THE PETROGENESIS OF 77135, A FRAGMENT-LADEN PIGEONITE FELDSPATHIC BASALT - A MAJOR HIGHLAND ROCK TYPE

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Sample 77135, 10x8x4 cm. in size and weighing about 337 g., is a "green-gray breccia" (1). It is the youngest among the four samples collected from the Station 7 boulder (2).

Megascopically, 77135 is a gray, vesicular, fine-grained phyric crystalline rock containing scattered white feldspathic clasts and greenish yellow olivine xenocrysts. The matrix consists mainly of crinkly, pale brown pyroxene and grayish transparent plagioclase with black specks of ilmenite. Most of the sample is highly vesicular (designated below as part A) but a smaller part is less vesicular and finer-grained (designated below as part B). The grain size of the pyroxenes in the matrix ranges from approximately 0.2 to 0.8 mm. in A and is less than 0.5 mm. in B. Most vesicles are spherical and less than 2 mm. in diameter, but a few spherical and some elongated vesicles are as much as 1 cm. long. Some contain euhedral troilite.

Several kinds of xenoliths, mostly light colored, are enclosed in 77135. The most abundant kind is a light gray, vuggy, recrystallized troctolitic breccia with poikiloblastic orthopyroxene in the matrix. This breccia xenolith itself contains xenoliths of medium-grained olivine-rich troctolite and fine-grained granular troctolitic anorthosite and Ni-Fe particles. This type of xenolith is more abundant in B. (The largest clast of this kind is about 3x2x1 cm. and is being studied in detail by the Station 7 boulder consortium.) Another type of material present as large clasts is white, fine-grained, recrystallized troctolitic anorthosite with a sugary granular texture. (One such clast, 1.5x1x0.5 cm., enclosed in A is also being studied by the consortium.) Small, dark, very fine-grained xenoliths are present, but they have not been studied. Rare spinel-bearing troctolitic xenoliths are also present.

This suite of xenoliths, more than one generation, is characteristically highly feldspathic, grading from troctolitic anorthosite to troctolite in composition. All are crystalline. Most xenocrysts are probably crushed derivatives of some of the coexisting xenoliths; most are either olivine (Fo_{71-92}, some with rims near Fo_{71}) or plagioclase (An_{79-97} with rims ranging from An_{80} to An_{95}).

The matrix of 77135 consists of calcic plagioclase and poikilitic clinopyroxene with subordinate amounts of olivine and accessory ilmenite, interstitial K-rich material, apatite(?), troilite and metallic iron. The CIPW norm of the bulk rock gives about 53% plagioclase, 31% pyroxene, 13% olivine and 3% ilmenite (1). Texturally, the matrix is formed of abundant poikilitic clinopyroxene locally separated by patches of granular olivine and anhedral plagioclase. Plagioclase in the matrix occurs in two distinct morphological types: 1. as small, sharply defined laths or elongated platy inclusions (An_{91}) in the poikilitic clinopyroxene, and 2. as stubby laths and anhedral grains associated with granular olivine grains (An_{89}). Locally interstitial to the anhedral plagioclase are materials high in K_2O. The poikilitic clinopyroxene grains are of both pigeonite and augite. Dominant is a very pale brown pigeonite with very low to low content of CaO (3.2-5.2 wt. %). (The identification of pigeonite is based not on the chemical data but on

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qualitative optical properties and X-ray powder diffraction and single crystal investigations.) Augite with higher birefringence and much higher calcium content is minor. Traces of orthopyroxene were also detected but its specific occurrence and significance is still being evaluated. Olivine occurs both as rounded inclusions in the pigeonite and as irregular grains associated with anhedral plagioclase. Ilmenite and metallic iron occur as interstitial material between poikilitic pigeonite and anhedral plagioclase. The sequence of crystallization appears to be (1) olivine and lath-shaped plagioclase, (2) poikilitic clinopyroxenes, anhedral plagioclase and granular olivine, and (3) ilmenite, troilite, metallic iron and potash-rich residuum.

Mineral compositions of the matrix as well as those of several types of xenoliths are given in Table 1. In general, the plagioclase and olivine in the matrix of 77135 are respectively less calcic and richer in iron than those in the xenoliths. Pigeonite is the dominant pyroxene in the matrix and orthopyroxene in the xenoliths.

The bulk chemical composition of 77135 including some of the xenoliths and many xenocrysts it contains (Table 2) is characterized by its moderately high SiO_2 (about 47 wt.%) and Al_2O_3 contents (about 18 wt.%), relatively high MgO/FeO, and moderate contents of Na_2O, K_2O, P_2O_5 and TiO_2. It is a major rock type among the Apollo 17 samples returned. It is similar to a small group of Apollo 16 rocks represented by 60315, 62235, and 65015, and to a group of Luna 20 coarse fines particles, and to heterogeneous glasses of impact origin from Apollo 11, 12, 14, and 15 (Table 2). Some of the Apollo 16 rocks cited may have a metamorphic history and the glasses do not necessarily represent the same rock type. We wish to point out and emphasize that rocks with composition such as 77135 are widespread on the lunar surface, and it is probable that pigeonite feldspathic basalt like 77135 is more abundant than anorthosite in the lunar highlands.

Petrographic data obtained so far suggest that 77135 crystallized from a fragment-laden melt of pigeonite feldspathic basalt composition. We have not found any evidence of shock or thermal metamorphism after it crystallized. Whether the melt was of impact or igneous origin is not easy to determine (3). Its bulk composition plots near the plagioclase-pyroxene cotectic line in the ternary system forsterite-anorthite-silica, particularly if the olivine and plagioclase xenocrysts could be subtracted from the analysis shown in Table 2 (4). Age information and source area information are being obtained, hence it would be premature to speculate on its origin. We are, however, impressed with many arguments in favor of an igneous origin. These will be fully developed as the consortium investigation of this rock progresses.

References

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Table 1. Composition of minerals in matrix and xenoliths in 77135, based on electron-microprobe data*

	Matrix in 77135,16 77135,26	Recrystallized troctolitic breccia in 77135,112	Medium-grained troctolite in 77135,112	Troctolitic anorthosite in 77135,27	77135,112
Plagioclase					
laths	An_{87}, An_{91}		An_{95}		
anhedral	An_{89}	An_{95}		An_{96}	An_{96}
xenocryst		An_{90}			
K-feldspars (?)	trace	trace plus			
Pigeonite					
poikilitic	$Wo_{5-12}En_{76-67}Fs_{19-21}$				
xenocryst		$Wo_{14}En_{69}Fs_{17}$			
Augite					
poikilitic	$Wo_{31-39}En_{55-45}Fs_{14-16}$				
non-poikilitic		$Wo_{24}En_{61}Fs_{15}$		$Wo_{20}En_{61}Fs_{19}$	n.d.
xenocryst		$Wo_{35}En_{51}Fs_{14}$			
Orthopyroxene					
poikiloblastic	none	$Wo_{5}En_{77}Fs_{15}$			
nonpoikiloblastic			$Wo_{5}En_{79}Fs_{16}$	$Wo_{4}En_{75}Fs_{21}$	n.d.
Olivine					
in poikilitic pigeonite	Fo_{66-79}				
in matrix	Fo_{64-72}	Fo_{78}	Fo_{78}	Fo_{74-75}	Fo_{77}
Ilmenite (wt.%)					
MgO	4.8-6.4				
FeO	38.4-39.8				
TiO_2	51.4-53.4				

*Analyzed by Jean A. Minkin and E.C.T. Chao

Table 2. Comparison of chemical composition of 77135 with other highland rocks in weight percent

	77135,2(1)	76315,2(1)	72435,2(1)	60315,3(5)	Luna 20 High-Al basalts (6)	Apollo 11 glass(7) A9	Apollo 12 glass(7) K12	Apollo 14 glass(8) 09	Apollo 15 glass* 25-12A
SiO_2	46.13	45.82	45.72	45.61	46.6	47.7	46.2	47.6	47.8
TiO_2	1.54	1.47	1.54	1.27	0.64	1.80	1.99	2.22	1.32
Al_2O_3	18.01	18.01	19.23	17.18	19.5	17.9	17.6	18.0	18.2
FeO	9.11	8.94	8.70	10.53	8.6	9.5	8.9	8.8	8.8
MnO	0.13	0.11	0.11	0.12	0.12	0.17	0.08	0.07	0.19
MgO	12.63	12.41	11.63	13.15	10.9	9.1	10.0	11.9	11.2
CaO	11.03	11.06	11.72	10.41	12.6	11.6	12.2	12.2	10.8
Na_2O	0.53	0.57	0.52	0.56	0.42	0.69	0.38	0.26	0.76
K_2O	0.30	0.27	0.23	0.35	0.14	0.30	0.12	0.14	0.39
P_2O_5	0.28	0.29	0.27	0.45	0.11	0.18	n.d.	0.10	0.16
S	0.08	0.08	0.08	0.14	n.d.	n.d.	n.d.	n.d.	n.d.
Cr_2O_3	0.20	0.19	0.20	n.d.	0.20	0.10	0.19	0.32	0.26
Total	99.97	99.22	99.95	99.77	99.83	99.	98.	102.	100.

*Boreman and Minkin unpublished data 1973.