PGE Mineralization in the Paleoproterozoic Monchetundra Layered Igneous Complex (The Baltic Shield, Russia)

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The abstract presents the newest data on sulphide-poor PGE occurrences recently prospected by "Central Kola Expedition". Data reported result voluminous program of deep geological drilling aimed for recovering of PGE potential of the Monchetundra massif region and their magmatic environment, especially of the boundary zone between Monchegorsk and Monchetundra intrusions.

The Monchegorsk magmatic complex (MMC) is situated in transition faulted area between the Imandra and Pechenga rift zones of paleoproterozoic Pechenga-Imandra-Varzuga rift system (Fig. l). MMC consists of the Monchetundra intrusion and Monchegorsk pluton; both massifs intrude gneisses of Archean Kola-Belomorian complex and in turn are overlapped by volcanics and clastics of Early Proterozoic Imandra-Varzuga rift complex. According to various determinations, the absolute age of the Monchegorsk Pluton is estimated in 2504 - 2493 Ma, gabbro-anorthosites of Monchetundra massif - 2453±4 Ma; (Amelin *et al.,* 1995, Balashov *et al.,* 1993).

Magmatic stratigraphy of the Monchetundra massif comprises (1) lower ultrabasic zone of dunite, poikilitic peridotite and pyroxenite up to 100- 300 m in thickness; (2) middle zone (critical zone?) of rhythmically alternated pyroxenite, olivine pyroxenite and plagiopyroxenite, norite, gabbronorite, up to 300-400 m in thickness; (3) upper zones of gabbronorite and gabbro-anortosite at the top of the sequence up to 800-1000 m thick.

The Monchegorsk pluton of about 1.5 km in thickness consists of the number magmatic bodies composed NS trending zone of mostly ultrabasic massifs and WE trending zone of mostly gabbroic bodies (Fig. 1). The Monchegorsk Pluton contains economic or sub-economic PGE-Cu-Ni deposits (Eliseev et al., 1956), recently discovered chromitite horizons (Sopcheozerskoe deposit), and PGE-bearing disseminated sulfide mineralization in quartz gabbronorite of the Vuruchuaivench massif (Grokhovskaya et al., 1995, 2000).

Both massifs are synform, NW striking boundary zone between them contains a number of steeply dipping bodies of rhythmically layered norite, gabbronorite, pyroxenite, peridotite with rare chromitite seams enclosed by massive coarse gabbro and gabbronorites of Monchetundra massif. According to recent data, steeply dipping intrusions are of 2487± 12 Ma in age (Smolkin et al., 2001). Thickness of these massifs ranges from 100 to 300 m. In their lithology and geochemistry, rocks of these bodies are similar to rocks of the middle (rhythmically layered) zone of the Monchetundra massif. Possibly, all the boundary zone is the set of contiguous sheet-like intrusions (Kozlov et al, 1967).

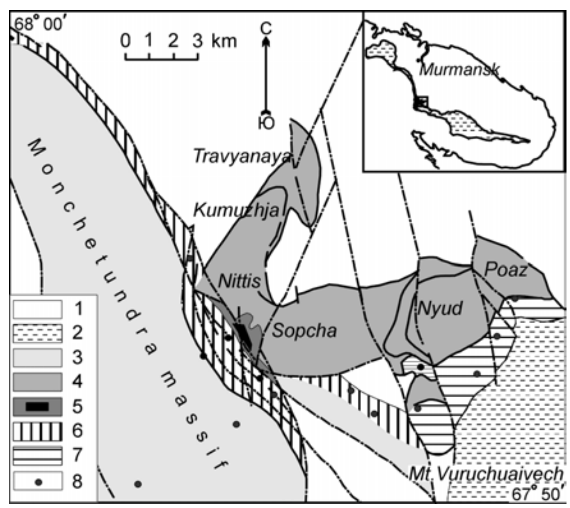


Figure 1. *Location and sketch map of the Monchegorsk Magmatic Complex. 1 - Archean gneisses, 2 - volcanogenous-sedimentary rocks of the Imandra-Varzuga complex, 3 - coarse-grained gabbro and anorthosite of Monchetundra massif, 4 - mafic and ultramafic rocks of Monchegorsk Pluton, 5 - alternating sequence of dunite, peridotite and chromitite of "Dunite block", 6 - boundary zone between Monchetundra and Monchegorsk layered intrusions, 7 - Vuruchuaivench gabbronorite massif, 8 - some of key boreholes.*

__Table 1.__ PGM in Monchegorsk (1), Monchetundra (2), Vuruchuaivench (3) massifs, Boundary zone (4), Genkin et al.,1963 (+), Yushko-Zaharova et al., (v), Orsoev et al., 1982 (o), the data of the authors (*).

Mineral	1	2	3	4
(Cu,Ni,Fe,Pt,Pd)				*
Cu3Pt, Cu3Pd				*
Native Au, Ag			*	*
Electrum	*	*	*	*
Cooperite		*		*
Braggite		*		*
Vysotskite		*		*
Zvyagintsevite				*
$(Pd,Pb)_2(S,Se)$				*
Guanglinite		*	*	*
Palarstanide				*
Isomertieite			*	*
Majakite			*	*
$Ni_6Pd_2As_3$				*
$Pd_3Ni_2As_3$			*	*
Nigglyite	v*			
Palarstanide				*
Kotulskite	+*	*	*	*
Michenerite	+*	*	*	
Merenskyite	+*	*	*	*
Moncheite	+*	*	*	
Sobolevskite			*	
Sopcheite	o*		*	*
Pd_6AgTe_4			*	*
Frudite	*			
Pd_5Te_2		*		
Sperrylite	*	*	*	*
Laurite	*			
Hollingworthite	*		*	*
Platarsite			*	
Irarsite			*	*
Pd - cobaltite			*	*

Three deep boreholes cut any horizons with abundant disseminated sulfides in rocks of middle rhythmically layered zone of the Monchetundra massif. Horizons, which are of 1-3 m in thickness, contain from 0.5 up to 5 ppm Σ PGE (average 1.6 ppm Σ PGE, 0.05 wt. % Ni, 0.06 wt. % Cu, with Pd/Pt =2.3). PGE occurrences in the boundary zone were studied in detail both in outcrops and in numerous boreholes (see key boreholes on fig. 1).

Enriched PGE contents have been established in irregular-shaped bodies of pegmatoid or coarse-grained gabbronorite, and in steeply dipping sheet-like intrusions composed of rhithmically layered gabbronorite, norite and pyroxenite (±peridotite, chromitite) with disseminated base-metal sulfides within coarse-grained gabbro. These occurrences are featured by very erratic PGE distribution from 1-2 to 15-32 ppm Σ PGE) (average from 1.8 to 3.8 ppm Σ PGE, Pd/Pt ratio ranges from 2.5 to 5.1), and lack of strong correlation with Ni, Cu, S.

Major base metal sulphides in PGE occurrences are pyrrhotite, chalckopyrite, pentlandite in various relations, millerite, pyrite, bornite, violarite, with minor polydimite, cobaltite, gersdorffite, sphalerite, galena, clausthalite, molybdenite, covelline. Other ore minerals are chromite, titanomagnetite and ilmenite. PGE form their proper minerals and isomorphic admixture in Ni-Co-Fe sulfarsenides and pentlandite. PGM occur in base metal sulphides, in contacts between sulphide and silicate, and also in silicate matrix (sometimes within quarts and amphibole in turn these gangue form inclusions within PGM (Fig. 2a).

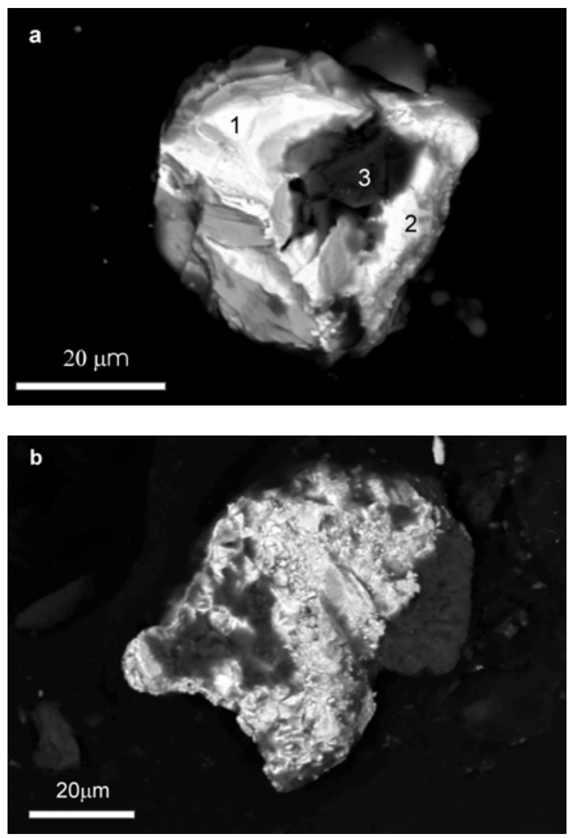


***Figure 2.** Backscattered electron images of PGM in heavy mineral concentrate from Boundary Zone occurrence: a - the composite grain of sperrylite (1), alloy $(Cu,Ni,Fe)_3$ (Pt,Pd) (2), and Fe-Mg-amphibole (3); b - segregation of (Ni,Pt,Cu,Fe)(AsO) phase.*

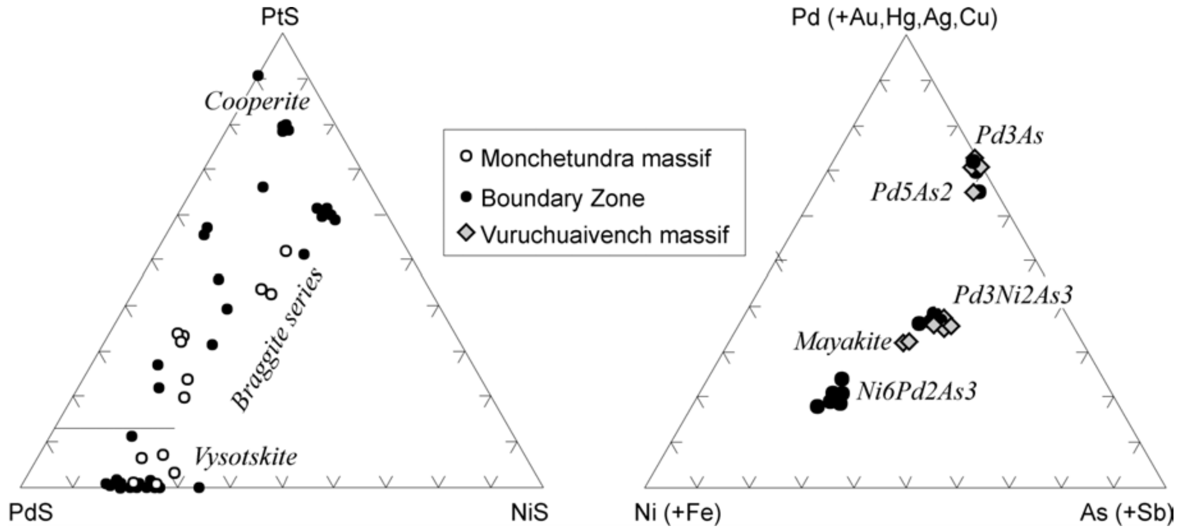
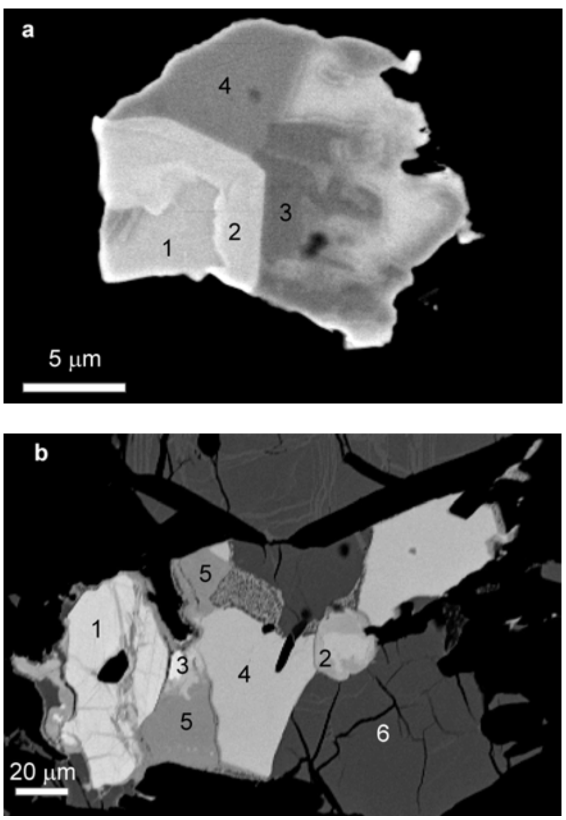


Figure 3. *Chemical composition of the Pd-Ni-As phases and Pd-Pt-Ni sulphides (atomic %).*



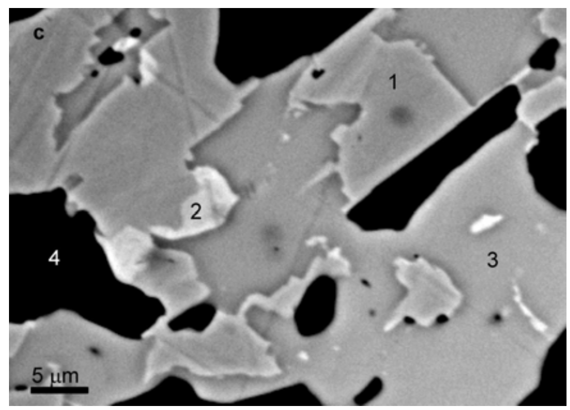


Fig. 4. *Backscattered electron images of PGM in polished sections from Boundary Zone occurrences (JSM 5300): a - composite intergrowth of kotulskite (1), sperrylite (2), guanglinite (3) and palarstanide (4) in bornite-millerite-chalcopyrite assemblage; b - sperrylite (1), hollingworthite (2), kotulskite (3), isomertieite (4),* $Ni_6Pd_2As_3$ *(5) and pentlandite (6) in silicate matrix. c - inclusion of zvyagintsevite (1), electrum (2) and unknown phase* $(Pd,Pb)_2(S,Se)$ *(3) in bornite-chalcopyrite assemblage.*

Pt-Pd-bismutotellurides and sperrylite prevail in Cu-Ni-PGE ores of the Monchegorsk pluton. The most numerous and diverse PGM association is revealed in the boundary zone of the Monchegorsk and Monchetundra intrusions and Vuruchuaivench massif (Table 1.).

Braggite, cooperite and vysotskite assemblage is found only in the Monchetundra massif and its boundary zone. Minerals of Pd-Ni-As, Pd-As-Sb and Pd-As-Sn systems feature the Boundary Zone and the Vuruchuaivench massif (Fig. 3,4).

PGM are of irregular structure and composition, with mutual isomorphic substitution of elements (see backscattered electron images, Fig 4a). PGM contain admixture of Hg, Ag, Se and Au. The assemblage of sperrylite, pd-bismutotellurides, Cu_3Pt, guanglinite, nickeline, Cu_3Pd and (Ni,Pt,Cu,Fe)(AsO) is established in strongly tectonized cyclic units of gabbronorite, pyroxenite, peridotite, chromitite in the boundary zone (Fig. 2 a,b).

Similarities in petrology, geochemistry and mineralogy of PGE occurrences in the region allow us to suggest existence of the arch-shaped platinum-bearing belt localised along the Monchetundra fault zone. This zone, which was primarily originated as transform fault in the Pechenga-Varzuga rift system, then became area of re-distribution, concentrating and accumulation of PGE. These processes were happened in sharply changed geochemical environment affected by fluid and hydrothermal impulses.

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