FERROAN ANORTHOSITES AND THE MAGMA OCEAN: SEARCHING FOR TRENDS IN THE SEA OF CONFUSION

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Many investigators (e.g., 1-3) have postulated that the ferroan anorthosite (FAN) suite of pristine lunar rocks arose from an essentially Moon-wide magma body, the magma ocean. If the FAN suite was derived from a magma ocean, the rocks within itshould show coherent oxide differentiation trends. We are investigating this by studying minor-element concentrations in minerals in a large suite of pristine highland rocks, from both the FAN and Mg-rich groups. We have analyzed for MnO, Cr_2O_3, NiO, P_2O_5, CaO, Al_2O_3, and TiO_2 using a JEOL 733 electron microprobe, with a beam current of 200 na and an accelerating voltage of 15 kv (see (4) for more details of the method). Calculated detection limit for all oxides is about 10 ppm. We present here some results of our investigation.

Fig. 1 shows the mg# in low-Ca pyroxenes from both the FAN and Mg-suites of highland rocks, plotted against MnO concentrations. There is a fairly smooth trend of increasing MnO content with decreasing mg#, until FANs are encountered. The FANs show two divergent trends: 1) a normal trend of increasing MnO and decreasing mg#, and 2) a weird trend with increasing MnO and constant mg#. The two different trends in the FANs may indicate different starting magmas or different differentiation histories of the same magma type. Another interesting feature of this diagram is the general smooth progression from troctolites to norites to anorthosites, with increasing MnO. One might be tempted to infer a single magma type was responsible for the entire trend and what we observe is a differentiation sequence in both rock type and composition. However, this has been shown not to be so by analysis of major elements, e.g., An content of plagioclase *vs.* mg# of coexisting olivine and/or low-Ca pyroxene (5). Analyses of olivines and low-Ca pyroxenes in FANs show that most minor element concentrations are low compared to rocks in the Mg-suite (6). Fig. 2 is a plot of TiO_2 concentrations in high-Ca pyroxene against Na_2O concentrations. The FAN suite and the Mg-suite show almost complete separation on this plot, implying that the two suites are unrelated. The one FAN that plots in the Mg-suite field is 73217,41, which Warren (7) describes as "quasi-pristine." We were unsure whether any of the mafic minerals in this sample were *not* in the melt breccia portion of 73217. Thus, this sample is suspect. This plot also shows that the Na depletion so evident in FAN plagioclases, extends to the mafic minerals. This strongly argues against any hypothesis that uncouples plagioclase crystallization from mafic minerals in the FAN suite. Another feature of Fig. 2 is the positive correlation between Na_2O and TiO_2 among the FANs.

Fig.3 shows MnO concentrations of low-Ca pyroxenes in FANs plotted against Cr_2O_3 concentrations. There is a good negative correlation. We have tried to see if a similar trend is seen in olivines (Fig. 4). This is hampered, however, by the low number of FANs that contain olivine and by the low concentration of Cr_2O_3 in the olivines. Nevertheless, there appears to be a general negative correlation. The MnO-Cr_2O data, somewhat in contrast to the MnO-mg# data, may imply that all of the FANs are related to a single magma, perhaps the magma ocean. (Apollo 17 sample 73217,41 plots above this trend, again indicating that it may not be pristine.)

Our data indicate that within the entire FAN suite coherent differentiation trends are shown by minor element concentrations. This gives credence to the magma ocean hypothesis. Ryder (8) studied 60025, a breccia composed of FAN clasts and mafic clumps and which spanned the range in mg# of the entire suite, and arrived at a similar conclusion. However, several samples show deviations from overall trends and probably represent localized heterogeneities as the magma ocean crystallized.

References. 1) Wood, J. A. *et al.* (1970) *Proc. Apollo 11 LSC*, 965-968. 2) Smith, J. V. *et al.* (1970) *ibid.*, 897-925. 3) Walker, D. *et al.* (1975) *PLSC 6th*, 1103-1120. 4) Bersch, M. G. *et al.* (1986) *Proc. Microbeam Analy. Soc. 21st*, 138-140. 5) Warner, J. L. *et al.* (1976) *LS VII*, 915-917. 6) Bersch, M. G. *et al.* (1986) *LS XVII* 44-45. 7) Warren, P. H. *et al.* (1983) *PLPSC 14th, JGR* **88**, B151-B164. 8) Ryder, G. (1982) *Geochim. Cosmochim. Acta* **46**, 1591-1601.

For all figures, note the following:

1) The oxide concentrations plotted are average concentrations. The concentration range within each sample may be relatively large or small. This internal range and variance will be the subject of another paper.

2) mg# = 100(MgO/(MgO + FeO)), oxide values in moles.

3) Legend by rock type (Figs. 1 and 2): 1 = FAN; 2 = troctolite; 3 = norite; 9 = other.

4) Legend by mission (Figs. 3 and 4): 5 = Apollo 15; 6 = Apollo 16; 7 = Apollo 17.

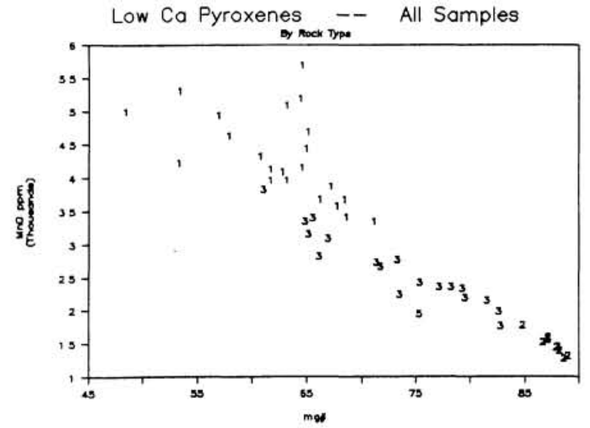

Figure 1

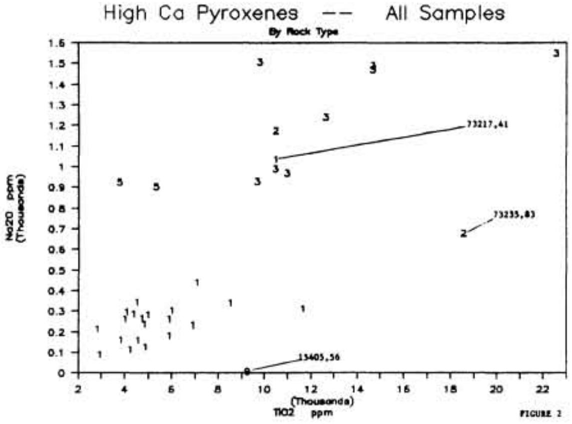

Figure 2

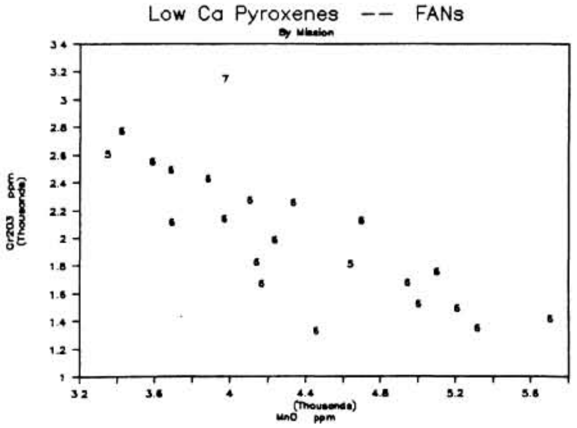

Figure 3

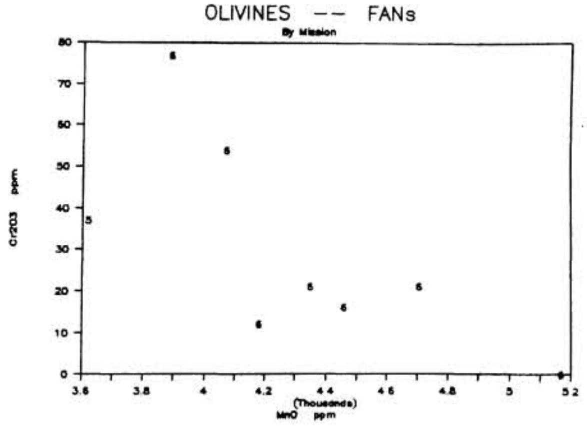

Figure 4