PETROLOGY OF THE 2-4 mm SOIL FRACTION FROM APOLLO 16; J. W. Delano, A. E. Bence, J. J. Papike and K. Cameron, Department of Earth and Space Sciences, State University of New York, Stony Brook, New York 11790

Thin sections of three hundred and fifteen 2-4 mm soil fragments returned from seven Apollo 16 sampling stations have been examined by optical petrographic and electron microprobe techniques, in conjunction with an $^{40}Ar/^{39}Ar$ study[1], to establish dominant rock types and interstation variations of lithologies. Six textural-compositional rock types have been recognized: ANT[2] (crystalline anorthositic suite), LMB (light matrix breccias of varying metamorphic grade), DMB (dark matrix breccias of varying metamorphic grade), POIK (pyroxene poikiloblastic breccias), FIIR (feldspathic intersertal igneous rocks), and G (glass and devitrified glass).

The ANT group consists of anorthosites, troctolitic anorthosites, and spinel-bearing troctolitic anorthosites. Textures include igneous, metamorphic, and cataclastic. The compositions of the major phases are: plagioclase ($>An_{90}$), olivine ($>Fo_{80}$), and coexisting pigeonite and augite ($Fe/(Fe + Mg) \leq 0.3$). The accessory spinel is similar to pleonaste in composition ($Fe_{1.2}Mg_{6.9}Cr_{0.5}Al_{15.7}O_{32}$).

The LMB rocks are feldspathic breccias with anorthositic bulk compositions (Fig. 1). Generally some recrystallization is observed and in several fragments a complex history is indicated by the presence of both recrystallized and unrecrystallized plagioclase single crystals. In other cases the light matrix breccias can be interpreted as severely granulated anorthosite. Although chemically similar, the textural distinction between ANT and LMB has proven significant.

The dark matrix breccias (DMB) contain lithic clasts (ANT and LMB types), angular to spherical glass fragments, and single crystal fragments of plagioclase, pyroxene, and olivine set in a matrix of brown glass. Broad beam microprobe analyses indicate that these breccias are identical in major element abundances (Fig. 1) to the shallow local regolith[3].

The POIK lithology consists of pyroxene poikiloblasts measuring up to 2 mm in maximum dimension enclosing plagioclase and olivine grains normally $\leq$1/5 mm in size. The composite pyroxenes sometimes consist of orthopyroxene cores rimmed by pigeonite and augite with $Fe/(Fe + Mg) \leq 0.35$. Olivine poikiloblasts have also been reported[3,4]. Low-Ni iron and ilmenite have been observed along with K_2O-rich areas up to 300μ in size. The plagioclase is typically more calcic than An_{90}. Many of the POIK's have rusty assemblages frequently associated with the metallic phase.

The feldspathic intersertal igneous rocks (FIIR) are highly variable in modal mineralogy, bulk chemical composition, and texture. They range from troctolitic anorthosite to olivine-bearing feldspathic basalt. Plagioclase is more calcic than An_{90}, olivine ranges from Fo_{78} to Fo_{90}, and pyroxene occurs as orthopyroxene and pigeonite with $Fe/(Fe + Mg) \leq 0.2$. One textural and compositional subgroup (labelled A on figure 1) has been recognized and is characterized by plagioclase and olivine crystals in a matrix of dark brown to nearly opaque interstitial glass. The glass is variable in composition. Accessory spinel, $MgAl_2O_4$, is present in this group. The average composition of this rock type with the range of analyses given in parentheses is:

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SiO_2 = 43.7% (41.2-45.1); Al_2O_3 = 24.6% (22.7-29.2); TiO_2 = 0.5% (0.2-1.0); FeO = 6.2% (4.7-6.9); MnO = 0.1%; MgO = 11.3% (8.8-14.8); CaO = 13.1% (11.4-15.2); Na_2O = 0.5% (0.3-0.7); K_2O = 0.1%; Cr_2O_3 = 0.3% (0.2-0.4). This composition is similar to the Luna 20 soil[5], and the "average of highland rocks" and "anorthositic norite and troctolite" of Prinz et al.[6]

One mare basalt fragment containing titanaugite with atomic Ti/Al = ½, plagioclase (An_{85}), and ilmenite was found in our sample from station 6. This basalt is very similar to Apollo 11 basalt and may have been transported from the northwestern edge of Mare Nectaris by the Theophilus impact nearly 350 kilometers east of the landing site.

Interstation variations of the various lithologies are given in Table 1 and shown in Fig. 2. We make the following observations and interpretations:

(1) A southerly increase in abundance of ANT, DMB, and FIIR groups from North Ray Crater suggests that these components are important at Stone Mountain and in the shallow levels of the Cayley plain.

(2) The absence of POIK on the rim of North Ray Crater indicates that this group decreases in abundance with increasing depth.

(3) The strong northward concentration of LMB indicates that this rock type dominates in the deeper levels of the Cayley plain.

$^{40}Ar/^{39}Ar$ determinations by Husain and Schaeffer[1] indicate that the ages of POIK, FIIR, and ANT cluster in the range 3.9-4.1 G.y. Some of the LMB fragments give older ages up to 4.24 G.y. and range from 4.1 G.y. The high solar wind content of the DMB suite precluded the determination of a reliable $^{40}Ar/^{39}Ar$ age.

The origin of the FIIR group is uncertain. The presence of shocked relict crystals suggests an impact-melting process. If group A (FIIR) samples are shock-melts and since they are distinctly more mafic than the local regolith[3] (Fig. 1), they cannot have been derived locally. A difficulty with the shock-melt origin, however, is the necessity of having a regolith this mafic in composition at 4.0 G.y. Thus, a volcanic origin cannot be discounted.

Preliminary conclusions are:

(1) Since in general the LMB's have older $^{40}Ar/^{39}Ar$ ages they cannot be derivatives of the ANT suite that we have studied.

(2) The high solar wind content, the glassy character, the high stratigraphic position, and the similarity in composition to the soil indicates that the DMB's are locally-derived soil breccias.

(3) No major lithologic differences have been observed between the Cayley plain and Stone Mountain.

(4) A sample of Mare Nectaris may have been acquired.

References

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(2) Kurat, G., K. Keil, M. Prinz, and T. E. Bunch (1972), A "chondrite" of lunar origin: Textures, lithic fragments, glasses and chondrules. "Lunar Science-III", ed. Carolyn Watkins (Houston: Lunar Science Insti-

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(3) Apollo 16 Preliminary Examination Team (1973), The Apollo 16 lunar samples: A petrographic and chemical description: Science, 179, 23-34.
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(5) Vinogradov, A. P. (1972), Luna 20 samples from the moon; preliminary results: Geotimes, 17, 16-18.
(6) Prinz, Martin, Eric Dowty, Klaus Keil, and T. E. Bunch (1973), Mineralogy, petrology, and chemistry of lithic fragments from Luna 20 fines: Origin of the cumulate ANT suite and its relationship to high-alumina and mare basalts: Geochimica et Cosmochimica Acta (in press).

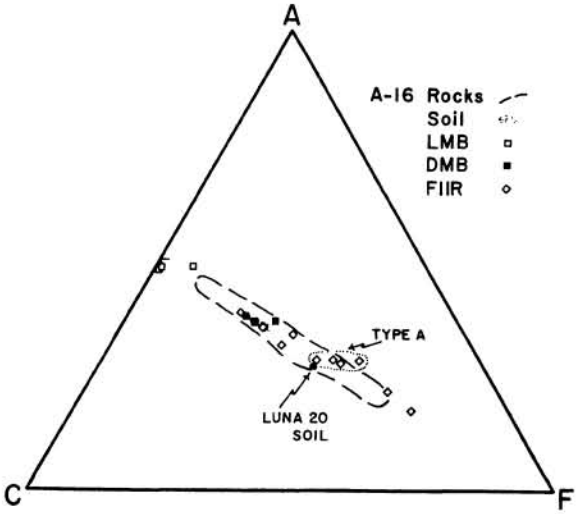

Fig. 1

Sta.	No.	ANT	LMB	DMB	POIK	FIIR	G
		# %	# %	# %	# %	# %	# %
11	48	3(6)	21(44)	17(36)	0(0)	4(8)	3(6)
13	66	5(8)	19(29)	24(36)	8(12)	1(2)	9(13)
10	44	4(9)	5(11)	20(46)	8(18)	0(0)	7(16)
1	27	2(7)	6(23)	8(30)	3(11)	6(22)	2(7)
8	54	8(15)	9(17)	12(22)	6(11)	12(22)	7(13)
6	39	5(13)	3(8)	17(43)	3(8)	7[a](18)	4(10)
4	37	9(23)	4(11)	12(33)	5(14)	3(8)	4(11)
Total:	315	36(12)	67(21)	110(35)	33(10)	33(10)	36(12)

[a]Includes 1 mare basalt.

Table 1

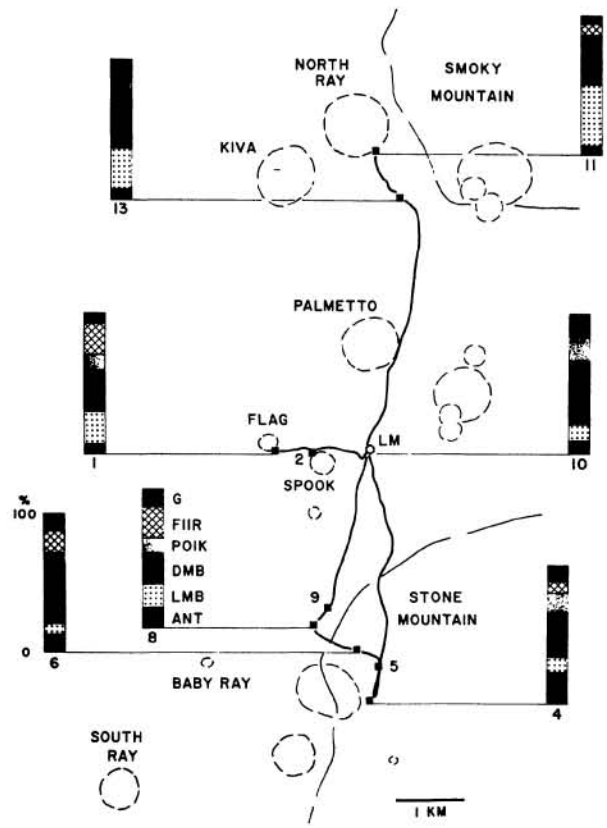

Fig. 2