ABSTRACT

Shock Effects in Apollo 12
Returned Lunar Samples

by

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Although the two igneous rocks examined in this study (12017-15 and 12053-83) appear to be unshocked, the breccias and the constituents of the fines show abundant evidence of shock metamorphism. In addition, the occurrence of fragments of breccia within breccia is indicative of multiple shock events.

Microstructural damage resulting from shock events is manifested as intensive microfracturing of plagioclase and the development of one or more sets of fine multiple twin lamellae in clinopyroxene and ilmenite. The twin lamellae in clinopyroxene are principally developed parallel to (001). The associated olivine appears to be relatively undamaged. All of these phenomena were observed in the Apollo 11 samples. Shock-induced thermal effects are also evident. These include the occurrence of spheroidal to angular fragments of glass, although such materials appear to be much less abundant than in Apollo 11 samples, and partial to complete recrystallization of plagioclase and clinopyroxene clasts to microgranular aggregates.

Two breccia samples (12057-22 and 12010-6) show extraordinary shock-induced melting phenomena not observed in Apollo 11 samples. These are complex breccias consisting of angular fragments of coarse-grained igneous rock, older microbreccia, dark-brown glass, plagioclase, clinopyroxene, olivine, and ilmenite set in a vesicular fine-grained groundmass composed of plagioclase and pyroxene microlites in random orientation with interstitial brown glass and opaques. Locally, the plagioclase forms relatively large skeletal crystals and the clino-

pyroxene forms relatively large sheaf-like aggregates enclosed in glass. The groundmass has a microtexture which closely resembles that of basalt with hyalopilitic to hyaloophitic texture. Some of the plagioclase and clinopyroxene clasts and the plagioclase and clinopyroxene of the igneous rock fragments were partly to completely recrystallized to fine-grained aggregates which indicate that they were reheated. Correspondingly, the development of large dendritic crystals of pyroxene in the brown glass fragments suggests that they were remelted. It is concluded that these shock-produced breccias were involved in a subsequent shock event of such magnitude that their fine-grained fragmental groundmass was completely remelted. The angular rock fragments and mineral clasts were apparently reheated and possibly partly resorbed in the liquid matrix which then crystallized to a plagioclase-pyroxene-glass mixture whose texture resembles that of basalt.

Many investigators described the fine sigmoidally bent and microfaulted multiple twin lamellae in ilmenite of the Apollo 11 microbreccia and fines and concluded that this was a shock-induced feature because it was absent in ilmenite of the unshocked igneous rocks. This conclusion has been verified by experimentally reproducing this microstructure in a particulate ilmenite sample subjected to an experimental shock with a peak pressure of about 250 kilobars. As anticipated, hematite has a similar deformation mode under experimental dynamic conditions, and experimentally shocked pyrrhotite shows the development of fine sets of multiple twins. On the other

hand, experimentally shocked apatite shows well-developed sets of shock-induced planar features corresponding to first- and second-order pyramids, and, rarely, to the third-order pyramid; fractures parallel to (0001) are common. Experimentally shocked alkali feldspars (microcline and albite) show pronounced shock-induced Al/Si disordering as based on X-ray powder diffraction and optical data. An attempt is being made to apply these new shock criteria to the returned lunar materials.