The hornblende and biotite in an anomalous lodranite Yamato 983119.

Masahiro Yasutake[1], Akira Yamaguchi[1, 2]
[1]*SOKENDAI (The Graduate University for advanced studies)*
[2]*National Institute of Polar Research*

Introduction: Acapulcoite-lodranite clan is the second largest clan of primitive achondrite [1]. Acapulcoites have finer-grained textures, modal abundances similar to ordinary chondrites, and roughly chondritic bulk chemical compositions [2, 3]. On the other hand, lodranites have coarser-grained textures, modal abundances poor in plagioclase, augite and/or troilite [4]. It is generally accepted that acapulcoites and lodranites are residues after partial melting less than 20 %. Similar oxygen isotopic compositions among acapulcoites and lodranites indicate that they originated from the same parent body or from similar bodies.

Yamato (Y) 983119 is an anomalous lodranite consisting of large amount of orthopyroxene (~40-70 vol%). We found inclusions containing hornblende and biotite in Y 983119 [7]. Since hornblende and biotite have pressure dependence in their compositions and stability, these minerals give us information about formation pressure of Y 983119. We tried to estimate the formation condition of Y 983119 and the size of acapulcoite-lodranite parent body.

Sample and methods: We prepared three polished thin and thick sections (PTS) of Y 983119. All PTSs were observed under photomicroscope and FE-SEM (JEOL JSM7100F). Modal abundances were obtained by using an EDS on the FE-SEM (Oxford Instruments AZtec Energy). We identified mineral phases by using of a Raman microscope (Renishaw InVia) and EBSD detector (Oxford instruments AZtec) on the FE-SEM. Chemical compositions of minerals were measured by using of EPMA (JEOL JXA 8200).

Textures and occurrences of melt inclusions: Y 983119 has a coarse-grained texture (~0.5mm) consisting of orthopyroxene (44-71 vol%, Wo_3En_{94}), plagioclase (9-14 vol%, Or_2Ab_{67}), olivine (4-30 vol%, Fo_{97}), Fe,Ni metal (4-14 vol%) and augite (2-5 vol%, $Wo_{46}En_{53}$). Olivine shows clear extinction (S1-2). Weathering products were found around Fe,Ni metal and along cracks. Minor minerals include chromite, phosphate, troilite, phosphide and carbon minerals.

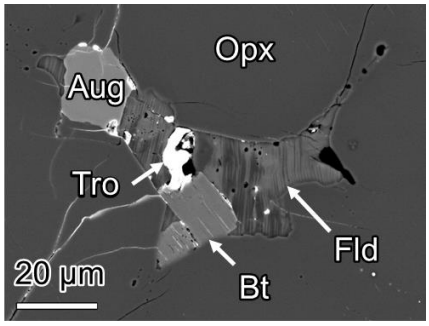

Fig. 1. Melt inclusion mainly consists of plagioclase-alkali-feldspar lamellae (Fld) with grains of augite (Aug) and troilite (Tro), and lathes of biotite (Bt). Host phase is orthopyroxene (Opx).

Melt inclusions were found in orthopyroxene (N = 24) and olivine (N = 19). Most melt inclusions are very small (few tens of μm). Melt inclusions mainly consist of augite ($Wo_{47}En_{52}$), alkali-feldspar ($Or_{85}Ab_{14}$), plagioclase (Or_5Ab_{83}), and Si,Al-rich glass (Si: 75 wt%, Al: 15 wt%). Alkali-feldspar and plagioclase often have lamellae textures. Alkali feldspars contain pores. Minor minerals include F-rich hornblende ($Na_{0.5}K_{0.2}(Ca_{1.7}Na_{0.3})_{2.0}(Fe_{0.1}Mg_{4.2}Cr_{0.2}Ti_{0.4})_{4.9}(Si_{6.6}Al_{1.4})_{8.0}F_{1.0}O_{22}$), F-rich biotite ($K_{1.7}Fe_{0.1}Mg_{4.8}Cr_{0.1}Al_{2.0}Ti_{0.4}Si_{5.7}O_{20}F_{1.9}$), chromite, Fe,Ni metal, troilite, rutile (TiO_2), baddeleyite (ZrO_2), carbon mineral and silica mineral. Hornblende and biotite were found in only orthopyroxene.

Thermobarometer: Since some hornblendes coexist with plagioclase, we can estimate equilibrium temperatures from amphibole-plagioclase thermobarometer from compositions of three hornblende and plagioclase in three inclusions [8]. The equilibrium temperature was estimated to be ~740-790°C assuming the pressure at 0-1 GPa.

We could obtain pressure from several hornblende thermobarometers. We assumed that equilibrium temperature is ~740-790°C. The pressure was estimated to be ~90-400 MPa from the thermobarometer based on the Al_2O_3 content of hornblende by [9]. We also estimated the ~0-300 MPa from another thermobarometer using Al_2O_3 and TiO_2 content by [10].

Since biotite dissolves at low pressure, presence of biotite is an indicator of lower limit of pressure. McCanta et al. (2008) calculated lower limit of pressure from mineral assemblage in amphibole- and biotite-bearing R chondrite LaPaz Icefield 04840. The constraining reaction is as follows: phlogopite + enstatite = forsterite + K-feldspar + H_2O. In Y 983119, all biotites coexist with orthopyroxene (Fig. 1). Therefore, we can apply this constraining reaction for Y 983119. If we assume that the temperature was same to hornblende-plagioclase equilibrium (~740-790 °C), the lower limit of pressure is estimated to be ~60-180 MPa. The estimated pressure might contain errors, because there are large differences in fO_2 between R chondrites (ΔQFM +0.5) and lodranites (ΔQFM -4 ~ -5).

Discussion: The parent body size was estimated from the formation pressure obtained above. We assume that parent body has no porous regolith layer, and has homogeneous density with 3.5 g/cm^{-3}. If Y 983119 located in the center of the parent body, the formation pressure of Y 983119 is corresponding to the radius of the parent body less than ~340 km. The

estimated size is partly consistent with previous studies that suggested a small parent body less than 100 km [5]. However, this result also implies that the parent body may have been larger than the size of previous estimations.

References: [1] M. Weisberg et al., Systematic and Evaluation of Meteorite Classification, Meteorites and the early solar system II, 19-52, 2006. [2] H. Palme et al., The Acapulco meteorite: Chemistry, mineralogy and irradiation effects, Geochim. Cosmochim. Acta., 45, 727-785, 1981. [3] McCoy et al., A petrologic, chemical, and isotopic study of Monument Draw and comparison with other acapulcoites: Evidence for formation by incipient partial melting, Geochim. Cosmochim. Acta, 14, 2681-2708, 1996. [4] McCoy et al., A petrologic and isotopic study of lodranites: Evidence for early formation as partial melt residues from heterogeneous precursors, Geochim. Cosmochim. Acta, 61, 623-627, 1997. [5] McCoy et al., Partial melting and melt migration in the acapulcoite-lodranite parent body, Geochim. Cosmochim. Acta, 61, 639-650, 1997. [6] M. Touboul et al., Hf – W thermochronometry : II . Accretion and thermal history of the acapulcoite – lodranite parent body, Earth. Planet. Sci., 284, 168-178, 2008. [7] M. Yasutake and A. Yamaguchi, Petrogenesis and History of Orthopyroxene-rich lodranite Y 983119, Lunar and Planetary Science Conferrence, abst., #1821. [8] T. Holland and J. Bullundy, Non-ideal interactions in calcic amphiboles and their bearing on amphibole-plagioclase thermometry, Contrib. Mineral. Petrol., 116, 433-447, 1994. [9] J. L. Anderson and D. R. Smith, The effects of temperature and fO2 on the Al-in-hornblende barmeter, Am. Mineral., 80, 549-559, 1995. [10] W. G. Ernst and J. Liu, Experimental phase-equilibrium study of Al- and Ti-contents of calcic amphibole in MORB — A semiquantitative thermobarometer, Am. Mineral., 83, 952-969, 1998. [11] M. McCanta et al., The LaPaz Icefield 04840 meteorite: Mineralogy, metamorphism, and origin of an amphibole- and biotite-bearing R chondrite, Geochim. Cosmochim. Acta, 72, 5757-5780, 2008.