PETROGENETIC RELATIONSHIPS OF SPINEL-TROCTOLITES, TROCTOLITES, AND ANORTHOSITIC-NORITES, P.W.Weiblen*, B.N.Powell**, and F.K.Aitken**, *Dept. of Geology and Geophysics, University of Minnesota, Minneapolis, Minn., 55455; **Dept. of Geology, Rice University, Houston, Tex., 77001.

Current interpretations of the growing volume of chemical data on lunar samples of all types reveal that impact processes on the Moon have left intact the chemical signatures of a relatively few sequential large scale magmatic events [1,2] . Analysis of petrographic data, on the other hand, reveals a bewildering diversity which reflects the local complexity of impact processes. Despite this, the petrographic data have aided in the development of a generally accepted model for the origin of the lunar crust. Plagioclase fractionation is conceded to be the dominant mechanism for the formation of the feldspathic crust. This implies complementary cumulates at depth, the volume and mineral assemblages of which reflect the original bulk composition [3]. Subsequent magmatic events could have produced a variety of rock series by partial melting of different cumulates with or without subsequent differentiation. The fundamental petrologic problem is to recognize the total diversity of rocks and distinguish the early cumulates from younger <u>derived</u> rocks.

The current literature on the petrogenetic relationships among highlands rocks is particularly confusing. For example, the suggestion has been made that the spinel-troctolites and anorthositic-norites are all part of a single rock series [4]. However, experimental work [5] suggests that the spinel-troctolites are near-surface melts generated from source rocks which are <u>not</u> simply related to the anorthositic-norites. To clarify these relationships we have compiled textural information and applied mass balance methods to mineral compositional data on a variety of relevant lithic fragments to provide constraints on proposed genetic relationships between spinel-troctolites and anorthositic-norites. We have examined the 1-4mm fraction of several lunar soil samples and report here textural and mineral compositional data on lithic fragments containing either Sp+Pl+Ol(±Opx) and Pl+Ol(±Opx). Similar data on the polymict breccia 67915 discussed below are presented in a companion abstract [6]. The lithic fragments exhibit textures which reflect a variety of processes including deep-seated and near-surface magmatic crystallization as well as several impact-related processes such as shock, melting, and thermal metamorphism. We consider fragments with basaltic textures to be of particular interest because a common near-surface environment of crystallization can be inferred. In our samples such materials fall into two distinct textural groups: those in which olivine appears to precede plagioclase in the crystallization sequence (Group A) and those in which plagioclase precedes olivine (Group B). In Group A fragments the assemblages Sp$<$Ol$>$Opx$<$Pl, Sp$<$Ol$<$Pl and Ol$<$Pl were found. In contrast, Group B fragments contain Sp$<$Pl$>$Ol$>$Opx, Pl$>$Ol$>$Opx, and Pl$>$Ol$<$Opx.

Unusual features found include subhedral grains of rutile in and interstitial to olivine in a Group A fragment; melt inclusions in spinel and interstitial glasses which texturally suggest two immiscible melts in a Group B fragment. In both groups spinel occurs both in and interstitial to olivine; but we observe that euhedral spinels are most common in fragments with relatively large amounts of glass, while glass is less abundant in fragments containing resorbed, rounded, or no spinel. Thus preservation of spinel in both groups can be attributed to rapid crystallization. Because of a similar environment of crystallization for both textural types we conclude that the difference in olivine, pyroxene, and mesostasis modal abundances must be related to differences in composition of two distinct parent melts of whatever origin.

An FeO-MgO variation diagram provides a convenient framework in which to summarize and discuss some of the compositional data (Fig. 1). There appears to be a continuum of olivine compositions, but Group A olivines fall in the range of the VHA basalts (e.g. 62295) (Fo 94-80) and do not overlap with those from Group B (Fo 80-70). Group B low-Ca pyroxenes and olivines fall in the range of those of poikilitic norites [7 and this study]. The most Mg-rich spinels occur in Group A fragments and the most Fe-rich pleonastes are found in Group B fragments. The compositions of olivines in polymict breccia 67915 span those of Groups A and B and extend to more Fe-rich compositions. Low-Ca pyroxene and spinel in the peridotite and sodic ferrogabbro clasts in 67915 are all more Fe-rich than those in Group B fragments. Thus, although the textural data suggest possibly two distinct parent liquids for the fragments studied, the mafic phase chemistry appears to be interpretable in terms of a simple differentiation sequence. This continuum and overlap in Fe-Mg data for possible liquid compositions as well as minerals has been illustrated by Steele and Smith [8].

From the similarity of the phase chemistry of the VHA basalt 62295 [9] to that of Group A fragments and a similar relationship between Group B fragments and poikilitic anorthosite 60315[7] (Fig. 1), it appears that our data are pertinent to the question of the relationships between these two feldspathic rock types. Could a melt or cumulates of the composition of 60315 be generated from a VHA basalt? Mass balance for Si, Al, Ti, Fe, Mg, Ca, Mn, and Na show this to be possible by plagioclase and olivine fractionation. However, such fractionation does not produce adequate enrichment of K (62295 contains 0.11% K_2O c.f. 0.49% in 60315 [10]). (It is interesting to note that the most abundant occurrence of possible high-K mesostasis was found in Group B fragments.) Furthermore, the observed Fe-Mg trends in analyzed melt compositions from 62295 [5,9,11] do not show the necessary Fe enrichment (Fig.1). The observed trends are consistent with the early and abundant olivine crystallization in Group A fragments. The concave upward trend for Fe enrichment requires early and abundant plagioclase separation, but this is evidenced only in Group B fragments, in which the olivine compositions are not appropriate. Both of these observations, which argue against a simple fractionation relation between 60315 and 62295 rock compositions, are in agreement with the interpretation of REE and Sr systematics of these samples [2]. Thus our data support the concept that two distinct feldspathic lunar rock series have been sampled. One is inherently low in LIL elements and is exemplified by a variety of troctolites and spinel-troctolites (Group A).

PETROGENETIC RELATIONSHIPS OF HIGHLANDS ROCKS

Weiblen, P.W. et al.

The other may include similar rock types (but Group B varieties) but is dominated by anorthositic-norites which contain higher LIL element and Fe contents than the former. The idea that the two rock series could be derived from related cumulates of an unspecified liquid as suggested by Hubbard et al. [2] and Walker et al. [3] is supported by our data and implicit in our interpretation. Mass balance calculations indicate that the peridotite and sodic ferrogabbro clasts in 67915 could be derived from a 60315 melt but not from a 62295 melt. This is due to the high Fe/Mg ratios and K contents of these clasts. The troctolite clasts in 67915 on the other hand could be derived from a 62295 liquid. Thus we see evidence that polymict breccia 67915 contains clasts which could be part of a sequence of possible source rocks which gave rise to the two postulated magma series.

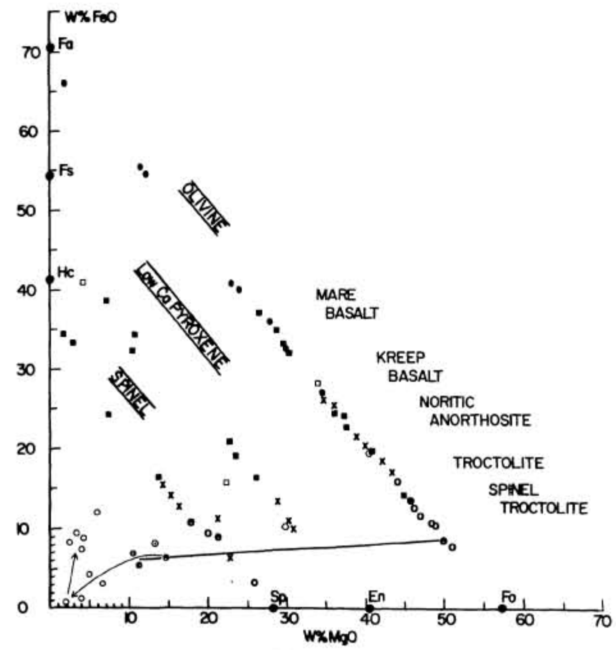

FIGURE 1. FeO-MgO wt.% variation diagram. Microprobe compositional data for olivine, low-Ca (<3%CaO) pyroxene, low-Ti (<6%TiO_2) spinels and melt inclusions; also some bulk compositions. Light arrows indicate possible 62295 fractionation trend; heavy line is a possible tie line between an observed olivine in 62295 and a derived liquid. Symbols plotted are:
Θ: 62295 [9]
0: Group A fragments
X: Group B fragments
■: 67915 [9]
⬭,⊙: 60315 [7] and bulk comp. [10]
□: 68415 [12]
⊙: 62295 bulk composition [10]
○: 62295 melt inclusions [9]
⊖: 62295 experimental melt [11]
⦶: 62295 experimental melt [3]
●: Mare basalts for comparison [9]

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