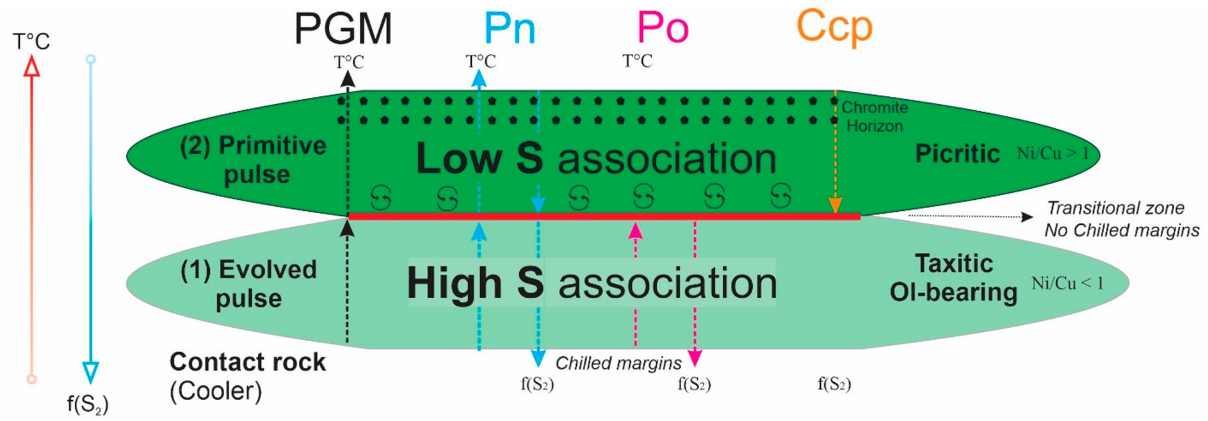

Figure 3. Summary of the main geochemical features, that suggest formation of the MOH of Norilsk 1 intrusion (middle part) from at least two different magma pulses. PGMs trends from [3].

gradually to the base of the sill, as well as an increase in $f(S_2)$ in the same direction (Figure 1).

Furthermore, composition of olivines and pyroxenes varies significantly between layers, with olivine and clinopyroxene picritic g-d being higher in Mg# and Cr_2O_3 and lower in MnO, while the opposite trend is observed for taxitic and olivine-bearing g-d. Plagioclase shows widespread variation of An% between core and rim, in taxitic and olivine-bearing g-d, with an overall trend gradually decreasing downwards. Whereas picritic g-d shows a more uniform compositional trend with less variability between zones. An%, Mg# and Fo% trends for plagioclase, clinopyroxene, and olivine, respectively, reveal a compositional basal reverse in the MOH, as well as an abrupt change in the composition at the petrographic contact between picritic and taxitic g-d (Figure 2). Ostensibly, the reported characteristics in ores and silicates suggest an evolution of the ore system from two relatively different sulphide melts, associated with two distinct magma pulses (Figure 3).

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Sulphide-poor PGE ores of the Noril'sk-1 intrusion: mineralogy, geochemistry and genetic constraint

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Noril'sk-type intrusions (Noril'sk-1, Talnakh and Kharaelakh) are renowned for their vast resources of Cu, Ni and platinum-group elements (mainly Pd). Most of these metals are mined from massive and disseminated sulphide ores from lower parts of the intrusions. Along with these ores, there are chromite-rich rocks, which are rich in PGEs (up to 70 ppm) and relatively poor in S, Cu and Ni [1]. Such mineralisation resembles chromitiferous PGE reefs occurring in some layered intrusions (e.g., Bushveld, Stillwater), and are hereafter referred to as 'sulfide-poor ores'. Despite their substantiated economic potential,

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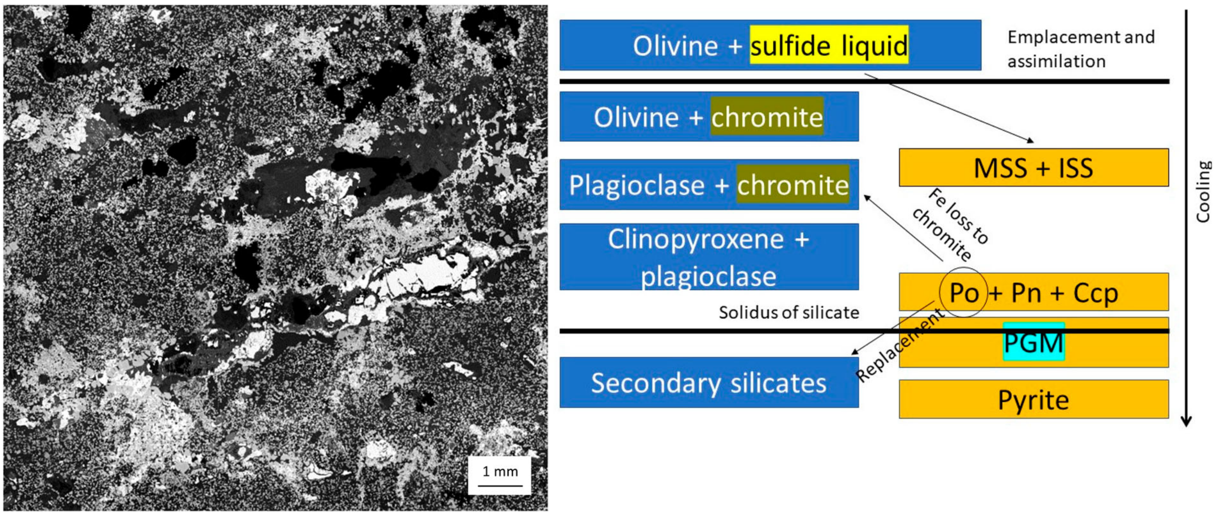

Figure 1. Left panel – typical example of the 'low-sulfide' assemblage in the Noril'sk-1 intrusion (BSE-photo): dark grey matrix – silicates, light grey grains – chromite, white segregations – sulfides. Right panel – a generalised genetic scheme, assuming that a part of olivine and sulfide liquid are brough from a deep chamber as inferred by Krivolutskaya et al. (2021). [3]

sulphide-poor ores in Noril'sk-type intrusions have not been as well studied as the disseminated and massive ores, and no comprehensive genetic model has yet been proposed. We performed a complex study of sulphide-poor ores from six drill cores of the Noril'sk-1 intrusion, as well as from an open-pit mine. In addition, chromite-hosted inclusions were examined in detail, including heating-quenching experiments with subsequent chemical analysis of the quenched glasses. Based on the data obtained, a basic genetic scheme for the formation of low-sulphide ores of the Norilsk-1 intrusion is proposed. We suggest that contamination of primitive melt with argillites of the Tunguska Formation, triggered crystallisation of chromite and redistribution of Cr in the rock-forming medium, which is inferred from an *in situ* crystallisation of Cr-spinel around their xenoliths and features of chromite-hosted inclusions [2]. The resulting depletion of silicate melt in Fe resulted in enrichment of the coexisting sulphide liquid in Cu and Ni. PGEs, during the evolution of the system, apparently, accumulated in Cu–Ni sulphides, the content of which is higher in the chromite-rich rocks. Post-magmatic decomposition of sulphide under conditions of intense metasomatism by deuteric fluids led to an increase of the PGE tenor, resulting in the actual 'low-sulfide' feature of the studied type of ores. Most of the platinum group minerals are associated with partially replaced sulphides and might have formed in their present form at the post-magmatic stage. However, large-scale hydrothermal migration of PGEs is unlikely due to the absence of Pt/Pd differentiation in the 'sulfide-poor' ores as compared to the disseminated sulphide ores. A key question as to the origin of the 'sulfide-poor ores' is how Cr concentrated in abundances 10–50 times exceeding its normal values for Noril'sk traps. As soon as it has been shown that most of chromite crystallised *in situ* [2], we suppose that rapid crystallisation of chromite within strongly contaminated by argillite volumes of magma caused a concentration gradient and flow of Cr to these areas. However, the exact reasons of such a flow or any other mechamisms of chromite concentration remain unclear and deserve a detailed physiochemical study.

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