PETROGRAPHY AND MINERALOGY OF CALAMA 001, CATALINA 037 AND NORTHWEST AFRICA 2895: NEW AUGITE-BEARING UREILITES. M. Inoue[1], T. Mikouchi[1] and C.A. Goodrich[2], [1]Department of Earth and Planetary Science, The University of Tokyo (m.inoue@eps.s.u-tokyo.ac.jp), [2]Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058, USA.

Introduction: Ureilites are ultramafic meteorites that mainly consist of olivine, pigeonite, and carbon [1,2]. Ureilites are subdivided into three subgroups based on the dominant pyroxenes; olivine-pigeonite, olivine-orthopyroxene and augite-bearing ureilites. Augite-bearing ureilites are distinguished from olivine-low Ca pyroxene (lpx) ureilites by chemical and textual properties. Silicates in ureilites are Mg-rich and show a wide compositional range reflecting redox variation (olivine: Fo_{74-97}). Fe/Mn-Fe/Mg data for olivine of augite-bearing ureilites show divergence from an olivine-lpx trend that is thought to be a partial melt residue trend. The offset in Fe/Mn-Fe/Mg of augite-bearing ureilites is thought to reflect igneous fractionation, in contrast to the olivine-lpx ureilite trend [3]. Augite-bearing ureilites often have poikilitic textures consisting of oikocryst of orthopyroxene or pigeonite enclosing olivine and augite [e.g., 4,5]. Some of them show a reaction texture with melts similar to a heteradcumulate seen in terrestrial layered igneous complex [5-7]. Furthermore, many of them contain melt inclusions in mostly olivine, suggesting crystallization from melts [8,9]. From these characteristics, augite-bearing ureilites are not interpreted to be a residue but cumulates or paracumulates [e.g., 10]. Therefore, these ureilites are indicative of crystallization from Ca-rich melts that are different from olivine-lpx ureilites. However, some samples do not indicate all of these features and thus it is important to characterize petrographic and mineralogical properties of more augite-bearing ureilites for understanding igneous processes of the ureilite parent body (UPB). In this abstract, we report mineralogy of three new augite-bearing samples.

Samples and Methods: We observed polished thin sections (PTS) of three new augite-bearing ureilites, Catalina 037, Calama 001, and Northwest Africa (NWA) 2895. BSE and SEI observation and quantitative mineral analysis are performed on electron microprobe, JEOL JXA-8530F at University of Tokyo.

Results: *Catalina 037* shows clear appearance and weak undulatory extinction of silicates through optical microscopy. It mostly consists of olivine (1-1.5 mm), rare pigeonite ($En_{73}Wo_{11}$, 0.5-2 mm), and graphite with minor metal and sulfide. Only one augite grain (~50 μm) enclosed in olivine is observed in our PTS. A few large pigeonites (~2 mm) poikilitically enclose olivines. A grain boundary between silicates is blackened being filled with silicates and glasses similar to A-881931 [11]. These interstitial materials are composed of quench crystals of augite, orthopyroxene, and submicron Fe-metal, suggesting rapid cooling. Augite is the dominant phase of interstitial materials. Interstitial pyroxenes are generally reduced by C, showing a Mg-rich composition. Fe-oxides, products of terrestrial weathering, are often deposited at grain boundary and preferentially overprint glasses. The origin of these interstitial materials would be interpreted to be formed by shock-induced partial melting during breakup of UPB [11-13], though shock degree of Catalina 037 is very low. Pyroxenes are partly melted and formed cracks. Interstitial materials are also present along these cracks. Glass composition is heterogeneous but albitic. Olivine in Catalina 037 is $Fo_{80.5}$ and its Fe/Mn-Fe/Mg composition falls on the olivine-lpx trend (Fig. 1).

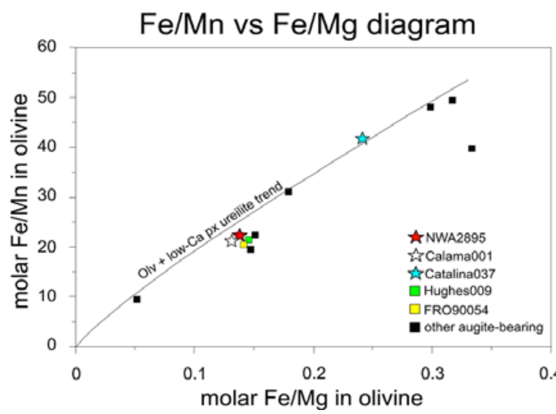

Fig. 1. Fe-Mn-Mg compositions for olivine cores of NWA 2895 and Calama 001 show divergence from the olivine-lpx trend (shown as a line).

Calama 001 consists of olivine (1-1.5 mm), orthopyroxene ($En_{87}Wo_{4.8}$, 0.5-1.0 mm), augite (~0.5 mm), and graphite. It shows high pyroxene abundance (50%), but the augite/orthopyroxene ratio is low. Many of pyroxene grains show triple junctions and a partially melting texture as veins (Fig. 2). However, unlike Catalina 037, glasses at grain boundary are almost absent. Trains of tiny metal grains are present with Mg-rich pyroxenes and silica in pyroxene along crack. Some orthopyroxene grains show fine exsolution lamellae (<1 μm) with blebs. These suggest that pigeonite were present at high temperature and so, three pyroxenes may coexist. Olivine grains are extensively reduced being affected by secondary smelting. Calama 001 is moderately shocked since silicates show undulatory extinction and its appearance is blackened because of brecciation by abundant Fe-metal (now oxide) veins as found in Hughes 009 [9], rendering grain boundaries unclear. Silicates are also extensively brecciated (Fig. 3). A few silicate grains contain melt inclusions of augite, Fe-metal, and glass. It is notable that some augite grains display diffusive outline (Fig. 2). Diffusive augites show interference color by polarized light, and so it is not glass. Moreover, they indicate no zonation. Olivine is $Fo_{88.2}$ and the Fe/Mn-Fe/Mg plot of olivine is deviated from the olivine-lpx trend (Fig. 1).

NWA 2895 is predominantly composed of large pigeonite ($En_{80}Wo_{9.1}$, 3-4 mm), olivine (1-1.5 mm), orthopyroxene ($Enxx_{85}Wo_{4.8}$, ~0.5mm), graphite showing dusty appearance, and minor metal and sulfide. Modal abundance of pyroxene is roughly 60%. Pigeonite poikilitically encloses ellipsoidal olivine, orthopyroxene, and augite. Only one augite grain (0.3mm), which is enclosed in pigeonite, exists in our PTS. Grain boundaries are partitioned by metal (now oxide) or terrestrial weathering products. Shock degree is higher than Catalina 037 since silicates show clear wavy extinction. Pyroxenes indicate a partially melted texture similar to Calama 001. NWA 2895 also contains brecciated areas, but they are very small. Mineral composition of NWA2895 is more magnesian than Catalina 037 (olivine: $Fo_{87.7}$). The Fe/Mn-Fe/Mg composition of olivine is offset from the olivine-lpx trend (Fig. 1) Olivine core composition is affected by secondary smelting, and Fe/Mn-Fe/Mg data suggest pure Fe-loss.

Discussion and Conclusion: Both NWA 2895 and Calama 001 display an "igneous" trend while Catalina 037 is close to a "residue" trend [3]. They can be distinguished in terms of some textual features as previous study reported. Namely, NWA 2895 has large poikilitic texture and Calama 001 shows extensive brecciation of silicates [8]. In addition to these features, in comparison to Catalina 037, their modal abundances of pyroxene are higher. They are similar characteristics found in Hughes 009 and FRO 90054 [9], but augite/low-Ca pyroxene ratios of Calama 001 and NWA 2895 are lower. Their mineral compositions are quite similar although Fe-Mn-Mg compositions are slightly different. NWA 2895 is thus different from Calama 001 (+Hughes and FRO) in terms of the absence of melt inclusions and dominant pyroxenes. Moreover, note that Calama 001 has a typical ureilite texture while NWA 2895 shows large poikilitic texture. This difference would be important for understanding petrogenesis of augite-bearing ureilites.

From textual and chemical similarities, Calama001, Hughes 009, and FRO 90054 are similar in many characteristics. In particular, the brecciated area of silicates and high modal abundance of pyroxene (not augite) characterize them. These textural features may mean that these ureilites were formed at a similar area of UPB. However, the great difference between them is abundance of carbon. Hughes 009 and FRO 90054 contain no or little carbonaceous material. Therefore, the abundant presence of carbon in Calama 001 is expected to bridge the gap between Hughes 009/FRO 95004 and other main group ureilites.

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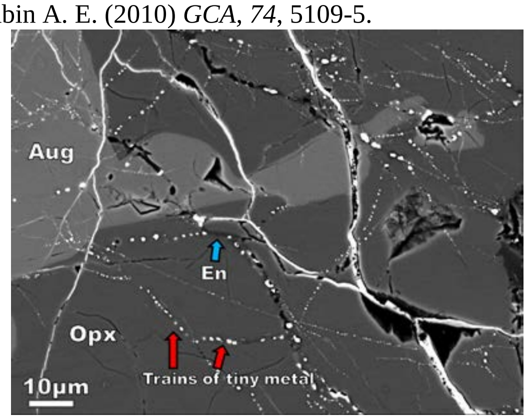

Fig. 2. Augite in Calama 001 shows "diffusive" morphology. Trains of tiny metals and enstatite are deposited along cracks (red and blue arrows). Aug: augite. Opx: orthopyroxene. En: enstatite.

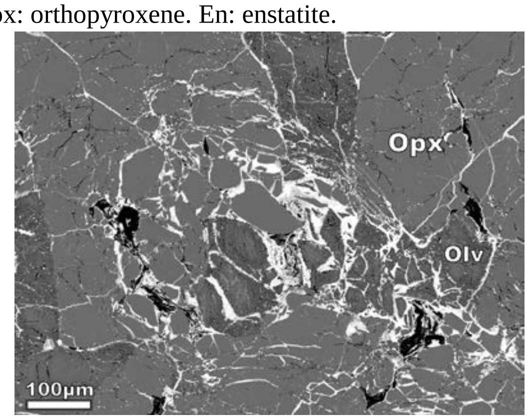

Fig. 3. A brecciated zone in Calama 001. Pigeonite and olivine are highly brecciated similar to Hughes 009 and FRO 90054. Olivine is reduced by secondary smelting that probably predates brecciation. Olv: olivine.