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Self-Destructive Sulfide Segregation Systems and the Formation of High-Grade Magmatic Ore Deposits

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Abstract

The metal concentrations of sulfide liquids depend upon the mass of silicate magma that they are able to process for metals. Some high-grade magmatic Ni-Cu (±PGE) deposits and many magmatic platinum group element (PGE) (±Ni-Cu) deposits demand very high magma/sulfide ratios that seem improbable in the light of physical and kinetic constraints. Recent models for some high-grade deposits invoke multistage upgrading processes, in which an early-formed sulfide liquid reacts with multiple later batches of silicate magma. Quantitative models of this open-system process demonstrate that it is indeed more efficient than a closed system. However, it is likely that most later magmas in such a system will be sulfur undersaturated and will thus partly redissolve preexisting sulfide liquids, further increasing metal concentrations in the remaining sulfide liquids. This combined process is termed "multistage-dissolution upgrading," and quantitative models show that it could reduce the mass of silicate magma that must be processed by as much as two orders of magnitude. Furthermore, if sulfide liquids are extensively dissolved during enrichment, their base metal concentrations will generally stabilize at a limiting value, whereas their PGE concentrations will generally increase without limit. This divergence could account for unusually high PGE concentrations and high PGE/base metal ratios in many PGE-dominated deposits. The multistage-dissolution upgrading model is tested, using reasonable degrees of dissolution, in the context of natural deposits in the Noril'sk area and the Bushveld intrusion. The models reproduce the observed sulfide compositions significantly better than previous models and are also consistent with other aspects of the geology of these deposits. Thus, dynamic sulfide-forming magmatic systems may be intrinsically self destructive, but this apparently undesirable attribute could play an important role in forming high-grade deposits.

However, dissolution could lead to the complete destruction of sulfide liquids and the return of all metals to later magma batches. In this case, no sulfide deposit would remain, but metal-depletion signatures indicating sulfide liquid segregation would be preserved in rocks that crystallized from early magmas. Caution is therefore advised in the use of magmatic depletion signatures to infer overall mineral potential or to estimate the possible sizes of undiscovered magmatic sulfide deposits.

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