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; intergrain areas are distinctly brown relative to II; no bimineralic 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 bimineralic 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 En65Fs31Wo4 (anal.4) with detectable ~ 0.2 wt.% Na_2O; 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 ~ An_{96} up to .3mm uniformly distributed (2) <0.05mm pink spinel mg ~ .65 cr ~ .07 unevenly distributed (3) large <.5mm low-Ca pyroxene, uniform bimodal compositions En60Fs36Wo4 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; polymineralic 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 (~ 7.5 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 [$(Mg,Ca,Fe)Aℓ_2SiO_6$], evenly-distributed whitlockite grains, sporadic "Ca-Cr-Zr-armalcolite", and a Zr-rich titanate similar

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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 biminerallic 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 (~ 0.5mm) 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 Fo_{77} 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 $MA\ell_2SiO_6$ phase.

Selected Analyses: 14063,14

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Na_2O	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
$A\ell_2O_3$	21.3	nd	62.5	.65	nd	20.6	.71	1.1	46.8
SiO_2	46.3	39.4	nd	52.8	nd	nd	52.7	2.2	25.4
P_2O_5	nd	nd	nd	nd	nd	nd	nd	45.1	nd
K_2O	nd	nd	nd	nd	nd	nd	nd	nd	nd
CaO	13.6	.23	nd	2.31	nd	nd	1.89	42.8	11.8
TiO_2	.8	nd	.30	.77	nd	1.95	.69	nd	.46
Cr_2O_3	nd	nd	4.59	.33	nd	45.4	nd	nd	2.2
MnO	nd	nd	nd	.16	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	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.

References: Ridley (1975) 6th Proc. p.131; Peckett et al (1972) Nature 236 p.216.

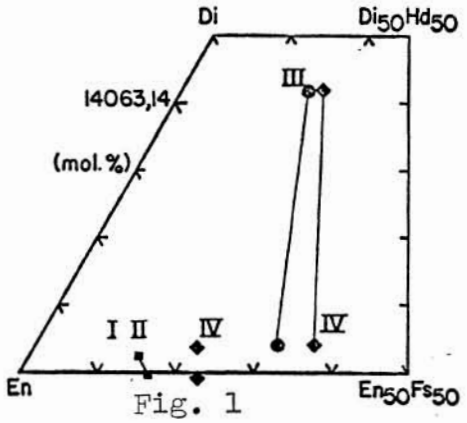

Fig. 1

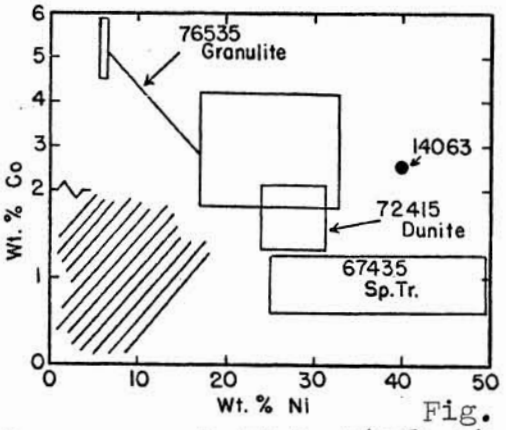

Fig. 2

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.