
Based on data from three traverses and from a 10mx10m outcrop, we have demonstrated that the two thick anorthosite units of the Stillwater intrusion consist of meter- to 10-meter sized "regions" that differ in average pyroxene mode and in trace-element composition [1-5]. We interpret the compositional variations observed among 2kg hand specimens collected from within single regions as reflecting the manner in which the regions formed into rocks. Plagioclase suspended in a crystal mush formed a network whose interstitial spaces filled with acumulus pyroxene plus plagioclase, or with frozen trapped liquid, or a combination of both. Minor magnetite is present, as are trace sulfides andapatite.

We collected a 10kg boulder from the outcrop, sliced it, polished its sawn faces, and extracted 23 samples ranging in weight from 1.6 to 63g for major- and trace-element analysis. The purpose was to observe the distribution on a cm scale of products of cumulus, acumulus, and orthocumulus growth. The pyroxene distribution is shown in Fig. 1. Samples were selected as pyroxene-rich, magnetite-poor; pyroxene-poor, magnetite-poor; and pyroxene-poor, magnetite-rich. Magnetite occurs mainly as clots in pyroxene-poor sections of the rock. A microprobe study showed the pyroxene to occur almost exclusively as oikocrysts [3].

The effects of plagioclase (~89 vol%) and pyroxene (~11 vol%) on elemental distributions can be seen to a first approximation on 2-element diagrams with $\text{Al}_2\text{O}_3$ or MgO. Samples richest in pyroxene are richest in MgO and poorest in $\text{Al}_2\text{O}_3$ and in pyroxene-incompatible trace elements (e.g., La, Fig. 2). Acumulus growth within the boulder was not entirely efficient as evidenced by a range in Mg$^+$ of up to 8 mole% within analyzed oikocrysts [3]. However, the pyroxene-incompatible trace elements were efficiently excluded from the pyroxene-rich portions of the boulder by growth of this mineral as extensive single crystals. These elements now reside in pyroxene-poor portions of the boulder, but because they are not in general compatible with plagioclase either, they were distributed to sites within the plagioclase framework that had not been filled by acumulus plagioclase. Thus, variation diagrams of incompatible elements with $\text{Al}_2\text{O}_3$ show positive trends but with considerable scatter (Fig. 3).

Scatter is also observed when the concentrations of the pyroxene-compatible elements Sc and Co are plotted vs. that of MgO (Fig. 2). Some scatter for Sc is evident in the outcrop whole-rock data, but in those Co is almost perfectly correlated with MgO. Scatter for the boulder samples illustrates that the MgO-Co correlation does not stem from a constant ratio of those elements in all material of the boulder. Rather, different ratios developed under localized conditions, owing partly to the difference between acumulus pyroxene (growing in an environment of constant MgO and Co concentrations) and orthocumulus additions to the oikocrysts (growing from a liquid that rapidly becomes depleted in Co and MgO, but presumably not at the same rate because FeO also enters pyroxene), and partly to the entrapment of Co in localized regions within the pyroxene-poor portions of the boulder.

The scatter for trace-element concentrations among boulder samples supports our suggestion that these elements were distributed over cm to dm distances to favorable crystal sites [4]. The absence of a correlation between Hf and Lu (Fig. 4) contrasts with the smooth curve relating those elements in the outcrop whole-rock samples. The HREE (e.g., Lu) preferentially partition into pyroxene over plagioclase, thus the pyroxene-rich samples cluster on Fig. 4 at high Lu. The data points for the pyroxene-poor samples display considerable scatter on Fig. 4. These samples contain mixtures of cumulus and acumulus plagioclase (low Lu and Hf concentrations) with varying proportions of the liquid that had been excluded from the growing pyroxene oikocrysts (high Hf and varying concentrations of Lu depending on the degree of equilibration of the liquid with pyroxene). Normative mineralogies of the 23 samples display a range in rock type.
from norite and gabbronorite to anorthosite. Even the most pyroxene-rich of these samples has a high proportion of plagioclase. Had sample sizes been comparable to those of typical lunar breccia clasts (generally $<1$g), the range in rock types would have been greater and included plagioclase-laden fragments of pyroxene oikocrysts. This, and the breakdown of good whole-rock correlations in such small samples, indicates that soil and breccia fragments are hard to interpret in terms of their parent rock characteristics [See also ref. 6].

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