

NEARLY PURE PLAGIOCLASE ANORTHOSITES; LUNAR AND St. URBAIN;
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It has been tempting to use the concentrations of REE and other trace elements in ferroan lunar anorthosites (FAN) in conjunction with values for plagioclase/liquid distribution coefficients to calculate concentrations for the presumed parental liquid of FAN. While such rocks are undoubtedly of ultimate igneous origin, it is unclear whether the nature of their parental liquid(s) can be determined under the assumption that FAN preserves its initial equilibrium crystal-melt trace-element distributions. If not, such simple calculations may yield misleading information about the nature of lunar magma.

From our studies of anorthosites from the Stillwater intrusion (1) and the Etaugalet massif (2) it is evident that simple relationships between trace-element concentrations of plagioclases and of parent magmatic liquids are tenuous. Application of those results directly to FAN is difficult because those terrestrial anorthosites contain substantially higher proportions of mafic and FeTi-oxide minerals than does FAN. Accordingly, we have initiated studies on anorthosite from the St. Urbain, Quebec (StU) massif (3,4) which consists almost entirely of plagioclase (>95%).

In our preliminary study of 15 samples, we find that the relationships among elemental concentrations in StU anorthosites and FAN are strikingly similar, both having the following characteristics: The ranges of most incompatible trace-element concentrations are low relative to those in many terrestrial anorthosites. There is no single level or pattern of trace-element abundances in the plagioclases or among anorthosite samples with low FeO concentrations; spread in relative abundances and concentrations is the rule. Total iron (as FeO) concentrations correlate strongly with Sc, Co, and Cr concentrations, with a few samples deviating from otherwise tight trends (Fig. 1). There is no correlation between concentrations of FeO and those of LREE, although samples with highest La concentrations have lowest FeO concentrations (Fig. 1). FeO concentrations correlate with those of HREE (Fig. 1). Plagioclase is probably the principal host for the LREE; nevertheless, (Na₂O,LREE) diagrams show scatter. There is fair correlation between FeO and Hf, with one or more points well off the correlation line. There is no correlation between FeO and Ba or between REE and Ba, and at least one sample has an anomalously high Ba concentration. There is no correlation between Ba and Sr (Fig. 1). La and Ce show strong correlation, La and Sm show weak or no correlation, and La and HREE no correlation at all. The ratio of LREE to HREE is much higher in the StU anorthosites than in FAN.

The patterns of correlation or of scatter are very similar for StU and FAN despite their very different plagioclase compositions (An₃₈₋₄₅ vs. An₉₅₋₉₇), strikingly different levels of concentration for Sr, Ba, and Cr, and different levels of concentration for most other elements. These similarities arise in part because plagioclase dominates both systems and because only traces of other minerals are present in most samples. Whether similar processes produced the anorthosites and what the processes were is unclear.

One proposed means of producing nearly monomineralic rocks is adcumulus growth, an equilibrium process (e.g., 6). If the anorthosites were assembled by such a process and have not been modified by other processes, then their detailed chemical properties should reflect it; i.e., the plagioclase and pyroxene of each sample should be "equilibrium pairs." The trend in ratios of REE in plagioclase to those in associated orthopyroxene [data from (4)], deviates from that for plagioclase/orthopyroxene distribution coefficients

PURE PLAGIOCLASE ANORTHOSITES
Haskin, Dymek, and Korotev

(7), so the analyzed mineral pairs may not reflect equilibrium. Presence of minor but variable amounts of occluded clinopyroxene and lesser apatite within plagioclase may contribute to the discrepancy. In addition, a substantial fraction of the HREE is labile to rinsing in acid (4), suggesting that mobilization of HREE may also contribute to the disparity.

We are examining models in which the HREE and other elements may be extracted from the anorthosites by a fluid or melt that contained mafic silicates and Fe-Ti oxides. In this model, extraction would be imperfect, with the extent of reaction varying locally in accord with values of physical parameters such as pore space, in addition to chemical conditions. The extractant might have been a hydrous fluid, perhaps a brine, that gave rise to the interstitial calcic myrmekite (An80 plagioclase + quartz) by late-stage replacement (7), or it might have been an Fe,Ti,P-rich liquid that segregated from the anorthosite to produce the associated ilmenite ore bodies (8), some of which contain abundant apatite. We note that REE-rich apatite and whitlockite are prominent in some lunar anorthosites (9).

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