2006) *Rad. Meas., 41(4),* 369-39. [6] Podoll, A. & Lepper, K (2005) GSA *Abst. w/ Prog., 37(7),* 208.