ESTIMATION OF TRAPPED LIQUID CONTENTS IN THE STILLWATER COMPLEX
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Stratiform layers of "monomineralic" rock (orthopyroxenite, anorthosite, dunite and chromitite) make up ~30% of the exposed part of the Stillwater Complex. The remainder consists of 2- and 3-phase cumulates (harzburgite, norite, gabbro, gabbronorite and troctolite) in which the cumulus minerals are present in roughly eutectic proportions (1). Anorthosites and orthopyroxenites are not monomineralic, sensu stricto, but are so called if they contain a single cumulus mineral (defined on the basis of texture). Other minerals, which make up between <1 and ~25% of such rocks, occur as interstitial grains and are assumed to have formed by crystallization of the intercumulus melt. The amount of this melt and its compositional changes during cooling are not well known. Estimates of the amount of liquid present when the rock became chemically and mechanically closed are commonly based on the relative volumes of an excluded, i.e., non-cumulus phase in the rock and the same "phase" in the coexisting magma (2,3). For example, an anorthosite containing 10% poikilitic pyroxene would imply a minimum trapped liquid content of 25% since a plagioclase + pyroxene saturated magma crystallizes those minerals in the ratio 3:2. This method was used by Raedeke and McCallum (3) in their model to calculate the fractionation trends (or lack thereof) in the Stillwater and lunar anorthosites. However, the compositions of pyroxenes calculated in this way were more Fe-rich than observed which led Raedeke and McCallum to postulate the presence of some "cumulus" pyroxene in these rocks.

As shown by Salpas et al. (4), the La-Sc systematics of Stillwater anorthosites (shown in the envelope in the lower left corner of Fig. 1) indicate that the bulk of the interstitial pyroxene has the composition of cumulus pyroxene. Also shown in Fig. 1 are La and Sc abundances of a representative suite of whole rocks and mineral separates from the complex. From data on mineral separates and published distribution coefficients (5,6), a range of coexisting liquids is calculated and plotted in Fig. 1. As shown in Fig. 2, the REE abundances increase by a factor of only 2.5 from the base (gabbronorite 100) to the top (gabbronorite 150) of the Banded Series; liquid compositions must change by the same factor. An average liquid composition is chosen for the sake of discussion. If the interstitial minerals crystallized from the intercumulus melt and if the system were closed, whole rock data on anorthosites should plot close to a line joining plagioclase separates and liquid and orthopyroxenites close to a line joining opx and liquid. However, it is clear that anorthosites and pyroxenites define segments of a single, continuous trend indicating that textural differences are not reflected in chemical differences. Additional evidence for the "cumulus" nature of intercumulus minerals is provided by whole rock analyses of pyroxenites; samples with more than 5% interstitial plagioclase show a positive Eu anomaly, e.g., sample 663 in Fig. 2.

A graphical method of calculating the trapped liquid content is illustrated in Fig. 1. For example, gabbronorites should plot in a triangle formed by liquid-plag-(opx+px) and norites should plot within the triangle liquid-plag-opx. It can be seen from Fig. 1 that all gabbronorites plot well below the 10% trapped liquid contour, most plot below the 5% contour and several plot on the base (0% T.L.). That a small amount of trapped liquid is present in most samples is indicated by the positive correlation of La content with the amount of quartz and fluorapatite. The latter mineral contains up to 1500 ppm La indicating crystallization from a strongly fractionated liquid. Detailed outcrop mapping provides clear evidence for extensive migration of

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interstitial melt on a mesoscopic scale (see abstract by Salpas et al., this volume). The "cumulus" compositions of oikocrysts in monomineralic rocks is consistent with the crystallization of these crystals at or near to the main crystallization front. The fine-grain size of plagioclase within pyroxene oikocrysts tends to support this model. The degree of undercooling appears to be the most significant control on the particular texture developed.

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Fig. 1. La vs. Sc plot of mineral separates (diagonal ruled areas) and whole rocks from all major zones of the Stillwater Complex. Liquid composition is calculated (see text for details).

Fig. 2. Chondrite normalized Ba and REE abundances of whole rocks. 100: Gabbro (GNI); 138: Anorthosite (AN II); 150: Gabbro (GNIII); 425: Norite (NI); 663: Orthopyroxenite (Ultramafic Series).