Paleoproterozoic (2.5-2.4 Ga) Plume Magmatism in the North-Eastern Baltic Shield and Origin of the PGE, Sulphide and Chromite Ore Deposit

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The petrology, isotope geochemistry, geochronology, and ore genesis of the Monchegorsk pluton have been studied. The Monchegorsk intrusion is located in the central part of the Kola Peninsula, Russia (Fig. 1). Based on the geology, petrology and geochronological U-Pb data (on zircon and baddeleyite) we have distinguished three main stages of intrusions (Fig. 2).

At the earliest stage (2507-2500 Ma) the large-scale layered Monchepluton, which consists of dunites, harzburgites, bronzitites, norites, gabbro-norites and anorthosites, was formed. It contains spatially disconnected deposits of disseminated and veined sulphide ores, a body of thick-disseminated chromite ores, and horizons of PGE-bearing mineralization poor in base-metal sulphides. The mantle source of the primary melts was enriched in LREE, $\varepsilon_{Nd}(T)$ = up to -1.5. The Monchepluton has a complicated structure because of multiple melt injections ranging in composition from ultrabasic to basic. Initially the melts came from the steeply pitching southwestern channel and then moved in the subhorizontal direction along sublatitudinal and submeridional faults. Partially crystallized chromite-bearing ultrabasic rocks of the feeder were emplaced as a result of plastic deformation.

At the end of this first stage (until 2487 Ma) but before the complete cooling of the Monchepluton rock sequences, the injections of mafic dykes and small intrusions (such as Yarva-Varaka) took place. They represent the products of residual liquid fractionation enriched to variable degrees in crustal components ($\varepsilon_{Nd}(T)$ = up to -2.5). The felsic melts represent material of the remelted Archean basement. After this stage, late orogenic events occurred and part of the Monchepluton was eroded, and then overlaid by the weathering products and conglomerates of the Imandra-Varzuga zone.

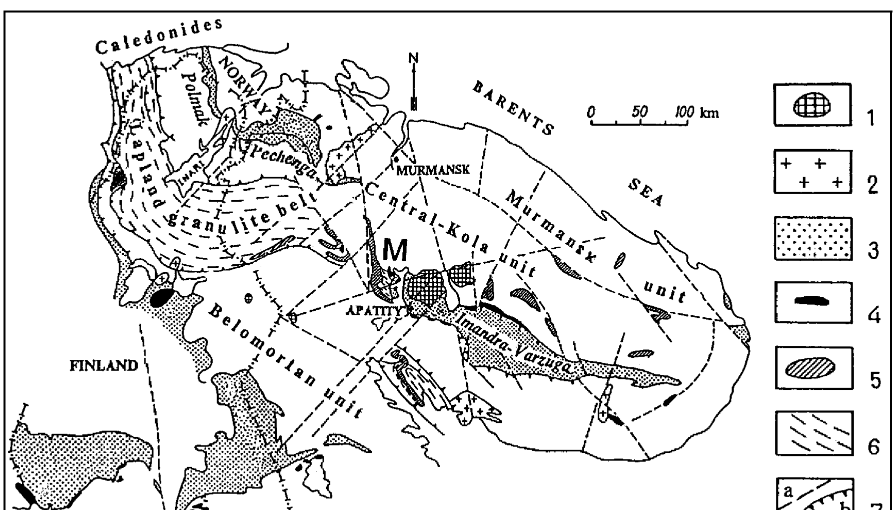

Figure 1. *Locations of the Monchegorsk area and the layered Monchepluton. 1 – Paleozoic alkaline intrusive complex; 2 – Paleoproterozoic orogenic granites; 3 – sedimen-tary-volcanic formation of the Paleoptoterozoic; 4 – Paleo-proterozoic layered intrusions (M – Monchepluton); 5 – Archaen and Paleoproterozoic gabbro-anorthosite intrusions; 6 – granulite; 7 – faults (a) and trusts (b).*

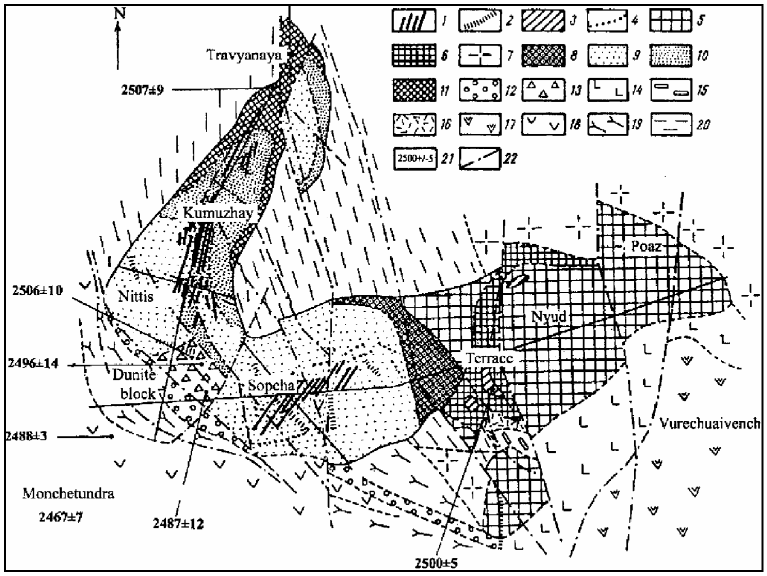

Figure 2. *Geological map of the Monchepluton and U-Pb geochronological data*. 1 – Ni-Cu sulphide veins; 2 – dolerite dykes; 3 – rocks of the "critical horizon" of Mt. Nyud; 4 – ore beds od Mt. Sopcha; 5 – norite; 6 – olivine norite; 7 – diorite and granodiorite ; 8 – plagioclase bronzitite; 9 – bronzitite; 10 – alternating bronzitite, olivine bronzitite and harzburgite; 11 – harzburgite; 12 – melanocratic norite; 13 – dunite, plagioclase dunite and chromitite; 14 – metamorphosed gabbro-norite and anorthosite; 15 – metagabbro and titanomagnetite ore; 16 - diorite; 17 – metamorphosed volcanic ana vesicular rocks; 18 – gabbro-norite and anorthosite of the Monchetundra intrusion; 19 – metamorphosed and schitose gabbro-norite and anorthosite; 20 – amphibole-biotite gneiss and amphibolite; 21 – U-Pb data; 22 – faults.

During the second stage (2488-2453 Ma) the large intrusions of the eastern Baltic Shield of Glavny Khrebet (Monche-, Chuna and Volch'i tundras) were emplaced. They consist of differentiated series comprising norites, gabbro-norites, leucogabbro and anorthosites. The rocks contain mainly Ti-magnetite mineralization. Geochemical and isotope features of the Glavny Khrebet rocks (ε_{Nd}(T) = up to -1,3) are similar to gabbroid rocks of the Monchepluton, suggesting similar petrogenetic relationships.

Intrusion of large amounts of high-temperature mantle melts into the upper part of the crust caused a thermal dome in the crust, that predetermined subsequent initiation of an extensive rift through the Kola Peninsula.

At the last stage (2445-2437 Ma) small intrusions (Mt. Ostrovskaya for example) consisted of lherzolites, websterites and gabbro-norites, and intrusions of the Imandra chromite-bearing lopolith comprising norites, gabbro-norites and metagabbro were emplaced. They also display anomalous isotope features (ε_{Nd}(T) = up to -2,5). Rocks of the Imandra lopolith intrude both the Archean basement and volcanogenic series of the Paleoproterozoic Imandra-Varzuga zone and were accompanied by partial melting of felsic volcanites and by formation of granophyres. The youngest monzodiorite dykes and pegmatite vein with the U-Pb zircon-baddeleyite age of 2398-2395 Ma crosscut rocks of the Imandra lopolith.

All the ore deposits of the region resulted from presence and ascent of plume magmatism during the 100 Ma from 2.5 until 2.4 Ma. The mantle plume activity has involved heating and consequent fusion of the magma melts partially enriched in upper and lower crust material.

The Monchepluton contains various deposits of Cu-Ni sulphide, chromite, and PGE-bearing ores. The Monchepluton sulphide ores are represented by syngenetic pocket-disseminated and epigenetic vein types. There are several deposits within the pluton, among which are (1) Nittis-Kumush'ya-Travyanaya near the bottom of the intrusion, (2) ore layer in the Sopcha ultrabasites named "horizon 330", (3) ore layers in the Nyud olivine norites, (4) "critical horizon" of the Nyud massif (the Terrace), (5) the Nittis-Kumush'ya-Travyanaya subvertical veins, and (6) the Sopcha crosscutting harzburgites and bronzitites. There are pyrrhotite, pentlandite-chalcopyrite-pyrrhotite and pyrrhotite-pentlandite-chalcopyrite bearing ores. More than 60 minerals have been identified in the sulphide ores. The major minerals are pyrrhotite, pentlandite, chalcopyrite, magnetite, pyrite, and the minor are Ti-magnetite, ilmenite, bornite, cubanite, millerite, and mackinawite. The sulphide ores contain Pt-Pd minerals, such as native platinum, niggliite, kotulskite, merenskyite, sopcheite, sperrylite, michenerite, braggite, cooperite, iridosmine, stannopalladinite, vysotskite, Pt-gersdorffite, native osmium etc. They include native gold and copper, Au and Ag tellurides (hessite, sylvanite, calaverite). Within the zone of oxidation there are violarite, marcasite, chalcosine, covellite, ochres and Fe oxides.

Recently, PGE-bearing mineralization poor in base-metal sulphides and confined to gabbro-anortosites, has been discovered in the Vurechuaivench massif and in large noritic dykes cutting the dunite located within the Monchepluton. The mineralization which is poor in base-metal sulphides has specific PGE-bearing minerals, such as hollingworthite, platarsite, irarsite, associated with naumannite.

A large chromite body composed of massive, thickly-disseminated and disseminated ores, is located within the dunite. Chromite is heterogeneous in genesis and composition. Al-chromite, which is always found disseminated in the host rocks, the ores include early chromite as inclusion within the olivine, chromite ore is the most enriched in Cr, late interstitially chromite, and secondary ferrochromite. The crystallization of chromite ore occurred under the low oxygen fugacity, lack of S, and in equilibrium with olivine. Ores are barren in Pt minerals PGM are only represented by laurite.

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