COMPLEX BRECCIA STUDIES: 14063. I. M. Steele and J. V. Smith, Dept. of the Geophysical Sciences, University of Chicago, Chicago, Ill. 60637

Most lunar samples, especially Apollo 14, 15, 16 and 17, are complex breccias which may contain clues to early lunar rocks. We used rapid quantitative energy-dispersive analysis to characterize the components in 14063, an especially complex unmetamorphosed breccia. An Al-rich basaltic component was described by Ridley (1975).

General Description: Four distinct types of breccia, each with sharp boundaries, are obvious from color, texture and gross mineralogy of sections 14063, 14 and 23:

I: very fine-grained <0.05mm Mg-rich olivine Fo 84 and tiny chromite; rare larger (0.1mm) plagioclase An 95; intergran areas are distinctly brown relative to II; no bimineratic clasts.

II: fine-grained 0.1mm Mg-rich olivine Fo 84 breccia with ~ 20% plagioclase 0.1-0.5mm An 95; rare low-Ca pyroxene En87Fs11Wo2 and small chromites mg .39 cr .60 (anal. 6); no bimineratic clasts.

III: very fine-grained <1mm composed of clasts of opx-plag-il-K, Ba feldspar-K, Ba, Si glass and rare baddeleyite, cpx, Ti-Zr oxide; larger single grains of plagioclase ~ An 95 are distinct from clast plagioclase ~ An 85; low-Ca pyroxene is extremely uniform En55Fs31Wo4 (anal. 4) with detectable ~ 0.2 wt.% Na2O; plagioclase megacrysts are often included within clasts.

IV: polymict breccia composed of distinct components including single mineral and rock clasts; although mineral clasts >0.1mm are common, no coarse rock clast occurs; distinct mineral clasts include (1) plagioclase ~ An96 up to .3mm uniformly distributed (2) <0.05mm spinel mg ~ .65 cr ~ .07 unevenly distributed (3) large <.3mm low-Ca pyroxene, uniform bimodal compositions En50Fs30Wo4 and En76Fs21Wo3, some with exsolution lamellae, distributed complementary to pink spinel (4) 20µm nickel-iron near-uniform at Ni = 40, Co = 2.5 wt.% (5) zoned olivine Fo 86-80 up to .3mm restricted to spinel-bearing areas; polymineratic clasts include: (1) clear to brown glass with olivine Fo77 (anal. 2) and spinel mg ~ .65, cr ~ .08 (anal. 3) crystals; glass is low-KREEP (K,P <0.1) but relatively rich in Na and Al (anal. 1) (2) dark, extremely fine-grained clasts with mineral clasts of diverse composition, mostly pyroxenes; (3) fine-grained igneous-textured clasts composed of low-Ca pyroxene En65Fs31Wo4 (anal. 7), plagioclase, Mg-rich (~ 2.5 wt.%) ilmenite, and K-Ba interstitial glass; these resemble area III clasts but have slightly different pyroxenes and no Ti-Zr phases. Other area IV minerals include zircon closely associated with ilmenite, one grain of a unique Al-rich phase (anal. 9) which resembles a very Al-rich pyroxene in stoichiometry [(Mg, Ca, Fe)Al2SiO6], evenly-distributed whitlockite grains, sporadic "Ca-Or-Zr-armalcolite", and a Zr-rich titanate similar
to the #15 Ti-Fe-Zr phase of Peckett et al (1972). The intergranular matrix of area IV is very fine-grained suggesting little or no recrystallization.

Discussion: The clear distinctions between the different areas indicates lack of metamorphism during and after breccia formation.

Areas I-III are near-monomict breccias. The Mg-rich olivine, pyroxene and Mg,Cr-rich spinel of areas I and II fall in the composition ranges believed to correspond to ultrabasic lunar rocks. Although no bimetallic clasts occur, individual plagioclase grains are highly calcic and Mg-rich (up to 0.3 wt.%), which would be consistent with derivation from ultrabasic rocks.

Presence of Na, Ba, K, Zr-rich phases indicates that area III is KREEP-like. The homogeneity of the minerals indicates solid-state equilibration in the precursor.

Area IV has diverse components but lack of rock clasts hinders interpretation. The relative coarseness (~0.5 mm) of mineral clasts requires parent rocks at least as coarse. Association of grains of zoned Mg-rich olivine and pink spinel implies a spinel troctolite component like that found in Apollo 16. Glass clasts containing tiny spinel and olivine crystals may result from (shock?) melting of olivine-plagioclase assemblages: the olivine in the source rock must have been less magnesian than Fo70, thereby ruling out Mg-rich lunar rocks. Large calcic plagioclase grains may result from anorthositic rocks: uniform optical extinction indicates simple mechanical disintegration without shock melting. Metal and whitlockite grains are compositionally uniform indicating equilibrated precursors. The Ni and Co of the metal are even higher than in 72415 dunite and 76535 granulite, but the general similarity suggests derivation of the metal from a deep-seated lunar rock. Taenite in some meteorites is also rich in Ni and Co but is associated with low-Ni iron (kamacite). Fine-grained igneous-like clasts are KREEP-like but differ from area III material in containing Fe-richer pyroxenes. The large pyroxene clasts with exsolution lamellae add to the evidence from 67075 polymict "anorthosite" and scattered grains in soils and breccias for existence of pyroxene-bearing plutons.

The above evidence can be interpreted as the result of mixing of highly disintegrated components of several rock types including ultrabasic (chromite-dunite?), spinel troctolitic, anorthositic, pyroxene-bearing plutonic and KREEPy ones. At least some of these components must have been deep-seated originally. The preservation of very dark fine clasts and the lack of reaction rims indicates absence of metamorphism after formation of 14063 breccia, thereby precluding deep burial in an ejecta blanket. Taken together, the data can be explained by complex processes before, during and after the Imbrian
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Impact. Particularly noteworthy are the high-Ni,Co metal and the unexplained MA2Si06 phase.

Selected Analyses: 14063.14

(1) (2) (3) (4) (5) (6) (7) (8) (9)
Na2O 1.1 nd nd .21 nd nd nd 1.1 .2
MgO 11.5 40.0 16.7 22.6 nd 8.53 21.4 4.0 7.1
Fe2O3 21.3 nd 62.5 .65 nd 20.6 .71 1.1 46.8
SiO2 46.3 39.4 nd 52.8 nd nd 52.7 2.2 25.4
P2O5 nd nd nd nd nd nd 45.1 nd
K2O nd nd nd nd nd nd nd nd
CaO 13.6 .23 nd 2.31 nd nd 1.89 .42 .8 11.8
TiO2 .8 nd .30 .77 nd 1.95 .69 nd .46
Cr2O3 nd nd 4.59 .33 nd 45.4 nd nd 2.2
MnO nd nd nd nd nd nd nd nd
FeO 5.6 21.6 15.3 19.4 56.6 24.1 21.8 .6 6.6
NiO nd nd nd nd 41.5 nd nd nd

Σ 100.2 101.23 99.39 99.23 100.61 100.58 99.19 96.9 100.56

(1) Glass with fine crystals of ol and sp; (2) olivine in glass (1); (3) spinel in glass (1); (4) low-ca pyx in area III; (5) typical Ni-Fe, Co2.51; (6) chromite, area II; (7) area IV opx-il-pl clast-opx; (8) typical phosphate; (9) unusual Al-rich analysis.


Fig. 1. Pyroxene compositions from areas I-IV in 14063.14. Olivine are plotted on base. Solid lines connect coexisting phases.

Fig. 2. Fe-metal in 14063.14 and other lunar rocks. Note that most metal in breccias, soils and clasts plot in shaded region.