OLIVINE XENOCRYSTS IN ASUKA-881371 ANGRITE REVISITED. T. Mikouchi[1], H. Hasegawa[1], A. Takenouchi[1], H. Kagi[2], [1]Department of Earth and Planetary Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan, [2]Geochemical Research Center, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan, E-mail: mikouchi@eps.s.u-tokyo.ac.jp.

Introduction: Angrite is among the oldest known achondrites and its petrogenesis is still controversial [e.g., 1]. Especially, the presence of olivine megacrysts in quenched angrites is enigmatic because of their large sizes (~5 mm) and extremely magnesian compositions (~Fo_{96}) [e.g., 2]. Since these megacrysts are out of equilibrium with the groundmass, they are xenocrysts and apparently predate the groundmass formation as their textures suggest trapping in the groundmass melt followed by quenching. The O isotope analysis shows that all xenocryst-bearing angrites fall on the same mass fractionation line [3], suggesting that xenocrysts are "angritic" materials. In fact, large olivine grains with matching chemical compositions are not found in other meteorite groups. Thus, the origin of these olivine xenocrysts in the context of the inner structure of the angrite parent body (APB) is important to understand the early differentiation of APB and its subsequent evolution. We have recently undertaken a mineralogical study of olivine xenocrysts in Asuka-881371 because the presence of xenocrysts in this sample is most remarkable among quenched angrites [2,4].

Methods: We observed a polished thin section of Asuka-881371 using petrographic microscope and FE-SEM (Hitachi S-4500). Mineral compositions were determined with FE-EPMA (JEOL-8530F). We performed micro-Raman spectroscopy of olivine at Geochem. Res. Center at Univ. of Tokyo to determine inclusion phases and to estimate residual pressure by following the method in [5]. Plagioclase was analyzed by Fe-XANES using synchrotron radiation at PF, KEK (BL-4A) to estimate redox state of the groundmass [6].

Results: Asuka-881371 does not show evidence for shock metamorphism. However, as is already reported in [4], olivine xenocrysts in Asuka-881371 show variable deformation features although the groundmass minerals are essentially undeformed. Some xenocryst grains show extensive deformation (e.g., undulatory extinction under cross polarizers of petrographic microscope and kink bands), whereas some others are completely undeformed (e.g., sharp extinction) similar to the groundmass minerals. Another deformation feature is partial recrystallization into fine-grained polycrystalline olivine (up to 0.1 mm in size) within xenocrysts, probably along planar deformation. A similar polycrystalline xenocryst is found in D'Orbigny, showing a fine-grained granoblastic texture [7], which would be more extensively deformed. Simi-

larly, olivine xenocrysts in the NWA 1670 quenched angrite show deformation textures [4,8].

Several types of inclusions are found within olivine xenocrysts in Asuka-881371 and some form along healed cracks (Fig. 1). FE-SEM observation revealed that most common inclusions are Si-Al-rich glass and chromite. Because fluid inclusions may be present in healed cracks, we analyzed these inclusions by micro-Raman spectroscopy. However, we did not find any signals relating to either CO_2 or H_2O, and they appear to be solid glass. Tiny inclusions of Fe-Ni metal and troilite are also contained, suggesting the formation under a reducing condition [4]. [8] also argued the formation of magnesian olivine in NWA 1670 under reducing condition. In contrast, Fe-XANES of the groundmass plagioclase shows nearly equal amounts of Fe^{2+} and Fe^{3+}, suggesting an oxidizing condition probably above the IW buffer [6]. This is consistent with other studies estimating redox states of angrites [e.g., 9]. Thus, the xenocryst formation occurred under relatively reducing condition, and later melt generation to form the groundmass was under oxidizing condition.
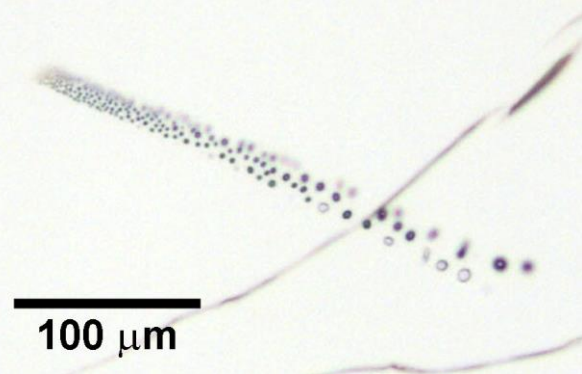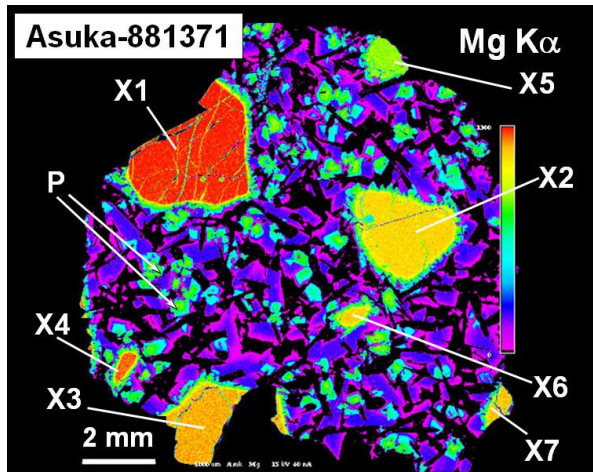

Fig. 1. Optical photomicrograph showing a healed crack in one of the olivine xenocrysts in Asuka-881371.

Although the xenocryst compositions are homogeneous in each grain except the overgrowth rims, they show distinct chemical compositions from one grain to another (Fig. 2). The chemical composition of olivine xenocrysts is characterized by their magnesian (Fo_{89-70}), Ca-poor (0-0.7 wt% CaO) and Cr-rich (0.1-0.7 wt% Cr_2O_3) compositions compared to the groundmass olivine ($Fo_{\leq70}$, ≥0.7 wt% CaO, ≤0.1 wt% Cr_2O_3) (Fig. 2). There is no correlation between Fo and Ca-Cr contents [4] as well as size and deformation degrees.

Fig. 2. Above: Mg X-ray map of Asuka-881371. The below table summarizes deformation degrees (L: low, I: intermediate, H: high) and core compositions (both CaO and Cr_2O_3 in wt%) of xenocrysts ("X1-7": shown in Mg map) and phenocrysts ("P" in Mg map).

	X1	X2	X3	X4	X5	X6	X7	P
Defor-mation	L	H	I	H	L	H	H	L
Fo	89	83	85	87	70	83	83	70
CaO	0.4	0	0.3	0.7	0.3	0	0.4	0.7
Cr_2O_3	0.3	0.7	0.3	0.2	0.1	0.7	0.3	0.1

Discussion and Conclusion: The large size and magnesian compositions of olivine xenocrysts may suggest that they are fragments of the APB mantle. Because APB was large enough (>100 km in radius) to have core-dynamo magnetism [10], it could form dunitic mantle as residue of the partial melting of chondrite and have zoned olivine compositions by different depth, as is similar to the ureilite parent body (UPB) [11]. In the UPB case, pressure control in the presence of C is important. Interestingly, carbonate is found in quenched angrites and the role of carbonate is discussed in the formation of angrite magma [8]. Another interesting observation is found by comparison with partial melting experiments of Allende and Murchison [12]. The forsterite content of olivine residue (~Fo_{76}) in their experiments does not reach those of olivine xenocrysts in Asuka-881371, but reducing condition (log-fO_2=IW-1) produced Cr-rich olivine with similar Fe/Mn ratios to angrites (Fig. 3), which may be a key process for the xenocryst formation. Similar experiment of H chondrite produced Cr-rich magnesian olivine (~Fo_{98}), but Mn content is different from angrites [13]. Therefore, partial melting of C chondrite at variable reducing condition could produce olivine with xenocryst compositions, which is consistent with the mineralogical observation of xenocrysts, and formed APB

mantle. Later partial melting event at high fO_2 may be related to the formation of the groundmass melt.
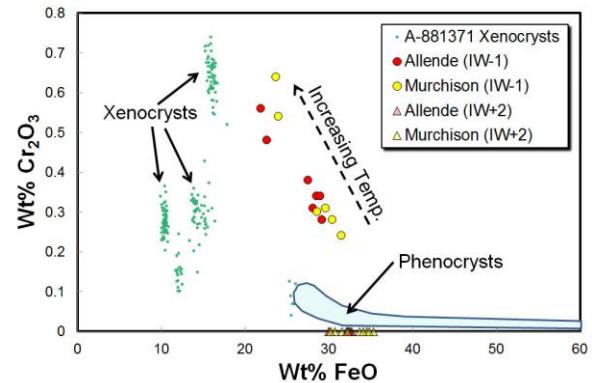

Fig. 3. Fe and Cr of olivine in Asuka-881371 and olivine residue of the partial melting experiment of [12].

The origin of the xenocryst deformation is unclear. One possibility is shock metamorphism. In this case, the groundmass melt could be shock melt and olivine xenocrysts are relict grains. However, as discussed in [1,4], this is not a likely scenario. The other possibility, we favor, is xenocryst deformation by internal stress while they were resided in the APB mantle. If this is the case, xenocryst deformation suggests rheology of the APB mantle as found in the terrestrial mantle xenoliths [e.g., 14]. In order to estimate residual pressure of xenocrysts, we performed Raman spectroscopy and found that the most extensively deformed olivine (X2 in Fig. 2) has strong peaks at 821.6 cm^{-1} and 853.9 cm^{-1}, which correspond to 0.3 kbar and 3.2 kbar of residual pressure, respectively. Although the discrepancy of the two results is large and we could not obtain a meaningful pressure, it is suggested from the Raman results that the residual pressure seems related to the deformation degree as suggested by optical microscopy.

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