COMPARISON OF ORTHOPYROXENES IN LUNAR NORITES AND DIOGENITES.

Hiroshi Mori and Hiroshi Takeda, Mineralogical Inst., Faculty of Science, Univ. of Tokyo, Hongo, Tokyo 113, and M. Miyamoto, Dept. of Pure and Appl. Sci., College of General Education, Univ. of Tokyo, Komaba, Meguro-ku, Tokyo 153, Japan.

Although orthopyroxene-rich rocks are presumed to have been the most abundant lithologic type to compose the deep crust of the howardite parent body, such rocks are not as well represented among pristine nonmare rocks. Thermal and deformatonal histories of diogenites were investigated by examining their microtextures of orthopyroxene (1)(2). Untwinned clinobronzite (low-Ca pigeonite) lamellae up to 0.1 μm in width observed in the Johnstown bronzites in addition to augite lamellae only several unit-cell wide with (100) in common, has been interpreted to have been produced by stress-induced transformation due to meteorite impacts and excavation of its parental mass. We observed in single crystal diffraction studies, weak reflections of secondary pigeonite in the 72255 orthopyroxene as well as the exsolved augites (3). It is expected that this pigeonite is clinobronzite produced by shock.

Two orthopyroxene-rich lunar norites, Civet Cat norite clast (72255,202) and 78236,14(4) and 15445,226 and 15455,237, have been examined by analytical transmission electron microscopy (ATEM), X-ray diffraction and electron microprobe, in order to provide limits on the thermal and shock deformatonal histories of lunar norites and diogenites.

Small chips of 72255,144, from which the single crystals for the X-ray study were selected, were first mounted in epoxy, polished and examined by optical microscope and electron microprobe, and selected areas were ion-thinning. The ATEM observations were made in a Hitachi H-600 ATEM operating at 100kV. Unfinished section, 78236,14 were first examined by the above method and single crystals of the orthopyroxene were separated after the microprobe study, for the single crystal X-ray diffraction study.

The 72255 clast is a monomict breccia with fragments of orthopyroxene crystals up to 0.3 μm set in a dark brecciated matrix. The microstructure in the 72255 orthopyroxene Ca2.0Mg73.3Fe24.6 is different from that of Johnstown in the following features: (1) There is no G.P. zones nor fine augite lamellae, (2) the thickness of the (100) augite lamellae is up to 0.4 μm (ave. 0.2 μm), (3) opaque inclusions are present in the augite lamella by blocking out the entire width for some lengths and (4) abundant fine clinobronzite lamellae up to 200 A are present with (100) in common (Fig. 1). The width of 72255 clinobronzite lamellae is larger than that in the orthopyroxene from Yamato 7308 (90A), but is smaller than that of Johnstown (ca. 3000A).

The 78236,14 is coarse-grained crystalline norite with about 14% orthopyroxene, 85% plagioclase, and 1% silica mineral. The plagioclase is gray and the pyroxene up to 1 mm is a yellow-tan. The silica is light brown and is shocked showing almost isotropic character. It has triangular shape with few metal grains and reveals blue fluorescent color by electron irradiation. The compositions of orthopyroxene Ca3.4Mg76.0Fe20.6 is close to that of 78235(5), confirming that the sample is similar to other samples of the boulder 8. It shows slight enrichment of Mg at the rim (Ca2.7Mg76.5Fe20.6). The X-ray precession photographs show elongated reflections due to intense shock effect, and thus it is difficult to detect the reflections of augite or clinobronzite.

The presence of the clinobronzite lamellae in 72255 detected by ATEM, confirms our prediction by the X-ray method, and suggest shock deformatonal processes due to meteoritic impacts. An evidence of twinning detected by the X-ray method for clinobronzites does not exclude a possibility that they were formed thermally. Because the exsolution lamellae of augite in 72255 are thicker than those of Johnstown, the meteorite impact that produced the clino-
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Bronzite lamellae may have taken place after considerable cooling. In an attempt to compare the cooling rates of exsolved orthopyroxenes in lunar norites and diogenites as a first approximation, the method used previously (6) to estimate the depth of burial of the exsolved pigeonites in a crustal model of the eucrite parent body, has been applied for the Ibbenbüren diogenite and 72255 norite (by M. Miyamoto). The shape of the Opx-Aug solvus has been adopted from the previous work (7), but the most Ca-poor host composition was also taken as equal to the host value of Ibbenbüren (1.4 mol%) determined by ATEM (by H. Mori). The range of the atomic diffusion coefficient(D) for the simulation was estimated from the width-length ratios of the blebby augites in a presumably decomposed pigeonite in Moama. By the combination of many possible parameters, the depth of burial of the Ibbenbüren varies from 5km to 18km, and that of 72255 from 11km to 19km. The depth for diogenites in agreement with the expectation that it is deeper than the deepest layer of the cumulate eucrites, ca. 12km (6).

In conclusion, (1) the exsolution lamellae of (100) augite in orthopyroxene is in agreement with deep origin, and (2) the shear transformation from orthopyroxene to clinobronzite proposed for the diogenite may also take place in lunar environment and can be used as an indication for the shock effects.

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References.

Fig. 1. An electron micrograph of the 72255 orthopyroxene. α axis: vertical, a axis: horizontal. Intervals of thick periodic fringe is 18A of orthopyroxene. Thickness of clinobronzite lamellae (white) is variable.