MINERALOGY AND COMPOSITIONAL VARIATIONS IN LUNAR FERROAN ANORTHOSITES; James J. McGee, U.S. Geological Survey, Reston, VA 22092.

As part of continued detailed studies of the mineralogy of the ferroan anorthosites [1, 2], mineral compositional data have been obtained for sixteen "typical" ferroan anorthosites that contain ~2-3% ferroan low-Ca pyroxene and olivine (mg'= 100 x molar {Mg/Mg+Fe} < 70) [3]. High-precision (~1% or better) microprobe analyses, with minimum detection limits of 20-60 ppm were obtained for the major and minor elements in pyroxene, olivine, and plagioclase in anorthosites 15415, 60015, 60025, 60055, 60215, 61016, 62255, 64425, 64435, 65035, 65315, 67525, 67535, 67536, 68515, and 69955. Most of these anorthosites have been analyzed to varied extents in previous studies [5-8]. However, comparison of an internally consistent data set should improve our knowledge of the petrogenesis of the ferroan anorthosites. These anorthosites have been affected to varied degrees by brecciation, shock, and reheating during meteorite bombardment of the lunar crust. These impact effects make it extremely difficult to ascertain the compositions of the original anorthosites, information that is needed to help elucidate the processes of lunar crust formation.

Samples 15415, 60015, 60025, 60055, and 69955 are hand samples of cataclastic anorthosite. Samples 67525, 67535, and 67536 are rake samples of fine-grained, granulated and recrystallized anorthosite. The other eight samples are clasts of cataclastic anorthosite from breccias [4]. The anorthosites show varied degrees of shock and recrystallization; in some samples, some plagioclase has been converted to maskelynite. Several samples have vesicular glass rinds on one or more surfaces. Plagioclase grains are seriate, with fragment sizes as much as 5-6 mm in 15415, 60015, 61016, and 62255, and 1-3 mm in all of the other samples, except the finer (<0.5 mm) rake samples. In 15415, 60055, and 65035 low-Ca and high-Ca pyroxene are present in approximately equal proportions. In the rest of the samples low-Ca pyroxene is the dominant mafic mineral. Sparse olivine is present in only five of the anorthosites. Most of the anorthosites also have trace ilmenite, chromite, and troilite. Three samples (64435, 65315, and 68515) also have rare (ZnFe)S.

Pyroxene. The low-Ca pyroxenes cluster into two subtle but distinct groups. In nine of the anorthosites this mineral has relatively high magnesium (mg'= 61-67) and low calcium contents ($Wo_{1.9}$). In the other seven anorthosites the low-Ca pyroxene is more ferroan (mg'= 55-59) and more calcium rich ($Wo_{2.4}$). Low-Ca pyroxenes in individual anorthosites show varied compositions, predominantly due to varying Mg and Fe (not Ca) contents. Low-Ca pyroxenes are homogeneous (< 2% range in En) in seven of the anorthosites. Five samples have low-Ca pyroxenes with a continuous range of approximately 5-10% En. Three anorthosites (61016, 62255, and 64425) have a bimodal distribution and one sample (69955) has a trimodal distribution of pyroxene compositions. High-Ca pyroxenes are generally more homogeneous than low-Ca pyroxenes in their Mg and Fe contents. Pyroxenes with relict igneous texture show major and minor element compositional trends similar to those of the entire pyroxene population.

Cr and Ti contents of low-Ca pyroxenes are nearly constant across the entire range of mg'. High-Ca pyroxenes are slightly more varied in their Cr and Ti contents. Both the low-Ca and high-Ca pyroxenes have Al contents in excess of that required for coupled substitution of Cr-Al (as $CrAlO_3$) and Ti-Al (as $CaTiAl_2O_6$) in the pyroxene structure, indicating the presence of the $^{VI}Al^{IV}AlO_3$ component. Overall, the enrichment of Al in the pyroxenes is uniform.

Mn concentrations show more varied behavior than those of the other minor elements in the pyroxenes. The ratio Mn/(Mn+Fe) is approximately constant in low-Ca pyroxenes with mg'= 48 to 60. Low-Ca pyroxenes with mg' > 60, however, have a larger range and overall higher value of Mn/(Mn+Fe). Low-Ca pyroxenes in most of the anorthosites show a fairly regular positive correlation of MnO and FeO contents; however, in two samples (68515, 60015) the low-Ca pyroxenes are homogeneous in mg' and other minor element contents but have highly variable MnO.

Plagioclase. Plagioclase compositions in the anorthosites show only slight variations (Figs. 1, 2). Within individual samples, An contents of plagioclases have a maximum range of approximately 2 percent. Among the samples average compositions vary by less than 2% An, ranging from $An_{96.5}$ in 64425 to $An_{98.1}$ in 61016 and 67525. FeO and MgO concentrations in plagioclase are varied, but most samples show systematic decreases in MgO (Fig. 1) and FeO with increasing An content. However, the abundances of these elements in plagioclase are somewhat varied among the samples and trends for FeO concentrations are less well defined than those for MgO. Plagioclases in relict lithic clasts generally show the same trends as plagioclases in the entire anorthosite (Fig. 2).

Discussion. Differences in texture and grain size of the ferroan anorthosites appear to be a function primarily of post-crystallization shock and brecciation history. Exsolution or pigeonite inversion and equilibration of pyroxene compositions are also attributable to post-crystallization, subsolidus thermal processes.

Most of the data presented here are consistent with derivation of the ferroan anorthosites from a common parent magma. The prevalent trends of increasing MgO and, less distinctly, FeO with decreasing An in the plagioclase in most of the anorthosites are consistent with derivation of those anorthosites from the same, normally fractionating magma. The pyroxenes show a continuous compositional progression, consistent with crystallization from an evolving magma. The Cr, Ti, and Al contents of the pyroxenes show generally smooth trends, also consistent with derivation from a common magma under crystallization conditions that remained approximately the same. Some anorthosites, such as 60025 [2], 60015, and 65035, show positive correlation of mg' in plagioclase with An content. There may also be a positive correlation of mg' in plagioclase versus mg' in relic low-Ca pyroxenes among most of the anorthosites, although this correlation is poorly constrained due to the large errors (±5) in plagioclase mg'.

Some aspects of the mineral chemistry are not easily explained by crystallization of all these rocks from a single parent magma: the enrichment of Mn in pyroxenes in some of the anorthosites; the slight variations in Fe and Mg abundances in plagioclase; and the lack of a well-defined trend of increasing mg' in pyroxene with increasing An in plagioclase in most of the anorthosites. To date, a strong positive correlation of relict pyroxene mg' versus plagioclase An content has been identified in only one sample, 62255. Variations in plagioclase Mg and Fe concentrations may reflect local heterogeneities in the crystallizing magma. The varied proportions of mafic minerals in the anorthosites suggests that the amount of trapped liquid varied during crystallization. Redistribution of Fe and Mg in plagioclase during post-crystallization shock and annealing may also have contributed to the heterogeneities in their concentrations. The anomalies in the mineral compositions in the anorthosites do not overwhelmingly preclude derivation of these rocks from a single parent magma; the consistences in mineral compositions are more common than the inconsistencies, which probably reflect complex processes during crystallization.

REFERENCES. [1] McGee J.J. (1989) *Lunar Planet. Sci. XX*, 664. [2] James O.B., McGee J.J. and Lindstrom M.M. (1990) *Lunar Planet. Sci. XXI*, this volume. [3] James O.B., Lindstrom M.M. and Flohr M.K. (1989) *PLPSC* 19, 219. [4] James O.B. (1981) *Lunar Planet. Sci. XII*, 506. [5] Ryder, G. (1982) *Geochim. Cosmochim. Acta, 46*, 1591. [6] Nord G.L., Jr. (1983) *LPI Tech. Rep. 83-02*, 62. [7] Dixon J.R. and Papike J.J. (1975) *PLSC* 6, 263. [8] Ryder G. and Norman M. (1980) *Catalog of Apollo 16 Rocks, JSC* 16904, 1144pp.

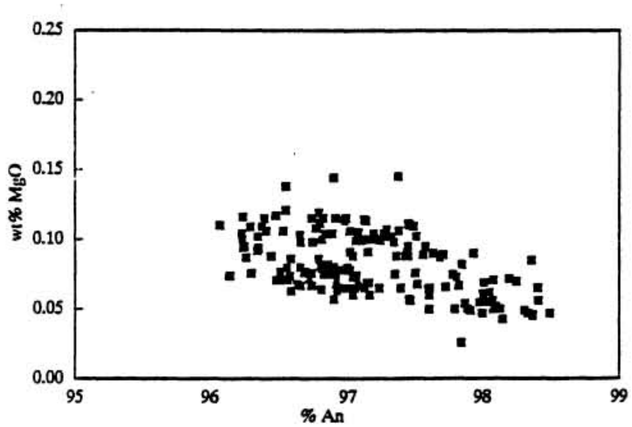

Fig. 1 MgO versus anorthite (An) content of individual plagioclase grains in six different anorthosites.

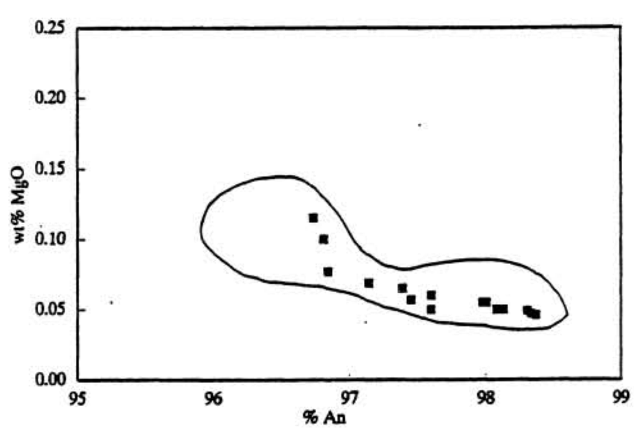

Fig. 2 MgO versus An content of plagioclases in sample 69955,28. Field represents range for entire sample; points represent data for a single relict clast.