

**PETROGENESIS AND SHOCK EFFECTS ON LARKMAN NUNATAK 12011.** T. Niihara<sup>1,2</sup> and K. Misawa<sup>3</sup>,  
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**Introduction:** Larkman Nunatak (LAR) 12011 was found in Antarctica and was classified as an enriched olivine-phyric shergottite paired with LAR 06319. Petrological and mineralogical studies of phosphates as well as halogen and Cl isotopic systematics have been conducted for this meteorite [1,2]. On the basis of phosphate chemistry, Howarth et al. [1] suggested that the meteorite experienced post crystallization metasomatism (interaction with volatile-rich martian crust), however timing of the event is still unclear.

Petrogenesis of enriched shergottites is more complex than previously thought [3-7]. Zagami contains at least four different lithologies in a single rock and is considered to be fractional crystallization products from a single magma [3-5]. On the basis of chemical zoning in pyroxenes, we suggested that Zagami might experience crustal assimilation and/or magma mixing in late stage of crystallization [6,7]. Another enriched shergottite, Roberts Massif (RBT) 04261, also shows two distinct textures; poikilitic and non-poikilitic. Olivine grains in both lithologies have similar chemical zoning trend (homogeneous in Fe and Mg contents and decrease Ca trend from core to rim), therefore crystallization sequence of two lithologies are not so largely different [8]. Both Zagami and RBT 04261 experienced shock metamorphism that formed melt pockets, veins, however we could not observe disturbance in major element chemical zoning on olivine and pyroxene grains. Therefore, zoning patterns of constituent minerals are important to infer crystallization sequence



Fig. 1. Thin section of LAR 12011 (transmitted light). Olivine grains appear as brown color due to shock metamorphism.

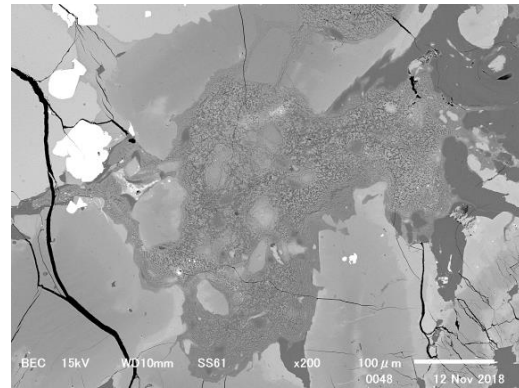


Fig. 2. LAR 12011 contains abundant melt pockets with corroded texture.

of LAR 12011.

**Sample and method:** A thin section of LAR 12011 allocated from the Meteorite Working Group was observed under an optical microscope. Scanning electron microscope observation has conducted at the Chiba Institute of Technology using a JEOL JSM-6510LA. Electron microprobe analyses were performed on a JEOL JXA-8900 at the University of Tokyo.

**Results:** LAR 12011 contains euhedral to subhedral olivine phenocrysts (~1 mm; Fig. 1) surrounding rectangular subhedral to anhedral pyroxene (~500 µm long, ~250 µm wide) and maskelynite (~250 µm long, ~100 µm wide). Melt pockets are ubiquitous in the section and are found in maskelynite and/or pyroxene (Fig. 2). Melted olivine grains are not significant. Texture of melt pockets are corroded and irregular shape with some lath of relict grains and newly formed fine-grained materials.

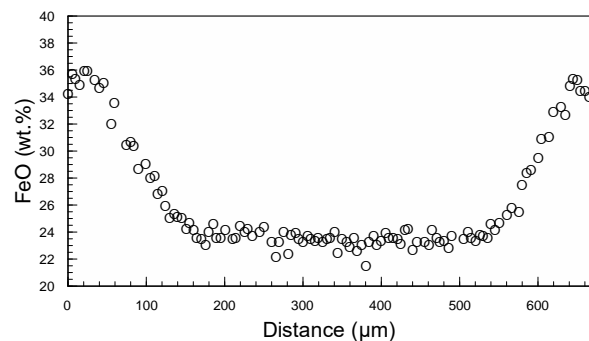


Fig. 3. Zoning profile of an olivine grain in LAR 12011. Olivine grains show an igneous Fe and Mg zoning, while CaO contents are homogeneous.

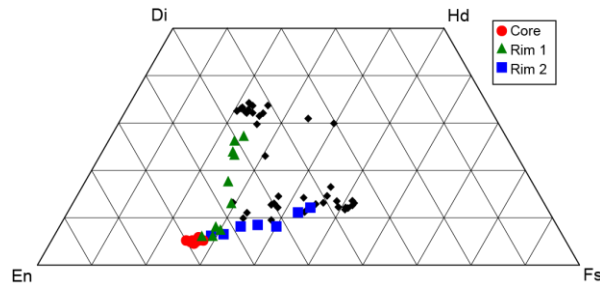


Fig. 4. Pyroxene composition of LAR 12011 showing two types of zoning trend at the rim of grain. Black diamonds: compositions of pyroxene in the fine-grained lithology of Zagami.

Olivine grains show brown color under optical microscope (Fig. 1) due to formation of micro- to nano-scale metallic iron or iron-oxides. Brown olivine grains are often observed in shocked shergottites. Composition of olivine grains shows wide range from Fo<sub>76</sub> to Fo<sub>55</sub> with zonal structure (Fig. 3). Core of grains have homogeneous composition of Fo<sub>77</sub>. FeO concentration increases from core to rim. At the most outer edge, FeO concentration slightly decrease (~2 wt.%). Calcium contents do not show zonal structure unlike RBT 04261 [8]. Pyroxene grains also have wide range compositions En<sub>70-44</sub>Fs<sub>44-23</sub>Wo<sub>27-4</sub> showing chemical zoning trend. We confirmed two types of zoning patterns. One shows Ca increase trend (CaO; 3 to 12 wt.%); the other is Fe increase trend (FeO; 18-26 wt.%) at the rim of pyroxene grains (Fig. 4). Al-Ti atomic ratios also differ between these two zoning trends. The former shows Al increase trend whereas latter show Ti increase trend from core (Fig. 5). Core of grains shows homogeneous composition. Maskelynite (primary plagioclase) has homogeneous composition (An<sub>64-55</sub>Ab<sub>41-33</sub>Or<sub>6-2</sub>).

**Discussion:** Evidence of shock metamorphism on LAR 12011 is recorded as brown olivine, cracks, and melt pockets as seen on other shergottites. However, olivine and pyroxene grains retain original chemical zoning structure, thus effect of shock is limited. The chemical zoning trend in olivine and pyroxene toward iron-rich compositions observed in LAR 12011 is consistent with those observed in the Zagami fine-grained and coarse-grained lithologies [3,6] although olivine and pyroxene cores of LAR 12011 have more magnesian compositions. This trend is not the case with RBT 04261; olivine and pyroxene in RBT 04261 [8]. Therefore, LAR 12011 might be experienced a similar crystallization sequence with the Zagami coarse grained lithology at least two-stage fractional crystallization sequence; 1) crystallized in a deep magma chamber with relatively primitive compositions and 2) rapid crystallization sequence likely shallow magma chamber [3].

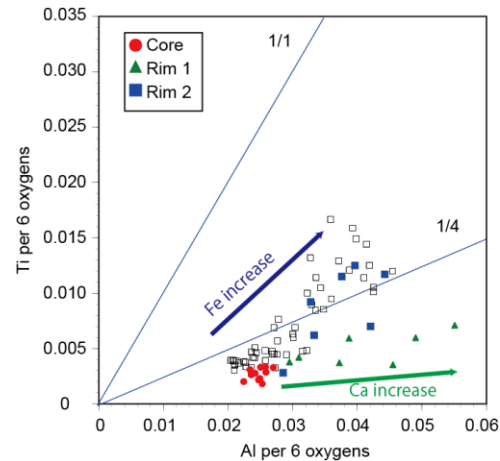


Fig. 5. Al and Ti composition of a pyroxene grain.

Rim of pyroxene grains shows zoning trend in CaO. Enrichment of Ca is also observed in evolved shergottites, Zagami dark mottled lithology and Los Angeles [6,7,9]. Occurrence of phosphate is also different among Zagami lithologies. Volatile-rich apatite grains are found in late-stage portions of Zagami [10]. In addition, different lithologies in Zagami have different initial <sup>87</sup>Sr/<sup>86</sup>Sr ratios [11], indicating magma mixing or crustal assimilation [7,10,11]. Howarth et al. [1] interpreted that LAR12011 has interacted with or assimilated with volatile-rich martian crust at a late stage of crystallization.

**Conclusion:** LAR 12011 is a product from fractional crystallization. Chemical zoning trend at edge of olivine and pyroxene grains might record timing of mixing phenomena such as volatile rich materials occurred at late stage of crystallization.

**References:** [1] Howarth G. H. et al. (2016) *Meteoritics & Planet. Sci.* 51, 2061–2072. [2] Bellucci et al. (2017) *Earth Planet. Sci. Lett.* 458, 192–202. [3] McCoy T. J. et al. (1992) *Geochim. Cosmochim. Acta* 56, 3571–3582. [4] Vistisen L. et al. (1992) *Physica Scripta* 46, 94–96. [5] McCoy T. J. et al. (1999) *Geochim. Cosmochim. Acta* 63, 1249–1262. [6] Niihara et al. (2012) *Meteorit. Planet. Sci.* 47, #5074. [7] Niihara T. et al. (2015) *LPS XXXVI*, Abstract #1721. [8] Niihara T. (2011) *Journal Geophys. Res.* 116, E12008. [9] Warren P. H. et al. (2004) *Meteorit. Planet. Sci.* 39, 137–156. [10] Niihara T. et al. (2018) *LPS XXXIX*, Abstract #2652. [11] Nyquist L. E. et al. (2010) *Meteorit. Planet. Sci.* 45, A154.

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