Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

PPS25-11 Room:213 Time:May 2 11:45-12:00

A unique lithology in the NWA 1232 CO3 chondrite containing clasts of different metamorphic grades

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Northwest Africa 1232 (NWA 1232) is a CO3 carbonaceous chondrite consisting of three lithologies (A, B, and C) that went through different thermal histories [1,2]. Kiriishi et al. [3] found that lithology A contains many small clasts (100-400 micron in diameter) scattering throughout the lithology. These small clasts typically consist of one chondrule surrounded by matrix and show little evidence of thermal metamorphism. Such unique lithology has not been known in other CO3 chondrites and potentially provides new insights into the formation of CO3 chondrites. Here we report the results of detailed mineralogical and petrological study of NWA 1232. The study was performed using SEM-EDS, TEM (STEM)-EDS, EPMA, and SR-XRD.

The thin section of NWA 1232 studied consists of lithologies A (738 mm^2), B (624 mm^2), and C (196 mm^2) that are separated by sharp boundaries. In lithology C, olivine phenocrysts in type I chondrules have relatively homogeneous compositions (Fa_{3-13}) and exhibit weak Fe-Mg zoning; these correspond to metamorphic grade 3.4. The matrix consists mainly of fine grained (100-500 nm in diameter) olivine that is relatively homogeneous in composition ($\sim Fa_{60}$). In lithology B, olivine phenocrysts are more Fe-rich (Fa_{19-42}) and exhibit distinct Fe-Mg zoning; these correspond to metamorphic grade 3.7. The matrix is mainly composed of relatively coarse-grained (>500 nm in diameter) olivine that is very homogeneous ($\sim Fa_{40}$).

In contrast, chondrules and matrix in lithology A exhibit considerable chemical and textural diversities. Olivine phenocrysts in chondrules vary widely in composition from Fa_1 to Fa_{43}. Most of Mg-rich olivine phenocrysts in Mg-rich chondrules show almost no Fe-Mg zoning; these are similar to those in CO 3.0 chondrites. Their surrounding matrix consists mainly of very fine-grained Mg-Si-Fe-rich amorphous material. On the other hand, most of Fe-rich phenocrysts in Fe-rich chondrules show distinct Fe-Mg zoning and their surrounding matrix consists mainly of coarse-grained (>500 nm in diameter) Fe-rich ($\sim Fa_{40}$) olivine; these are similar to those in highly metamorphosed CO 3.7 chondrite. There are also many other chondrules whose olivine phenocrysts have compositions intermediate between the Mg-rich and Fe-rich olivines described above. The matrix surrounding these chondrules mainly consist of fine-grained (100-500 nm in diameter) Fe-rich olivine similar to those mildly metamorphosed CO chondrites.

The chemical and textural heterogeneities observed in lithology A cannot be explained by thermal metamorphism of a single lithology. The results suggest that lithology A is composed of many clasts that underwent various degrees of thermal metamorphism in different locations of the parent body. The results further imply that CO chondrites had once experienced various degrees of thermal metamorphism in different locations in the parent body and subsequently went through extensive brecciation and mixing.

References: [1] Kiriishi and Tomeoka (2008), JMPS, 103, 161?165. [2] Umehara et al. (2009), JAMS Annual Meeting (abstract). [3] Kiriishi et al. (2009), JAMS Annual Meeting (abstract).

Keywords: CO chondrite, thermal metamorphism, brecciation, clast, TEM, SR-XRD