
What is the average proportion of plagioclase in lunar ferroan anorthosite (FAN), an important early crustal igneous rock? Is it >95% or even >98%, as reported for many samples? The extent to which trapped parent liquid and co-crystallizing mafic minerals were excluded during the formation of FAN strongly constrains the mechanism by which FAN formed. In turn, if FAN is the principal constituent of the crust, instead of there being a range of plutonic rocks with the average composition of anorthositic norite like the lunar highlands surface, then we would know that rock-forming conditions during early planetary crustal differentiation were very specialized and that the overall anorthositic norite composition of the crust requires exhumation of substantial residual material from depth (1,2).

The "pristine" plutonic rocks retain some residual cumulate character, and as an extreme position, we might presume that each anorthosite sample, however cataclastic now, represents a single intact igneous rock prior to brecciation. Most other possibly plutonic rocks have been designated as polymict, mainly on the basis of variation in mafic mineral compositions, a conclusion that might erroneously be drawn for fragments of Stillwater anorthosite, owing to zoning of olivocristals.

In a companion abstract (3), we describe preliminary modeling of changes in fragment mineral mode with fragment size (number of grains observed), expected from random sampling of Stillwater anorthosite. Here, we show one application of those results to lunar plutonic rocks. An important conclusion of (4) is that, owing to the heterogeneous distribution of pyroxene in Stillwater anorthosites, a high proportion of fragments with few mineral grains appear to be pure-plagioclase anorthosite, although the average pyroxene proportion in the boulder is 11.9%. We might have concluded from its bimodality over a wide range of grain size that the distribution represented two rock types. Might the same be true for FAN, and has our sampling misled us to believe that FAN is poorer in mafic minerals than is representative of its formation? To examine this, we use the effects of fragment size on the distribution of rock compositions, using FeO as an example. Lunar plutonic rocks seem to be heterogeneous in the same manner as the Stillwater boulder. Troctolite 76535 has clots of feldspar and of olivine. Mafic minerals are heterogeneously distributed in FAN samples 60025 and 67075. If such heterogeneities are common, has our sampling of FAN seriously biased our impression of how impoverished lunar anorthositic rocks are of mafic materials?

A key factor in the comparison is the number of mineral grains per analyzed sample. Relict textures indicate that crystals of FAN may have been 1x1x1cm or larger, prior to brecciation. If so, the largest FAN sample, 60015, would contain only 2,000 crystals, a small sample even if every grain of it had been examined. 60015, however, is brecciated to the extent that it may sample a larger volume of its parent formation (4). If its grains were only 0.3x0.3x0.3cm, 60015 would contain some 74,000. Many FAN samples are small; 62237, relatively rich in mafic minerals, has a mass of 62g. Grains of Stillwater plagioclase are relatively small for anorthosites, most being in the 2-4mm size range, or about 3-9 pixels per grain on the boulder map (Fig.1, ref. 4). The mass of most analyzed lunar samples is probably 0.5-3g and the number of crystals analyzed 3 to 50. At 3-9 pixels per grain (to make it comparable to the boulder), the number of pixels per lunar fragment is 25-360.
Suppose we treat every analyzed sample of FAN as if it were a fragment of breccia from a single precursor formation. Fig. 1 is a histogram of percent of analyzed FAN samples (total of 57, refs. 5,6) vs. FeO concentration per "fragment." Similarly shown are FeO concentrations for the Stillwater boulder, modeled as if it were merely lunar plagioclase (0.25% FeO) plus pyroxene (22% FeO) because compositions of FAN approximate such mixtures. The distribution for the FAN "fragments" (Fig. 1) has features in common with those for the boulder for 25-, 100-, and 400-pixel fragments. Of particular interest is the flat region at about 5% of the analyses, which suggests that FAN also has pyroxene-rich and poor areas. However, the highest FAN FeO concentration is 6.6%, less than the maxima of 12.5%, 10.2%, and 7.7% calculated for the modeled 25-, 100-, and 400-pixel fragments, and there is no indication of a peak corresponding to the plagioclase-laden pyroxene oikocrysts of the boulder. About 84% of the lunar fragments have FeO <2%. Only 58%, 46%, and 41% of the boulder fragments at the 25-, 100-, and 400-pixel levels have FeO <2%. The mean concentration of FeO for the FAN samples is 1.07% and that for the boulder samples is 2.6%. The greater frequency of fragments with FeO <2% and the shorter tail for the FAN distribution indicate that the average amount of pyroxene in FAN must be less than half the value of 10.9% for the boulder, consistent with the >95% plagioclase reported from direct observation for most samples. This distribution for FAN may be biased toward plagioclase, however, as some associated mafic "fragments" not recognized as FAN may have been omitted. Thus, considerations based on the uneven distribution of pyroxene in the Stillwater anorthosite do not alter our impression that FAN has a very high proportion of plagioclase and that it did not form under conditions entirely analogous to those under which Stillwater anorthosite formed. This work was supported in part by NASA through grant NAG-956.