PETROGRAPHY OF FELDSPATHIC FRAGMENTAL BRECCIA 67016: ANALOG OF TERRESTRIAL SUEVITE? Marc D. Norman, Lunar Curatorial Lab, Northrop Services, Inc., P.O. Box 34416, Houston, Tx. 77034.

Feldspathic fragmental breccias are the most abundant rock type associated with North Ray Crater and its ejecta. They probably represent the upper layer of Descartes material exposed at Smoky Mountain (1). The characterization and interpretation of this unit is of fundamental importance in understanding the geology of the Apollo 16 site.

67016 is a fragmental matrix breccia with abundant clasts of dark, fragment-laden melt breccia and lesser amounts of light-colored granulitic and possibly cumulate clasts. Other clast types are rare. It was picked from the lunar surface just outside the southern rim crest of North Ray Crater, and is similar petrographically and chemically to the rounded boulders of "light matrix breccia" predominant on the rim of North Ray. Following recent nomenclature revisions (2) these rocks will be referred to here as "feldspathic fragmental breccias". These rocks may be analogous to terrestrial suevite if the melt-breccia clasts formed in the same event that assembled the breccia.

The texture of 67016 is seriate: mineral and lithic fragments grade continuously in size from ∿1 cm to the limit of resolution of the petrographic microscope. The arbitrarily defined matrix (<0.05 mm) makes up ∿80% of the rock and is ∿90% angular plagioclase grains, with minor pyroxene and olivine, and trace amounts of ilmenite, Fe-metal (usually rusty), and spinel. A small amount of glass at grain contacts bonds the matrix (3), making 67016 considerably more coherent than most other feldspathic fragmental breccias.

Monomineralic grains of plagioclase, olivine, and pyroxene in 67016 show a compositional range that extends beyond the extremes yet measured in the lithic clasts (all electron microprobe analyses of thin section 67016,105). In particular, monomineralic plagioclases are more sodic, olivines and pyroxenes more ferroan than like phases in the lithic clasts. Monomineralic plagioclase ranges from An_{82-98}, averages An_{94}. Low-Ca pyroxene ($Wo_{2-5}En_{53-79}$, average En_{67}) and high-Ca pyroxene ($Wo_{32-43}En_{21-56}$, average $Wo_{39}En_{41}$) grains are subequal in abundance. Olivine (Fo_{59-74}, average Fo_{62}) fragments are less abundant than pyroxenes.

The clast population of 67016 is dominated by dark, rounded to angular fragments of fine-grained melt breccia (Fig. 1). These clasts are ∿80-90% angular plagioclase fragments (virtually all An_{95-97}, rarely down to An_{90}), implying an Al_2O_3 content of ∿30%. The melt matrix of these clasts is usually dark brown, and is apparently crystalline, not glassy: electron petrographic studies show micron-sized plagioclase and pyroxene in a subophitic texture (3). Rare plagioclase laths (An_{96}) that apparently crystallized from the melt matrix reach a few tens of microns in length.

Lithic clasts of feldspathic granulites and possible anorthositic cumulates are also common. Clasts with textures intermediate to granulitic and cumulus are also present. The granulites (∿70-85% plagioclase) have granoblastic to poikiloblastic textures with anhedral mineral grains often meeting in triple junctions (Fig. 2). Granoblastic anorthosite (>90% plagioclase) has not been observed.

Plagioclases in the granulitic clasts are unzoned but heterogeneous in composition from grain to grain (i.e. unequilibrated). Compositions range from An_{91-97} (average An_{95}) among all the clasts analyzed and are only slightly more restricted within individual clasts. Olivine (Fo_{60-78}, average Fo_{69}) is the most common mafic mineral in the granulitic clasts so far

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analyzed, and occurs as equant, 0.1-0.5 mm crystals interstitial to plagioclases, and as smaller, rounded inclusions within plagioclases. Lesser amounts of low-Ca pyroxene (En_{72-80}, average En_{77}) and very rare high-Ca pyroxene ($\sim Wo_{40}En_{50}$) occurs interstitially and as poikiloblasts surrounding rounded plagioclases. The mafic minerals are also homogeneous within single grains but are unequilibrated, showing wide compositional ranges within clasts. The unequilibrated nature of these clasts contrasts with other lunar granulitic rocks, e.g. 67955, 77017 (4,5) which show a very equilibrated mineralogy.

Clasts interpreted as possible anorthositic cumulates (Fig. 3) are distinguished from the granulitic clasts by their coarser grain size, the blocky, more irregular habit of their mafic minerals, and their mineralogy. Many of these clasts have been mildly affected by shock and cataclasis. Most of them display a coarse-grained, annealed texture with plagioclases up to 4 mm long often meeting along gently curving grain boundaries and at triple junctions.

Mineral compositions of the "cumulate" clasts tend to be more restricted than those of the granulitic clasts implying a higher degree of equilibration in the former. Within any single cumulate clast the range of mineral compositions is much less than the overall range of these clasts. Compositions of coexisting plagioclase and low-Ca pyroxene or olivine fall within the "pristine ferroan anorthosite" field of the Mg/Mg+Fe vs An diagram (6) suggesting that these clasts may indeed represent pristine igneous rocks. Plagioclase compositions of the cumulate clasts are more calcic (An_{94-98}, average An_{97}) than those of the granulitic clasts. Low-Ca pyroxene (En_{52-67}, average En_{62}) and high-Ca pyroxene ($Wo_{40-45}En_{35-47}$, average $Wo_{43}En_{42}$) are subequal in abundance in most of these clasts, occurring in places as high-Ca exsolution lamellae in a low-Ca host. Olivine (Fo_{63}) is rare in these clasts, and may be partially or completely replaced by a fine-grained, troilite-rich intergrowth.

Other types of lithic clasts are rare in 67016. They include subophitic-textured impact melt, small "granitic" clasts of intergrown K-feldspar and silica (3) and small fragments of metal-and-silica rich breccia similar to material in 67475 (7). Two different clasts of subophitic-textured impact melt were observed and analyzed in thin section ,105. The first clast is $\sim$1 mm long and is composed of $\sim$90% plagioclase laths (<0.25 mm long) and 10% cryptocrystalline mesostasis. This fragment occurs at the boundary of a dark melt breccia clast and the matrix, and may actually be a clast within the dark melt breccia. Compositions of the laths are An_{94-97}. The second subophitic-textured clast is $\sim$0.4 mm long, and contains $\sim$40% irregularly distributed mafic silicates (probably not representative of the bulk rock) and a single large grain of ilmenite. Plagioclase in this clast is An_{87-91}, olivine is Fo_{60}, and pyroxene $Wo_{9-16}En_{63-59}$.

Discussion: Although many igneous and/or impact events may have been responsible for the formation of the components of 67016, the components must have been assembled and emplaced in a single event. It is the position of the feldspathic fragmental breccias within the context of this last, breccia-assembling event that is of the most relevance to the geology of the Apollo 16 site.

By analogy with the Ries and other terrestrial impact craters, impact melt-bearing, fragmental-matrix breccias (suevites) are deposited predominatly within the central crater cavity (fallback suevite) and, to a lesser extent, just outside the crater rim crest (fallout suevite) (8,9).

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The impact melt in these terrestrial breccias occurs most commonly as discrete bombs and clasts, and is very similar in major and minor element composition to the bulk suevite (see data in 8). If a significant amount of the melt breccia clasts in the Apollo 16 feldspathic fragmental breccias were formed in the breccia-assembling event, then these breccias could be considered analogous to terrestrial suevite and their probable position within the ejecta could be closely constrained. The crucial piece of evidence is whether or not the melt breccia clasts have the same major and minor element composition as the bulk breccia in which they are found. Data are sparce. Based on plagioclase abundances, the estimated alumina contents of the melt clasts in 67016 are probably similar to that of the bulk rock (∿30%, see, e.g., analysis by 10). Analyses of feldspathic breccia 67455 and of a "fragment-laden melt" clast from that rock are also very similar to one another in major and minor element composition (11), suggesting that the analog of these breccias with terrestrial suevite may be valid. More chemical data are needed to help resolve this question.

At this time the identification of the specific impact event responsible for assembling the feldspathic fragmental breccias is problematical at best, and even a cautious extrapolation of terrestrial experiences to the Moon is fraught with uncertainties. It is, however, a reasonable starting point for a discussion of the origin of these unique rocks.

Fig. 1. Melt breccia clast, 0.2mm wide.

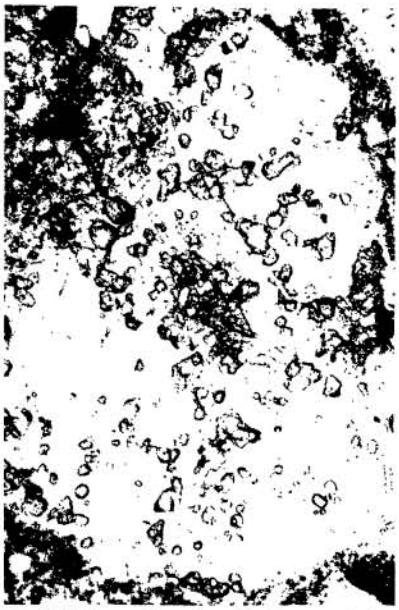

Fig. 2. Granulitic clast, 0.8mm wide.

Fig. 3. Cumulate clast, 1mm wide.

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