IGNEOUS ROCKS FROM APOLLO 16 RAKE SAMPLES, Eric Dowty, Klaus Keil and Martin Prinz, Dept. of Geology and Institute of Meteoritics, Univ. of New Mexico, Albuquerque, N.M. 87131.

We report on 8 crystalline rocks from the Apollo 16 rake samples (Table 1): 1 possibly primary (plutonic) rock; 6 "melt" rocks; 1 mare basalt. In addition, 20 anorthosites (mostly cataclastic, some granoblastic, none with igneous textures), and a wide variety of recrystallized and non-recrystallized breccias, including "poik" rocks [1,2] are among the 151 rake specimens examined [3].

Spinel Troctolite. Rock 65785 is inhomogeneous, consisting of a fine-grained feldspar-rich main mass and a coarse-grained troctolitic area (~9 x 4 mm) [3]. The troctolitic part has plagioclase (65%, avg. An_{97}, 0.1-1.0 mm) and one 1.0 mm grain of Mg-Al spinel (5%, Cr_2O_3 2.6-12.6%), poikilitically enclosed in a large olivine crystal (30%, avg. Fo_{83}). The texture may be igneous, probably cumulate, but some metamorphic recrystallization cannot be ruled out. Accessories: very minor pyroxene (Fig. 1), ilmenite, metallic Ni-Fe, troilite, zirconian rutile (3.8% ZrO_2), whitlockite, Cr-Zr-REE-armalcolite, K-feldspar, chromite, magnesium orthophosphate (probably farringtonite).

Melt Rocks. 60666 contains 1 very large relict plagioclase (An_{96}). The melt portion consists of ~0.2 mm phenocrysts or relicts of olivine (Fo_{93}) in a fine matrix of feathery olivine and plagioclase (An_{96}) with sparse Mg-Al spinel. Parts of the matrix may be glassy. Metallic Ni-Fe (4.21% Ni, 0.4-1.3% Co), troilite, schreibersite and very sparse chromite are present. 65779 is very fine grained, subophitic to intergranual; plagioclase needles are ~0.05 mm long. Relict plagioclase grains (~8.5%, An_{95}) occur. Olivine is Fo_{78} and pyroxene is magnesian pigeonite (Fig. 1). Accessories: ilmenite, Cr-Zr-REE-armalcolite, metallic Ni-Fe, troilite, schreibersite. 60615 is texturally similar to 65779, but somewhat coarser; elongate feldspars are ~0.1 mm long. A few large plagioclase relicts [~4%] are clearly distinguishable from the melt portion (both An_{96}). Olivine is Fo_{86}; pyroxene is somewhat similar to that in 60618,1-2 (Fig. 1). Accessories: ilmenite, Cr-Zr-REE-armalcolite, metallic Ni-Fe, troilite, schreibersite and Zr-rutile (to 6.0% ZrO_2). 60618,1 is inhomogeneous; 60618,1-1 is cataclastic spinel-olivine anorthosite; 60618,1-2 is a melt rock containing abundant, irregular plagioclase grains (~0.5 mm, apparently relicts), elongate crystals (~0.5 x 0.1 mm, An_{95}), subophitic pyroxene (Mg-rich with limited Fe/Mg variation, Fig. 1), minor olivine (Fo_{82}). Accessories: ilmenite, Cr-Zr-REE-armalcolite, metallic nickel-iron (2.7% Ni, 0.6-1.2% Co), troilite, schreibersite. 65795 is coarse-grained with abundant feldspar (An_{98}), but grains are irregular and variable in size; some may be relicts. Pyroxenes are somewhat similar to those in 60635 (Fig. 1), and some are poikilitic; minor olivine is Fo_{69}. Accessories: ilmenite (~2.6% MgO), metallic Ni-Fe (5-25% Ni, 0.5-0.8% Co), troilite, high-silica glass (~75% SiO_2, 7-10% K_2O). 60635 has abundant (~1.0 x 0.4 mm) laths or prisms of plagioclase (An_{94}), with pyroxene (predominantly low Ca, with zoning toward higher Ca and Fe, Fig. 1), plagioclase and accessories in the angular interstices. Accessories: nearly pure ulvöspinel (<0.7% Cr_2O_3),

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metallic Ni-Fe, troilite, K-feldspar.

Mare basalt, large lithic fragment in breccia 60639, has subophitic texture and mineral compositions typical of Luna 16 basalts [4]. Plagioclase avg. An_{88} , olivine (Fo_{66}), pyroxene generally zones from high-Ti augite to subcalcic ferroaugite, and ilmenite has low (0.5%) MgO. Low bulk FeO, high Al_2O_3, and intermediate TiO_2 are within the range of Luna 16 basalts.

Origin of the spinel troctolite. Rock 65785 is one of the best possible candidates for a primary cumulate from the original differentiation of the lunar crust, as suggested by its overall composition, mineralogy and, possibly, texture. However, its origin is still uncertain because of the low (4.0 AE) age obtained with the ion microprobe on three armalcolite grains [5], some dissimilarities in composition and texture to the other spinel troctolite 67435 [6], internal variations in spinel and olivine compositions, and wide variety of accessory minerals. The possibility that it is an altered primary rock or a cumulate from a later primary liquid or from a shock-melt, cannot be ruled out.

Origin of the melt rocks. Three modes of origin must be considered: (1) primary liquids; (2) partial melting of a single rock type such as "highland basalt"; (3) melting with or without differentiation of heterogeneous rocks or breccias. The primary liquid origin can be ruled out because most of the melt rocks show evidence for shock-melt origin, such as presence of relicts, textural and compositional inhomogeneities, schreibersite and "excess" metal (whether schreibersite -metal blebs are meteoritic contaminants or in situ shock-produced on the moon is uncertain; however, they are usually found only in rocks which otherwise appear to be shock melted, and not in presumed primary rocks). Furthermore, the bulk compositions do not show any particular concentration near the proposed primary liquid compositions "Highland basalt" [7] or "VHA basalt" [8] (Fig. 2). The melt rocks cannot all be partial melts from a single parent composition, for example, of "Highland basalt" [9]. Partial melts of this composition are restricted to the dashed line in Fig. 3 and only one of the rocks (65779) approaches this line. Thus, the melt rocks apparently represent shock melts of heterogeneous highland soils, breccias or rocks. The most reasonable explanation for the heterogeneity of the highland materials is that they are composed primarily of heterogeneous, cumulate rocks. In many cases,the material which was melted was probably breccia or soil, and there was evidently some admixture of KREEP-like material with the cumulate ANT rocks [10].

References: [1] A.E. Bence et al., Proc. 4th Lunar Scie. Conf. Vol. 1, p. 597 (1973). [2] C.H. Simonds et al., Proc. 4th Lunar Sci. Conf., Vol. 1, p.613. [3] K. Keil et al., J.S.C., Houston (1973). [4] K. Keil et al., Earth, Planet Sci. Lett. 13, 243 (1972). [5] C.A. Anderson and J.R. Hinthorne, personal comm. (1973). [6] Prinz et al., Science 179, 74 (1973). [7] A.M. Reid et al., Geochim. Cosmochim. Acta 36, 903 (1972). [8] N.J. Hubbard et Science 181, 339 (1973). [9] C.H. Simonds et al., [abstr.] GSA Ann. Meeting Abstr., Prog. 5, 811 (1973). [10] E. Dowty et al., Science, in press. [11] D. Walker et al., EPSL, in press.

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Table 1. Bulk analyses of Apollo 16 igneous rocks from the rake samples, obtained with the broad-beam electron microprobe technique (in weight percent).

	Spinel Troctolite	Melt rocks							Mare Basalt
	65785	60666	65779	60615	60618, 1-2	65795	60635	60666* melt portion only	60639*
SiO_2	41.1	42.7	45.6	44.9	45.7	45.2	45.8	45.1	44.8
TiO_2	0.07	0.21	0.77	0.49	0.24	0.19	0.34	0.27	6.3
Al_2O_3	29.9	20.8	22.8	22.1	28.5	31.4	27.6	18.9	15.1
Cr_2O_3	0.18	0.11	0.13	0.11	0.06	0.05	0.07	0.14	0.15
FeO	3.7	4.2	6.1	4.7	2.04	2.25	4.7	5.0	16.0
MnO	0.03	0.05	0.06	0.05	0.03	0.02	0.04	0.05	<0.01
MgO	9.6	18.6	10.1	14.2	5.6	2.78	4.1	19.0	5.2
CaO	14.8	11.7	13.3	12.8	16.0	17.3	15.8	11.0	11.5
Na_2O	0.29	0.39	0.58	0.45	0.57	0.44	0.54	0.36	0.68
K_2O	0.04	0.10	0.27	0.14	0.21	0.07	0.09	0.11	0.15
P_2O_5	0.04	0.04	0.19	0.09	0.06	0.08	0.09	0.06	0.12
ZrO_2	0.01	0.01	0.05	0.03	0.03	0.01	0.01	0.01	<0.01
Total	99.76	98.91	99.95	100.06	99.04	99.79	99.18	100.00	100.00

*Normalized to 100%

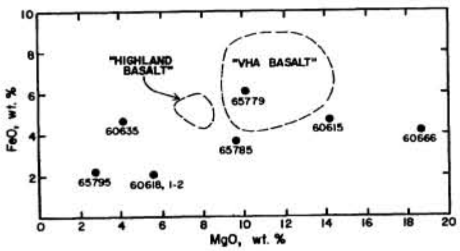

Fig. 2: MgO and FeO contents of melt rocks. Fields for "Highland basalt" and "VHA basalt" are after references [7] and [8].

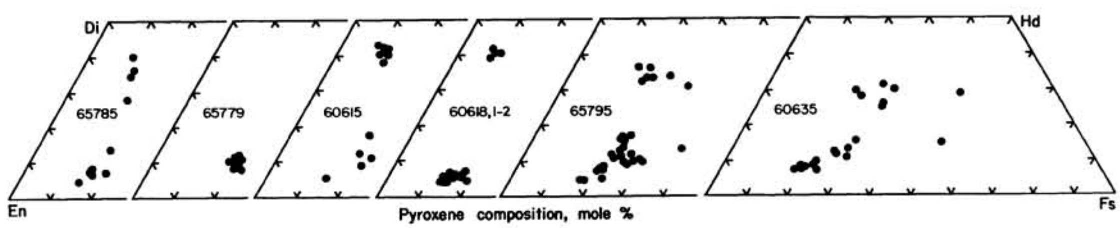

Fig. 1: Pyroxene compositions for crystalline rocks.

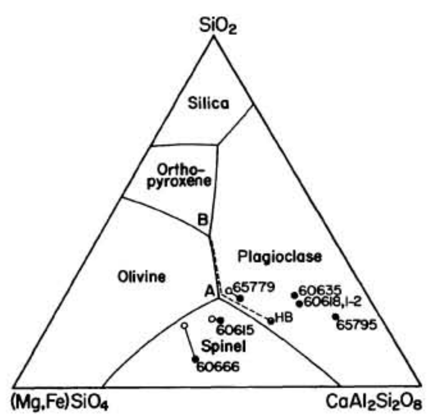

Fig. 3: Liquidus diagram for system plagioclase-olivine-silica, at Mg/(Mg+Fe) of about 0.7; phase boundaries after Walker et al.[11]. Overall compositions of the melt rocks are shown by the solid dots; compositions corrected for the contents of relicts are shown by circles (the circle for 60666 represents a reanalysis of a portion of the rock with no relicts). The amount of feldspar relicts in 60635, 65795 and 60618,1-2 is impossible to estimate accurately, but is close to zero for 60635, and in the neighborhood of 10-30% for 65795 and 60618, 1-2.