

NEW ACHONDRITES WITH HIGH-CALCIUM PYROXENE AND ITS IMPLICATION FOR IGNEOUS DIFFERENTIATION OF ASTEROIDS.

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Introduction: High-Ca pyroxenes have been a minor component in chondrites, primitive chondrites, and the HED achondrites. We report two new achondrites from hot deserts, which contain more high-Ca pyroxenes than previously described. With additional data of silicate inclusions in the IAB and IIE irons, we propose that the high-Ca pyroxenes are important component in partial melts of chondritic source materials.

Sunshine et al. [1] performed analyses of reflectance spectra of several S-type asteroids (Thetis and the Merxia and Agnia family members) and found that ratios of high-Ca pyroxene to total pyroxene are clearly inconsistent with any known chondritic material. We reported that a coarse-grained material rich in plagioclase and diopside (Di) occurs in the Caddo County IAB iron meteorite [2,3]. This material represents a new type of chemically differentiated extraterrestrial andesitic silicate material. We report two new meteorites from hot deserts, which contain significant amount of augite (Aug) and discusses igneous processes in the asteroidal objects in the earliest solar system.

Samples and Experimental Techniques: PTSSs of NWA2235 [4], NWA2236 [4] and Caddo County, were studied by an optical microscope and an electron probe micro-analyzer (EPMA) at Ocean Res. Inst. (ORI) of Univ. of Tokyo and NIPR. The Area Analysis technique of the JEOL 8900 and 8200 EPMA was applied to obtain elemental distribution maps of Na, Si, Ca, Fe, K, Mg, Al, Cr, Ti, S and Ni. Mineral distribution maps of PTSSs were constructed by combining the elemental maps of Ca, Na, Mg, Si. Modal abundance (vol. %) of minerals was derived from these maps.

Results: NWA2235 lodranite and NWA2236 ureilite found in hot deserts provide us with examples of uncommon members of these groups.

NWA2236 ureilite. It is composed of medium to coarse (1-2 mm), olivine (Fo of cores, 97), orthopyroxene (Opx) ($\text{Ca}_{4.8}\text{Mg}_{92.3}\text{Fe}_{3.0}$) and Di ($\text{Ca}_{38}\text{Mg}_{60}\text{Fe}_2$) are present. Carbonaceous matter occurs as narrower, intergranular veins than common ureilites. A few olivine crystals grow larger (up to ca. 3 mm) than average grains along one direction. This meteorite is weakly shocked, with rare mosaicism in olivine, but the orthopyroxene grains show fine linear features along

(100) under cross polarized light. This texture is similar to those observed for Y791538 [5], with presence of minor unit-cell scale twinned clinoenstatite sequence with common (100). Modal abundance of minerals: Olivine 46 vol.%, Opx 41, Di 6, Others 7.

NWA2235 lodranite. The PTS shows a coarse-grained aggregate (ca. 0.5 to 2 mm in the longest dimension) with triple point juncture (Fig. 1), consisting mainly of olivine (Fo88), Opx ($\text{Ca}_2\text{Mg}_{85}\text{Fe}_{13}$), Aug ($\text{Ca}_{40}\text{Mg}_{54}\text{Fe}_6$), Fe-Ni-metal, troilite and minor chromite [$\text{Cr}/(\text{Cr}+\text{Al})=0.85$ atomic ratio, $\text{Fe}/(\text{Fe}+\text{Mg})=0.63$]. The mineral compositions are within the range reported for lodranites [6]. It is weakly shocked, with rare mosaicism in olivine. The textures and mineral distribution are similar to those of Yamato 791491 [6], but amounts of opaque minerals are less than Lodran. Modal abundance of minerals are: Olivine 55 vol.%, Opx 17, Aug. 7, metal 8.5, troilite 1, chromite 2.5, Others 9.

Caddo County IAB iron. Two new PTSSs (EH 0.8×0.7 cm and 027, 9.5×7.4 mm) were examined. The modal abundance of minerals in the EH clast is: Albite (Ab) 45.6 vol.% (40.5 wt%), Di 53.2 (58.1wt%), Opx 1.2 (1.3), Olivine 0.02 (0.00). Because of the high abundance of Na-rich plagioclase (Ab), the bulk composition (SiO_2 59 wt%) is within the field of andesites. Andesitic materials previously studied are surrounded by orthopyroxene and olivine, and it has been difficult to estimate their bulk compositions. A new Caddo sample contains a large inclusion of mainly Di and Ab surrounded by metal.

Discussions: Some members of the primitive achondrites are believed to be residues of partial melting [1], but in spite of extensive petrologic studies of these achondrites, basalts representing their partial melts are almost unknown [7]. The augite-albite-rich material found in the Caddo County is the first andesitic materials found in the asteroidal belt. Based on the quartz-olivine-plagioclase diagram, we proposed that this andesitic materials were formed by inhomogeneous segregation of partial melts from chondritic source materials [2]. Accepting a similar idea that the eutectic melt of the above system is highly enriched in both plagioclase and high-Ca pyroxene, Sunshine et al. [1] used high-Ca pyroxene (HCP) as an indicator of igneous differentiation in asteroids. Hiroi et al. (Personal Comm., 2004) measured reflectance spectra of

the Caddo County diopside, which should be used in searching for such andesitic materials.

Similar andesitic materials were found in silicate inclusions in many IIE irons [8]. The scale of partial melt segregation is much larger than that of the IAB irons, and a crystal mush was formed. Thus, the andesitic materials can be a partial melt product of the chondritic source materials in general. The Caddo County materials will provide us with further information on formation mechanisms by inhomogeneous segregation of partial melts from chondritic sources. However, it is to be noted that albite is the important component, which cannot be detected by their reflectance spectra [1].

In contrast to chondrites, olivine and low-Ca pyroxene (LCP) are major mafic phases in lodranites, which exhibit generally low HCP/(HCP+LCP) ratios [1]. Although Sunshine et al. [1] used the Y791491 lodranite as a representative residue of partial melting, some lodranites, such as MAC8177 [6] includes a significant augite content. The amounts of augite in the NWA2235 lodranite are more than those described previously.

Most ureilites consist principally of olivine, pigeonites, but NWA2236 contains orthopyroxene and diopside. This ureilite is similar to LEW85440 [9,10]. However, the amount of diopside in NWA2236 is larger, and the olivine and pyroxene compositions of NWA2236 are more magnesian than LEW85440.

There are two other ureilites described previously, which contain significant amounts of augite [11]. Majority of MET78008 is an augite-olivine ureilite, and a part of Y74130 is similar to MET78008. In a part of the MET78008 PTS, an augite crystal poikilitically includes an ellipsoidal pigeonite grain. The mode of occurrence of pigeonite and the chemical compositions of three pyroxene phases are also similar to those of Y74130. In spite of the high augite abundance, albite rich in the andesitic materials like those found in the IAB and IIE irons are absent in these ureilites.

In some polymict ureilites from hot deserts, such as Dar al Gani 319 [12], 1023 [13] contain fragments of Na-rich plagioclase. Such plagioclase may be parts of partial melts erupted on the surface of the ureilite parent body. Because the source materials of ureilites are carbonaceous materials rich in volatiles, the partial melt rich in Na might have been removed from the partly differentiated body by explosive volcanism induced by impacts. Sunshine et al. [1] did not consider such differentiation processes of asteroids.

Despite their common derived mineralogy and petrogenesis, the asteroids discussed in the Sunshine paper [1] differ in their overall spectral slope and band strength. They attribute this difference to the addition

of metal, either through “space weathering” and production of nonaphase iron or admixture of larger metal particles [1]. Y74357 and ALH81187 show dusty inclusions in olivine [14]. Miyamoto and Takeda [15] attributed this phenomenon to reduction resulting in opaque depositions at dislocations that took place when the parent body was exposed to vacuum after break-up and while the interior was still hot. Their reflectance spectra [16] give better fit for those of S asteroids and may have relationship to space weathering.

In conclusion, identification of basaltic types based only on the presence of HCP may be difficult because the spectroscopic observation cannot identify Na-content of plagioclase. Our findings of augite-diopside in new hot desert meteorites suggest that further studies are required for recognition of types of the differentiation processes of asteroids. To make eucritic basalts from the chondritic, andesitic partial melts, we have to loose one tenth of Na.

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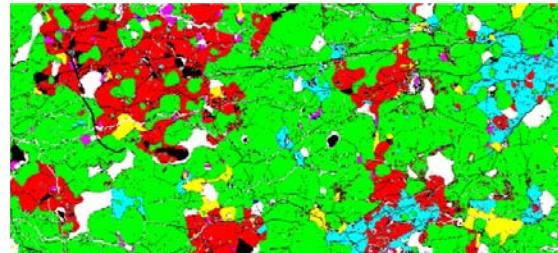


Figure 1. Mineral distribution map of the NWA2235 lodranite. Green: olivine, red: Opx, blue: diopside, yellow: chromite, white: metal, purple: troilite. The EPMA work was supported by the cooperative programs provided by ORI and NIPR.