CRYSTALLIZATION OF LUNAR BASALTIC METEORITES NORTHWEST AFRICA 032 AND 479: PRESERVATION OF THE PARENT MELT COMPOSITION AND RELATIONSHIP TO LAP 02205. E. Koizumi, T. Mikouchi, J. Chokai, M. Miyamoto, Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan, E-mail: koi@eps.s.u-tokyo.ac.jp.

Introduction: Only 5 meteorites were classified into unbrecciated lunar mare basalt so far, although there are about 40 lunar meteorites known to date. NWA 032 and its paired meteorite NWA 479 (NWA) are such crystalline mare basalts, and show a porphyritic texture composed of euhedral olivine and pyroxene grains with dendritic mesostasis of pyroxene, plagioclase and accessory minerals (ilmenite, chromite, ulvöspinel and fayalite) (Fig. 1). Olivine grain is chemically zoned from the Fo_{66} core to the Fo_{48} rim. Pyroxene is also zoned from pigeonite ($En_{59}Fs_{31}Wo_{10}$) to Fe-rich pyroxene rim via augite mantle ($En_{37}Fs_{24}Wo_{39}$). This meteorite is similar to Apollo 12 ilmenite basalt in major element chemistry although REE patterns between these samples are different [1].

In this abstract we report results of MELTS calculation and ongoing crystallization experiments to investigate the formation history of NWA. We also compare the results of this study to that of LAP 02205 [2], which is the fifth and newest crystalline lunar mare basalt having many mineralogical similarities to NWA.

MELTS calculation: We calculated the liquidus temperature and phase assemblages from the bulk composition of NWA with MELTS program [3]. According to the calculation results, the liquidus temperature is 1192 ^oC and the liquidus phase is olivine (Fo_{66}). Then, spinel immediately starts crystallization at 1190 ^oC and pyroxene ($En_{60}Fs_{30}Wo_{10}$) and plagioclase (An_{83}) begin to crystallize at 1166 ^oC and 1126 ^oC, respectively. Both olivine and pyroxene compositions from the MELTS calculation are similar to the core compositions of those in NWA.

Crystallization experiment: We performed crystallization experiments by using a wire loop technique [4]. We prepared a starting material having the bulk composition of NWA [1]. The pellets were homogenized above the liquidus temperature (1245 ^oC) for 48 hours. Homogenized glass charges were kept for another 48 hours at target temperatures (1180, 1150 and 1100 ^oC) or cooled to 1000 ^oC at 5 ^oC/hr. Oxygen fugacity was controlled at IW–1.0 during all experiments using the gas mixture of CO_2-H_2. Experimental temperatures were measured with thermocouples calibrated by using a melting point of gold (1064.4 °C)

The observed mineral phases from isothermal experiments at 1180, 1150 and 1100 ^oC were shown in Table 1. Only olivine grains crystallized at 1180 ^oC (Fo_{65}) and 1150 ^oC (Fo_{62}). A run product from the 1100 ^oC isothermal experiment includes a few plagioclase grains in addition to large olivine grains (Fo_{53}: hundreds of μm) and many small pyroxene (a few μm). This pyroxene has a similar composition to that of augite mantle of NWA pyroxene phenocryst ($En_{43}Fs_{26}Wo_{31}$). The olivine composition from the 1180 ^oC run is identical to the core composition of olivine in NWA, suggesting the phenocryst origin. This result and MELTS calculation result indicate that the bulk composition of NWA represents its parent melt composition.

We also performed a cooling experiment with the bulk composition of NWA at 5 ^oC/hr. A run product from this experiment consists of the pyroxene phenocryst with the dendritic mesostasis that was composed of pyroxene and plagioclase (Fig. 2). No olivine crystallized in this experiment. The obtained pyroxene composition is more Mg-rich than that in NWA (Fig. 3). This is probably because of the absence of olivine grains. There are three possible reasons that there is no olivine in this cooling experiment. (1) Olivine failed to crystallize due to fast cooling. If this is the case, slower cooling is needed to produce olivine phenocrysts. (2) Olivine melted during cooling. We think that this is unlikely because 5 ^oC/hr cooling experiment of LAP02205 [2] retained abundant olivine without melting. The third idea is that NWA might experience two-stage cooling history: slow cooling at first to grow large olivine phenocrysts followed by fast cooling to form mesostasis as suggested by [1]. Because pyroxene and plagioclase grains in the NWA mesostasis is smaller than those from our 5 ^oC/hr cooling run, NWA may have experienced faster cooling rate than 5 ^oC/hr when mesostasis formed.

Comparison with the LAP 02205: LAP 02205 (LAP) mainly consists of coarse-grained pyroxene, plagioclase and rare olivine, and does not show a cumulate texture. Pyroxenes are extensively zoned from Mg-rich pigeonite cores ($En_{55}Fs_{30}Wo_{15}$) to nearly Mg-free rims via augite mantles ($En_{40}Fs_{25}Wo_{35}$). Olivine grains are zoned from Fo_{67} cores to Fo_{48} rims. Both olivine and pyroxene compositions are very similar to those of NWA (Fig 4). Furthermore, crystallization ages and trace element concentrations are similar between these meteorites [1,5,6]. Therefore, NWA and

LAP are considered to have derived from the same magma source [7-8].

Our previous crystallization experiments with the bulk composition of LAP showed that Mg-rich olivine as observed in LAP did not crystallize from the LAP bulk composition, although pyroxene seems to be a phenocryst [2]. Because olivine abundance is small in LAP (a few vol. %), the LAP bulk composition seems to be similar to its parent melt composition. One of the largest differences among the different cooling rates experiments was seen in olivine petrology, and this difference suggested 1-5 ^{o}C/hr cooling rate during the crystallization of the LAP magma [2].

Although NWA and LAP have slightly different bulk compositions, the mineral compositions are similar and the pyroxenes in both meteorites are phenocrysts according to the experimental results. This can be explained by the hypothesis that olivine grains were removed when pyroxene started crystallizing in LAP. Another difference is cooling rate during the crystallization history of both meteorites. NWA seems to have cooled at 5 ^{o}C/hr or faster when the pyroxene crystallized, that should be faster than the 1 – 5 ^{o}C/hr cooling rate of LAP. We are working on more cooling experiments and results will be presented at the time of the conference.

Conclusion: According to the experimental and calculation results on NWA and LAP, the formation history of these meteorites could be inferred as following. Both NWA and LAP crystallized from the parent melt whose compositions are very close to the NWA bulk composition. NWA crystallized in rapid or two stages cooling producing a porphyritic texture with dendritic mesostasis, and preserved the parent melt composition. In contrast, most olivine grains were removed from the LAP melt during the early stage of its crystallization. This difference is due to the difference of the cooling rate during their crystallization histories.

References: [1] Fagan T. et al. (2002) *Meteoritics & Planet. Sci., 37,* 371–394. (2005) [2] Koizumi E. et al. (2005) *Meteoritics & Planet. Sci, 40,* A85 (Supple). [3] Ghiorso M. and Sack R. (1995) *Contrib. Mineral Petrol., 119,* 197-212. [4] McKay G. et al. (1994) *GCA, 58*, 2911-2919. [5] Nyquist L. E. et al. (2005) *LPS XXXVI,* Abstract #1374. [6] Day J. M. et al. (2005). *LPS XXXVI,* Abstract #1419. [7] Jolliff B. L. et al. (2004) *LPS XXXV,* Abstract #1438. [8] Zeigler R. A. et al. (2005) *Meteoritics & Planet. Sci., 40,* 1037-1101.

Table 1. Phase assemblages from isothermal experiments

temperature (^{o}C)	*mineral phase*
1180	*olivine (Fo_{65})*
1150	*olivine (Fo_{62})*
1110	*olivine (Fo_{53}), pyroxene ($En_{43}Fs_{26}Wo_{31}$), plagioclase*

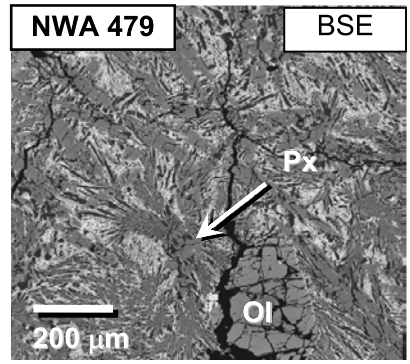

Fig. 1. BSE image of NWA 479 having the porphyritic texture Ol: olivine, Px: pyroxene

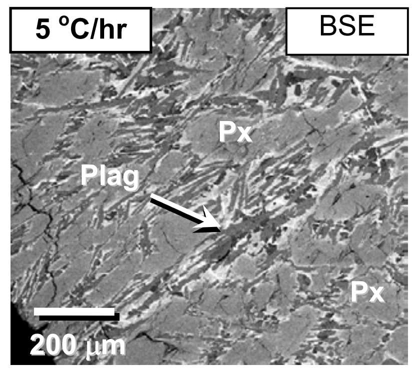

Fig. 2. BSE image of the run product from 5 ^{o}C/hr cooling experiment. Px: pyroxene, Plag: plagioclase

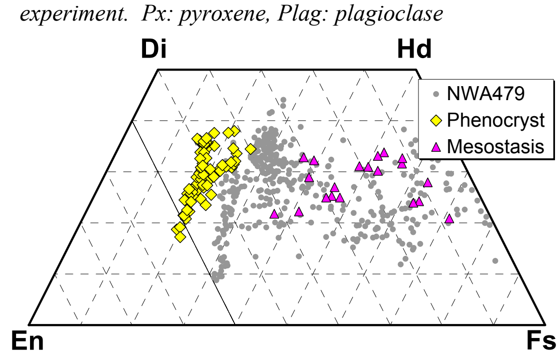

Fig. 3. Pyroxene quadrilateral from 5 ^{o}C/hr cooling experiment with the bulk composition of NWA 032.

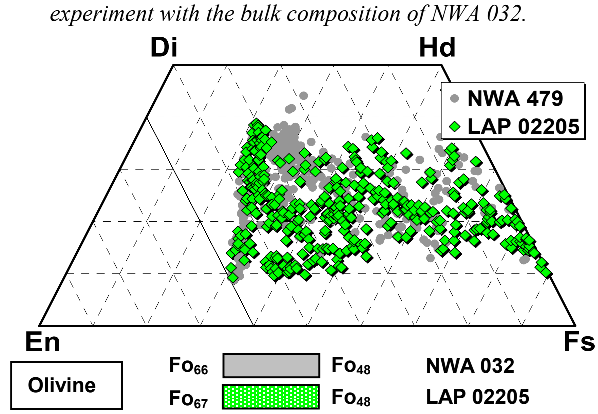

Fig. 4. Comparison of pyroxene and olivine composition between NWA 479 and LAP 02205.