PLAGIOCLASE-AUGITE-RICH GABBRO IN THE CADDO COUNTY IAB IRON, AND THE MISSING BASALTS ASSOCIATED WITH IRON METEORITES.

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Abstract: Absence of basalts related to the formation of iron meteorites in the meteorite collections has been a mystery in Meteoritics. We found Gabbroic materials rich in plagioclase and augite in the Caddo County IAB iron meteorite in the polished thin sections (PTS) made from areas rich in Al and Ca detected by the microfocus X-ray fluorescence (XRF) mapping technique. Discovery of another type of basaltic materials associated with iron meteorites, which are the products of partial melting, suggests that they were not lost into space as the explosive volcanism model proposed.

Introduction: Eucrites are major basalts extruded on the surface of the Vesta-like asteroid in the early solar system, but absence of basalts related to the formation of iron meteorites in the meteorite collections has been a subject of controversy in the meteorites-asteroids connection [1]. Angrites are the only other basalts known in the early solar system, but their presence as a lava extruded on a surface of a large protoplanet like Vesta has not been well established. Mg-rich silicate varieties of lodranites/acapulcoites and winonaites/IAB iron group have been identified as residues of partial melting [2], but basalts representing the solidified partial melt have not been found in the meteorite collections or asteroids. We had some indications of the presence of such materials in silicate inclusions in the IAB irons, Y791058 and Caddo County and lodranite/acapulcoite, EET84302 [3,4,5]. By applying a large area chemical mapping techniques with microfocus XRF analysis equipment, we found plagioclase-augite (Aug)-rich regions in a large slab of Caddo County. Arguments on the partial melting model *versus* the crystal fractionation are discussed partly in connection with the HED meteorites.

Samples and Methods: A cut surface of one thick slab of Caddo County IAB iron supplied from the Planetary Materials Database Collection of Mineralogical Institute, Univ. of Tokyo was examined by microfocus X-ray fluorescent (XRF) method for detection of the Ca-,Al-rich portions [6]. Elemental distribution maps of the slab (5.2×3.5 cm) were obtained by Kevex Omicron XRF unit equipped with EDS and microfocus X-ray tube. Concentration of Fe, Ca, Ni, Co, Cr, Mn and S were measured by XRF with 100 μm collimator, in air and those of Mg, Ca, Al and Si with 2 mm collimator in vacuum on an uncoated cut surface [6]. Three PTSs of the Ca-,Al-rich portions thus detected and a normal mafic silicate-rich portion were prepared parallel to this cut slab surface. The modal abundance of minerals (Fig. 1) in the plagioclase-Aug-rich areas of the PTSs of Caddo County were obtained via the Chemical Map Analysis (CMA) technique of the JEOL 8900 EPMA and by processing the maps by the Photoshop program.

Results: Three PTSs parallel to the cut slab surface, showed the existence of basalt or gabbro in PTSs, especially in B3A and B2A. PTS B3A represents an area adjacent to metal and consists of augite (Aug) crystals up to 1 mm in diameter set in a much larger plagioclase crystals. Modal abundance of plagioclase of the silicate portions is over 43 vol. % and that of Aug 30 %. Orthopyroxene (Opx) and olivine are less abundant (less than 13 %), and Opx $Ca_{2.5}Mg_{90.1}Fe_{7.4}$ and Aug $Ca_{43.7}Mg_{54.1}Fe_{2.1}$ often coexist and olivine crystals exhibiting rounded shape are found far from the gabbroic area. The Aug crystals show slight zoning in Cr_2O_3 contents, with 0.49 wt % in the core and 1.09 to 1.21 at the rim. Plagioclase is fairly calcic $Or_3Ab_{75}An_{21}$ among those of the primitive achondrites [3]. Another PTS Caddo County B2A has much larger plagioclase showing a poikilitic texture including rounded mafic silicates. Fine networks of metal distribute in some plagioclase-rich regions.

PTS Caddo County B1A representing a Mg-rich area in the XRF elemental distribution map, shows textures, grain sizes, and modal abundances of minerals as in Acapulco and Winona. The area is finer grained than B3A. Opx and olivine are the most abundant minerals. Aug and plagioclase occur in much smaller amounts, and together with troilite, FeNi metal, and minor chromite, fill the interstices of grain boundaries of the mafic silicates. In some areas, vein-like plagioclase enclosing also elongated Aug penetrates into the fine-grained mafic silicate-rich regions.

Discussions: Discovery of plagioclase-Aug-rich gabbro associated with the IAB iron meteorites gives us strong support that there is another type of basaltic material in the asteroidal belt distinct from eucrites. This basaltic melt is a more plausible material resulting from partial melting, because many investigators on lodranites agreed that they are the residues of partial melting [2,3]. The points of disagreements were whether the partial melts were lost by explosive volcanism [2] or migrated to other places [3] and what kind of heat sources

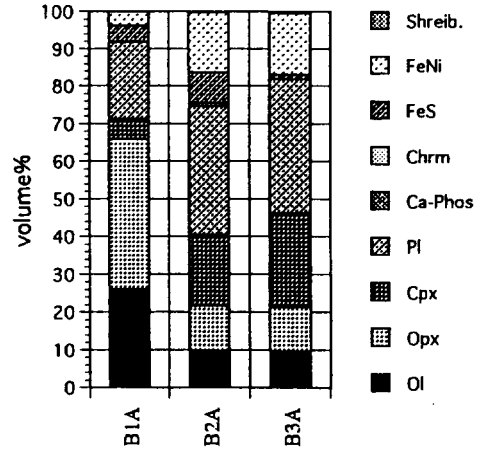

Fig. 1. Modal abundances of minerals.

they ascribe for the partial melting. Now, plagioclase-Aug-rich materials found in IAB irons, associated with metal support the idea that the two types of partial melt, Fe-Ni-S eutectic and Ca-Al-rich partial melt were migrated side by side not too far away from areas where lodranite/winonaite-like materials were formed.

Because the Ca-,Al-rich partial melts are mostly brought to boarder regions between iron meteorites and mafic silicates, the basaltic regions may remain around the surface of an iron meteorite body. Occasional collisions of such asteroidal fragments will loose plagioclase-Aug-rich materials preferentially, because of their fragile nature. Another reason why they have not been observed by reflectance spectroscopic searches is that plagioclase does not give strong absorption and that the albedo will be decreased by fine penetration of metallic veins into silicates, which were often observed in the PTS of Caddo County B2A. This is a kind of space weathering. Mineralogical records of space weathering were noted by shock annealed lodranites [7].

The plagioclase-Aug area can be interpreted as a region where all partial melt extracted form the mafic silicate-rich source regions are collected and brought together with another Fe-Ni-S eutectic melt. Discovery of such basalt and their close association of plagioclase-Aug area with metal is in support of the model of the partial melting model of the primitive achondrites and a true product of partial melt is distinct from the eucrites. Absence of basalts associated with iron meteorites in our meteorite collections [1] cannot be used as an evidence against the Vesta origin of the HED meteorites because of our discovery of gabbro rich in plagioclase and Aug, associated with an IAB iron meteorites. We acknowledge Miner. Inst., Univ. of Tokyo for supplying us with the samples of the Planet. Materials Database Collections, and Mr. J. Holder of the NASA/JSC Curatorial Staff for making the large PTSs of the Caddo Co. samples. This work was supported by a grant of the Ocean Res. Inst. and by a Grant-in-Aid for Sci. Res. from the Japanese Ministry of Education, Sci. and Culture. We are indebted to Mr. M. Tomobuchi, H. Kumada, Dr. T. Ishii, for their help in microanalysis, and to Dr. D. Mittlefehldt and Profs. M. Miyamoto, P. Warren, K. Keil and Mr. T. Mikouchi for discussion.

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