REMOTE LIBS ANALYSES OF ZAGAMI AND DAG 476 MARTIAN METEORITES

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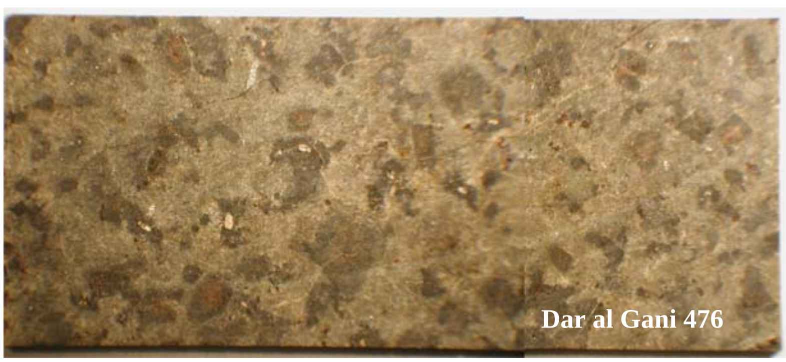
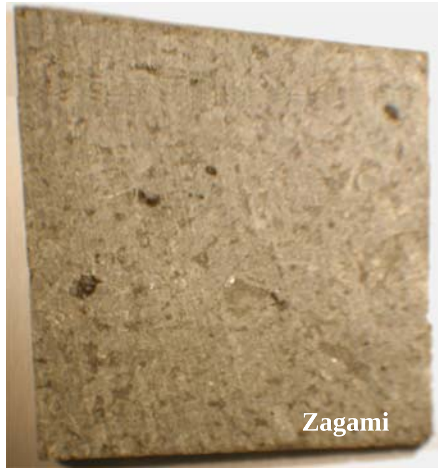
Overview: Remote Laser-Induced Breakdown Spectroscopy (LIBS) was selected as part of the ChemCam instrument package for the Mars Science Laboratory (MSL) rover to be launched in 2009. Here we investigate the ability of LIBS to remotely determine differences between basaltic rock types on Mars by analyzing two different shergottite meteorites from Mars.

Introduction: Laser-induced breakdown spectroscopy has been under development for planetary science applications because it can remove dust or weathering layers remotely, at distances to several tens of meters, and thus perform analyses on the pristine rock samples. A number of studies have shown that LIBS easily distinguishes between rocks of widely differing compositions, such as between dolomites and basalts [e.g., 1]. Other studies have shown that LIBS yields relatively high accuracy (e.g., error/composition < 0.1 for a number of elements) [e.g., 2, 3]. However, there are still relatively few real-world studies, either using LIBS in field work, or comparing LIBS results in the lab for rock compositions that differ only slightly. We are beginning a study of two Martian basaltic meteorites whose compositions differ slightly, but which also differ in morphology. This abstract is a progress report on the initial portion of this study.



Samples: Zagami is a shergottite basalt, consisting of 70-80% fine grained pyroxene, and most of the rest as maskelynite, but also contains small amounts of amphibole, phosphates, and glass. A glass inclusion can be seen in the photo. There are at least three different lithologies. The larger-grained lithology is the one that typically contains the glass. The mean grain size in this lithology is 0.36 mm, 0.24 mm in the fine-grained material [4-7]. This sample was obtained from UNM, and measures roughly 1x1 cm.



DAG 476 is also a basaltic shergottite, but has olivine phenocrysts/megacrysts up to 5 mm in size. The modal mineralogy is ~60% pyroxene, 15% olivine, 15% feldspathic glass (maskelynite), with minor phases of impact melt pockets, carbonate, chromite, ilmenite, whitlockite, Cl-apatite, and pyrrhotite. The olivines are zoned core to rim Fo76 to Fo58. Mn correlates with FeO at a ratio of 1/50, with MnO abundances of 0.4-0.8%. Chemically, DAG476 is ultramafic (high Mg) and more like lherzolitic shergottites than basaltic shergottites. High Ba/La and Sr/Nd ratios indicate terrestrial weathering has taken place [8,9]. The scale of this photo is roughly 1x3 cm.

Experimental: The initial LIBS analyses of these samples was done at a distance of 8.3 m from the instrumentation at U. Hawaii. A Continuum Nd:YAG laser, frequency doubled to 532 nm, operating at 20 Hz and a pulse power of ~35 mJ, was used to interrogate the samples. The light was sent through a 5x beam expander and was focused on the target. Subsequent examination of the samples showed that the analysis pits produced from 8.3 m away were 600 μm diameter with sharp walls. The plasma light was collected by a 10.8 cm diameter reflecting telescope and was focused into a 200 μm diameter optical fiber. The fiber alternately fed the light into one of two Ocean Optics HR2000 spectrometers configured for 225-320 nm (“UV unit”) and 385-460 nm (“VIS unit”) wavelength ranges. These are similar in their optical properties to the units to be flown on the ChemCam LIBS instrument on MSL. A third spectral range was provided by a similar telescope and a Holospec spectroscope. The integration times were 3 and 10 seconds for the VIS and UV spectrographs, and 30 sec at a gain of 150 for the Holospec/ICCD.

Results: An initial spectrum of DAG476 is shown in Fig. 1. Qualitatively it shows a relatively silicon-rich analysis spot, relatively rich in Mg, with Ca, Na, and Al intensities typical of basalts, and slightly Fe-rich relative to terrestrial basalts. The initial Zagami spectrum appears to show higher Fe and lower Mg, in agreement with the compositions in Table 1.

Future Work: We plan to analyze additional spots on these samples. The ChemCam strawman investigation plan calls for approximately six analysis spots on a given rock when quantitative analyses are desired. This is probably a minimum number necessary for whole-rock composition estimates. Comparison of these analysis spots will determine, without visual clues, if the sample is heterogeneous on a mm scale (e.g., such as for DAG476), and should identify individual large-grained minerals. Analysis of a suite of basalt standards will also be carried out, and the results will be used to produce calibration curves. The meteorite compositions will be determined from these curves. In addition, we plan to apply the calibration-free LIBS method, and compare its results with those given by the basalt standard calibration curves.

References: [1] Wiens R.C. et al. (2002). *J. Geophys. Res. Planets.*, 10.1029/2000JE001439. [2] Knight A.K. et al. (2000) *Appl. Spectrosc. 54*, 331-340. [3] Sallé B. et al. (2004) *Spectrochim. Acta B 59*, 1413-1422. [4-9] as compiled in the Mars Meteorite Compendium: [4] Easton A.J. and Elliott C.J. (1977) *Meteoritics* **12**, 409-416. [5] Haramura H. (1995) *Catalog of the Antarctic Meteorites.* (*eds.* Yanai and Kojima) page 48. Nat. Inst. Polar Res., Tokyo. [6] Stolper E. M. (1979) *Igneous petrology of differentiated meteorites*. PhD Thesis, Harvard U, Cambridge. [7] McCoy T.J. et al. (1992) *Geochim. Cosmochim. Acta* **56**, 3571-3582. [8] Zipfel J. et al. (2000) *Meteoritics & Planet. Sci.* **35**, 95-106. [9] Folco L. et al. (2000) *Meteoritics & Planet. Sci.* **35**, 827-839.

Table 1. Compositions, in wt. %, of DAG476 and Zagami from [4-9].

	DAG476			Zagami			
SiO2	45.76	47.72	48.91	50.9	50.52	50.8	51.2
TiO2	0.39	0.35		0.73	0.84	0.77	0.81
Al2O3	4.37	4.19		5.7	6.27	5.67	6.19
FeO	16.06	16.52	17.17	17.3	18.03	18	18.2
MnO	0.45	0.394		0.5	0.44	0.5	0.55
CaO	7.66	7.83	5.84	10.5	9.57	10.8	10.7
MgO	19.41	19.36	20.75	11.4	12.14	11	10.4
Na2O		0.55		1.2	0.13	0.99	1.29
K2O	0.038	0.033		0.1	0.08	0.14	0.13
P2O5	0.32	0.49		0.48	0.46		0.58
TOTAL	94.458	97.437	92.67	98.81	98.48	98.67	100.05

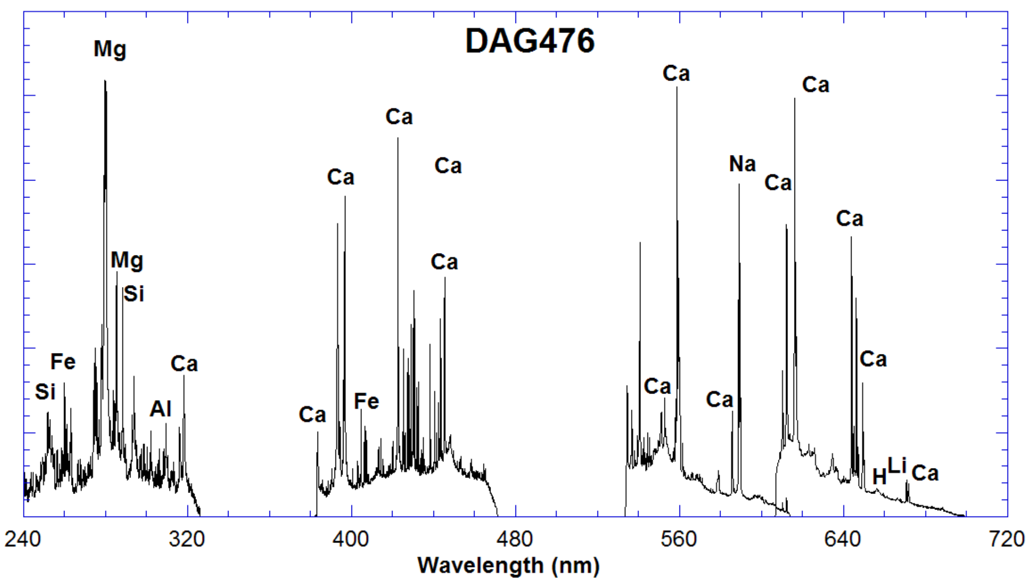


Fig. 1. LIBS spectrum of Mars meteorite DAG 476 taken from a distance of 8.3 m in air.