CHEMICAL COMPOSITION OF FOUR SHERGOTTITES FROM NORTHWEST AFRICA (NWA 2800, NWA 5214, NWA 5990, NWA 6342).

S. Yang[1], M. Humayun[1], G. Jefferson[1,2], D. Fields[1,3], K. Righter[4] and A. J. Irving[5], [1]National High Magnetic Field Laboratory and Dept. of Earth, Ocean & Atmospheric Science, Florida State University, Tallahassee, FL 32310, USA (syang@magnet.fsu.edu; humayun@magnet.fsu.edu); [2]Carter High School, Rialto, CA 92376, USA; [3]Rickards High School, Tallahassee, FL 32306, USA; [4]Mailcode KT, NASA-JSC, 2101 NASA Pkwy., Houston, TX 77058 (kevin.righter-1@nasa.gov); [5]Department of Earth & Space Sciences, University of Washington, Seattle, WA 98195, USA (irving@ess.washington.edu).

Introduction: Shergottites represent the majority of recovered Martian meteorites. As basic igneous rocks, they formed from magmas that were emplaced in the Martian crust [1]. Due to the low ambient pressure of the Martian atmosphere, subaerial lavas and shallow magma chambers are expected to outgas volatile metals (e.g., Cd, Te, Re, Bi) [2]. The planetary abundances of the volatile siderophile and chalcophile elements are important at establishing the depth of core formation for Mars, and must be known as a baseline for understanding volcanic outgassing on Mars, particularly the large enrichments of S and Cl observed in modern Martian soils [3]. There is little data on volatile siderophile and chalcophile elements from Martian meteorites, excluding a few well-analyzed samples [2]. Further, a large number of shergottites being recovered from North West Africa are in need of chemical analysis. All of the shergottites are in need of state-of-the art analysis for such ratios as Ge/Si and Ga/Al, which can now be accomplished by LA-ICP-MS [2].

Samples and Analytical method: LA-ICP-MS was used to obtain a complete dataset for the abundances of 71 elements in the following Martian meteorites: Shergotty, Los Angeles, Zagami (USNM, ZAG 289), Yamato 980459, Yamato 000097, EETA 79001, NWA 2800, NWA 5124, NWA 6342 and NWA 5990. Polished sections of these Martian meteorites were analyzed by a New Wave UP 193FX excimer (193 nm) laser ablation system coupled to a Thermo Element XR Inductively Coupled Plasma Mass Spectrometer (ICP-MS) at the Plasma Analytical Facility, National High Magnetic Field Laboratory (FSU). The sections were rastered using a 75 µm beam spot, at 15 µm/s, 50 Hz over about 4 mm^2 surface area. For NWA 2800 and NWA 5214 pyroxene and plagioclase were analyzed by using 50 µm spots at 50 Hz. All element peaks were collected in low resolution with (mainly) triple mode detection. Elemental abundances were obtained by using relative sensitivity factors obtained from reference values for USGS glasses, BCR-2g, BHVO-2g and BIR-1g, and from NIST SRM 610.

Result and Discussion: Because some of the shergottites are fairly coarse-grained, the scale of analysis may not be sufficient to obtain representative bulk analyses. For many lithophile elements, inter-element ratios are more important than bulk abundances. New chemical analyses of these four samples are given in Table 1, and additional data is shown in figures 1-3. The REE pattern of four NWA samples is shown in Fig. 1, compared with Los Angeles and QUE 94201, which represent the enriched and depleted shergottites, respectively. Also shown are the REE abundance in NWA 5990 [4] and NWA 6342 [5]. Our new NWA 5990 REE data agree reasonably well with the bulk rock REE [4]. But there are obvious discrepancies between our NWA 6324 REE abundances and the bulk rock [5], which is an artifact of lower phosphate abundance encountered in the analyzed surface since NWA 6342 is texturally heterogeneous [5]. The REE patterns of NWA 5214 and NWA 2800 are similar to Los Angeles, which agrees with the description of NWA 2800 [6] and NWA 5214 [7]. The HREE abundances in NWA 5990, NWA 5214 and NWA 2800 are almost the same. Fig. 2A shows good correlation between Ga and Al_2O_3, with averaged pyroxene and plagioclase compositions measured on NWA 2800 and NWA 5214 defining the two extremes. Compared to other shergottites, NWA 5214, NWA 2800 and Los Angeles are closer to the plagioclase end, which is consistent with their enriched REE pattern. Fig. 2B shows that the shergottites exhibit near CI chondrite ratios for Zr/Hf. The depleted shergottites (NWA 5990, EETA 79001) exhibit a lower Zr/ Hf ratio (~25) than other shergottites (>31), perhaps reflecting differences between enriched and depleted mantle sources.

Ir vs. MgO plot is given in Fig. 3, together with recent isotope dilution analyses for SNCs [8]. There is good agreement between the isotope dilution data performed on 10-200 mg samples with our LA-ICP-MS data performed on ≤ 1 mg samples. Triplicate analyses of Y 980459 yielded 14-20 ppb Ir (and other siderophiles) by isotope dilution [8], but in our study Y 980459 has Ir (0.6 ppb) which is within the range of other shergottites. Conversely, Zagami (0.035 ppb [8]; 0.48, this study) is significantly lower in [8] compared with this study. Otherwise, EETA 79001A (1.1 ppb [8]; 0.85 ppb, this study) and Shergotty (0.37 ppb [8]; 0.61 ppb, this study) are in good agreement between the two studies. Thus, for highly siderophile elements which are strongly concentrated in minor (sulfide?) phases, sample heterogeneity appears to be a significant issue even at the 100-mg scale.

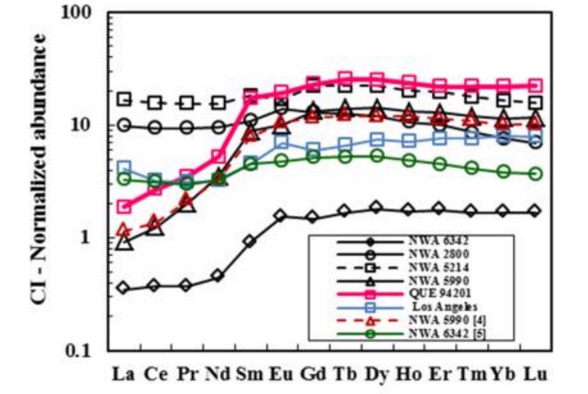

Fig. 1: CI chondrite-normalized REE abundances for NWA 2800, NWA 5124, NWA 6342 and NWA 5990, from this study compared with Los Angeles [6], QUE 94201 [6] shergottites, NWA 6900 [4] and NWA 5214 [5].

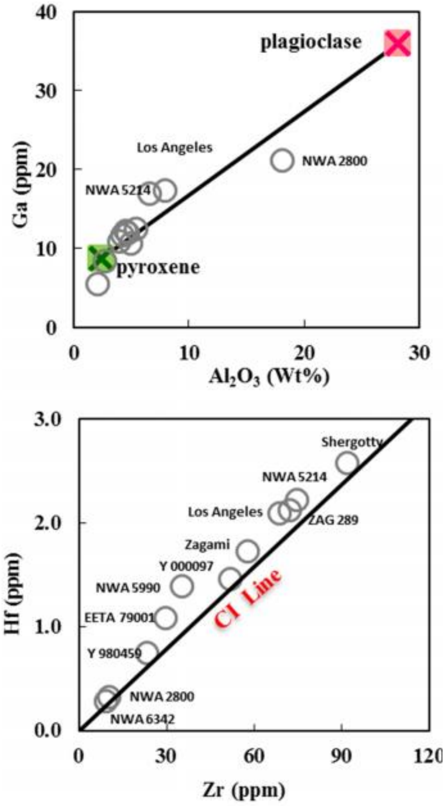

Fig. 2A, 2B: Ga-Al (A, top) and Hf-Zr (B, bottom) correlations for Martian meteorites. Pink and green squares with cross represent average compositions of plagioclase and pyroxene measured on NWA 2800 and NWA 5214, and the line between them shows the mineral fractionation trend. CI chondrite line is shown in Hf-Zr plot.

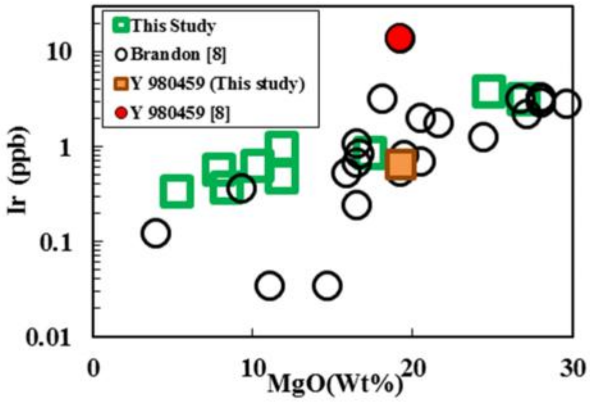

Fig. 3: Ir- MgO plot comparing LA-ICP-MS data (this study) and isotope dilution abundances [8].

References: [1] Treiman A. H. et al. (2000) *Planet. Space Sci., 48*, 1213-1230. [2] Righter K. and Humayun M. (2012) *LPS 43*, Abstract #2465. [3] McSween H. Y., Jr., et al. (2009) *Science*, *324*, 736-739. [4] Irving A. J. et al. (2010) *LPS*, *41*, Abstract #1833. [5] Irving A. J. et al. (2011) *LPS, 42*, Abstract #1612. [6] Meyer, C. (2008) Mars Meteorites Compendium. [7] Sanborn M. E. et al. (2010) *M&PS*, *73*, Abstract #5294. [8] Brandon A. D. et al. (2012) *GCA*, *76*, 206-235.

Table 1. Elemental abundances of new Shergottites

		NWA 6342	NWA 2800	NWA 5214	NWA 5990
SiO_2	wt %	46.09	50.28	47.35	41.5
TiO_2	wt %	0.27	0.35	0.87	0.55
Al_2O_3	wt %	2.06	18.03	6.50	5.38
FeO_T	wt %	19.19	10.19	20.54	24.28
MnO	wt %	0.52	0.29	0.56	0.59
CaO	wt %	4.28	11.75	12.39	6.66
MgO	wt %	26.94	5.23	8.42	19.19
Na_2O	wt %	0.38	2.96	1.54	0.78
K_2O	wt %	0.02	0.10	0.34	0.02
P_2O_5	wt %	0.16	0.76	1.45	1.04
S	wt %	0.09	0.05	0.03	0.22
Li	ppm	3.99	2.71	4.78	2.00
Be	ppm			0.32	0.04
Sc	ppm	27.82	35.68	72.90	39.96
V	ppm	182	169	320	112
Cr	ppm	5819	270	832	2587
Co	ppm	65.5	22.0	36.7	52.1
Ni	ppm	294	36.3	50.5	90.7
Cu	ppm	10.93	5.23	13.77	19.11
Zn	ppm	42.81	37.31	80.96	93.22
As	ppm	0.08	0.06	0.35	0.07
Se	ppm	0.16	0.16	0.37	0.61
Rb	ppm	0.83	1.29	17.66	0.42
Sr	ppm	7.90	101.37	62.88	24.40
Y	ppm	2.62	16.10	29.42	17.96
Zr	ppm	8.94	10.09	74.36	35.14
Nb	ppm	0.27	0.53	4.06	0.19
Mo	ppm	0.004		0.111	0.077
Sb	ppm	0.007	0.008	0.014	0.049
Cs	ppm	0.15	0.16	1.14	0.10
Ba	ppm	5.08	16.39	45.69	2.73
Lu	ppm	0.04	0.17	0.38	0.28
Hf	ppm	0.29	0.32	2.23	1.40
Ta	ppm	0.012	0.027	0.187	0.013
W	ppm	0.050	0.123	0.451	0.067
Th	ppm	0.020	0.193	0.602	0.033
U	ppm	0.007	0.028	0.154	0.030