GEOLOGICAL AND ISOTOPE-GEOCHEMICAL CHARACTERISTICS OF PREDICTION AND SEARCH METHOD FOR THE PGE-BEARING MAFIC-ULTRAMAFIC LAYERED INTRUSIONS OF THE EAST-SCANDINAVIAN LIP

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ABSTRACT. For the East-Scandinavian Large Igneous Province (LIP), the indicators for important mineralization (low-sulfide Pt-Pd) in the Early Proterozoic mafic-ultramafic layered intrusions of the plume origin have been evaluated (Bayanova et al., 2009; Mitrofanov et al., 2013). These criteria are useful for predicting the occurrence of low-sulfide Pt-Pd mineralization in the mafic-ultramafic layered intrusions and the potential at the beginning of geological survey. The selected criteria reflect a combination of geological, geodynamic and geochemical factors that control the sizes and metal tenors of the low-sulfide (Pt-Pd) economic deposits. These methods are useful for regional exploration target selection and for regional resource evaluation of PGE and base metals.

The proposed criteria (Table 1) are for the prediction and exploration of low-sulfide Pt-Pd ore deposits in the mafic-ultramafic layered intrusions in the East-Scandinavian LIP. They can be used to identify areas that have potential for low-sulfide Pt-Pd mineralization in the layered maifc-ultramafic intrusions in the Archaean crystalline shields during the early stages of regional geological studies. The method is developed based on the geological characteristics of the mafic-ultramafic intrusions with variable degrees of PGE and base metal mineralization (Mitrofanov et al., 2013).

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Table 1

Prediction and exploration indicators for low-sulfide Pt-Pd (with Ni, Cu, Au, Co and Rh) mineralization in mafic-ultramafic intrusions

№	*Search indicator*	*Parameters*
1	Geophysics	Presence of granulite-mafic (anorthosite) layer with crust-mantle characteristics (Vp = 7.7-7.1 km/s) due to plume-derived magma underplating (composition of the layer is defined on the basis of deep crustal xenoliths in the volcanic pipes) detected by the deep geophysical methods in the base of the crust.
2	Structure	Regional: distribution of a discordant rift-related volcano-sedimentary strata, dikes, and polyphase layered mafic intrusions over a vast area of Archaean basement. Local: ore bodies occur in the lower intrusive contacts, extended reefs, pegmatoid zones of mafic rocks, veins and offset.
3	Geodynamic setting	Large-scale, protracted, and multiple episodes of deep mantle plume or asthenosphere upwelling, the vast non-subduction-type basaltic magma in an intraplate continental setting (LIP's). Change of Archean orogenic regime to intracontinental rifting (with origination of variously oriented ensialic belts). Ore-controlling mafic-ultramafic intrusions formed at an initial (pre-rift) stage of continental rifting.
4	Composition	Siliceous high-Mg (boninite-like) and anorthositic magmas. Cyclic (regular polystage style) structure of the layered intrusions and abrupt change of cumulus lithology and lithogeochemistry. There are two to five and more megacycles in the majority of the Palaeoproterozoic layered intrusions. The megacycles represent regularly layered series from ultramafic varieties to gabbro. The ore is confined to the most contrasting series of alternating thin rock layers with different compositions from leuco- and mesocratic gabbro to norite, anorthosite, plagiopyroxenite, and with different textures from leucocratic (leucogabbro, anorthosite, "spotted" gabbro), inequigranular to coarse-grained and pegmatoidic. All known stratiform reef-type deposits are confined to the borders of the megacycles, which mainly reflects the interaction between high-Cr magma with low-Cr one. Intense interaction with deeply derived reducing fluids resulted in the enrichment of volatiles such as C, F, Cl and H_2O in the rock. Mineralogical factors: PGMs in disseminated sulfide mineralization, anomalously high concentrations of PGEs in the bulk sulfides, inferred platinum distribution coefficient between silicate and sulfide melts of >100000.
5	Isotope geochemistry	Deep mantle magma source enriched in ore components (fertile source) and lithophile elements. It is reflected in the isotope indicators such as εNd(T) from -1 to -3, I_{Sr}($^{87}Sr/^{86}Sr$) from 0.702 to 0.704, $^{3}He/^{4}He = (10^{-5}\text{-}10^{-6})$. Magma and ore sources differ from those of Mid-Ocean Ridge basalts, subduction-related magma but are similar to EM-I.
6	Geochronology	Intraplate mafic LIP with low-sulfide Pt-Pd mineralization (the East Scandinavian Province in the Fennoscandian (or Baltic) shield, the East Sayany Province in the Siberian Platform, the Huronian Province in the Canadian shield) formed at the very beginning of supercontinent break-up, mostly between Archean and Proterozoic, or at 2.6-2.4 Ga. For the East-Scandinavian province, it was the Sumi – Early Sariola epoch, or 2.53-2.40 Ga. Ore-bearing mafic complexes formed during a long period of time and by different episodes (2490±10 Ma; 2470±10 Ma; 2450±10 Ma; 2400±10 Ma), and by mixing between the boninitic an anorthositic magmas.
7	Metamorphism	Known economic ore deposits occur in the regionally unmetamorphosed rocks. Only Pt-Pd ore prospects are found in the regionally metamorphosed layered mafic complexes. There is evidence that amphibolite-facies metamorphism lead to metal decrease in the deposits.