MAGMATISM OF THE EARTH AND RELATED STRATEGIC METAL DEPOSITS

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The combination of ultrabasic rocks of the dunite-harzburgite formation with apatite-pyroxene-phlogopite rocks of the alkali-ultramafic formation looks very unusual, taking into account differences of their nature. However, an increasing number of publications on the finding of carbonatite in atypical tectonic settings (Jones et al., 2013) allows to consider those settings as potentially valuable for trace element and rare-earth ores.

In the Taimyr Peninsula, a carbonatite are known as gold-bearing, copper-polymetallic-sulphide-bearing and having a fluorite-barite mineralization (Proskurnin et al., 2010). The conducted study has demonstrated that alkali magmatism took place in the NE Taimyr. It is potentially ore-bearing and associates with trace-element and REE mineralization. The described rock association is promising for further identification of ore-bearing carbonatite bodies.

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FLOOD BASALT AND ORE-BEARING INTRUSIONS OF THE NORILSK REGION: SOURCES AND CONDITIONS FOR THE FORMATION OF ORE-BEARING MAGMA

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Deposits of sulfide ores of the Norilsk region are among the largest deposits of nickel and platinum metals. They are confined to stratified intrusions, the formation of which is associated with the permo-triassic flood basalt magmatism of the Siberian platform. Although a large number of publications (Dodin et.al., 2000; Gorbachev 2005, 2006, 2010, 2012; Krivtsovet.al., 2001; Lightfoot et.al., 1990, 1994, 2005; Naldrett et.al., 1992, 1998; Sobolev et.al., 2009), the main problem is the sources and conditions for the formation of super-concentrations of sulfides and metals in them in small (up to 10 km^3) intrusions are still debatable. In this connection, the features of tectono-magmatic activation of the Noril'sk region, stratigraphy and geochemistry of the effusive strata, intrusions of the Norilsk type and its ores are considered. Based on geological, geochemical and experimental data, a genetic model for the formation of ore-bearing magma is proposed, scales and further perspectives of the region in relation to sulfide mineralization, and their search characteristics are estimated.

Geology and magmatism. The Permian–Triassic flood basalt magmatism of the Noril'sk district developed in part of the Siberian Platform with Archean–Paleoproterozoic basement broken into blocks and overlapped by a sedimentary cover up to 13 km thick and a volcanic sequence reaching 3.7 km in thickness. The geophysical data show that remnants of the subducted ancient oceanic crust exist in the mantle and fragments of transitional magma chambers and conduits are retained at different levels of the Earth's crust. The cyclic tectonomagmatic evolution of the territory was characterized by alternation of extension with intense volcanic activity and compression accompanied by waning of volcanic eruptions. The early rifting, transitional stage, and late dispersed spreading are distinguished. The associations of volcanic (lavas and tuffs) and intrusive rocks were formed during each stage. The volcanic sequence is subdivided into 11 suites. Two of primary magmas differ in geochemistry of lavas and intrusions: (1) OIB type high-Ti magma (iv, sv, gd formations of the first stage from bottom to top) and (2) low-Ti magma (hk, tk, nd formations of the second stage and mr–mk formations of the third stage). The nd formation depleted in ore elements and the ore-bearing cumulus composed of

silicate and sulfide melts in combination with early silicate minerals and chromite are products of the fractionation of the primary low-Ti magma.

The intrusions of the Talnakh and Noril'sk ore fields are distinguished by two level structure with the Upper Noril'sk ore-bearing intrusions above and the Lower Noril'sk barren intrusions below. As follows from geochemical parameters, intrusions of the Lower Noril'sk type are comagmatic to the evolved lavas of the nd_3 subformation, whereas intrusions of the Upper Noril'sk type are comagmatic to the lavas of the mr–mk formations. Geochemical similarity with volcanic rocks provides evidence for the composition of the initial magma and the time of intrusion emplacement. The ore bearing intrusions of the Upper Noril'sk type were formed at the onset of the third stage, when the primitive low-Ti magma similar to the lavas of mr–mk formations in composition was emplaced. When intruding, this melt captured and transported ore-bearing cumulus (drops of sulfide melt, early olivine and chromite grains) into the magma chamber. Separate portions of sulfide liquid were involved into movement as a self-dependent intrusive subphase during formation of the Talnakh and Kharaelakh intrusions.

Sulfur solubility. An extremal effect of pressure on sulfur concentration in fluid-bearing and sulfide-saturated mafic magmas has been established in experiments at P = 1–4 GPa. In this interval of pressure, the S concentration in sulfide-saturated magmas increases in the following sequence: dry magma ≤ (H_2O+CO_2)-bearing magma < H_2O-bearing magma. In the regions of low (< 0.3 GPa) and high (> 2.5 GPa) pressures, the S contents (0.1–0.2 wt.%) are commensurable. The experimentally established extremal nature of the effect of pressure on the sulfur concentration in fluid-containing mafic magmas under conditions of sulfide saturation with a maximum (up to 0.9 wt.% S) in the range P = 1.0-2.0 GPa and very low solubility (≤ 0.1 wt.% S) at P ≤ 0.1 GPa and at P ≥ 2.5 GPa can play an important role in the formation of ore-bearing magmas and the transport of sulfides from deep magmatic foci to the upper horizons of the earth's crust.

Isotopic composition of sulfur. The sulfur enrichment of the sulfides of the deposits with a heavy isotope at a constant ratio of mantle and crustal sulfur to them can be explained by the admixture of the sulfur crust in the mantle source containing protoliths of the subducted oceanic crust, during melting of which sulfide-silicate and silicate magmas, and also the fluids were initially enriched with 34S.

Experimental simulation of the formation of ore-bearing magmas from mantle chamber containing protoliths of the subducted oceanic crust could serve as a source of volatile and primary trap magma. Our experimental modeling of magma formation from such a source showed that in the interval P=1.5-4.0 GPa, the formation of melts of the picrite-basalt composition occurs already at T=1250-1350°C and is accompanied by pyroxenization of the mantle peridotite resulting from the reaction with the melt. These features determined the large volume of generated melts, their enrichment with olivine-compatible elements.

Sulfide ores. Fractional crystallization and emanation differentiation of sulfide magma and related mineralogical and geochemical zoning are exemplified in massive sulfide ores of the Oktyabr'sky deposit, Noril'sk district. The mineralogical zoning is expressed in the change of mineral types of ore from pyrrhotite (Po) to chalcopyrite (Cp) (from the flanks to the center of the ore lode). In terms of geochemistry, the Cu content, Cu/(Cu + Ni) ratio, and contents of noble metals incompatible with Mss (Pt, Pd, and Au) increase in this direction, while the S and Fe contents decrease. The distribution of elements compatible with Mss (Ir, Os, Rh, and Ru) is more complex. Their contents decrease from Po to high-Cu Cp ore, although there is a second maximum for Cb-type ore. The distribution of ore elements in the vertical and horizontal sections of massive ores at the deposit is different. The upper outer contact zone and frontal parts of massive ore lodes are enriched in all ore elements and a light sulfur isotope. The succession of enrichment is correlated with the relative affinity for sulfur and remains independent of the affinity of these elements for Mss (Pd–Rh, Os–Au). The possible role of liquid immiscibility of sulfide magma in the development of the mineralogical and geochemical zoning of massive ore is discussed.

Conclusion. The calculation results show that the amount of sulfides in the known deposits does not exceed 2% of geological resources of the sulfides separated from the flood basalts. Therefore, the

chance of discovery of new deposits remains rather high. Proceeding from the conditions of ore-bearing magma formation and geological setting of the known deposits, criteria for recognition of potentially ore-bearing areas are proposed and such areas are outlined.

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SUWAŁKI VS. SEJNY JOTUNITES – AN ATTEMPT OF COMPARISON (NE POLAND)

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The crystalline basement of Polish part of East European Craton (EEC) is covered by a thick layer of Phanerozoic sediments ranging from 600 m in NE part of Poland up to 6,500 m along the Trans European Suture Zone (TESZ) and it is explored only by geophysics and drillings (Wiszniewska at al., 2002). The Mezoproterozoic Mazury Complex (Fig. 1) is composed mostly of rapakivi type granites, which have been interpreted as A-type, and several more mafic intrusions of anorogenic character and bimodal composition. Three massive-type anorthosite-norite massifs were recognized: Suwałki, Kętrzyn and the smallest one – Sejny (Wiszniewska and Bagiński, 2003), which together