Olivine-Phyric Shergottite LAR 06319: Its relation to the enriched components in Martian basalts. A. Basu Sarbadhikari[1,2], J.M.D. Day[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, Tottori 682-0193, Japan, [3]Department of Geology, Univ. of Maryland, College Park, MD 20740, USA

Introduction: There has been considerable controversy about the genesis of enriched and depleted signatures in shergottites, with two competing hypotheses of crustal assimilation [1-3] or sampling of heterogeneous mantle [4-6]. Detailed petrology of Larkman Nunatak (LAR) 06319 provides insight into the nature of the olivine megacryst population in olivine-phyric shergottites, as well as the nature of the incompatible-element enriched component in Martian basaltic magmas [7]. LAR 06319 (78.6 g, dark-brown to black fusion crust) is a recently discovered olivine-phyric shergottite from Antarctica. Our analysis of this meteorite demonstrates that it has close affinities to another olivine-phyric shergottite, NWA 1068, and an olivine-rich basaltic shergottite, NWA 4468.

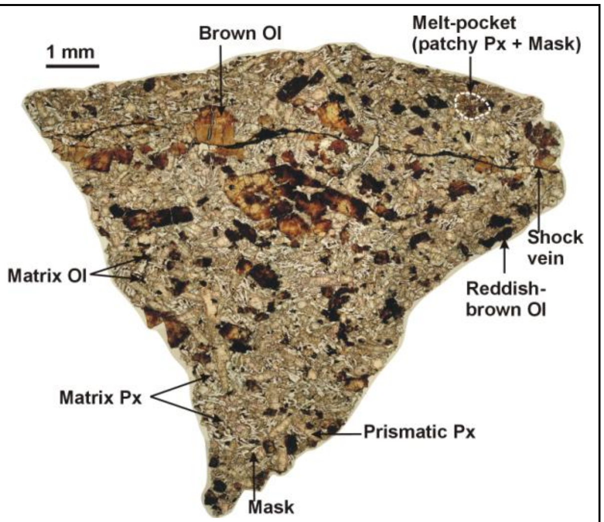

Fig. 1: Thin-section photomicrograph of LAR 06319, 37, in transmitted light.

Methodology: Analyses of mineral major-element compositions of the minerals in melt inclusions were conducted using a Cameca SX50 electron microprobe at the University of Tennessee. Minor- and trace-element concentrations of minerals were determined using a laser-ablation system coupled to an ICP-MS at the University of Maryland (details in [7]). Major- and trace-element compositions of whole-rock were performed on fused beads by the EMP and LA-ICP-MS analyses, respectively, at the University of Maryland (details in [7]).

Petrography and Mineral Chemistry: LAR 06319 is porphyritic, consisting of megacrysts of olivine (≤2.5 mm in length) and prismatic, zoned pyroxene crystals (Fig. 1). The groundmass is composed of finer-grained olivine (<0.25 mm), Fe-rich augite and pigeonite, maskelynite, with minor quantities of chromite, ulvöspinel, magnetite, ilmenite, phosphates, sulfides, and glass. Olivines are brownish to reddish-brown in color (Fig. 1). Shock features indicate LAR 06319 was involved in a major impact shock event (S5), equivalent to pressures of ~30-35 GPa. This range of shock pressure is similar to most other olivine-phyric and basaltic shergottites.

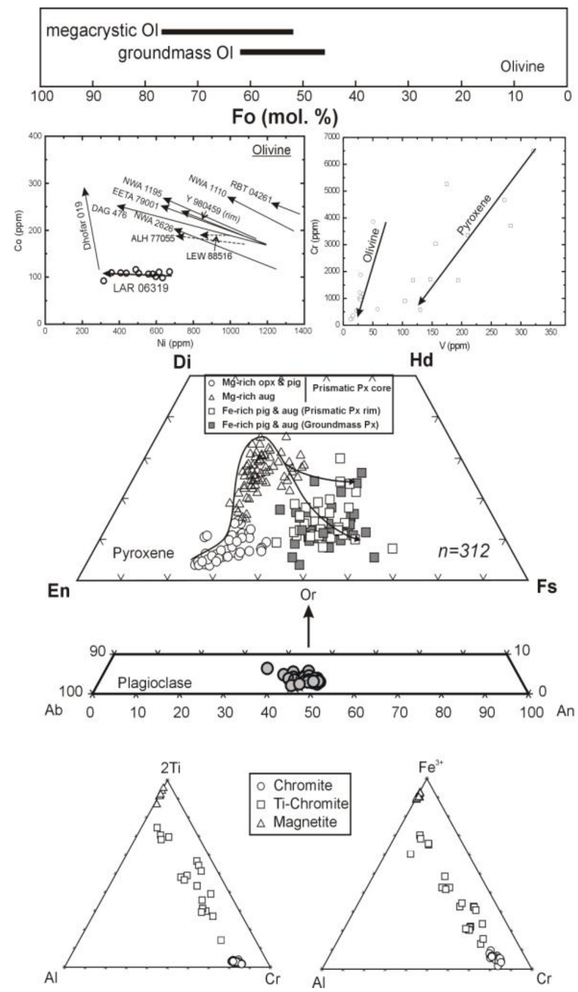

Fig. 2: Chemical compositions of olivine, pyroxene, plagioclase and spinels in LAR 06319.

Megacrystic olivine ranges from Fo_{77} in cores to Fo_{52} in rims, and groundmass olivine ranges in composition from Fo_{62} to Fo_{46} (Fig. 2). Trends of Ni-Co and V-Cr in olivines show a continuum from the megacryst core through to the rims and into the groundmass olivine. Prismatic pyroxenes are zoned from core to rim from Mg-rich orthopyroxene (Wo_3En_{71}, Mg# 75), to Mg-rich augite ($Wo_{36}En_{42}$, Mg# 55-68), and outward to Fe-rich rims ($Wo_{8-30}En_{23-45}$, Mg# 32-55). Groundmass pyroxenes ($Wo_{5-24}En_{26-50}$ and Mg# 28-53) are similar in composition to the rims of the large pyroxene grains (Fig. 2). Pyroxene cores are LREE-depleted, but to a lesser degree than for other olivine-phyric shergottites [7]. Rim pyroxenes are more REE- and LREE-enriched relative to pyroxene cores, indicating extensive fractional crystallization and varying D, with respect to the LREE, as a function of changing melt composition. Core pyroxenes have high concentrations of Cr and V compared to rim pyroxenes (Fig. 2). Maskelynites have a restricted range in composition (An_{51-37}) (Fig. 2). Chromites can be classified into a nearly pure chromite and Ti- and Fe^{3+}- rich chromites (Ti-chromite) (Fig. 2). Phosphates are merrillite and apatite. Sulfides are troilite, pyrrhotite, and pyrite.

Whole-Rock Composition: LAR 06319 has 15.8 wt.% MgO and >0.55 wt.% Cr_2O_3, and the Na_2O + K_2O and Rb concentrations of LAR 06319, along with NWA 1068, are elevated relative to other olivine-phyric shergottites, but are lower than for basaltic shergottites. The whole-rock composition of LAR 06319 (a relatively flat-REE pattern, ~8-9 × CI-Chondrite) is enriched in incompatible trace elements relative to depleted shergottites, with a trace-element pattern that is nearly identical to that of olivine-phyric shergottite NWA 1068 (Fig. 3).

Discussion and Conclusions: Olivine megacrysts in LAR 06319 are phenocrystic, with the most Mg-rich megacryst olivine being close to equilibrium with the bulk rock. A notable feature of LAR 06319 is that its olivine-megacryst grains contain abundant melt inclusions hosted within the forsterite cores. These early-trapped melt inclusions have similar trace-element abundances and patterns to that of the whole-rock (Fig. 3; also in accompanying abstract [8]), providing strong evidence for closed-system magmatic behavior for LAR 06319 [7,8]. Calculation of the parental-melt trace-element compositions indicate a whole-rock composition for LAR 06319 that was controlled by pigeonite and augite during the earliest stages of crystallization (Fig. 3). This is interpreted as phenocryst olivine that crystallized in magma conduits, followed by eruption and subsequent crystallization of the groundmass olivine.

LAR 06319 shows close affinity in mineral and whole-rock chemistry to NWA 1068 and NWA 4468 (Fig. 3). The remarkable features of these meteorites are that they have relatively similar quantities of mafic minerals, compared with other olivine-phyric shergottites, but flat- and elevated-REE patterns more consistent with the LREE-enriched basaltic shergottites (Fig. 3). This relationship can be interpreted as arising from partial melting of an enriched mantle source and subsequent crystal-liquid fractionation to form the enriched olivine-phyric and basaltic shergottites, or by assimilation of incompatible-element enriched Martian crust. The similarity in compositions of early-trapped melt inclusions and that of the whole-rock [7,8] indicates that any crustal assimilation must have occurred prior to crystallization of megacryst olivine, restricting any assimilation to the deeper portions of the crust (Fig. 3). Thus, we favor LAR06319 having formed from partial melting of an "enriched" and oxidized mantle reservoir, with fractional crystallization of the parent melt upon leaving the mantle [7].

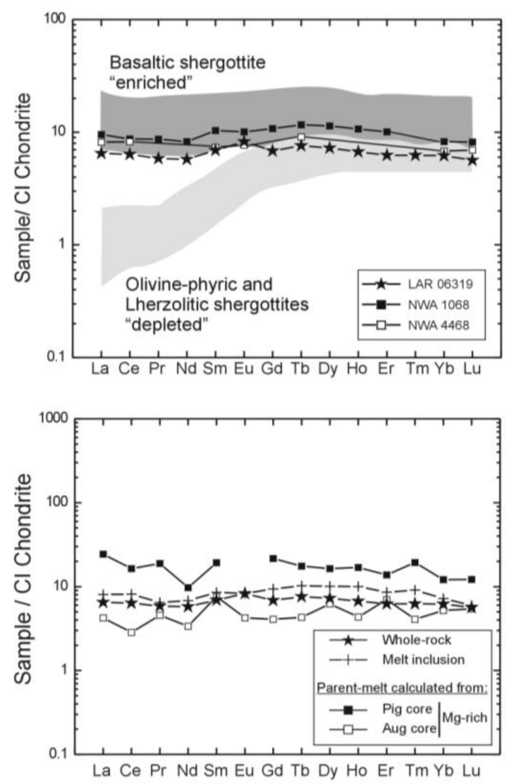

Fig. 3: CI-chondrite normalized REE patterns of LAR 06319, comparison with other shergottites, in particular NWA 1068 and NWA 4468. Calculations of parent melt composition from early-crystallized mineral assemblages, Mg-rich pigeonite and augite core.

References: [1] Jones (1989) *LPSC* 19; [2] Wadhwa (2001) *Science* 291; [3] Herd *et al.* (2002) *GCA* 66; [4] Herd (2003) *MAPS* 38; [5] Borg & Draper (2003) *MAPS* 38; [6] Symes *et al.* (2008) *GCA* 72; [7] Basu Sarbadhikari *et al*. (2009) *GCA*, in press; [8] Basu Sarbadhikari *et al*. (2009) this vol.