PETROGENESIS OF LUNAR FERROAN GABBRO METEORITE ASUKA 881757. Y. Srivastava[1,2], A. Basu Sarbadhikari[1], A. Yamaguchi[3], A. Takenouchi[3,4], J.M.D. Day[5]. (yash@prl.res.in). [1]Physical Research Laboratory, Ahmedabad 380009, India; [2]Indian Institute of Technology Gandhinagar, Gujarat 382355, India; [3]National Institute of Polar Research (NIPR), 10-3 Midori-cho, Tachikawa, Tokyo 190-8518, Japan; [4]The Kyoto University Museum, Kyoto University, Yoshida-honnmachi, Sakyo-ku, Kyoto-shi, Kyoto, 606-8317, Japan; [5]Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA 92093-0244, USA.

Introduction: Asuka-881757 is a coarse, holocrystalline (grains more than 5 mm in length), unbrecciated mare basalt with pyroxene and plagioclase as primary constituents. This meteorite is suggested to be launch-paired with lunar meteorites Y-793169, MIL 05035 and MET 01210 based on similar textural, chemical and isotopic signatures [1], together known as the YAMM group.

Compared to the other lunar meteorites and returned VLT/Low-Ti samples, YAMM basalts are older (~ 3.8-3.9 Ga age [2-4]) and have fairly Fe-rich (Mg# 32-41) bulk compositions with low bulk concentrations of the rare earth elements (REE) and other incompatible trace elements (e.g., 0.48 ppm Th). It is generally considered that mare basalt partial melt generation was facilitated by mixing of KREEP components in their source [5]. On the contrary, YAMM meteorites contain low Rb/Sr (Sr_i=0.69908 - 0.6991), high ε_{Nd}= +7.2-7.4 and unusually low U-Pb (μ = 11-20), suggesting the absence of KREEP (high Rb/Sr and low ε_{Nd}) and implying a distinct source from other lunar basalts.

In this study, we performed a detailed petrographic analysis on a polished section of A-881757, as well as whole rock geochemical analysis on a ~0.71 g rock chip. Our data, combined with results from several previous studies permits us to better understand the petrogenesis of A-881757 and the YAMM clan meteorites. Our analysis of this meteorite demonstrates that A-881757 and other YAMM members were produced by low degree partial melting of olivine and orthopyroxene dominated cumulate mantle without the presence of a KREEP component.

Methodology: The analysis of major element composition of minerals, BSE imaging and X-ray elemental mapping were conducted at the National Institute of Polar Research (NIPR), Japan. The bulk major and trace elemental analysis were performed at the Scripps Isotope Geochemistry Laboratory (SIGL) using methods similar to those outlined in [6].

Petrography and Mineralogy: A-881757 has a gabbroic texture comprising large grains of pyroxene (2-8 mm; 53 vol. %) and plagioclase (1-3 mm; 33 vol. %) along with relatively small (< 1 mm) discrete patches occupied by late phases (symplectites and mesostasis) (Fig. 1). Fayalite, pyroxene and silica rich symplectites (8 vol. %) occur throughout the section and are usually found associated with the Fe-rich rim of the pyroxenes. The mesostasis phases (6 vol. %) include fayalite (~2 vol. %), troilite (FeS; 0.5-1 vol. %), ilmenite ($FeTiO_3$; 1 vol. %), silica (~1 vol. %), P-rich phase (<1 vol. %), K-feldspar (<<1 vol. %), and spinel (~1 vol. %). A highly vesicular fusion crust is also seen along the boundaries (Fig. 1).

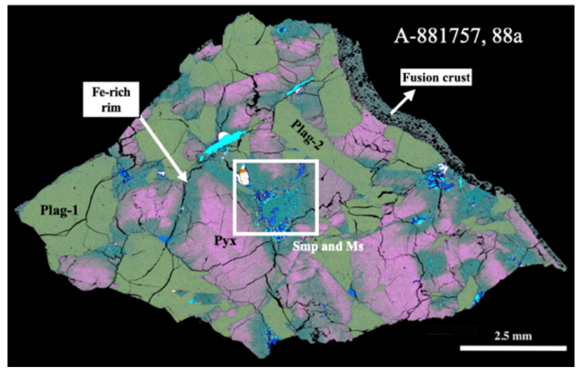

Fig. 1- X-ray composite images of studied section A-881757, 88a (Area ~0.55 cm²). Pyx: Pyroxene; Plag-1: plagioclase with fractures; Plag-2: plagioclase without fractures; Smp: Symplectites; Ms: Mesostasis. Composite image is made using Image J software. Green-Al, Blue-Fe, Magenta- Mg, Cyan-Si, Yellow-S, Red-Ca, and Gray-Ti.

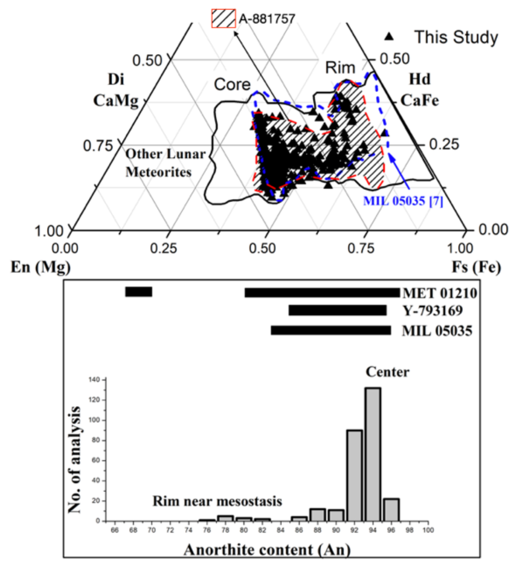

Fig. 2- Compositional range of pyroxene and plagioclase of A-881757. [7-9]

A-881757 primary pyroxenes show extensive compositional zoning, grading from relative Fe-poor cores ($Wo_{14-32}Fs_{31-43}$) to Fe-rich ($Wo_{20-35}Fs_{52-63}$) rims, while secondary pyroxenes within the symplectites have compositions similar to the rim of primary pyroxenes (Fig. 2). The zoning in maskelynitized plagioclase grains range from An_{96} cores to An_{87} rims (Fig. 2).

However, rims in close contact with late crystallizing phases are An_{75}. Olivine are Fe-rich (Fo_{8-10}) compared to the majority of the returned mare basalt samples. Spinel shows a compositional range within chromite-ulvöspinel solid solution ($2Ti_{52-85}$, Al_{6-15}, Cr_{7-32}).

Whole-Rock composition: The measured abundance of TiO_2 (1.35 wt.%), Al_2O_3 (10.3 wt.%) and K_2O (~400 ppm) in A-881757 suggests this sample is a very low-Ti, low Al and low K basaltic rock (Fig.3). The CI-normalized REE pattern of A-881757 from our study displays low Ti/Sm = 0.96, low Th/Sm = 0.16 and low Th/Hf = 0.24, a LREE-depleted profile ($[La/Sm]_{cn}$=0.68 and $[La/Lu]_{cn}$=0.67) and a relatively flat HREE value ($[La/Yb]_{cn}$=1.05 and $[Tb/Yb]_{cn}$=1.04), consistent with other YAMM basalts (Fig. 3).

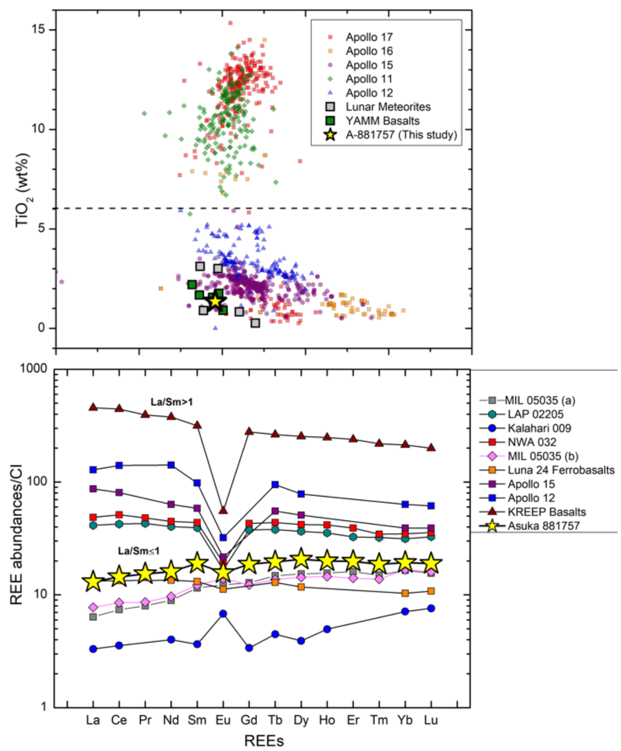

Fig.3- Major and trace element composition of A-881757 compared with other YAMM clan members and lunar samples. [7-13]

Major and trace element modeling: The MELTS model [14,15] was run at oxygen fugacity relevant to the Moon for the A-881757 bulk composition (Mg# 38.3). The first silicate appears is pyroxene of Mg# 69. This pyroxene has not been found in the sample so is likely a cumulate component prior to crystallization of the sample (~20-30%).

Based on lowest REE ($[La/Sm]_{cn}$=0.63 and $[La/Lu]_{cn}$=0.4; [7]) within the clan, MIL 05035 has been chosen as prime member to have composition in equilibrium with the parent melt. Further, our trace element modeling shows that these basalts have been sourced by low degree partial melting (3-6%) of mantle with composition of 78 Percent Solid (PCS) + ~1% Trapped Instantaneous Residual Liquid (TIRL) (Fig. 4).

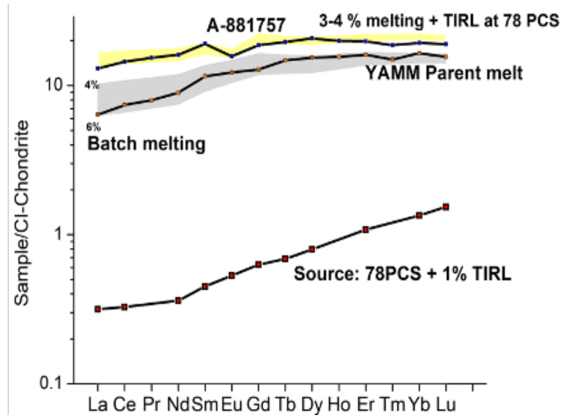

Fig.4- Source composition deduced from trace element modeling of YAMM basalts.

Discussion: The mineralogy, bulk chemistry and isotopic composition of A-881757 suggests a common source for the YAMM clan members but still there are subtle difference in the REE pattern of these basalts. The major and trace element modelling presented here highlights the likely reasoning behind the differences in the composition of these rocks. The absence of the KREEP component in the YAMM basalts suggests a non-KREEP origin for these low-Ti basalts. In turn, these findings indicate a relatively deep and pristine magma ocean cumulate source for the YAMM basalts, free from KREEP contamination. One of two possible ways to melt this source is from impact-related decompression of the lunar mantle. Given the coincidence of the ~3.9 Ga crystallization age of YAMM basalts with a putative Late Heavy Bombardment (LHB), this is a possibility. A perhaps more likely scenario is that latent heat from lunar formation and interior heat sources within the Moon at ~3.9 Ga were sufficient to engender low degree partial melting of preexisting mafic magma ocean cumulates.

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