MINERALOGY, PETROLOGY AND CHEMISTRY OF SPLITS FROM LUNAR FERROAN ANORTHOSITE 60025: Odette B. James and James J. McGee, US Geological Survey, Reston, VA 22092, and Marilyn M. Lindstrom, NASA Johnson Space Center, Houston, TX 77058

Introduction: This abstract reports preliminary results of studies of subsamples from the mafic-mineral-rich part of ferroan anorthosite 60025. This part of 60025 is unusually mafic and some of its mafic minerals are unusually magnesian (Mg' about 70) for a ferroan anorthosite [1]. Because this rock has nearly an end-member mode and composition among ferroan anorthosites, its characteristics should shed light on genesis of the suite.

Four splits from three subsamples are being studied: two mafic-mineral-rich splits from a single subsample (,699LM and ,699SM); one plagioclase-rich subsample (,702PR); and one whole-rock chip (,691LM). The three subsamples were taken from areas of the parent rock as much as 3 cm apart. All splits were previously analyzed by instrumental neutron activation analysis (INAA) [2], and the analyzed materials have been thin sectioned.

Textures and modes: All the splits have similar cataclastic textures. They are aggregates of angular fragments set in a matrix of very finely granulated minerals; relict igneous texture is present only locally. The two mafic-mineral splits consist almost entirely of olivine and inverted pigeonite and contain only minor plagioclase and trace chromite. The plagioclase split contains only a few percent olivine, orthopyroxene and augite. The whole-rock sample consists of dominant plagioclase, minor olivine, orthopyroxene and augite, and trace ilmenite and chromite.

Mafic-mineral compositions: The mafic minerals within the two mafic-mineral splits and the plagioclase split have fairly homogeneous compositions within each split (Fig. 1a). The mafic-mineral splits contain nearly identical, relatively magnesian olivine ($Fo_{65.3-66.0}$) and pyroxenes (low-Ca pyroxene is $En_{69.9-70.4}$) (similar compositions were found by Ryder [1] in the mafic-mineral-rich areas of 60025). The plagioclase split contains more ferroan mafic minerals; olivine is $Fo_{58.2}$ and low-Ca pyroxene is $En_{54.9-58.8}$.

In the whole-rock split, the olivine is fairly magnesian ($Fo_{64-65.3}$) and the pyroxenes show a wide range of compositions, from magnesian to ferroan. The low-Ca pyroxene compositional range is $En_{49.3-70.4}$, and there is a cluster at the magnesian end of this range. In this split, mafic minerals of similar compositions tend to be spatially associated, and there are discrete patches, 1-2 mm across, in which the mafic minerals are all magnesian or all ferroan. Most commonly, however, areas that contain mostly one type of mafic-mineral association, either magnesian or ferroan, also contain sparse small scattered mafic minerals of the other type. Locally, magnesian and ferroan mafic minerals are closely juxtaposed and have a common grain boundary. In areas rich in mafic minerals, the mafic minerals are relatively magnesian; in areas rich in plagioclase, however, the mafic minerals can be all magnesian, all ferroan or show a range of compositions.

Plagioclase compositions: The results of high-precision electron-microprobe analyses of plagioclase are shown in Figs. 1b-d. In the analyses of plagioclases in the whole-rock split, grains spatially associated with relatively ferroan or with relatively magnesian mafic minerals were distinguished. Reproducibility of individual data points between runs on different days is: An mostly within 0.1; FeO and MgO mostly within 0.007%. Because of uncertainties in the compositions of the standards, the accuracy of the data set is probably not as well constrained as its precision. The An and FeO contents we measured compare well with the values obtained by Ryder [1]; our MgO values appear to be more precise than Ryder's.

Our data show distinct negative correlations of MgO and FeO contents with An content (Figs. 1c-d) and a positive correlation of Mg' (100 x molar Mg/Mg+Fe) with An content (Fig. 1b). Plagioclases associated with relatively ferroan mafic minerals (+ and x on Figs. 1b-d) or with relatively magnesian mafic minerals (open squares and triangles on Figs. 1b-d) show nearly identical ranges of An contents, An_{96-99}. Trends of FeO versus An are identical in both associations, but the plagioclases associated with relatively magnesian mafic minerals may have slightly higher MgO.

Rare-earth elements: We have made estimates of the rare-earth element compositions of the liquids in equilibrium with the four splits, following some of the procedures we used in our studies of troctolitic anorthosite from 64435 [3]. These estimates suggest that the liquids in equilibrium with each of the splits had roughly flat rare-earth patterns. Rare-earth contents in the estimated equilibrium liquids for the plagioclase split and the whole-rock sample were about 12 times chondrites and in the estimated equilibrium liquids for the mafic-mineral splits were about 20 times chondrites. Unfortunately, we cannot be certain that this difference in rare-earth contents is real, because the estimated compositions of the equilibrium liquids for the mafic-mineral splits depend strongly on the experimentally determined distribution coefficients for pigeonite and olivine,

whereas the estimated compositions of the equilibrium liquids for the other two splits depend strongly on the experimentally determined distribution coefficients for plagioclase.

Discussion: Our data show that the splits differ in mafic-mineral compositions. The mafic minerals are relatively magnesian in the mafic-mineral-rich splits and relatively ferroan in the plagioclase split. The whole-rock split apparently consists of a mechanical mixture of at least two parent ferroan anorthosites that differed widely in Mg' of their mafic minerals. Thus, it is unlikely that the minerals of all these splits were in equilibrium with the identical magma.

Our high-precision plagioclase analyses have produced the most interesting results of the study thus far. The pronounced slopes of the plots of MgO and FeO versus An indicate that the observed compositional variations are preserved igneous trends. The nature of these trends, plus the close juxtaposition of mafic-mineral grains varying in Mg', indicates that postcrystallization reequilibration of mineral compositions has been minimal.

Our data show that plagioclase which is spatially associated with relatively magnesian mafic minerals has the same range of An contents as plagioclase associated with relatively ferroan mafic minerals; this range of An is considerable, nearly as great as shown by the ferroan anorthosite suite overall. Plagioclases associated with both relatively ferroan and relatively magnesian mafic minerals are also identical in FeO contents, and the only difference we can find is a possible slight difference in MgO contents. Mg' in plagioclase is positively correlated with An content, indicating "normal" igneous fractionation processes, with Na enrichment accompanying Mg depletion in a crystallizing parent magma. Mg' of the plagioclase and Mg' of the associated mafic minerals are not strongly correlated, however; this observation suggests complex processes, perhaps involving buffering of plagioclase compositions, during crystallization.

References: [1] Ryder G. (1982) Geochim. Cosmochim. Acta 46, 1591. [2] Lindstrom M.M., unpublished. [3] James O.B., Lindstrom M.M. and Flohr M.K. (1989) PLPSC 19, 219.

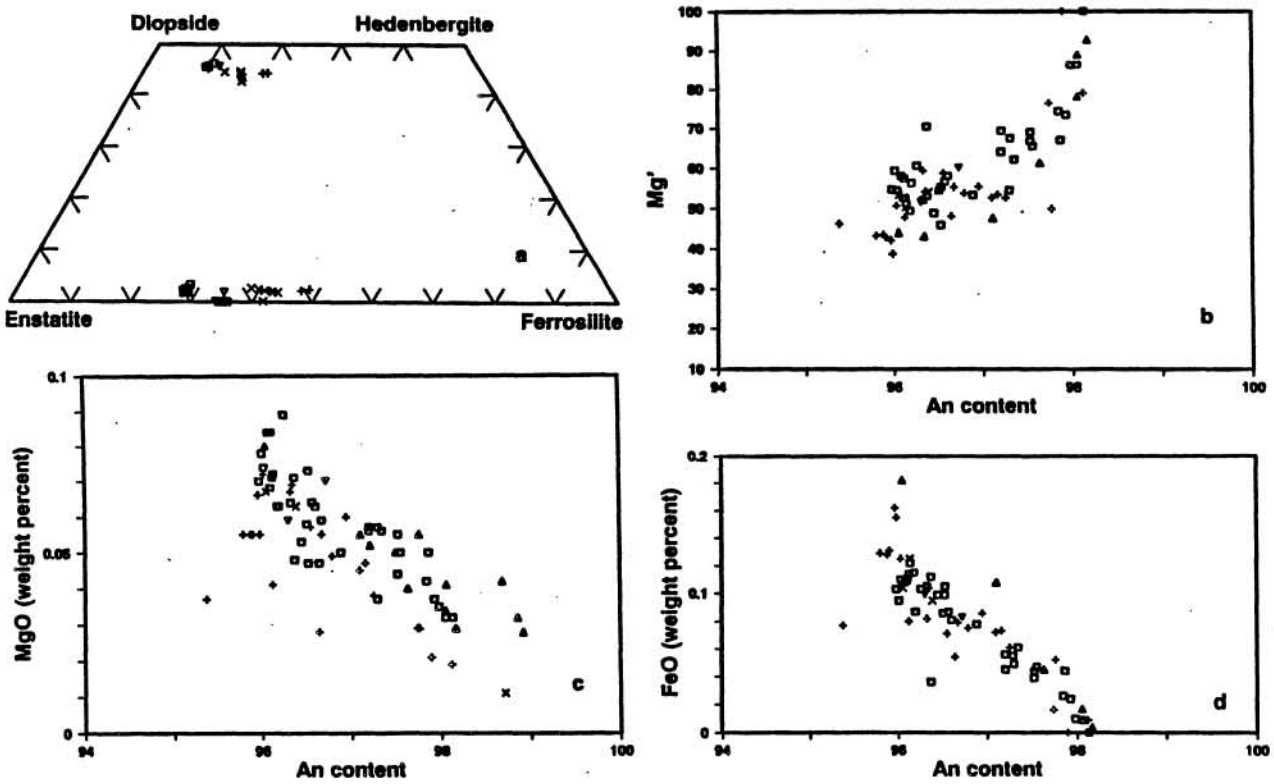

Figure 1. Compositions of minerals in 60025 splits, as determined by electron microprobe. Squares, magnesian pyroxenes and olivines, or plagioclases associated with these, in whole-rock split ,691LM. Crosses, ferroan pyroxenes and olivines, or plagioclases associated with these, in whole-rock split ,691LM. Triangles, grains in mafic-mineral-rich splits ,699LM and ,699SM (magnesian). Xs, grains in plagioclase split ,702PR (ferroan). a. Major-element compositions of pyroxenes and olivines. b. Mg' (100 x molar Mg/Mg+Fe) versus An content (100 x molar Ca/Ca+Na+K) in plagioclases. c. MgO versus An content in plagioclases. d. FeO versus An content in plagioclases.