
Noril'sk- and Lower Talnakh-Type Intrusions are not Feeder Channels for the Overlying Flood Basalts: Insights from Phase Equilibria Studies

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The Ni-Cu deposits of the Noril'sk region are the third largest economic concentration of Ni in the world (after Sudbury, Canada, and Jinchuan, China). They are also the world's largest repositories of platinum group elements (PGEs) aside from the Bushveld Complex, South Africa. The mineralization of the Noril'sk region is associated with hypabyssal differentiated mafic/ultramafic intrusions subdivided into two groups: the ore-bearing Noril'sk- and poorly mineralized Lower Talnakh-type bodies. These are intruded into sedimentary rocks immediately below the center of a 3.5 km-thick volcanic basin. Studies of overlying basalts have shown that basalts forming a 500 m-thick sequence (mostly Nadezhdinsky Formation) have lost 75% of their Cu and Ni and more than 90% of their PGE (Naldrett, 1997). This raises the question of whether the association of very sulfide-rich intrusions with a large volume of chalcophile element-depleted basalt has genetic significance (Naldrett, 1994). The question has received two radically different interpretations.

Naldrett et al. (1995) following the earlier ideas of Godlevsky (1959) and Rad'ko (1991) put forward the concept of mineralized intrusions as exit conduits for 5000-10000 km³ of volcanic magma. It was proposed that the sulfides precipitating from the first flow of contaminated basalt were trapped within the bodies of the Noril'sk-type intrusions, which acted as settling chambers at a shallow level in the crust. Subsequent magma flowing through these chambers interacted with the trapped sulfides, losing chalcophile elements and PGEs to the sulfides already present there. Thus, sulfides could interact with and concentrate metals from 5000 to 10000 times their own mass of magma resulting in the intrusion's present unusually metal-rich state. The poorly mineralized Lower Talnakh-type intrusions are also considered as exit conduits, with the only difference that magma flowing along them stopped much earlier than along those of the Noril'sk-type intrusions.

In contrast, Czamanske et al. (1994) have found no evidence to support the idea that the ores

were derived in large part from the Cu-, Ni and PGE-depleted overlying basalts. They found no obvious correlation between Pb and Sr initial isotopic ratios of the Noril'sk- and Lower Talnakh-type intrusions and those of basalts and came to the conclusion that none of the intrusion-forming magmas can be directly related to any of the magmas that erupted as lavas. In addition, Czamanske et al. (1995) stressed that the expected thick hornfels selvages border none of the apophyses to the ore-bearing intrusions; i.e., there is no indication that truly vast amounts of magma exited the intrusion chambers. Another argument against the lava-conduit model is the small likelihood that the depletion in chalcophile elements and PGE that so uniformly characterize the voluminous Nadezhdinsky basalts (14,000 km³) can be directly ascribed to processing in a rather small single chamber at the stratigraphic level of the ore-bearing intrusions (only 100 km³ in volume) (Czamanske et al., 1995).

It is possible to choose between these two opposing points of view on the relations between Noril'sk- and Lower Talnakh-type intrusions and flood basalts using constraints provided by liquidus phase equilibria. The study of phase equilibria has revealed a significant compositional difference between the parental magmas of the Noril'sk- and Lower Talnakh-type intrusions and flood basalts, with the first lying close to the silica-undersaturated plane *Ol-Cpx-Pl* and the second lying close to silica-saturated plane *Opx-Cpx-Pl* (Fig.). According to Yoder and Tilley's (1962) classification, these magmas can be defined as silica-undersaturated olivine basalt and saturated tholeiite, respectively. From this, it follows immediately that the products of the equilibrium crystallization of the parental magmas of the intrusions and the basalts will be considerably different. The plutonic equivalent of the parental magmas of the intrusions is olivine gabbro (or melagabbro) whereas that of the basalts is gabbro-norite. Phase equilibria relations clearly show that the liquid line of descent does not link the parental magmas of the intrusions and basalts. Consequently, these magmas cannot be considered as comagmatic. It is the common opinion among

Russian geologists that picritic basalts of the Gudchihinsky Formation have comagmatic relationships with the intrusions under study (e.g., Duzhikov and Strunin, 1994, and references therein). Trace and isotope data (Naldrett et al., 1995), together with a phase equilibria analysis (Latypov, in prep) provide, however, no support for this idea. Thus, it is not inconceivable that the Noril'sk- and Lower Talnakh-type intrusions have no direct comagmatic volcanics in the Noril'sk region at all.

The foregoing provides strong support to the conclusion of Czamanske et al. (1994) that the magmas, which produced the ore-bearing intrusions do not directly correspond to those parental to any of the erupted basalts. Therefore, the current model of intrusions as lava conduits (Naldrett et al., 1995), despite the fact that it does give a reasonable explanation for many perplexing aspects of the Noril'sk-type intrusions, cannot be regarded any longer as a satisfactory one. Some other mechanisms, which would be capable to account for an abnormally high ratio of sulfides to the volume of silicate in the ore-bearing intrusions, are probably needed. Obviously, at the present state of investigation it is reasonable to remain open-minded about the ore-forming and ore-emplacment processes in the Noril'sk region, which are as yet poorly constrained (Czamanske et al., 1994). It is reasonably safe to conclude, however, that the evidence for the non-comagmatic relationship between basalts and intrusions suggests that the association of the very sulfide-rich intrusions with a large volume of chalcophile element-depleted basalts of Nadezhdinsky formation in the Noril'sk region is likely coincidental rather than of genetic significance. On this ground, it would be misleading to use the presence of magmatic formations depleted in Cu, Ni and PGEs as a regional criteria when \ prospecting for sulfide deposits in the flood basalt provinces.

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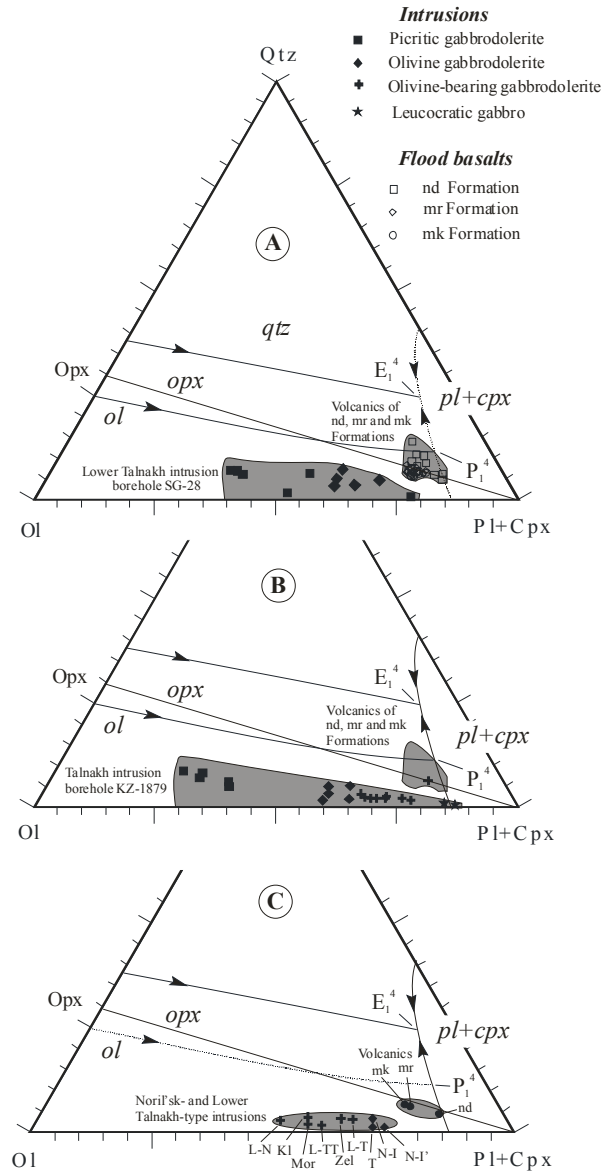


Figure 1. Projection planes of the isobaro-isoplethic section Ol-Cpx-Pl-Qtz showing fields with rocks of the Lower Talnakh (A) and Talnakh (B) intrusions and basalts of the nd, mr, and mk Formations and with average compositions of the Noril'sk (T, N-I, N-I') and Lower Talnakh-type (L-N, L-T, Kl, Mor, L-TT, Zel) intrusions and average compositions of the nd, mr, and mk volcanic Formations (C). Analytical data for the boreholes KZ-1879 and SG-28 are from Czamanske et al. (1994, 1995), data for the basalts of the nd, mr, and mk Formations are from Lightfoot et al. (1990), data on average composition of intrusions and volcanic formation are from Duzhikov and Strunin (1992). Abbreviations: T, Talnakh; N-I, Noril'sk I; N-I', Eastern Noril'sk branch of the Noril'sk intrusion; L-N, Lower Noril'sk; L-T, Lower Talnakh; Kl, Klukvenny; Mor, Morongo; L-TT, Lower Tulaek-Taassky; Zel, Zelyonaya Griva; nd, Nadezhdinsky; mr, Morongovsky; mk, Mokulaevsky. Note that a field with average compositions of the intrusions lies close to the critical Ol-Cpx-Pl plane of silica undersaturation whereas that of volcanic Formations are located near to the critical Opx-Cpx-Pl plane of silica saturation. E_1^4 - $Qtz + Opx + Cpx + Pl = L$; P_1^4 - $Opx + Cpx + Pl = L + Ol$.