FERROAN ANORTHOSITE 60025, ADCUMULATE GROWTH, AND BULK MOON CONSIDERATIONS. Graham Ryder, Lunar Curatorial Laboratory, Northrop Services, Inc., P.O. Box 34416, Houston, Texas 77034.

60025 is a large (1836 g) sample of coarse-grained cataclastic anorthosite which is not contaminated with meteoritic siderophiles. All of the original allocations were cut from a single slab containing sparse mafic mineral grains. Mafic mineral-rich clumps on one end of the rock, several millimeters by several centimeters in dimension, were not sampled. In conjunction with a radiogenic isotope study (K. Marti and G. Lugmair), I have sampled and made microprobe analyses of the minerals in both the mafic clumps and the slab. The mafic minerals in the clumps are more magnesian than those in the slab, and consist of olivine and inverted pigeonite, whereas those in the slab are inverted pigeonite and augite. However, the details of the mineralogy suggest that all pieces of 60025 are from a sequence of related anorthosites (below). An undocumented chip which was loose in the same sample bag as 60025, analyzed by (1), has a mineralogy identical to the clumps, hence it is undoubtedly a part of 60025. Therefore, to elucidate spatial relationships and more completely assess mineral variation, I have made many analyses of minerals in a thin section from this chip.

The microprobe analyses are summarized in Figs. 1-5. There is a range of compositions (Figs. 1 - 3) but individual grains are quite homogeneous (Figs. 2, 3). There are several systematic variations for the sample as a whole. The most magnesian mafic minerals are adjacent to the most calcic plagioclases, and the most ferroan mafic minerals are adjacent to the most sodic plagioclases. On an Mg* (mafics) v. An (plagioclase) diagram (Fig. 4), the data plot as a steep but positive (normal igneous) trend. Furthermore, FeO and Mg* <u>in plagioclase</u> correlate strongly with the Ab content (Fig. 5), and hence also with the mafic <u>mineral composition</u>. Such sympathy precludes the genesis of the mafic minerals by metamorphic exsolution from plagioclase, the accidental inclusion of the mafic minerals, or particularly complex relationships. The magnesian mafic clumps, which are large and contain chromite, are surely cumulus (not necessarily <u>settled</u>); and Haskin <u>et al</u>. (2) showed that the chemical variation among splits from the (more <u>Fe-rich</u>) slab could <u>not be</u> explained by varied amounts of trapped liquid, and that 60025 could in any case contain only negligible amounts of trapped liquid. There is no trace of the phosphate or other phase which would suggest the presence of trapped liquid in 60025.

The mineral and chemical data are consistent with the hypothesis that 60025 is a mixture of closely related materials, which formed by near-perfect adcumulate growth (<u>no</u> trapped liquid) from a liquid undergoing strong fractional crystallization. The parent <u>liquid</u> for the most primitive (i.e., highest Mg*) samples was saturated with olivine, plagioclase, pigeonite, and chromite, and evolved to one saturated with plagioclase, pigeonite, augite, and ilmenite. The steep trend for anorthosites on an Mg* v. An diagram (Fig. 4) can be attributed to the very low Na_2O content of the liquid, and its progressive fractional crystallization (3). While crystal accumulation is normally perceived as a pile of crystals with liquid between, near-perfect adcumulate growth can occur if growth takes place at the crystal-liquid interface. Then there is no physical accumulation of crystals grown elsewhere, nor trapped liquid at any stage. Such adcumulate growth of plagioclase is encouraged by shifts in phase boundaries with pressure: if a cotectic liquid convects upwards, it will be in the plagioclase field alone. The mineral and chemical data for most other anorthosites is consistent with such a model in general. For instance, a plot of calculated Mg* (liquid) v. Sm (rock) (Fig. 6) shows a correlation appropriate for the adcumulate model, but not for a trapped liquid model. {The two most aberrant samples are mafic mineral rich, 62236 and 62237 (11 and 13 in Fig. 6), and in these two cases Sm (rock) is not proportional to Sm (liquid)}.

If the adcumulate model is correct, the most primitive anorthosites, containing olivine, pyroxene, and plagioclase as cumulus phases, must have crystallized from a liquid at the ol-px-plag point in the Ol-Qz-An phase diagram. Trace element considerations suggest that the liquid had not undergone plagioclase separation (no negative Eu anomalies in calculated parent liquids) and little if any pyroxene separation, at least not pigeonite (flat heavy rare-earth pattern). If the liquid was undergoing strong fractional crystallization, olivine could not have persisted much after <u>any</u> pyroxene started to crystallize. Hence the crystallization path of the liquid was ol→opx?→pig→plag.

Because anorthosites are so widespread and complementary mafic cumulates have not been observed, they are probably the remnants of a crust floating on, and crystallizing at the surface of, a magma ocean originally of bulk Moon composition (4). If so, the inferred crystallization path suggests a Moon closer to the composition suggested by Ringwood (5) than most other postulated compositions, but even lower in alkalis. One can also infer that the Moon has REE abundances and patterns close to chondritic, but a subchondritic Ca/Al. According to experimental and trace element constraints, mare basalt sources are too magnesian (Mg* 75-85) and contain too much high-Ca pyroxene to be directly or simply complementary to the <u>known</u> anorthosites. Nor are other crustal rocks, such as the Mg-suite samples, closely <u>related</u> to anorthosites; in addition to their chemical differences they have a different crystallization sequence: ol→plag→px, in contrast with the ol→px→plag inferred for anorthosite parental liquid evolution.

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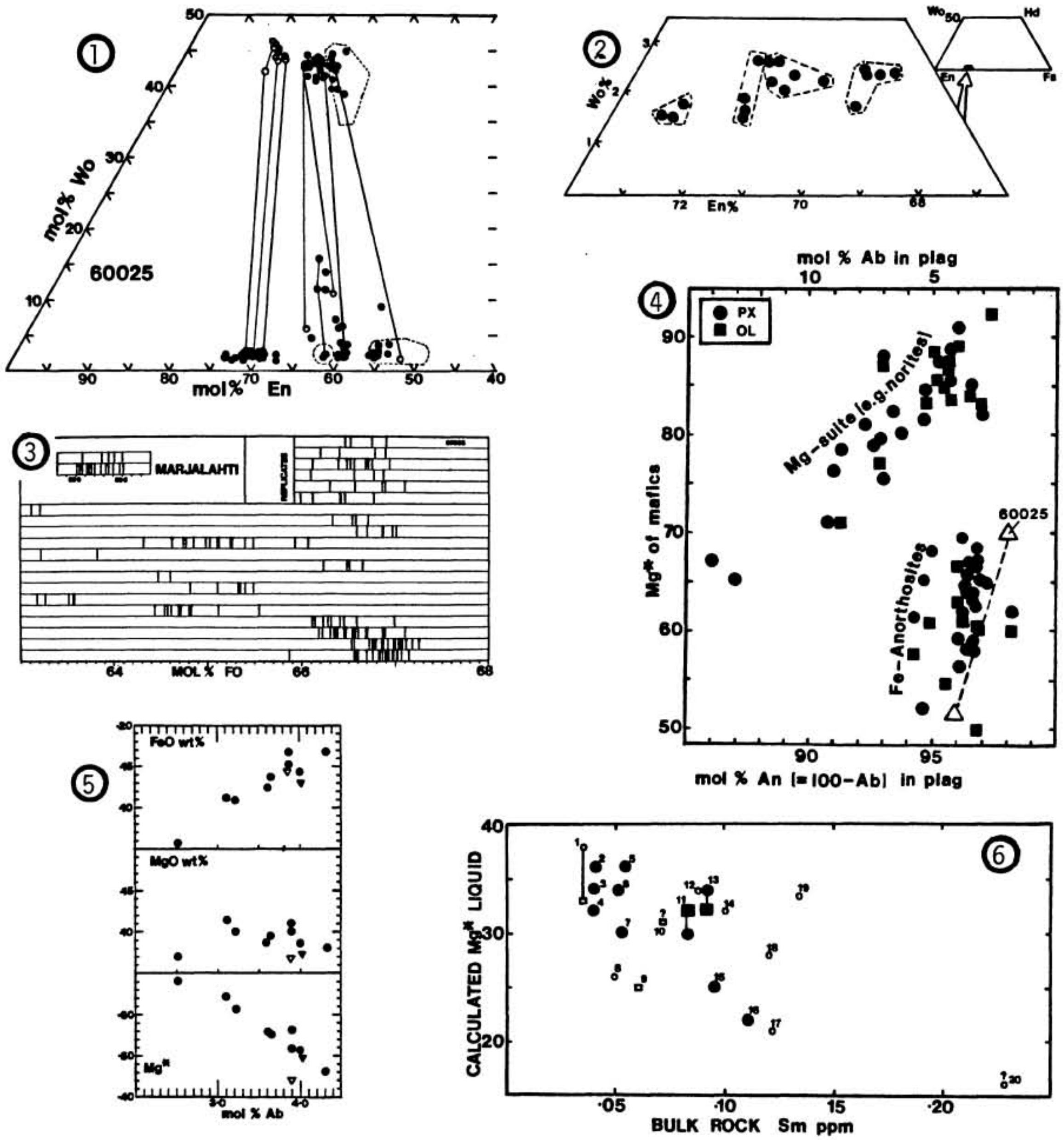

FIGURE CAPTIONS: (1) 60025. Px. compositions. Closed symbols, host. Open symbols, exsolved. Dashed lines, literature data fields. (2) 60025. Homogeneity and differences of 4 pyroxene grains from mafic clumps. (3) 60025. Olivine compositions: each horizontal band is a separate grain (except replicates of a single grain at top), each vertical stroke an individual point on the grain. Analyses of Marjalahti (standard) for comparison of dispersion. (4) Mg* (= atomic 100 Mg/(Mg+Fe)) v. An for lunar pristine highlands rocks, adapted from reference 6. (5) 60025. Minor element analyses for plagioclases. Triangles: slab samples. Solid, this study; open, reference 7. (6) Mg*, calculated for parent liquid from mafic mineral compositions, v. Sm (rock) for lunar anorthosites; literature data.

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