POSSIBLE ASSIMILATION BY A MAFIC MAGMA: THE ENDION SILL, DULUTH, MINNESOTA; J. E. Gardner, L. A. Haskin, and J. C. Brannon, Dept. of Earth and Planet. Sci. and McDonnell Ctr. for the Space Sci., Washington Univ., St. Louis, MO 63130

Partial melting of a mantle source, usually followed by fractional crystallization, is the most commonly considered mechanism for producing mafic magmas. This mechanism alone does not account for some magma chemical and isotopic compositions and may not account for those of lunar mare basalts. Mixing of magmas from different sources is an important composition-modifying process. Assimilation during ascent or in magma chambers may be another. Most assimilation must occur at depth and its nature and effects can only be inferred from the products that reach the surface. We have sought a situation in which the process of assimilation by a mafic magma might have been preserved and exposed to field observation and sampling. Such may be the case for the Endion Sill, Duluth, Minn.

The 425m thick Endion Sill is a composite intrusion exposed in two outcrops, one along the Lake Superior shoreline and the other along Tischer Creek. The lower half of the sill consists of gabbros (GZ). Overlying the GZ are 150m of acidic rock (AZ), mainly diorite and quartz monzodiorite. The uppermost 62m consist of intermediate rock (IZ), which is also gabbroic in mineral composition but whose trace-element concentrations resemble those of the AZ. The contact between the GZ and the AZ is wide (>30m) and is gradational; that between the AZ and the IZ is much narrower (10-15m) but still gradational. Small dikes of red material permeate the sill; these may be frozen residual liquid from crystallization of the gabbro (1). The sill intruded beneath a rhyolite of the North Shore Volcanic Group (NSVG). The rhyolite shows massive alteration, presumably from heating by the sill.

We have analyzed 27 samples from the different zones by INAA for trace elements and one sample of GZ and one of AZ for Nd isotopes. Concentrations of Rb, Zr, REE, Ta, and Th increase monotonically and those of Sc, Co, and Sr decrease from the GZ through the AZ-IZ to the red dykes (e.g., Figs. 1,2). REE concentrations are given in Fig. 3. Average GZ REE concentrations are roughly comparable to those of NSVG andesite (2).

The GZ sample analyzed for Nd isotopes has an epsilon value of -0.6 and the AZ sample analyzed has an epsilon value of -2.0. This indicates that fractional crystallization acting alone cannot produce the different rocks of the sill. Combined assimilation of overlying rhyolite by the intruding magma accompanied by fractional crystallization can produce the observed chemical and isotopic trends for the sill if the rhyolite has a strongly negative epsilon-Nd value (<-8). The upper portion of the IZ contains areas of altered gabbro that have the trace-element characteristics of the overlying, altered rhyolite, an indication that assimilation of the rhyolite was important at least on a local scale. Samples of altered rhyolite are depleted in REE, Th, Rb, and Ta and enriched in Sc, Co, Sr, and Ba, relative to unaltered rhyolite. The alteration zone of the rhyolite extends some 30m above the contact of the sill. Thus, we are examining the hypothesis that fluids may have exchanged trace elements between the gabbro and the rhyolite, particularly by reaction with lower-melting point minerals, after the temperature had dropped to the point that complete melting and assimilation of the rhyolite could not continue.

An alternative hypothesis for the formation of the sill is intrusion of separate mafic and acidic magmas. In this case, the wide gradational contacts between layers would be areas of local magma mixing. Fig. 4 shows the initial epsilon-Nd values for the Endion Sill samples, NSVG primitive basalts (2), and

Superior Province crust (3), vs. 1/Nd. Also shown are theoretical compositions of partial melts (5% and 10%) of the crust. Assimilation of these partial melts by the primitive basalts plus fractional crystallization might produce the different trace-element compositions and epsilon-Nd values of the Endion Sill samples. The primitive mafic magmas might encounter such partial melts during their ascent through the crust. There are several dikes of mafic and acidic materials that crosscut the sill and the NSVG lavas; this shows that magmas of different compositions were present.

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