CHEMISTRY, MINERALOGY, AND PETROLOGY OF MARE BASALTS FROM APOLLO 15 RAKE SAMPLES, E. Dowty, K. Keil and M. Prinz, Department of Geology and Institute of Meteoritics, University of New Mexico, Albuquerque, New Mexico 87106

Textures in 28 mare basalts from three Apollo 15 stations were studied microscopically, and bulk and mineral compositions were determined with the electron microprobe (Table 1; Figs. 1-6). In general, these basalts are more similar to those from Apollo 12 than Apollo 11 or Luna 16, particularly in their relatively low Ti contents. Rake basalts from Hadley Rille (9a) and St. George Crater (2) are similar in composition but may be divided into: pyroxene basalt (I); olivine basalt (II); and olivine microgabbro (III) when textures are also considered (Fig. 1). Three basalts from Spur Crater (7) form a separate group (IV).

I. Pyroxene basalt (116, 118, 125, 666, 682, 684) are characterized by highly and systematically zoned (Fig. 2) hollow pyroxene phenocrysts in a fasciculate groundmass of pyroxene, plagioclase and ilmenite laths. Silica is distinctly higher and magnesia lower than in the other groups; olivine is minor or absent in the norm. A few skeletal olivine phenocrysts are present in some of the rocks (125, 666, 682). Chromite and ulvöspinel approach the pure end members of the lunar series more closely, and the gap between the two is more pronounced, than in any other lunar basalt. Plagioclase is slightly more sodic than in the other two groups (Figs. 3 & 4). Rocks 116 and 684 are more gabbroic in texture, but their bulk and mineralogical compositions places them in group I. Rock 116 has the highest silica content of any of our basalts and contains long (ca. 1mm) needles of tridymite.

II. Olivine basalt (105, 607, 647, 665, 669, 676, 678) contain zoned (Fo_{70}-Fo_{45}) microphenocrysts of olivine (ca. 0.5mm)(Fig. 5) in a fine groundmass of pyroxene, plagioclase, ilmenite and a few smaller olivine crystals. Outer margins of olivine phenocrysts are euhedral but are embayed so that the overall outline tends to be ameboid. Groundmass pyroxenes are almost equant and often enclosed poikilitically in somewhat larger plagioclase laths which tend to be fasciculate. Pyroxene, plagioclase and spinel compositional trends appear to be similar to those in group III. Group II seems in general to have slightly lower magnesia content than group III.

III. Olivine microgabbro (610, 613, 615, 617, 620, 623, 633, 641, 643, 651, 663, 672) have somewhat variable textures with generally fairly uniform and coarser grain size. Olivines are zoned, but less than in group II. Pyroxenes may be large, but are only moderately zoned (Fig. 6) and are not hollow. Plagioclase is sometimes poikilitic, enclosing olivine and pyroxene, and sometimes has central cores of pyroxene. In groups II and III, spinel solid solution series appear to be more complete than in group I, although there is still a paucity of intermediate compositions.

IV. Two rocks from Spur Crater (385, 387) have gabbroic textures and mineralogical compositions similar to group III, but much higher Mg and lower Si contents, resulting in high modal olivine content (30-35%). Rock 388 is unique among rake basalts in having lower FeO and higher Al_2O_3. It is fairly coarse, lacks olivine and has abundant feldspar. Furthermore, plagioclase is

MARE BASALTS FROM APOLLO 15 RAKE SAMPLES

Dowty, E. et al

distinctly zoned (An_{94}-An89); spinel compositions cluster around $Cm_{28}Uv_{62}He_{10}$; and pyroxene and plagioclase laths show sub-parallel alignment. This rock has low KREEP component and a positive europium anomaly [1].

Conclusions: (1) There are probably at least three different mare basalt units at or near the Apollo 15 site, corresponding to groups I, II, and III. Groups II and III, however, could conceivably be part of the same flow or intrusive unit, group III representing a part enriched in cumulate olivine. Group I probably has no direct genetic relationship to groups II and III. Actually, trace element data suggest that there may be more than three units; rock 643, which we are unable to distinguish from other members of group III, has lower REE and a positive europium anomaly [1]. In view of the distinct nature of the three basalts from Spur Crater, we infer either that they were transported from a more distant mare location, or that they are from earlier strata now buried at Apollo 15.

(2) We find no evidence that the distinctly porphyritic texture of group I rocks indicates a multi-stage cooling history; rather, this texture was produced by essentially continuous and presumably rapid crystallization under supercooled conditions, because (a) a distinct tendency toward correlation of phenocryst and groundmass crystal size exists; (b) pigeonite cores of pyroxene phenocrysts always show a distinct, though relatively small, major element zoning; (c) phenocrysts increase continuously in Al and Ti from cores towards rims, suggesting that nucleation of plagioclase and ilmenite, which normally contain the major proportion of these elements, was delayed, and, thus, the liquid was metastably supercooled relative to these phases.

(3) The finest-grained and presumably most rapidly cooled group I rock (125) shows the most regularity in the pyroxene phenocryst zoning, with no evidence of sector or oscillatory zoning. The groundmass is extremely fine (vitrophric). Phenocrysts in other group I rocks with larger groundmass crystals, show oscillations and sectoral differences in their outer zones. We conclude that this is primarily the result of sudden onset of plagioclase crystallization, which would (a) cause rapid and locally variable depletion of the melt in Al and, particularly, Ca; (b) release latent heat of crystallization, which under supercooled conditions could cause the temperature of the melt to <u>increase</u> for a short time, in turn causing the path of crystallization to "backtrack" temporarily.

(4) Pyroxenes of groups II and III show no evidence for a miscibility gap between magnesian pigeonite and augite, as do those of group I. The former may have crystallized at sufficiently high temperatures that the pyroxene solvus was not intersected by the rock solidus. Group I probably crystallized at a lower temperature, either because of its greater Si and lower Mg contents, or of a greater degree of supercooling, or both.

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Reference: (1) Laul, J. C., and Schmitt, R. A. (1972) in "The Apollo 15 Lunar Samples," Lunar Science Institute, 225-228.

MARE BASALTS FROM APOLLO 15 RAKE SAMPLES

Dowty, E. et al.

Table 1: Average composition (in weight percent) of mare basalt groups from Apollo 15 rake samples.

	Group I Pyroxene basalt (6 analyses)		Group II Olivine basalt (7 analyses)		Group III olivine micro-gabbro (12 analyses)		Spur Crater		
	Avg.	St.dev.	Avg.	St.dev.	Avg.	St.dev.	15385	15387	15388
SiO_2	48.0	0.8	45.2	0.9	44.7	0.9	41.4	41.8	45.7
TiO_2	1.4	0.4	2.2	0.2	1.8	0.4	1.54	1.12	1.99
*Al_2O_3	12.2	1.1	11.6	1.0	11.4	1.3	11.4	10.0	14.2
Cr_2O_3	0.41	0.1	0.45	0.10	0.47	0.08	0.81	0.54	0.29
+FeO	19.0	1.0	20.6	0.8	20.5	0.8	19.1	21.5	15.5
MnO	0.26	0.02	0.27	0.02	0.25	0.02	0.24	0.28	0.20
MgO	8.1	1.5	8.8	0.8	10.7	1.1	15.9	17.1	9.5
CaO	10.7	0.9	10.5	0.7	10.1	0.6	7.9	7.5	10.4
Na_2O	0.37	0.05	0.34	0.03	0.33	0.07	0.32	0.28	0.39
K_2O	0.05	0.03	0.03	0.02	0.03	0.02	*	0.01	*
P_2O_5	0.07	0.03	0.08	0.01	0.09	0.05	0.03	0.04	0.02
Total	100.56		100.07		100.37		98.64	100.17	98.19

* not detected

\+ Comparison with other Apollo 15 basalt analyses suggests that our Al_2O_3 values may be systematically high by 1-2 wt.%, and our FeO values systematically low by 1-2 wt.%. We are currently investigating this problem.

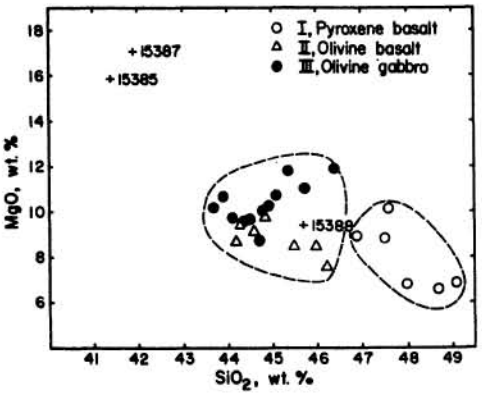


Fig. 1. MgO vs. SiO_2 for Apollo 15 rake basalts

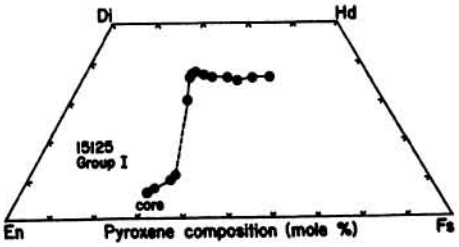


Fig. 2. Typical pyroxene zoning in phenocrysts of group I basalts

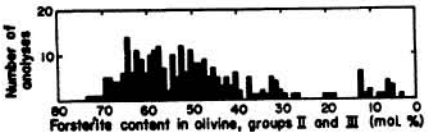
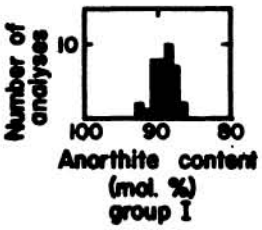
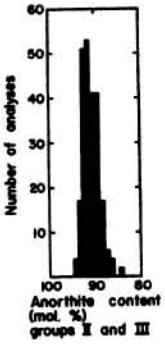


Fig. 5. Histogram of olivine composition in group II & III basalts





Figs. 3, 4. Histograms of feldspar compositions in group I and II & III rocks, respectively (excluding analyses with >1 mole % Or)

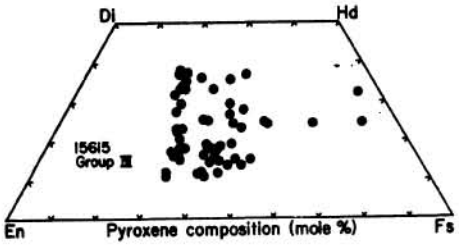


Fig. 6. Random pyroxene analyses from rock 15615. This pattern is typical for pyroxenes from group II and III basalts