

**VOLATILE BEHAVIOR IN LUNAR AND TERRESTRIAL BASALTS DURING SHOCK:**

**IMPLICATIONS FOR MARTIAN MAGMAS** Johny Chaklader<sup>1</sup> (jchaklad@unm.edu), C.K. Shearer<sup>1</sup> (cshearer@unm.edu), F. Hörz<sup>2</sup> and H.E. Newsom<sup>1</sup>. <sup>1</sup>Institute of Meteoritics, Department of Earth & Planetary Sciences, University of New Mexico, Albuquerque, NM 87131-1126. <sup>2</sup>NASA Johnson Space Center, Houston, Texas 77058.

**Introduction:** The amount of water in martian magmas has significant ramifications for the martian atmosphere-hydrosphere cycle. Large D-enrichments have been observed in kaersutitic amphiboles in Zagami, Chassigny and Shergotty meteorites (delta-D values up to 4400 per mil) suggesting that substantial amounts of H escaped Mars in its past [1]. Furthermore, martian meteorites with inclusions of biotite and apatite imply possible origins in a hydrous mantle [2], [3]. However, whether martian magmas ever possessed considerable proportions of water remains controversial and unclear. The H-content of mica and amphibole melt inclusions has been found to be low, while bulk-rock H<sub>2</sub>O content is also low ranging from 0.013 to 0.035 wt. % in Shergotty [4]. Hydrous martian magmas were considered responsible for light lithophile element (LLE) zoning patterns observed in Nakhilite and Shergottite pyroxenes [5]. Since LLEs, such as Li and B, partition into aqueous fluids at temperatures greater than 350 °C, workers interpreted Li-B depletions in pyroxene rims as evidence that supercritical fluid exsolution occurred during magma degassing [6]. In that many martian basalts experienced substantial shock (15-45 GPa) [7] it is possible that the magmatic volatile record preserved in martian basalts has been disturbed. Previous shock experiments suggest that shock processes may effect water content and H/D [8, 9]. To better understand the possible effects of shock on this volatile record, we are studying the redistribution of volatile elements in naturally and experimentally shocked basalts. Here, we report the initial results from shocked basalts associated with the Lonar Crater, India and an experimentally shocked lunar basalt.

**Analytical Approach:** Lonar samples are on loan from the Smithsonian National Museum. The extent of shock was estimated by morphology of plagioclase and the conversion of plagioclase to maskelynite [10]. Apollo 17 (A17) high-Ti lunar basalts were experimentally shocked at the Johnson Space Center as described by [11]. Pyroxenes were imaged and analyzed with a JEOL JSM-5800 LV SEM and a JEOL JXA-8200 EMP. Pyroxenes were analyzed for <sup>7</sup>Li, <sup>9</sup>Be, <sup>11</sup>B, <sup>48</sup>Ti, <sup>88</sup>Sr, and <sup>140</sup>Ce using a Cameca ims 4f. To minimize surface B contamination, thin sections were soaked for 2 hours in 1 % mannitol solution and rinsed in ultrapure (18 MΩ) water. Analyses were made by bombarding samples with primary O<sup>-</sup> ions at a potential of 10 kV.

A primary ion current of 15 nA was focused on the sample to a spot diameter of 10-15 μm. Sputtered secondary ions were energy filtered using a sample offset voltage of 75 V and an energy window of 50 V. Beryllium was analyzed separately at higher mass resolution to eliminate a potential interference with <sup>27</sup>Al<sup>3+</sup>.

**Sample Description:** The basalts associated with the Lonar Crater are tholeiitic in composition and contain plagioclase, pyroxene (augite and pigeonite), Fe-Ti oxides, and devitrified basaltic glass. The shocked basalts used in this study contain maskelynite and correspond to 20-40 GPa [10]. Unshocked lunar basalt 75035 is a high-Ti, medium-grained, subophitic basalt consisting of clinopyroxene, plagioclase (An<sub>87</sub>), ilmenite, cristobalite, pyroxferroite, native iron, troilite, and some mesostasis. As with all lunar basalts it crystallized near the IW buffer at extremely dry conditions. This basalt was shocked at the JSC facility at various pressures (9.3-99.9 GPa); see [11].

**Results: Pyroxenes from Lonar Crater Basalt:** Unshocked Lonar basalt pyroxenes are euhedral and exhibit broad zoning in pyroxene quadrilateral components. Figure 1 illustrates differences in element contents and differences in enstatite (En), wollastonite (Wo) and ferrosillite (Fs) components in an unshocked Lonar pyroxene. Manganese and the Fs component vary similarly. Ti-content diminishes rapidly at rims. Cr-content is low at rims but varies inversely with Ti and the Fs component near the core. Na and Al-content varies inversely with Fs-component. Shocked Lonar pyroxenes are granulated and displaced along microfaults. Microporphyratic textures in these pyroxenes were destroyed and associated plagioclase was converted to maskelynite. Shocked and unshocked pyroxenes display similar zoning in pyroxene quadrilateral components, and in major and minor elements. Trace element variations between shocked (red points) and unshocked (blue points) pyroxenes are shown in Figure 2. Considerable Li and B depletions are observed in the Fe-enriched rim of the shocked Lonar pyroxene. Li and B-content variations from core to rim are less extensive in the unshocked pyroxene.

**Pyroxenes from A17 Basalt:** Unshocked A17 pyroxenes are euhedral. Figure 3 illustrates well-defined zoning in En, Wo, Fs components near the rims of an unshocked pyroxene. Mn-content and the Fs component vary similarly while Cr, Na, Al and Ti-contents vary inversely with the Fs-component. Ti-content di-

minishes at rims reflecting the onset of ilmenite crystallization. Shocked pyroxenes from A17 basalt are granulated and displaced along microfaults. Subophitic textures in these pyroxenes were destroyed and associated plagioclase was converted to maskelynite at pressures exceeding 20 GPa. Major and minor element zoning as well as variation in En, Wo, Fs components are similar to those of the unshocked A17 pyroxene. Trace element variations between shocked (red points) and unshocked (blue points) pyroxenes are shown in Figure 4. Considerable Li-depletions are observed in zones of Fe-enrichment and Wo-depletion for both shocked and unshocked Apollo 17 pyroxenes. The shocked pyroxene exhibits B-depletion in the Fe-enriched rim. The unshocked pyroxene does not show significant variation in B-content.

**Discussion:** Light lithophile element zoning in pyroxenes of basaltic martian meteorites have led some to conclude that Mars once had hydrous magmas [5]. Li and B may have partitioned into supercritical fluids during magmatic degassing to generate depletions in pyroxene rims [6]. However, given the dry crystallization conditions of lunar basalts, mechanisms besides fluid activity are necessary to explain rim depletions observed for A17 pyroxenes of this study. While Lunar pyroxene data show a relationship between Li-B variations and shock, A17 pyroxene data are less clear (Figures 2, 4). Since Li-depletions are accompanied by substantial Fe-enrichments and Wo-depletions in both shocked and unshocked lunar pyroxenes, it is suggested that changes in pyroxene composition affected the Li-partitioning between melt and pyroxene. Further work is needed to investigate why the range in B-data for all naturally and synthetically shocked pyroxenes of this study exceed the range observed for unshocked pyroxenes. The potential for B-contamination in shocked pyroxenes from natural environment and laboratory sources needs to be explored.

**References:** [1] Watson, L.L. et al. (1994) *Science*, 265, 86-90. [2] Johnson, M.C. et al. (1991) *GCA*, 55, 349-366. [3] Mysen, B.O. et al. (1998) *Am. Min.*, 83, 942-946. [4] Dann, J.C. et al. (2001) *MAPS*, 36, 793-806. [5] McSween, H.Y. et al. (2001) *Nature*, 409, 487-490. [6] Lentz, R.C.F. et al. (2001) *GCA*, 65, 4551-4565. [7] Fritz, J. et al. (2003) *LPSC XXXIV*, abst. 1335. [8] Miniti et al. (2003) *LPSC XXXIV*, abst. 1524. [9] Monkawa et al. (2003) *LPSC XXXIV*, abst. 1524. [10] Kieffer, S.W. et al. (1976) *Lunar Sci. Conf.* 7<sup>th</sup>, 1391-1412. [11] Schaal, R.B. and Horz, F. (1977) *Lunar Sci. Conf.* 8<sup>th</sup>, 1697-1729.

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Figure 1. Variation in an unshocked Lunar pyroxene.

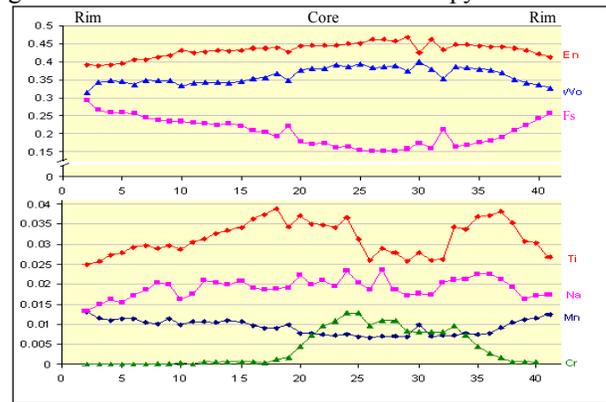


Figure 2. Trace Element Variation in Lunar pyroxenes.

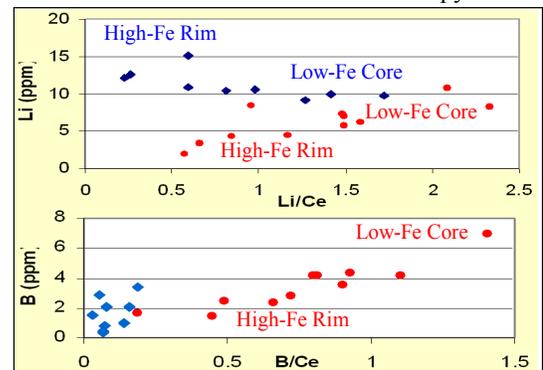


Figure 3. Variation in an unshocked A17 pyroxene.

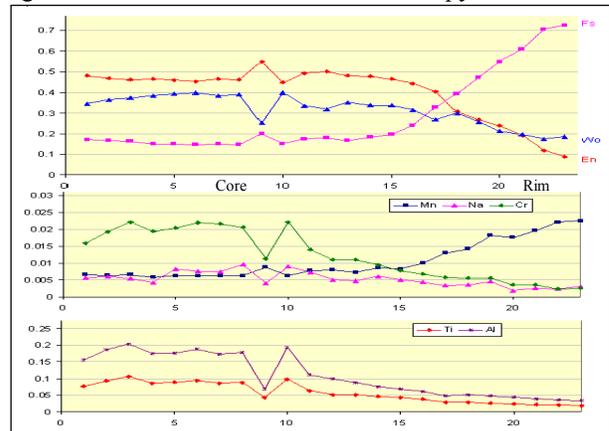


Figure 4. Trace Element Variation in A17 pyroxenes.

