ACCESSORY MINERALS IN NORTH RAY CRATER BRECCIAS, APOLLO 16.
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Some 500 accessory mineral constituents (metal particles, schreibersites, troilite, ilmenite and spinel) of the matrix and clasts of North Ray crater breccias 67455, 67475, 67915, 67935, 67936, 67937, 67955, 67975 have been analyzed by the reflected light microscope and by the electron microprobe following techniques of (1). The relationship between the composition of the accessory minerals and the types of their host matrix or clast should provide considerable information about the provenance and the aggregation of the breccia material.

The composition of metal particles (Fig. 1) falls into distinct groups for different types of host breccia which are classified according to (2). The majority of metal from granulitic rocks and breccias and from fine-grained feldspatic crystalline melt breccia clusters around 6% Ni (α-phase) with a broad variation of the Co-content. An appreciable number of metal particles in this breccia group, however, contains more than 10% Ni (γ-phase). This observation can be explained by fractional crystallization from a meteorite-contaminated impact melt as proposed by various authors (3). Metal with high Co-values which exceed the meteoritic range as defined by (5) may be produced by simultaneous crystallization of metal along with various amounts and proportions of different silicates (3). The composition of metal within the clastic matrix of fragmental breccias 67455 and 67975 forms two narrow clusters which are within the field of anorthosites (3). Metal from subphotic crystalline melt breccias (67935, 67937) are only partly within the meteoritic range (Fig. 1) and may represent either a mixed population of lunar and meteoritic metal or a population of recrystallized and reequilibrated meteoritic metal. Similar to the composition of metal, ilmenite fragments from the matrix of the fragmental breccias 67455 and 67975 display a rather narrow compositional range in the MgO-FeO-plot (Fig. 2). Ilmenites in cataclastic granulitic rocks are distinctly higher in MgO in accordance with their high temperature crystallization. In the finely granular crystalline melt breccia 67475 ilmenite clasts cover a broad range of Mg/Fe-ratios depending on the color of the breccia matrix (Fig. 2). This ilmenite population obviously represents a mixture of various source rocks.

Intergrowths of schreibersite and metal have been used by various authors (4, 6, 7) as indicators for the equilibration temperatures in lunar rocks. Schreibersites and coexisting metal from the subphotic crystalline melt breccias 67935 and 67937 indicate an equilibration temperature at about 500°C of less according to the experimental data of (8) (Fig. 3). This implies that these breccias must have had a rather low cooling rate which is supported by the fact that coexisting troilite does not reveal any detectable Ni-concentration in accordance with equilibrium conditions (9). The phosphides are distributed as little bars or rounded blebs within the α-phase of the metallic matrix. They also occur at the rims of the metal particles. Considering this texture and the relatively low Co-content of the coexisting metal, a meteoritic origin seems to be more probable than reduction from lunar phosphate. No relics of such phosphates were observed in these breccias.

Spinels with variable chemistry ranging from Mg-aluminian chromite to Alltitanian chromite were observed in granulitic breccias and fragmental breccias (Fig. 4). The compositional range of the Aluminian chromites from the fragmental breccias 67455 and 67975 is similar to those analyzed by (10) in fragmental breccia 67075. Some of them show chemical zoning as indicated by the arrow in Fig. 4. According to the compilation of (11) spinels of this composition

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may be derived from anorthositic to noritic source rocks.

Spinel clasts of pleonast composition are rare in fine-grained crystalline melt breccias 67936 and 67937 and are similar in composition to spinel from Luna sample 20,515-23 (12). Chromian pleonast was also found rarely in fragmental breccias and is comparable in composition to Cr-rich pleonasts of Apollo 14 samples (12). The source rock lithologies for these spinels may be spinel-troctolites and spinel-cataclasites (11).

Conclusions. The clastic accessory minerals in various types of North Ray crater breccias are relics from distinct groups of igneous and metamorphic highland rocks and from meteoritic projectiles. Crystalline melt breccias and granulitic rocks contain mainly meteoritic metal which appears to be re-equilibrated with coexisting silicates in the melt matrix. Schreiberite-metal troilite intergrowths in subophitic crystalline melt breccia (67937 and 67935) indicate slow cooling rates and equilibration below 500°C (Fig. 3). The clastic matrix of the polymict fragmental breccias is free of meteoritic metal and has only low-Yi metal derived from anorthositic rocks (Fig. 1). Also the ilmenite population of the fragmental breccias appears to be monomict in contrast to crystalline melt breccia 67475 which has a polymict ilmenite population (Fig. 2). Chromite in fragmental breccias indicates an anorthositic source lithology, again in contrast to the melt breccias which contain pleonast.

In spite of the polymict nature of the feldspathic fragmental breccias which contain lithic clasts of all other breccia types, the clastic matrix is predominantly monomict and derived from anorthositic rocks based on the metal, spinel and ilmenite population. It must be concluded that multiple reworking and impact comminution of a polymict target lithology (anorthositic and mafic-rich melt rocks) must be subordinate in the formation of the feldspathic fragmental breccias (see also 13).


Figure captions:

Fig. 1: Co-Ni diagram for metal particles. Composition fields: A, high Fe-field (for mare basalt); B, coarse anorthosites (3); C, meteoritic range (11) (Samples: 67455, 67475, 67915, 67935, 67937, 67975, 67902) low Ni-low Co-plots (crosses): 67975; medium Ni-high Co-plots (crosses): 67455; open circles: 67915 and 67955; open squares: 67475; solid triangles: 67935 and 67937

Fig. 2: MgO-FeO diagram for ilmenites in crystalline, finely granular melt breccia (Sample: 67475)

Fig. 3: P-Ni diagram for coexisting schreibersite-metal particles. Dashed lines indicate the 550°C-thermometer derived from the work of Doan and Goldstein (1970) (8) (Samples: 67935, 67937)
Fig. 4: Trigonal spinel prisma as described by Haggerty (1972) (14) (Samples: 67455, 67915, 67937, 67955, 67975); crosses on solid triangle: measurements from a single grain in 67975; solid triangles: 67937; open squares: 67936; open circles: 67915 and 67955 crosses inside of squares: 67455; crosses: 67455 and 67975.

Fig. 2

Fig. 3

Fig. 1

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