CONSORTIUM BRECCIA 73255: ELECTRON PETROGRAPHY OF APHANITIC LITHOLOGIES AND ANORTHITE CLASTS. G.L. Nord, Jr., and O.B. James, U.S. Geological Survey, Reston, VA 22092

Introduction. 73255 is a light-gray breccia, consisting of aphanitic rock that contains a varied suite of coherent and granulated fragmental materials. The breccia is considered to have formed as a fragment-laden melt during a large lunar impact [1]. A petrographic overview and exposure age data for the bulk breccia were presented previously [1]; companion abstracts present rare-earth-element, light-element and Rb-Sr data [2], ^{40}Ar-^{39}Ar stepwise heating data [3] and optical petrographic data [4] for the aphanitic fraction of the rock. The aphanitic material consists of ∿30% 5 μm- 1 mm lithic and mineral clasts and ∿70% <5 μm groundmass; the groundmass texture is only barely resolvable optically but appears to be igneous [4]. The breccia contains several types of aphanite that vary greatly in groundmass grain size, vesicularity, and volume of small vugs; each type has a distinctive occurrence and distribution [4]. The major types of aphanite, which we have studied, are: nonvesicular, which forms the core of the breccia; vesicular, which forms a distinct rind; and cryptocrystalline, which forms small globules within the core aphanite (fig. 1). The clasts within the aphanites show a wide range of shock features; many appear unshocked, many show weak undulatory extinction, and a few appear to have been strongly shocked. This study utilizes the high resolution and electron diffraction capabilities of transmission electron microscopy (TEM) to investigate the textures of the groundmasses in the various types of aphanite, and to set more precise limits on the thermal and deformational histories of the clasts.

Nonvesicular core aphanite. This aphanite has only a few percent porosity; optically its groundmass appears to be subophitic, with grain size averaging ∿2 μm [4]. TEM shows the groundmass texture to be subophitic to ophitic (fig. 2): plagioclase laths 1-4 μm long are partly or wholly enclosed by pigeonite.

Cryptocrystalline aphanite. This aphanite is the least porous in the rock. Its groundmass texture cannot be resolved by light optics but is shown to be subophitic by TEM (fig. 3). The plagioclase grains are 0.5-2 μm long; most are lath shaped but a few are blocky. The pyroxene is pigeonite and shows slight exsolution, by compositional modulations, along "(001)". No glass is observed.

Vesicular rind aphanite. This aphanite has abundant vesicles (∿30% by volume); optically its groundmass shows a relatively coarse-grained (4-5 μm) subophitic texture in which the pyroxene grains are blocky [4]. TEM confirms that the groundmass texture is subophitic to ophitic; 1-5 μm laths and blocky grains of plagioclase are totally or partly enclosed by pigeonite (fig. 4). One of the larger blocky pyroxene grains (∿40 μm across) was found to be pigeonite containing (100) twins and two sets of relatively thick exsolution lamellae of augite (fig. 5). The pigeonite also contains a third finer set of augite precipitates that nucleated and grew on antiphase domain boundaries formed during the $C2/c \rightarrow P2_1/c$ transition. At its edge, this grain does not contain any thick augite lamellae, and it encloses 2-3 μm laths of plagioclase. These relationships suggest that the core of the pigeonite grew as a microphenocryst.

Clast of unshocked anorthite. This 1 mm fragment of anorthite ($An_{97.1}$) optically appears to be undeformed, except that it contains a few short discontinuous twin lamellae developed along a healed fracture. TEM shows that the clast has a low dislocation density and unusually small c-domains (100 Å across) for

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a plagioclase of this composition. The c-domains arise when plagioclase cools through the $I\bar{1} \rightarrow P\bar{1}$ transition, which occurs at ∿600°C for An_{97}; the size of the domains is positively correlated with the rate of cooling through this transition [5]. Plagioclases of similar composition that are found in slowly cooled lunar rocks, such as 15415, have c-domains as much as 5000 Å across. The low dislocation density indicates that this clast has experienced no detectable shock deformation. The small size of the c-domains indicates that the last significant thermal event in the history of the clast was extremely rapid cooling through the 600°C temperature range. As the clast was almost certainly heated to >600°C when it was incorporated in the groundmass melt, this cooling probably occurred immediately after the breccia-forming event, indicating that the entire breccia also cooled rapidly through the 600°C temperature range.

Clast of shocked anorthite. This 400 μm irregular fragment of anorthite ($Or_{0.3}Ab_{5.7}An_{94.0}$) consists of a mosaic of tiny grains that show aggregate extinction; the extinction pattern defines a series of bands resembling irregular, slightly bent twin lamellae. TEM shows the tiny grains to be 0.1-1.0 μm across and butterfly shaped; each is slightly misoriented with respect to its neighbors and contains abundant 1-10 nanometer twins. Lamellae composed of partly devitrified glass are also present in the aggregate. These microstructures indicate that the plagioclase grain was almost completely converted to thetomorphic glass by shock, and most of the glass subsequently devitrified.

Conclusions. The TEM observations of the aphanites confirm that their groundmasses do have igneous textures, and verify their origin as fragment-laden melts. Groundmass texture in all the areas we examined is ophitic to subophitic. The finest grained groundmass (that in the cryptocrystalline aphanite) is mainly subophitic, whereas the coarser grained groundmasses in the other types of aphanite tend to be more ophitic. Groundmass pyroxene is pigeonite; no single crystals of augite or orthopyroxene have been identified.

The TEM observations confirm that different clasts in the aphanites have had different shock histories. The absence of shock effects in the groundmass minerals and in one of the anorthite clasts we studied indicates that the bulk breccia cannot have experienced any significant shock after it formed. Thus the shock effects that are observed in the clasts were produced prior to their incorporation in the breccia. The preservation of glass in the shocked anorthite clast and the small c-domain size in the unshocked anorthite clast are consistent with rapid cooling of the bulk breccia to temperatures below 600°C after the breccia-forming event. These observations, coupled with the very fine grain sizes of the melt-derived groundmasses, indicate that the 73255 fragment-laden melt solidified and cooled very rapidly after the clasts and the melt were mixed. Isotopic exchange between clasts and the surrounding groundmass should have been minimal, and the clasts may retain information on the chronology of events prior to their incorporation in 73255.

References. [1] James O.B. and Marti K. (1977) in Lunar Science VIII, p. 505. [2] Blanchard D.P., Budahn J.R., Kerridge J.F. and Compston W., this volume. [3] Staudacher T., Jessberger E.K. and Kirsten T., this volume. [4] James O.B. and Hedenquist J.W., this volume. [5] Heuer A.H. et al. (1976) Electron Microscopy in Mineralogy, Springer-Verlag, p. 345.

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Fig. 1. Reflected light optical micrograph of the thin section studied. The vesicular rind aphanite is at the left, the nonvesicular core aphanite is at the right, and the cryptocrystalline aphanite is outlined. The areas shown in the figures below are marked by their figure numbers. PTS 73255-314

Fig. 2. Plagioclase laths and interstitial pigeonite in groundmass of nonvesicular core aphanite. Electron micrograph, 200 Kv.

Fig. 3. Plagioclase laths and interstitial pigeonite in groundmass of cryptocrystalline aphanite. Electron micrograph, 200 Kv.

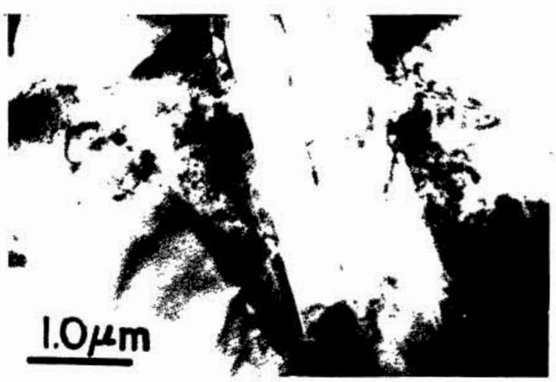

Fig. 4. Plagioclase laths and interstitial pigeonite in groundmass and vesicular rind aphanite. Electron micrograph, 200 Kv.

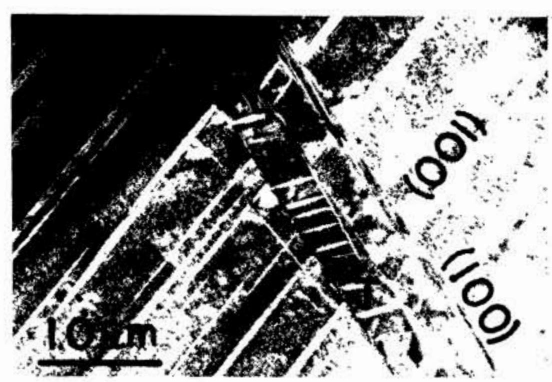

Fig. 5. (100) twin lamellae and "(100)" and "(001)" augite lamellae in core of blocky pigeonite in vesicular rind aphanite. Electron micrograph, 200 Kv.