MELT INCLUSIONS IN OLIVINE-PHYRIC SHERGOTTITE LAR 06319: IMPORTANT CONSIDERATIONS IN USING MELT INCLUSIONS TO RETRIEVE PARENT MAGMAS.

A. Basu Sarbadhikari[1,2], C.A. Goodrich[3], Y. Liu[1], and L.A. Taylor[1]; [1]Planetary Geosciences Institute, Dept. of Earth & Planetary Sciences, Univ. of Tennessee, Knoxville, TN 37996, USA (amitbasu_s@yahoo.co.in), [2]The PML for Geochemistry and Cosmochemistry, Institute for Study of the Earth's Interior, Okayama Univ. at Misasa, Japan, [3]Planetary Science Institute, Tucson, AZ 85719 USA.

Introduction: The chemical and isotopic compositions of SNC meteoritic minerals and rocks have been extensively used to study the origin and evolution of Martian mantle-derived magmas. However, since most martian meteorites are at least partial cumulates, various indirect methods must be used to determine the compositions of their parent magmas. One of the most promising of these methods is the use of melt inclusions trapped in early-crystallizing minerals such as olivine [1]. Unfortunately, due to effects of post-entrapment crystallization and reequilibration that are prevalent in martian melt inclusions, there are a number of methodological problems in retrieving the composition of the primary trapped liquid represented by a melt inclusion [2-6]. This work focuses on melt inclusions in coarse olivine grains in LAR 06319, an olivine-phyric shergottite derived from an ‘‘enriched” and oxidized mantle reservoir [7,8]. LAR 06319 appears to be one of the few martian meteorites that does not have a cumulate component [7]. Thus, its melt inclusions present a relatively simple case that allows us to address several methodological issues.

Melt inclusions in LAR 06319: Previously [8] we distinguished three types of melt inclusion in LAR 06319, based on the composition of their hosts: Type 1 inclusions occur in the most magnesian olivine (Fo_{77-69}), Type 2 in Fo_{71-66}, and Type 3 in Fo_{61-50}. Bulk compositions of the inclusions were obtained by modal recombination of constituent phases, and then averaged for each of the 3 types. A major concern in this approach is the high possibility of unrepresentative sampling when 3-D objects are studied in 2-D, and in general the only solution is to analyze and average a "sufficiently large" number of inclusions. We studied 5 Type 1, 6 Type 2, and 10 Type 3 inclusions. As we show below, results for Type 1 and Type 2 inclusions can be reasonably interpreted relative to the crystallization sequence of the bulk rock, whereas this is not the case for Type 3 inclusions. One possible reason for this is that Type 3 inclusions are much smaller, coarser-grained, and more crystallized than Type 1 and Type 2 inclusions; thus, we may not have obtained a representative sample of their bulk

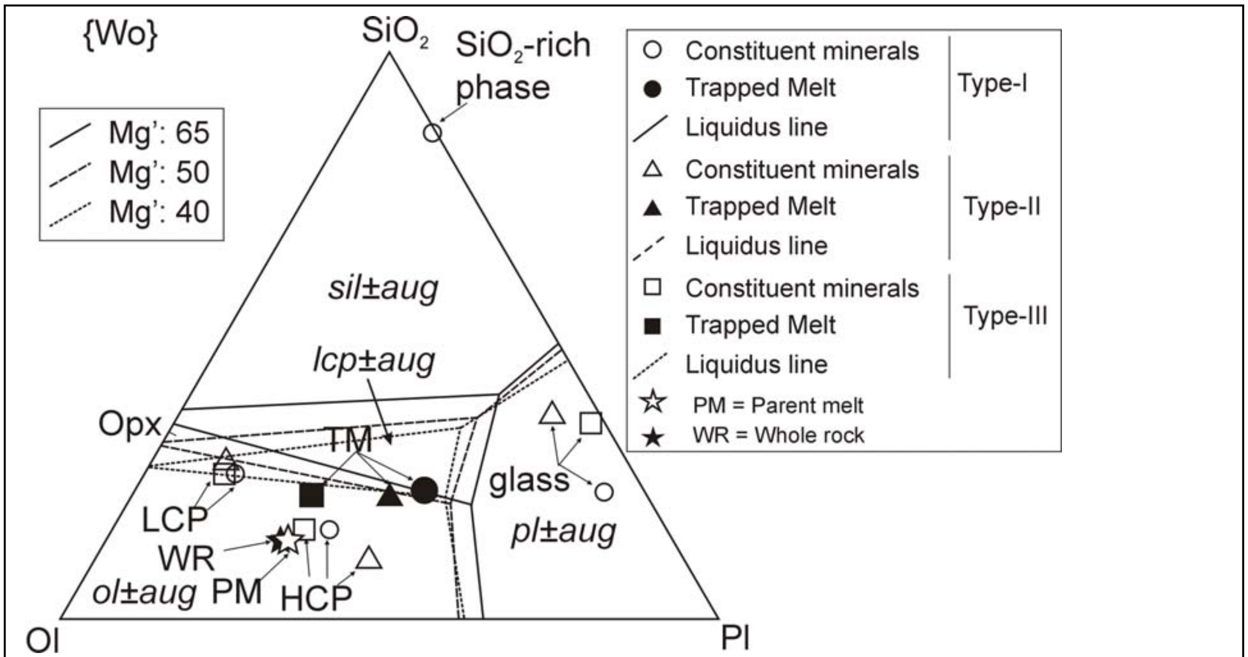

Figure 1: Olivine (Ol) – plagioclase (Pl) - quartz (SiO_2) phase diagram projected from wollastonite (Wo) [8], showing the composition of constituent minerals, parent melt (PM), whole rock and trapped melt (TM) composition of the melt inclusions. Abbreviations: Mg' = Mg/(Mg+Fe); ol, lpx, opx, aug, pig, pl and sil are liquidus fields of olivine, low-Ca pyroxene, orthopyroxene, augite, pigeonite, plagioclase and silica respectively.

composition even from 10 inclusions.

For Type 1 and Type 2 inclusions, primary trapped melt compositions (TM) were obtained from average bulk compositions by addition of olivine (to account for invisible wall olivine crystallized in the inclusions), followed by correction of Fe/Mg ratio to achieve equilibrium with the average host composition (to account for Fe/Mg reequilibration between inclusions and hosts). Unfortunately, due to the effects of reequilibration [9], it is not possible to constrain the amount of wall olivine except to a minimum, given by the assumption of olivine + low Ca pyroxene (lpyx) cosaturation (Fig. 1). Thus, either TM1 or TM2 could, and likely should, have a greater olivine component than the minimum shown in Fig. 1. Nevertheless, a first-order result of this work is that tie-lines from either TM1 or TM2 to olivine (Ol) pass through the composition of the whole rock (Fig. 1). This result gives us confidence that despite the small number of inclusions analyzed, we obtained a representative sample of their bulk compositions. In addition, it provides support for the interpretation that LAR 06319 represents a melt composition with little, if any cumulate component.

The most Mg-rich orthopyroxene observed in LAR 06319 is *mg*# 74, which would have co-crystallized with olivine of Fo_{70}. Therefore, it appears that during crystallization of Fo_{77} to Fo_{70}, olivine was the only silicate phase. Since Type 1 inclusions occur only in olivine within this compositional range, it is obvious that TM1 must have had a greater olivine component than the minimum. The upper limit is obtained by adding sufficient olivine to bring TM1 to coincidence with the whole rock. We estimate this to be ~35 wt.% olivine. Although it is possible that some olivine crystallized before any melts were trapped as inclusions, this amount is likely to have been small, given that the whole rock mg# (58) implies an equilibrium olivine composition of Fo ~80, very close to the most magnesian olivine observed.

An interesting observation made during this study, which may be applicable to melt inclusions in olivine in other SNC meteorites as well, is that most Type 1 and Type 2 melt inclusions have rims of low-Ca pyroxene directly in contact with (presumed) wall olivine. We suggest that these rims formed within the inclusions via the expected peritectic reaction olivine + melt = low-Ca pyroxene, and therefore represent some portion of the original wall olivine (usually invisible). We note that this interpretation raises the intriguing possibility that in some cases this reaction could consume original host olivine in addition to wall olivine, thus requiring that olivine be subtracted, rather than added, in the reconstruction. That does not appear to be the case here, however, since the bulk compositions of Type 1 and Type 2 inclusions are short of olivine saturation. Nevertheless, it may account for the relatively small amount of olivine that had to be added to achieve minimum olivine saturation (~5%), compared to the common case of extreme overcrystallization of wall olivine [10].

As noted above, unlike TM1 and TM2, our derived TM3 cannot be reasonably interpreted in terms of the predicted crystallization sequence of the bulk rock composition. Its Plag component is too low (Fig. 1) and its Wo component (not seen in the {Wo} projection) is too high, for it to have evolved from the parent melt. Currently, we do not understand this result, unless it is due to unrepresentative sampling.

Crystallization sequence: The low-Mg and low-alkaline compositions of most inferred martian magmas, and their relatively low-pressure origins, imply that they should have experienced the peritectic reaction olivine + melt = low-Ca pyroxene [8]. This reaction would lead to a gap in olivine composition in the crystallization sequence and the resulting rock. In fact, MELTS fractional crystallization modeling for the LAR 06319 whole rock and reconstructed parent melt compositions do predict such a compositional gap. Furthermore, as discussed above, this reaction appears to have occurred within the melt inclusions. In contrast, however, there is no gap in olivine compositions observed in the rock itself [7]. Textural evidence indicates that olivine of Fo_{77-69} trapped Type-I melt inclusions. At this point, orthopyroxene began to crystallize, but olivine growth did not stop. Rather, it continued to grow and trap Type 2 and 3 melt inclusions in sequence. This absence of the expected olivine gap may be ascribed to a number of factors, such as composition of the melt, relative proportions of olivine and orthopyroxene crystals, and relative settling and reaction rates [12]. We note that the LAR 06319 parent magma has relatively high Al_2O_3 compared to other inferred martian parent magmas [e.g. 6], which means that it was already close to plagioclase saturation when orthopyroxene appeared and its evolution along the olivine-lpyx reaction boundary would have been short.

Conclusions: Trapped melt compositions reconstructed from melt inclusions in early olivine in LAR 06319 can be reasonably interpreted in terms of the predicted crystallization sequence of the whole rock. Melt inclusions in late olivine, however, cannot, possibly due to unrepresentative sampling.

References: [1] Sobolev A.V. (1996), Petrology 4, 209. [2] Treiman A.H. (1993) GCA 57, 4753. [3] Harvey R.P., McSween H.Y. (1992) EPSL 111. [4] Ikeda Y. (1998) MAPS 33, 803. [5] Goodrich, C.A. (2003) GCA 67, 3735. [6] Goodrich C.A. et al. (2009) GCA 73, 3055. [7] Basu Sarbadhikari A. et al. (2009) GCA 73, 2190-2214. [8] Basu Sarbadhikari A. et al. (2009) LPSC 40, #1173. [9] Danyushevsky L. et al. (2000) CMP 138, 68. [10] Frezzotti M-L. (2001) Lithos 55, 273. [11] Longhi J., Pan, V. (1989) LPSC 19, 451. [12] Raedeke L.D., McCallum, I.S. (1984) J. Petrol. 25, 395.