

F AND Cl DISTRIBUTION IN APATITES OF THE STILLWATER COMPLEX. A. E. Boudreau and I. S. McCallum, Department of Geological Sciences, AJ-20, University of Washington, Seattle, WA 98195

The relative amounts of F, Cl and OH in apatite are not constrained by crystal-chemical factors (in contrast to micas and amphiboles), and thus changes in the abundance of these components provide an excellent indicator of variations in the fugacities of halogen species and the degassing history of igneous rocks. We have recently analysed intercumulus apatites from approximately 65 samples ranging from the Basal series to the uppermost exposures of the Upper Banded series of the Stillwater Complex. Some of our results are summarized in figures 1a-d.

Apatites from Basal Series norites are typically rich in F and poor in Cl and are compositionally similar to those found in the Complex above the level of OB I. An F-poor, Cl and OH-rich sample occurs in a Basal series orthopyroxenite with a micropegmatitic texture, which we interpret to be the result of local infiltration of formation water into the Basal series. Apatites from a single hornfels sample contains subequal amounts of Cl, F and OH.

The most Cl-rich apatites occur in the Ultramafic series and that part of the Lower Banded zone below the platiniferous J-M reef. These apatites may contain 100% endmember chlorapatite and there is no correlation of Cl content with rock type. The high Cl-contents are not the result of later, low-temperature alteration of the igneous assemblage; altered apatites are texturally distinct from primary apatites, and the alteration invariably results in lower Cl contents. La and Ce content of apatites show a marked peak at the level of the J-M reef. There is no evidence for lateral variations, e.g., apatite from the biotite and olivine-bearing rocks of the J-M reef from both the Minneapolis adit and the Contact Mountain area have essentially identical compositions.

An abrupt change in the Cl/F ratio occurs within OB I, host zone of the J-M reef. Within OB I, the olivine-rich rocks are Cl-rich, whereas norites and anorthosites are more F-rich. This sharp break in halogen concentrations is in contrast with the cryptic variations in cumulate mineral compositions, which show little evidence of other than normal fractionation trends through the section (1).

Above OBI, the apatites are typically F-rich, although olivine-bearing rocks tend to have apatites with elevated Cl abundances. However, the Cl contents are never as high as observed within or below OBI. F abundances tend to increase with stratigraphic height, particularly in the Upper Banded zone. The most OH-rich sample is from OBII. This zone contains the discordant "pillow troctolite" of Hess (2), and is generally believed to have formed by metasomatic replacement of the host plagioclase-augite cumulate (3).

Insofar as the Basal series F-rich apatites are representative crystallization products of the Stillwater magma, this magma was not markedly different in the relative abundance of halogens from that of other layered intrusions (e.g., the Skaergaard intrusion). The presence of F-rich apatite in the Basal series further implies that the Cl-rich apatites higher in the section are not the consequence of a Cl-rich fluid infiltrating from the country rock into the lower portion of the cumulate pile. Hence the chlorapatites must have resulted from some processes occurring during solidification of the intrusion. We suggest that the abrupt break from Cl-rich apatite to F-rich apatite at the level of the J-M Reef marks the level at which Cl-rich fluids exsolving from the interstitial melt in the footwall mixed with volatile-poor, melt-dominated environments higher in the crystal pile. The mixing event may have then led to the precipitation of the Reef PGE-sulfides (4,5) and the observed REE enrichment. The overall decrease of Cl and increase in F with stratigraphic height suggests that the Stillwater magma was vapor saturated at some point in its crystallization and lost Cl to the exsolving fluid.

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Refs. 1) Todd et al. (1982) *Econ. Geol.* **77**:1454-1480. 2) Hess (1960) *Mem. Geol. Soc. Am.* #80. 3) McCallum et al. (1980) *Am. J. Sci.* **280A**:59-87. Ballhaus and Stumpfl (1986) *Contrib. Mineral. Petrol.* **94**:193-204. 4) Boudreau (1988) *Can Mineral.* (in press).

Figure 1. Compositional variation of apatite as a function of stratigraphic height as determined by electron microprobe. A) Fluorine, B) Chlorine, C) X_{OH} and D) $Ce_2O_3 + La_2O_3$. X_{OH} is calculated by anion site difference (i.e., $F + Cl + OH = 1$ per formula unit). Abbreviations: JM, J-M Reef of OB I; U, top of Ultramafic series; B, top of Basal series.

