PETROGRAPHY AND MINERALOGY OF NORTHWEST AFRICA 3222: MAGMATICALLY ZONED AUGITE-BEARING UREILITE WITH ONLY LITTLE CARBON.

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Introduction: Ureilites are mostly composed of olivine and pyroxene, with carbon plus Fe metal and sulfide at their grain boundaries [1]. They are divided into three subgroups based on constituent pyroxene species. Augite-bearing ureilites are especially distinguished from the other two olivine + low-Ca pyroxenes (lCp) subgroups in terms of distinct chemical and textural properties. Fe/Mn-Fe/Mg data for olivine of some augite-bearing ureilites show divergence from an olivine-lCp trend that is thought to be a partial melt residue trend. The offset in Fe/Mn-Fe/Mg of augite-bearing ureilites is considered to reflect igneous fractionation, in contrast to the olivine-lCp ureilite trend [2]. Augite-bearing ureilites show two different textural types: 1) poikilitic type (e.g., LEW 88774 [3,4] and MET 78008 [7]); and 2) typical textural type (e.g., Hughes 009 and FRO 90054 [5,6]). Several of them have distinguishing features that suggest crystallization from melts, such as a reaction texture with melts and melt inclusions. These characteristics support the idea that augite-bearing ureilites are not residues but cumulates or paracumulates [e.g., 8]. Therefore, these ureilites are indicative of crystallization from Ca-rich melts that are different from olivine-lCp ureilites and it is important to characterize petrographic properties of more samples for better understanding igneous processes of the ureilite parent body (UPB). In this abstract, we report petrography and mineralogy of a new olivine-opx-augite sample (NWA 3222) and compare with other olivine-opx-augite ureilites.

Sample : NWA 3222 is a 79 g recovered mass and classified as a monomict (unbrecciated) ureilite [9]. We studied two thin sections of NWA 3222 (NWA3222-1 and -2). They are from the same chip and have matching surfaces. Therefore, they basically share the same textual features.

Petrography and mineralogy: NWA 3222 contains 37-41% augite, 36-37% opx, 22-27% olivine, interstitial Fe metal and sulfide. There are melt inclusions in some silicates. We do not find carbonaceous material in our thin sections, although they are reported in an intergranular vein with iron oxide [9]. It shows a coarse-grained texture with abundant triple junctions and slightly curved boundaries of silicates. The grain sizes of silicates (augite, opx and olivine) in NWA3222-1 range from 0.2 to 5.9 mm, 0.3 to 2.0 mm and 0.2 to 3.3 mm, respectively. There are larger olivine (6.2 mm) and opx (4.1 mm) crystals in NWA 3222-2. The composition of olivine core is $Fo_{86.4-88.8}$. The largest augite grain (5.9 mm) in our thin sections shows chemical zoning (from core to rim: 19-17.5 wt% CaO, 1.2-2.0 wt% Al_2O_3, 0.4-0.2 TiO_2 wt% and 1.0-1.2 wt% Cr_2O_3) although Fe-Mg is homogeneous. In contrast, the 2.4 mm augite grain displays no clear zonation. One of the other outstanding features of NWA 3222 is the presence of a fine-grained area. It consists of olivine (~1.5 mm) and opx (~0.4 mm) with intergranular metal-sulfide, and they are surrounded by coarser orthopyroxene (1.3 mm) mantle. This obviously indicates a magmatic reaction texture. This area is found in both thin sections and the modal proportions of olivine and opx are roughly 7:3 and 8:2, respectively. NWA 3222 is moderately shocked as indicated by undulatory extinction and polysynthetic twinning of pyroxene. Abundant metal-sulfide veins intrude silicates. Silicates along these metal veins are often reduced to variable extent and glasses are accompanied by them.

Comparison with Hughes 009, FRO 90054 and Calama 001: The remarkable petrography and mineralogy of NWA 3222 include metal-rich brecciated zone, presence of melt inclusions and high modal abundance of pyroxene and these are all similar to Hughes 009, FRO 90054 and Calama 001 [10]. All of these meteorites are olivine-opx-augite ureilites whose Fo content of olivine is Fo_{87}, which is identical to that of NWA 3222. Therefore, they are probably derived from a similar region on UPB. In addition, NWA 3222 shows clear minor-element zonation in augite and subtle zonation is also found in augite grain in FRO 90054 following the same trend with NWA 3222. Although augites in Hughes 009 and Calama 001 are homogeneous, their minor-element contents are identical to that of the rim of augite in NWA 3222 and FRO 90054. Therefore, these compositional changes of augite clearly show that they were derived from the same lithologic unit on the UPB and the chemical zoning of augite perhaps reflects the changing melt composition in a crystallizing melt body. These changes of melt composition recorded in augite may indicate magma mixing/assimilation. The formation of the fine-grained area surrounded by opx mantle may also be related to this event. Then, they were homogenized in terms of Mg-Fe during either the late magmatic stage or after solidification.

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