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Isotope-geochemical criteria in exploration for Cu-Ni sulphide ores associated with the Noril'sk-type intrusions (Russia): constraints from S and Cu isotope data

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Our study aims on isotope-geochemical fingerprinting of main types of intrusive bodies of the Noril'sk-Talnakh and Taimyr areas (northern Siberia), with particular focus on identifying isotope-geochemical criteria in exploration for PGE-Cu-Ni sulphide-rich ores associated with the Noril'sk-type ultramafic-mafic intrusions.

This study presents the extensive results of a multi-technique approach, which utilized isotope systematics of S and Cu for Cu-Ni sulphide samples of disseminated ores (167 S isotope and 79 Cu isotope analyses) from economic Noril'sk-1 (drill core MN-2), Talnakh (OUG-2) and Kharaelakh (KZ-844, KZ-963), subeconomic Chernogorsk (MP-2bis), Zub-Marksheider (MP-27), Imangda (KP-4), Vologochan (OV-29) and Yuzhnoe Pyasino (OV-25), prospective Mikchangda (MD-48), Binyuda (C-1, C-2) and Dyumtalei (DT-43), non-economic Nizhny Talnakh (TG-31), Nizhny Noril'sk (NP-37) and Zelyonaya Griva (F-233) intrusions. S and Cu isotope compositions have been also identified in massive sulphide ore samples (54 S isotope and 20 Cu isotope analyses) at Talnakh and Kharaelakh. Disseminated ore (*type 1*) occurs in both the ultramafic and the lower "taxitic" parts of intrusions. *Type 2* ore is massive in nature and is situated close to the bottom contact of intrusions. Pyrrhotite, chalcopyrite and pentlandite are predominant minerals in the ores.

The economic PGE-Cu-Ni deposits show similar **sulfur** isotopic signatures (δ^{34}S) for massive and disseminated ores at Talnakh (10.5 – 11.3, mean 11.0 and 9.9 – 11.4, mean 10.8, respectively) and Kharaelakh (11.8 – 13.6, mean 12.8 and 11.4 – 13.5, mean 12.5, respectively).

This feature allow us to compare disseminated ores from other ultramafic-mafic intrusions. According to increase of δ^{34}S in *type 1* ore, sequence of intrusions looks as follows: Zub-Marksheider (- 0.7 – + 0.2), Binyuda (0.7 – 3.0), Nizhny Noril'sk (3.8 – 7.7), Nizhny Talnakh (1.8 – 8.0), Vologochan (5.1 – 8.5), Imangda (6.4 – 8.7), Zelyonaya Griva (7.5 – 9.5), Noril'sk-1 (7.3 – 10.4), Yuzhnoe Pyasino (8.1 – 10.5), Chernogorsk (10.4 – 11.2), Talnakh (9.9 – 11.4), Dyumtalei (10.7 – 11.6), Kharaelakh (11.4 – 13.5) and Mikchangda (11.0 – 14.0). Frequently postulated so called "crustal" isotopic composition of S as evidence for high productivity of the mafic-ultramafic intrusion is contradicted by low mantle-like S isotopic composition (δ^{34}S = -0.7 – +0.2) of *type 1* ore from the subeconomic Zub-Marksheider intrusion (hosted by sulfate-rich Devonian sediments).

Cu-Ni sulphide ores from economic intrusions form a specific trend of distinct **copper** isotope compositions. *Type 1* and *type 2* ores at Kharaelakh are characterised by similar "isotope-light" Cu composition (-1.35 – -1.92 δ^{65}Cu/^{63}Cu), whereas those at Talnakh demonstrate a range of Cu isotope values between -0.04 and -0.59 δ^{65}Cu/^{63}Cu. A shift for "isotope-heavy" copper compositions characterize *type 1* ore at Noril'sk-1 (0.02 – 0.61 δ^{65}Cu/^{63}Cu). Most of Cu isotope compositions of disseminated ores from subeconomic, prospective and non-economic intrusions match compositional range of *type 1* and *type 2* ores at Talnakh.

In δ^{34}S – δ^{65}Cu/^{63}Cu diagram, disseminated and massive ores from economic intrusions are negatively correlated, with distinct compositional fields for the Kharaelakh, Talnakh and Noril'sk-1 intrusions. The compositional field identified at Talnakh is partly overlapped with that of *type 1* ore from the subeconomic Chernogorsk and Yuzhnoe Pyasino intrusions, whereas the prospective Mikchangda intrusion closely match or approach compositional fields at Talnakh and Kharaelakh, respectively.

It is noteworthy that increase in the range of δ^{34}S values negatively correlates with ore deposit reserves. We thus propose that the restricted range of S isotope values along with specific isotopic variations in copper and sulfur, which closely match those from sulphide-rich ores associated with economic intrusions, can be employed as a useful fingerprint in the assessment of deposit productivity.