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Stable isotope systematics of magmatic PGE-Cu-Ni sulphide ores of the Noril'sk Province: genetic constraints and implications for exploration

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This study assesses Cu and S isotopic data for PGE-Cu-Ni sulphide deposits associated with the economic Noril'sk-1, Talnakh and Kharaelakh intrusions, the subeconomic Chernogorsk, Zub-Marksheider and Vologochan intrusions, and the non-economic Nizhny Talnakh intrusion within the Noril'sk Province (Russia).

In terms of Cu-isotopes, the majority of the analysed samples fall within a tight cluster (δ^{65}Cu from -1.1 to 0 ‰) characteristic of the ores from the economic PGE-Cu-Ni sulphide deposit at Talnakh. The other samples that reflect overall δ^{65}Cu isotopic variability (from -2.9 ‰ to 1.0 ‰) are represented by the subset of sulphide samples from the Kharaelakh and Noril'sk-1 intrusions. Three economic deposits are characterized by distinct mean δ^{65}Cu values (–1.56 $\pm$ 0.27 ‰ at Kharaelakh, –0.55 $\pm$ 0.41 ‰ at Talnakh and 0.23 $\pm$ 0.28 ‰ at Noril'sk) matching those of the carbonaceous chondrites and iron meteorites. The determined δ^{65}Cu variability is interpreted to represent a primary signature of the ores, though a magmatic fractionation of copper isotopes and/or assimilation of the ore material from external source (in case of the Kharaelakh ores) can not be ruled out.

The overall δ^{34}S isotopic variability in the intrusions ranges from -0.7 ‰ to 13.8‰. Sulphur isotopic compositions of the three economic PGE-Cu-Ni sulphide deposits (e.g., Kharaelakh, Talnakh and Noril'sk-1) show distinct and restricted ranges of δ^{34}S values within each deposit (e.g. 12.6$\pm$0.5 ‰, 10.9$\pm$0.6 ‰ and 9.2$\pm$1.8 ‰, respectively). This implies that the 'isotopically-heavy' homogenous sulphur in PGE-Cu-Ni sulphide ores in the Noril'sk-Talnakh area is the result of processes of sulphur fractionation that may have taken place at deeper levels of the tectonosphere [e.g. where magmatic melt could have been enriched by heavy sulphur resided in the crust, similar to findings in diamonds (Chaussidon et al. 1987; Eldbridge et al. 1991)], rather than at shallow levels or at their current location. This is further corroborated with the mantle-like sulphur (a mean δ^{34}S value of 0.39 ‰ with a standard deviation of 1.55 ‰) charactristic of the subeconomic sulphide ore of the highly contaminated Zub-Marksheider intrusion hosted within sulphate-rich Devonian sediments. This finding is in contradiction to the model, which accepts assimilation of crustal isotope-heavy sulphur as a prerequisite to forming a magmatic deposit.

In terms of S-Cu isotope systematics, the sulphide ores of the Noril'sk Province show two compositional trends. The first one defines decoupling of S from Cu (major set of analysed samples with δ^{65}Cu ranging from 0 ‰ to -1 ‰, and δ^{34}S between 0 ‰ and 12 ‰), whereas the second one shows a negative correlation between δ^{34}S and δ^{65}Cu, characteristic of samples from the three economic deposits. This negative trend of S-Cu isotope compositions typical of economic intrusions along with their restricted range of distinctly different δ^{34}S and δ^{65}Cu values can be employed as useful fingerprints in the assessment the potential of a PGE-Cu-Ni sulphide deposit.

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