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THE ROLE OF MAGMA MIXING IN THE GENESIS OF PGE MINERALIZATION IN THE BUSHVELD COMPLEX: THERMODYNAMIC CALCULATIONS AND NEW INTERPRETATIONS

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Abstract

The elegant magma-mixing model for the formation of the platinum-group elements (PGE) mineralization associated with chromite and sulfide in the Bushveld Complex proposed by Naldrett and von Gruenewaldt (1989) has recently been questioned by Cawthorn (1999). Based on his own calculation, Cawthorn concluded that the concave-upward sulfur solubility curve of a fractionated basaltic magma, which is central to the model, does not exist. Cawthorn (1999) pointed out that both the hanging-wall and footwall sequences of the Merensky reef formed from sulfide-undersaturated magmas instead of sulfide-saturated magmas as predicted by the model. Cawthorn argued that there is a mass-balance problem with the model if these rocks did not contribute PGE to the sulfides in the reef. Our thermodynamic calculations indicate that the concave-upward curve of S solubility, though different in detail from the original, is very much in evidence. Our calculations also indicate that the content of S dissolved in the residual magma may fall below the S solubility curve when the rate of S increase in the magma, due to the removal of silicate cumulates, is less than the rate of increase in its S solubility, due to the change in its temperature and composition during fractional crystallization. Mixing of such fractionated and yet sulfide-undersaturated magma with appropriate amounts of a primitive magma is still capable of achieving sulfide oversaturation in the hybrid. Once the immiscible sulfides settle out of the magma, the content of S dissolved in the hybrid may fall below its solubility curve again during further crystallization, thus no sulfide segregation is expected in the rocks crystallized subsequently.

R-factor assessment needs to consider the consequence of sulfide suspension in magma. Small quantities of sulfide droplets formed during the normal course of fractional crystallization may remain suspended in magma until the next replenishment, and in this case they can be redissolved in the hybrid when the proportion of a new input is large enough. Because there is no early sulfide liquid segregation, both the residual and new magmas will not be depleted in PGE and are equally important for contributing PGE to the sulfide liquid segregated during a subsequent magma-mixing event.