REVISED COMPOSITIONAL ESTIMATE OF EETA79001 LITHOLOGY A GROUNDMASS.

M. J. Mellin, Y. Liu, D. W. Schnare, L. A. Taylor. Planetary Geosciences Institute, Dept. of Earth & Planetary Sciences, University of Tennessee, Knoxville, TN 37996, USA (mmellin@utk.edu).

Introduction: Elephant Moraine A79001 is a Martian shergottite discovered during the 1979 US ANSMET Field Expedition in Antarctica. This meteorite may be considered the most unique of the Martian SNC group because it is composed of two texturally distinct rock types that are separated by a planar geologic contact [1]. Lithology A is classified as an olivine-phyric shergottite (containing megacrysts of olivine, orthopyroxene and chromite), whereas Lithology B is a basaltic shergottite. The two lithologies show subtle differences in grain size, mineral chemistry, and mineral modes as summarized in [2]. Despite these differences, they share enough similarities in their mineral major- and trace-element chemistries to support a petrogenetic relationship [1, 3].

Currently, in the literature, there are several competing Lithology A formational theories [e.g., 1, 4-7], with each theory having its strengths and weaknesses. Much of this controversy stems from the uncertainty in the relationship between the megacrysts and groundmass in Lithology A. Could the Lithology A groundmass represent a primitive basaltic melt or is it a mixture of two or more components? This is a key issue that needs to be further investigated.

Previous Lithology A Groundmass Estimates:
In this study, we refer to the bulk chemical composition of Lithology A Groundmass as "AG". Previous AG estimates from the literature [e.g., 1, 8-10] vary in Mg# from 52.7 to 58.6 (Table 1), with Mg# defined as molar Mg/(Mg+Fe)*100.

Part of the discrepancies in the AG may be attributed to the methodology of obtaining "average" compositions for the megacryst crystals. Previous AG estimates in [1,8] used averaged compositional analyses of cores and rims of the megacrysts. It is unclear whether this was the basis for AG compositions reported by [9,10]. Because megacrysts are zoned and most of the mass of a grain resides in the outer portion of a crystal (especially near the rims), a direct average of random compositional data could be biased (depending on the number of analyses). A more accurate method for obtaining the chemical abundance of compositionally zoned megacrysts would be to apply a weighting-factor based on volume (i.e., mass) considerations for various EMP analyses; this accounts for analyses further from the cores of concentrically zoned crystals representing larger volumes/masses. If one assumes a constant spacing of compositional analyses from core to rim, each consecutive analysis away from the core represents a larger volume (mass) of the crystal. Therefore, an analysis at the core represents a significantly smaller volume (mass) than one taken at the rim.

In addition, some estimates (e.g. [1,8]) are based upon mineral modes obtained by optical point counting, which is subjective to some extent, and has a lower precision than newer methods that use compositionally-sensitive x-ray digital imaging. Here,

Table 1. Bulk-chemical compositions for EETA79001 Lithology A groundmass (AG).

	AG_1	AG_2	AG_3	AG_4	AG_5*
Ref.	[1]	[8]	[9]	[10]	
SiO_2	49.2	50.7	48.4	49.0	**50.2**
TiO_2	0.78	0.86	1.98	1.70	**0.61**
Al_2O_3	6.44	7.10	7.20	7.40	**5.42**
Fe_2O_3	0.39	n.d.	n.d.	n.d.	**n.d.**
Cr_2O_3	0.12	0.12	n.d.	0.15	**0.37**
FeO	18.1	18.7	17.7	18.4	**19.5**
MnO	0.51	0.52	0.55	0.52	**0.55**
MgO	14.4	12.2	12.0	11.5	**15.7**
CaO	7.96	8.74	9.00	9.20	**6.64**
Na_2O	0.97	1.07	0.80	0.90	**0.92**
K_2O	0.06	0.07	n.d.	n.d.	**n.d.**
P_2O_5	0.75	n.d.	n.d.	1.20	**n.d.**
Mg#	58.6	53.8	54.7	52.7	**59.0**

****This study**: Weighted average of cores and rims of groundmass crystals plus overgrowths of megacrysts

we introduce a new, hopefully more-precise, compositional estimate for the groundmass of Lithology A..

Methodology: Six polished thin-and thick-sections from Lithology A (79001, 616; ,439), Lithology B (79001, 457; ,392), and at the boundary between A and B (79001, 615; 39) were obtained from the Astromaterials Acquisition and Curation Office at Johnson Space Center. All slides range in surface area from 50-78 mm², except ,39, which has a surface area of approximately 170 mm².

A Cameca SX-50 electron microprobe (EMP) was used to obtain mineral compositions. Mineral modes were obtained on all sections using an Oxford Instrument energy dispersive spectrometer (EDS), coupled to the EMP. Modal analyses used a spot size of 1 μm and a step-size of 4 μm. A total of ~250,000 points per slide of megacryst free areas were analyzed, using the *Feature Scan Phase Distribution Software* (developed by Oxford Instruments), following the procedure of [11].

A new estimate: Our method calculates the bulk-groundmass composition directly using the weighted-averages of minerals in the groundmass and includes megacryst overgrowths. It has been reported [1, 7, 10] that the orthopyroxene and chromite megacrysts have overgrowths of pigeonite, and ulvöspinel, respectively. Here, we suggest that olivine overgrowths are present on olivine megacrysts (Fig. 1). Each profile shows a slight CaO enrichment at approximately 100 to 200 μm from the rim. We attribute this break to be the beginning of the olivine overgrowths. A plot of wt% CaO versus Fo of Figures 1 shows olivine overgrowths begin at ~ Fo 65.
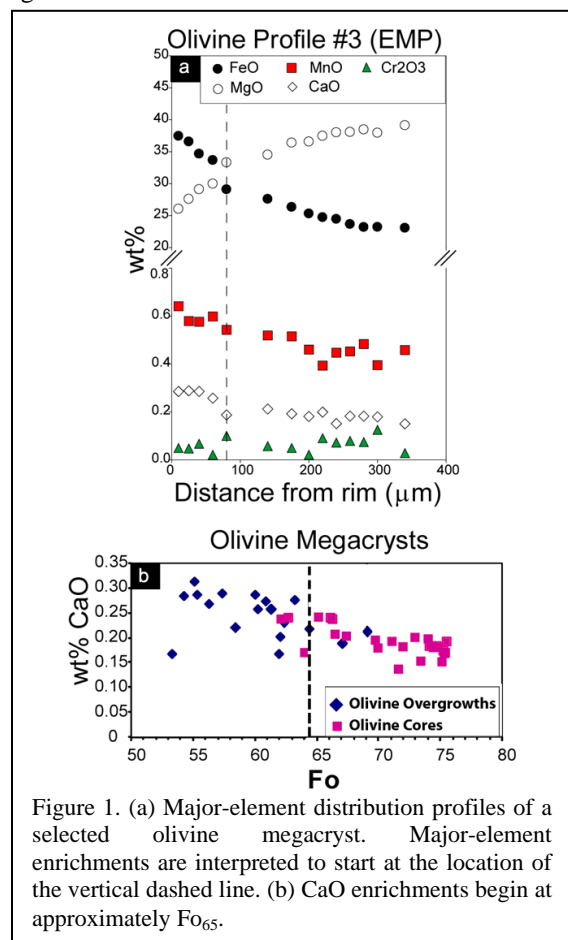

Figure 1. (a) Major-element distribution profiles of a selected olivine megacryst. Major-element enrichments are interpreted to start at the location of the vertical dashed line. (b) CaO enrichments begin at approximately Fo$_{65}$.

The pyroxene and maskelynite groundmass crystals show similar zonations, and the resulting EMP compositions are given a weight of 65% for the rims and 35% for the cores. The AG composition was then determined by using these weighted EMP compositions along with mineral modes (reported in [2]) of the groundmass and mineral densities. The calculated AG results are independent of any Lithology A bulk-rock values.

Interestingly, the resultant Mg# of 59.0 (AG$_5$, Table 1) is similar to the Ag$_1$ Mg# of 58.6 reported by McSween and Jarosewich [1]. The results of our method can be interpreted to indicate that McSween

and Jarosewich [1] may have fortuitously subtracted a representative amount of olivine and orthopyroxene megacrysts from the whole-rock composition when calculating AG$_1$. Therefore, the modification of AG$_1$ to form AG$_2$ by Longhi and Pan [8] may be inappropriate. Also, slight changes in AG$_5$ overgrowth abundances result in only minor changes in the calculated AG$_5$ composition.

We consider this AG$_5$ calculation as the most reasonable and precise of all reported compositions. Unlike some of the previous calculations (AG$_1$-AG$_4$), its derivation is based upon groundmass mineral abundances (from multiple sections) that were obtained from the x-ray digital-imaging technique with the EDS on the EMP.

Summary: We interpret that AG$_5$ is a composite composition formed by the interaction of Lithology B type magma with ultramafic material as described in mixing models by [1,4,6]. This olivine-normative magma then crystallized olivine on olivine megacrysts starting at ~Fo 65. This theory provides a reasonable answer to the observation that there is no olivine in the groundmass. Schwandt et al. [9] stated the lack of olivine in groundmass with their AG composition could be possible at low temperatures (~1100 °C), based on low temperature experiments on AG$_2$ by Wasylenki et al. [12]. Low temperature experiments on AG$_5$ may yield different results.

References:
[1] McSween H.Y. and Jarosewich E. (1983) *GCA*, 47, 1501-1513. [2] Mellin M.J. et al. (2007) *LPSC, XXXVIII,* Abstract #2179. [3] Mellin M.J. et al. (2007) *LPSC, XXXVIII,* Abstract #2324. [4] Wadhwa M., McSween H.Y., and Crozaz G. (1994) *GCA,* 58, 4213-4229. [5] Warren P.H. and Kallemeyn G.W. (1997) *Antarct. Meteorite Res.*, 10, 61-81. [6] Mittlefehldt et al. (1999) *M&PS*, 34,357-367. [7] Goodrich C.A. (2003) *GCA*, 67, No. 19, 3735–3771. [8] Longhi J. and Pan V. (1989) *Proc. of the 19th Lun. and Planet. Sci. Conf.*, 451-464. [9] Schwandt et al. (2001) *LPSC, XXXII*, Abstract #1913. [10] Herd et al. (2002) *M&PS*, 37, 987-1000. [11] Taylor L.A. et al. (1996) *Icarus*, 124, 500-512. [12] Wasylenki L.E. et al. (1993) *LPSC XXIV*, 1491-1492.