**MINERALOGY AND PETROLOGY OF LAR 12095 OLIVINE-PHYRIC SHERGOTTITE: A POSSIBLE LAUNCH PAIR FROM MARS WITH DAR AL GANI 476 ET AL. AND SAYH AL UHAYMIR 005 ET AL.**

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**Introduction:** LAR 12095 is one of newly found Antarctic shergottites that was recovered during the 2012-2013 ANSMET season [1]. It is reported that LAR 12095 and LAR 12240 are possibly paired, but they are distinct from LAR 12011 that is likely to be paired with LAR 06319 in their nearly identical petrography and mineral compositions [1]. We have obtained a small rock chip of LAR 12095 for a detailed FIB-TEM work on olivine and pyroxene, and in this abstract we report preliminary results on petrology and mineralogy of a prepared polished thin section that will be used for future FIB-TEM work.

**Petrography:** LAR 12095 is an olivine-phyric shergottite showing a porphyritic texture composed of millimeter-sized olivine megacrysts set in a fine-grained groundmass of pyroxene, plagioclase (now transformed to maskelynite) and olivine as reported in [1] (Fig. 1). The modal abundance is estimated to be 62.5% low-Ca pyroxene, 19.5% maskelynite, 12.2% olivine, 4.1% augite, 0.9% chromite, 0.2% Fe sulfide and 0.1% ilmenite by X-ray mapping, although these values may not be representative because of a small size of the section studied (~7 x 5 mm). The olivine megacrysts reach up to 3 mm in size, while the groundmass phases are generally less than ~0.5 mm. Olivine megacrysts contain small magmatic inclusions and tiny chromite grains associated with pyroxene and/or Si-rich glass. Some pyroxene grains are prismatic, reaching ~1 mm in longer dimension. No exsolution feature was observed for pyroxenes by FEG-SEM. Most maskelynite grains are anhedral and interstitial to pyroxene and olivine. There are rare shock melt pockets in the section, and the presence of maskelynite suggests severe shock metamorphism similar to other shergottites. Probably the dark color of olivine is also due to shock metamorphism and the presence of Fe-rich nano-particles is expected [2], which will be explored by future FIB-TEM work.

**Mineral Chemistry:** The X-ray mapping exhibits complex chemical zoning of pyroxene (Fig. 2) and its composition is plotted in Fig. 3. The core of the large prismatic pyroxene grains are the most Mg-rich ($En_{77}Wo_3$). The chemical zoning then extends to $En_{65}Wo_{10}$, and most low-Ca pyroxene grains range from this composition to slightly more Fe-rich pigeonite composition ($En_{59}Wo_{11}$). The $Al_2O_3$, $TiO_2$ and $Cr_2O_3$ contents of low-Ca pyroxenes are 0.5-1.3, 0.05~0.5, and 0.2~0.6, respectively (all in wt%). Augite is present unrelated to the distribution of low-Ca pyroxenes (Fig. 2), and its composition is $En_{51-44}Wo_{28-36}$. Olivine megacrysts show monotonous chemical zoning from Mg-rich cores ($Fo_{73}$) to slightly Fe-rich rims ($Fo_{59}$) (Figs. 1, 2). Small olivine grains in the groundmass are rather homogeneous ($Fo_{\sim 65-60}$). The CaO content is almost constant (~0.2-0.3 wt%). Maskelynite shows some Na-enrichment at their rims, but their chemical zoning is not simple. The range of maskelynite composition is $An_{67}Or_0$-$An_{46}Or_1$. Maskelynite contains ~0.3-0.6 wt% FeO. Chromite also exhibits chemical zoning, but FEG-SEM observation revealed ~1 μm exsolution lamellae. Chromite in olivine megacrysts and the core of large chromite grains (~0.2 mm) are the most Cr-rich (60-53 wt% $Cr_2O_3$, 6-11 wt% $Al_2O_3$ and ~1 wt% $TiO_2$). Then, they extend to more Ti-rich composition (up to 21 wt% $Cr_2O_3$, 5 wt% $Al_2O_3$ and 20 wt% $TiO_2$). Merrillite contains ~3 wt% MgO and ~1 wt% FeO.

**Relationship to Other Olivine-phyric Shergottites:** LAR 12095 is an olivine-phyric shergottite somewhat similar to LAR 12011 in petrography, but their distinct mineral compositions suggest that they are not paired as suggested by [1]. LAR 12011 appears rather paired with LAR 06319 [1, 3].

LAR 12095 is most similar to Dar al Gani 476 and its paired samples (DaGs) and Sayh al Uhaymir 005 and its paired samples (SaUs) [4-7]. The presence of millimeter-sized olivine megacrysts set in the finer-grained groundmass is common among these meteorites. In fact, the mineral compositions of present phases in LAR 12095 are almost identical to those of DaGs and SaUs, and distinct from other olivine-phyric shergottites. The most Mg-rich olivine composition of LAR 12095 is $Fo_{73}$, which is slightly more Fe-rich than that of Dar al Gani 476 ($Fo_{76}$). This is probably because olivine megacrysts in the section studied do not expose the most Mg-rich cores on the section surface.

Although we have not measured a bulk composition of LAR 12095, we consider that it is a depleted shergottite from the chemical composition of maskelynite [8]. The $K_2O$ and $Na_2O$ contents of plagioclase and the bulk $Al_2O_3$ composition are correlated with the bulk La/Yb ratio [8]. The identical mineral abundances and compositions of LAR 12095 to DaGs and SaUs suggest that the bulk $Al_2O_3$ composition of LAR 12095 is ~4 wt% [4,9]. If we employ this value, the estimated bulk

La/Yb ratio of LAR 12095 is within the range of depleted shergottites [8]. Thus, these results show that DaGs, SaUs, and LAR 12095/12240 are possibly all launch pairs: ejected from Mars by the same impact and fell in different places on the earth.

**Crystallization History of LAR 12095:** The petrography of LAR 12095 suggests that the crystallization sequence of the present phases are first chromite and olivine, then pyroxene, plagioclase and other accessory phases. The extremely large size of olivine megacrysts compared to the groundmass phases and their Mg-rich composition may indicate that these megacrysts are xenocrysts and LAR 12095 is a cumulate [5]. However, the megacrysts can be phenocrysts because the $Fo_{74}$ olivine is equilibrated with low-Ca pyroxene of $En_{76}Wo_3$ at 1250 °C, log$fO_2$=QFM-2.5 by the MELTS calculation [9] using the bulk composition of Dar al Gani 489 [10] (Fig. 4). Then, the crystallizing pyroxene follows the chemical composition observed in LAR 12095 (Fig. 4). This calculation implies that LAR 12095 (and DaGs and SaUs) first slowly crystallized after liquidus temperature (~1400 °C, liquidus phase: olivine ($Fo_{85}$) and chromite) down to ~1250 °C, and then experienced rapid cooling, preserving chemical zoning of olivine and pyroxene [9]. This rapid cooling is estimated to be 0.03-3 °C/hour from the Fe-Mg chemical zoning of olivine in Dar al Gani 476 [5].

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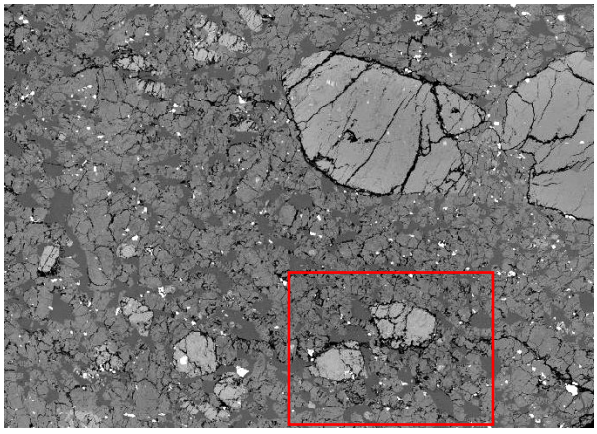

Fig. 1. Back-scattered electron image of LAR 12095. Olivine megacrysts are set in the fine-grained groundmass of pyroxene, maskelynite and olivine.

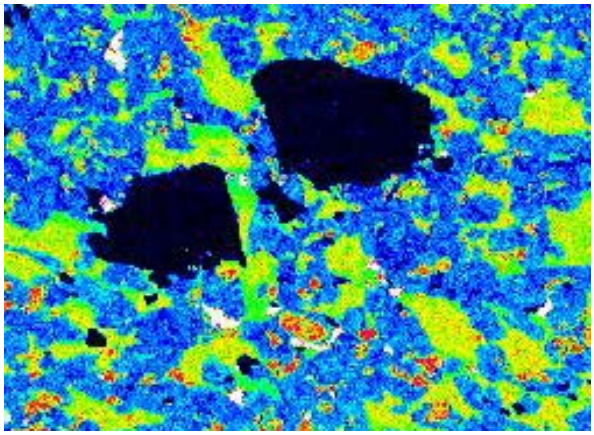

Fig. 2. Ca X-ray map of the red rectangle shown in Fig. 1. Black: olivine, Blue: low-Ca pyroxene, yellow-green: maskelynite, red: augite, white: merrillite.

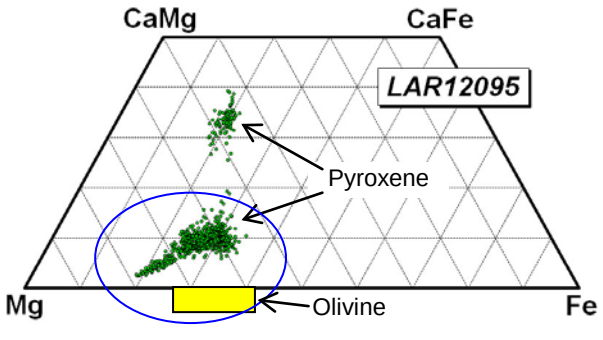


Fig. 3. Pyroxene quadrilateral and olivine composition of LAR 12095. These compositions are nearly identical to those of DaGs and SaUs.

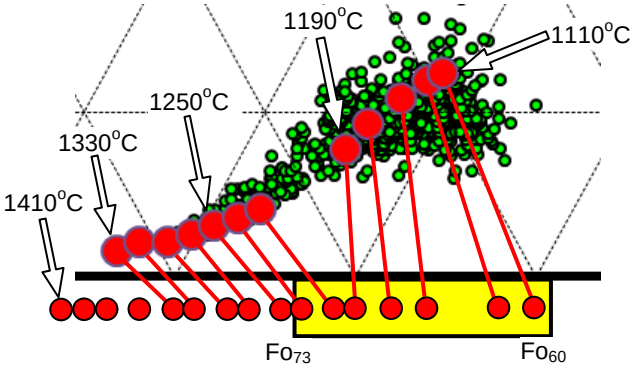


Fig. 4. Enlarged view of the blue circle portion of Fig. 3. Red circles are calculated compositions of olivine and pyroxene by MELTS. The red tie lines show equilibrated pairs at the same temperature.