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Large igneous provinces as the sites of magmatic (platinum-group element and nickel) ore deposits

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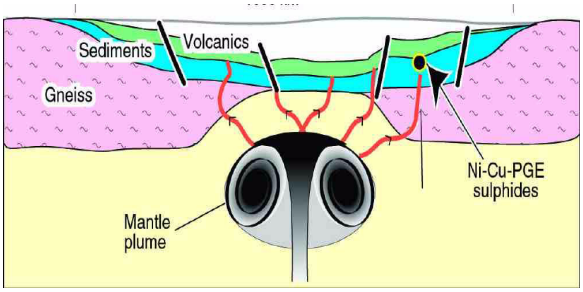
Most of the world's platinum-group element (PGE) and Ni-Cu sulfide deposits are found within or in contact with mafic and ultramafic rocks. In most cases these deposits can be related to a large igneous province (LIP), e.g. the Noril'sk-Talnak Ni deposits are associated with the Siberian flood basalts and the Merensky and UG-2 Pt deposits are found within the Rustenburg Layered series of the Bushveld Complex, which is the size of a LIP.

The reasons for this association are as follows.
I) In the mantle source of the Ni and PGE in the ore deposits, Ni is hosted by olivine and PGE are hosted in sulfides and possibly Fe-PGE alloys. High degrees of partial melting are required in order to release all the PGE from the sulfides and to melt as much olivine and possibly alloys as possible. Melts generated by high degrees of partial melting are formed in the stems of mantle plumes and LIPs are thought to form from mantle plumes. II) The magma must be transferred from the mantle to the crust before a sulfide liquid can segregate from it because sulfide segregation would remove the metals and thus improverish the magma. LIPs represent areas of the crust where primary magmas have reached the surface. III) When the magma approaches the surface it should segregate a sulfide liquid that collects the metals. The source of the sulfur is thought to be country rock that is assimilated into the magma. This requires that the sytem have a large amount of heat, heat that can be derived from the LIP magmas. IV) Once the sulfide liquid forms, it must interact with a large volume of silicate magma in order for the metal concentrations (grade) of sulfide liquid to be high enough to mine. In most ore deposits, the ratio of silicate to sulfide magma is thought to have been at least 1000. This requires a very high-energy system, which the heat from the LIP could supply. V) Finally, in order for a deposit to be large enough to mine, a large quanty of magma must undergo all these processes. LIPs represent large quanties of magma.



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New insights into metallogenesis of the Noril'sk-Talhahk Ni-Cu-PGE sulfide ores

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New high precision PGE, Cu and Ni data for the Permotriassic Siberian Trap flood basalts which overlie sub-volcanic sills hosting the giant Noril'sk-Talnahk Ni-Cu-PGE sulfide ores provide new insights into the generation of these deposits as well as flood basalts. The Pd and Pt contents of the "undepleted" basalts range from 3.4 to 17.4 ppb and 6.2 to 12.1 ppb, respectively, while their Pd/Pt ratios range from 0.45 to 2.0. By contrast, many of the PGE-depleted Nadezhdinsky basalts contain less than 0.06 ppb Pd and 0.1 ppb Pt (the detection limits of the analytical technique) and have Pd/Pt ratios of ~0.3. These Pd/Pt ratios are the reverse of those of the ores, which have Pd/Pt ratios of 3 to 5. The most PGE-depleted and crustally contaminated (as indicated by high La/Sm, Th/Nb, etc.) of the Nadezhdinsky lie close to the base of this formation; these have a factor of >200 less PGE than the underlying PGE-undepleted Tuklonsky.

The new data suggest that the ore-forming process was continuous and dynamic, and began in a deep-seated crustal "staging chamber" in which mantle-derived, S-undersaturated, PGE-undepleted, Tuklonsky-like magma interacted with crustal material and became S-saturated. This triggered formation of PGE-rich sulfides, which settled towards the bottom of the staging chamber at the same time as the contaminated magma was being erupted to form the most PGE-depleted Nadezhdinsky basalts. As new S-undersaturated, PGE-undepleted, Tuklonsky-like magma entered the magma chamber it mixed with the contaminated magma and progressively diluted this magma. The staging chamber was eventually totally emptied, with the last material to be removed from it being the PGE-rich sulfides which were transported upwards to their present locations. The formation of Noril'sk-type Ni-Cu-PGE deposits may therefore require complete evacuation of the staging chambers.