Science Research
2018; 6(6): 61-67
http://www.sciencepublishinggroup.com/j/sr
doi: 10.11648/j.sr.20180606.11
ISSN: 2329-0935 (Print); ISSN: 2329-0927 (Online)

Genetic Nature of Platinum Ore Deposit Pansky Tundra in Kola Peninsula, Fennoscandian Shield

Turchenko Stanislav Ivanovich

Department of Metallogeny and Ore Forming Processes, Institute of Precambrian Geology and Geochronology, Russian Academy of Sciences, Saint Petersburg, Russia

Email address:
turchsi@mail.ru

To cite this article:
Turchenko Stanislav Ivanovich. Genetic Nature of Platinum Ore Deposit Pansky Tundra in Kola Peninsula, Fennoscandian Shield. *Science Research*. Vol. 6, No. 6, 2018, pp. 61-67. doi: 10.11648/j.sr.20180606.11

Received: November 12, 2018; **Accepted**: December 10, 2018; **Published**: January 2, 2019

Abstract: The article examine petrologic-geochemical and isotope peculiarities of forming low sulfide PGE deposit in Palaeproterozoic layered intrusion Pansky Tundra at central part of Kola Peninsula. PGE mineralization concentrated within rhythmic layered horizons (RLH) lower and upper parts of intrusion's rocks mostly gabbronorite composition. Main feature rich PGE mineralization is close association with anorthosites and leiconorites located in RLH and subject of later magmatic metasomatic transformations. Isotope U-Pb age of anorthosites 2449 ± 12 Ma, and age of gabbronorites from RLH by zircons - 2491±1.5 Ma. Sm-Nd isotope dating of metasomatic ore bearing rocks shows age corresponding 2427±90 Ma with sign of εNd from -0.7 up to -1.7 and TDM = 2.5 Ga. For detail examination geochemistry ore bearing and host rocks it is applied neutron-activation analysis. Method factor analysis and estimation disposition REE were arranged affinity ore bearing and host rocks with specific of geochemical composition of lower crust. More later anorthosites enriched by fluids with Cu, Ni, PGE in combination with Cl, F, Se, S made executive metasomatic transformation of anorthosites and create possibilities for a forming reef type PGE deposit.

Keywords: PGE Deposit, Kola Peninsula, Fennoscandian Shield

1. Introduction

Mafic-ultramafic intrusion Pansky Tundra belong to group of mantle magmatic bodies with isotope age 2.5-2.4 Ga that widespread at northeast of Fennoscandian Shield and were intruded during Palaeproterozoic global epoch of rifting. For other Precambrian regions this period was also marked by rifting events, inclusions of layered mantle intrusions and swarms mafic dykes, examples which are: intrusion Jamberline and dykes Binnerindge in Australia, Great Dyke in Zimbabwe, swarm dykes Herst-Matachevan and intrusion East Bull Lake in Canada, belts of layered bodies Kemi-Suhanko in Northern Finland and Olanga in Northern Karelia of Russia. All layered mantle intrusions of age interval 2.5-2.4 Ga are ore bearing and include Cr, Fe-Ti-V, Cu-Ni, PGE (Platinum Group Elements) deposits. For exploration of forming such types intrusions it is proposed existence of two different melts: 1) magmas boninite-tholeite composition enriched by Cr and Ni formed ultramafic-mafic layered intrusions; 2) melts depleted by marked elements, which leaded to forming of norite-gabbronorite intrusions contained rhythmic layered horizons with lenses or layers of anorthosites. Latest are consider as platinum bearing rocks with PGE horizons – reefs [1].

2. Geologic Structure and Feature of PGE Mineralization in Layered Massif of Pansky Tundra

Mafic-ultramafic massif Pansky Tundra is a monoclinic body, which is stretch out on 70 km at latitude direction along Kola Peninsula. Massif contacted at south with Palaeproterozoic volcanic-sedimentary rocks of Imandra-Varsuga riftogenic structure and from north massif is marked by Archean granite-gneiss, amphibolites and shists (figure 1). Contacts the massif with these northern rocks are often laid along late Archean alkaline granites but all contacts in great part with host rocks have tectonic characters. Magmatic stripe ring in the rocks of massif is NW 280-290° and SW fall at 25-30° on the south and 50-60° at the north of intrusion. Vertical thickness of massif is from 4 up to 6 km in differing blocks.

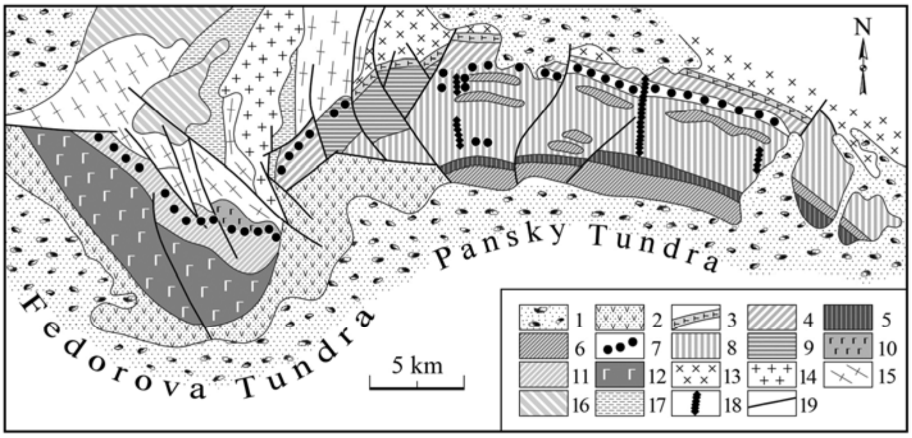

Figure 1. *Scheme geological construction layered intrusions Fedorova and Pansky Tundra. 1- Modern deposits, 2-Paleoproterozoic sedimentary-volcanic rocks of Imandra–Varsuga structure. Rocks of Fedorova-Pansky intrusion: 3-gabbro, norites, gabbronorites of lower boundary zone, 4-gabbronorites lower zone, 5- upper rhythmic layered horizon, 6-gabbronorites stripped and trachitoidal upper zone, 7- lower rhythmic layered horizon with PGE miheralization, 8-gabbronorites of middle zone, 9- schistose and milonitic gabbronorites, 10- gabbro, 11- gabbronorites of intrusion Fedorova Tundra, 12- highgrade amfibolized gabbro. 13- alkaline granites; 14- granites; 15- Arhean granite-gneiss, 16- amfibolites, 17- gneisses and schists. 18- dikes of gabbro-diabase. 19-faults.*

In peculiarities geological structure of intrusion Pansky Tundra is divided on West and East blokes. The last block is small naked and researched. The West Pansky block consist of slightly separate massifs divided by faults and on the whole has an extent up to 25 km and width 6.5 km.

In this block during 1986-1992 years owing to investigations geologists from AO "North West Geology" the PGE mineralization was discovered in separate parts of rhythmic layered horizons of gabbro-norite intrusion [2]. The PGE contents are average 8 g/t, but in separate parts up to 16 g/t. Complex rocks with PGE mineralization belong to knot part of crossing rift Imandra-Varsuga with Munozero-Tsaga meridional zone of depth faults. The general features PGE deposit Pansky Tundra are narrowly association with lenses anorthosite and leicogabbronorite located in rhythmic layered horizons (RLH) exposed by latemagmatic metasomatic reformations [3]. The RLH with thickness 150-200 m. observed along layering on 15 km and has fall in south rhombus up to 20-25°. These horizons consist of "layers" olivine bearing gabbronorite, melanonorite and troctolite between which lay sills of anorthosite and leicogabbronorite with thickness from centimeter up to firstly meters. Along stretch anorthosite trace up to hundred meters and have not hardening boundaries, sometimes it is observed cross contacts anorthosite with rocks of RLH. This can be testifying about later inculcation of anorthosite into primary magmatic layered rocks. The PGE mineralization forms horizons which concordant with layering of rocks and has thickness dozens centimeters up to 2.5m and long close to 10 km. The PGE mineralization consists of Pt-Pd-Bi-Te composition and associate with pentlandie, pyrrhotite, chalcopyrite. It was marked Pd/Pt ratios from 2.5 up to 20 and PGE enrichment in anorthosites and contacts these with gabbronorite rocks. Isotope U-Pb age of anorthosites detected by baddeyelite is 2449 ± 12ma, but age gabbronorite rocks from layered horizons detected by zircons is 2491±1.5ma [4]. Sm-Nd isotope dating these rocks also show its age near 2427±90Ma (MSWD = 1.73) and εNd from -0.7 up to -1.7 for age of depleted mantle TDM = 2.5 Ga [5].

3. Petrology and Geochemistry of PGE Bearing and Host Rocks

Important features of rocks RLH this are presence of horizons with sulfide and PGE mineralization located in anorthosites, leiconorites and zones its contacts with rocks of intrusion. Within the rocks of RLH such as the anorthosites observe maximum metasomatic altered. In connected with these the rocks of RLH are subdivided on two groups: 1) no related to host rocks and 2) ore bearing related rocks. First group – gabbronorites are main part rocks of RLH and consist of cumulative plagioclase (Pl), ortopyroxene (Opx) and clinopyroxsene (CPx). The Pl is N 60-70 and not owned is as intercumulative mineral. The Pl contents near 50%, but in olivine bearing rocks up to 70%. In all such rocks ilmenomagnetite and quartz are presented as intercumulative mineral. On the diagram AFM (figure 2) points the composition of gabbronorites form compact aerial of magnesia contents, but aerial more ferrous compositions typical for ore bearing anorthosites. Anorthosites consist of adcumulative plagioclase (75% An) and intercumulative pyroxene (5%).

Ore bearing metasomatic alterated rocks clear distinguish between rocks of RLH so as maintain such minerals as clinotzoisite, epidote, biotite, calcite, andradite and sulfide minerals. Pyroxene often replaced by uralite or chlorite and within its can be seen mixing rocks which consist of plagioclase and plagiopyroxene adcumulates. These rocks have likeness with "pudding" anorthosites typical for J-M reef of PGE bearing intrusion Stillwater [6].

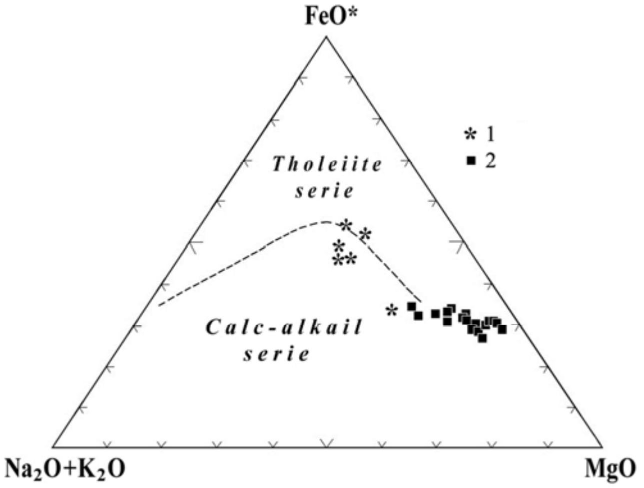

Figure 2. *Diagram AFM for ore bearing anorthosites (1) and gabbronorites (2).*

In intrusion Pansky Tundra PGE mineralization display in form of veins, thin veins or point of mineralization and connects with Cu and Ni sulfides. PGE mineralization introduces Te, Bi and sulfide combines with Pt and Pd. By method INAA in samples rocks were determined contents of 44 elements: Na, Mg, Al, Si, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, Br, Rb, Sr, Zr, Ag, Sb, Te, Cs, Ba, La, Ce, Sm, Eu, Tb, Dy, Yb, Lu, Hf, Ta, Ir, Au, Hg, Th и U. Ore bearing rocks visible are enriched by Te, Au, K, Se, Ir, Cu, Ni, Rb, Ga, Co Cs (in order of decreased meanings), but essentially depleted by Sc, Cr, V, Mn, Yb, Lu in compare with hosting gabbronorites (figure 3). Comparison ore bearing metasomatic alterated anorthosites with nonalterated anorthosites without Cu and Ni sulfides and PGE mineralization discovery enrichment first rocks of Te, Au, Ag, Se, Ir, Ni, Cu, Co, Br and Cl. This can be evidence about essentially bring of these elements during metasomatic processes. Simultaneously ore bearing anorthosites in comparison with empty anorthosites are enriched U, Rb и K (figure 4) that can be connect with bring these elements from continental crust.

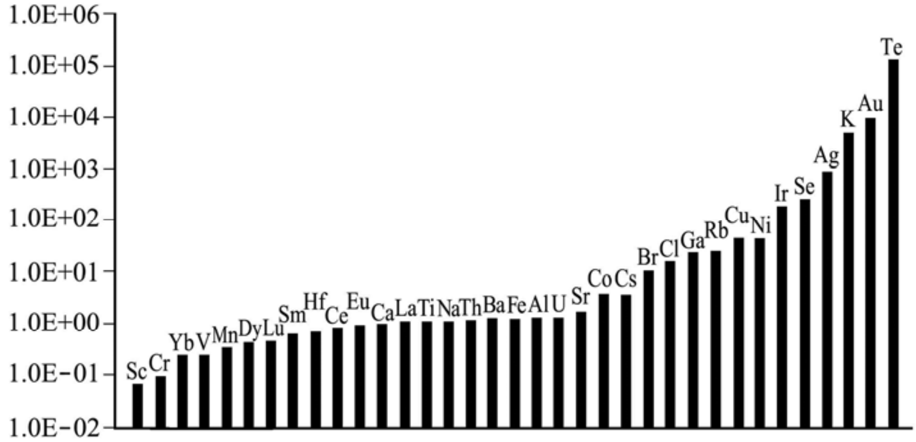

Figure 3. *Geochemical enrichment ore bearing anorthosites (example ys228p) in range elements from Co up to Te and depletion of Sc, Cr, Mn u HREE in comparisons with typical host gabbronorite (example yk217g). Diagram was composed by program Exel.*

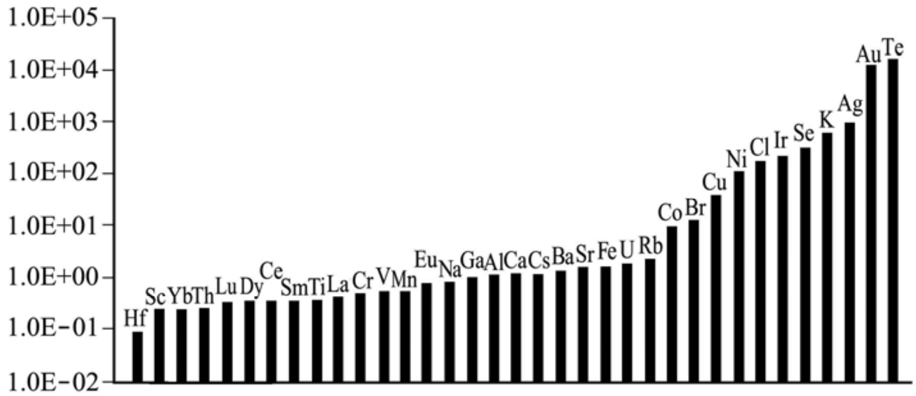

Figure 4. *Character geochemical enrichment and depletion: range of elements in ore bearing anorthosites (example ys228r) in comparisons with non ore bearing anorthosites.*

The character of distribution ore elements and rock forming elements in Palaeproterozoic gabbronorites in comparison with such clark of Archean upper crust [7] show that gabbronorites of Pansky Tundra intrusion are enriched by Sr, Sc, Ca and Cu. But these rocks depleted of K, Rb and Th, while whilst contain all other elements similar with clark these elements of Archean upper crust (figure 5).

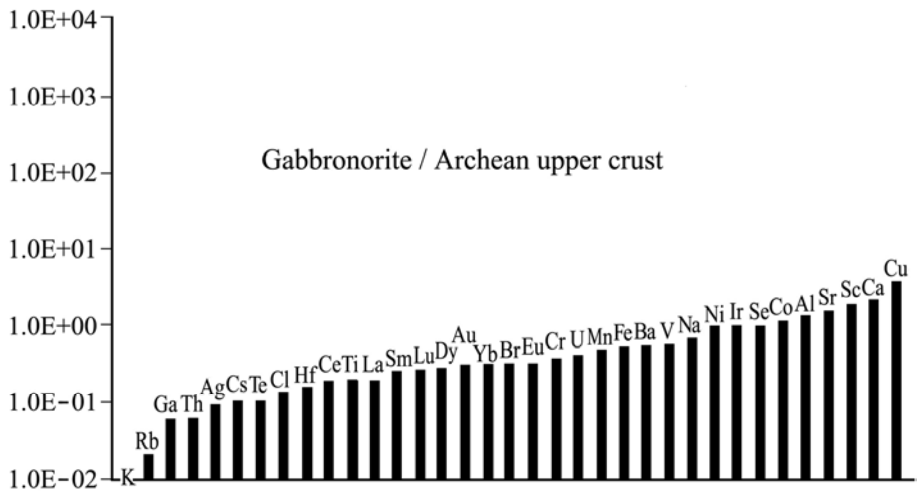

Figure 5. *Character dispositions of elements in gabbronorite (example yk217g) in comparison with disposition of clark these elements in Archean upper crust [7].*

Maximal similarity in geochemical features gabbronorites hosting ore bearing and empty anorthosites have with lover crust [4] with the exception small enrichment of U and Cu and depletion of K, Rb and Ga. These data can evidence about forming maternal magma of gabbronorites and connected with its leucocratic rocks during melting of rocks upper mantle or lower crust.

Statistic processing of INAA was carrying out by factor analysis. For this from full quantity elements (44) were taken only 25 elements that safely determinate in all examples (table 1). Selection contents 12 examples of rock intrusion: ore bearing anorthosites and gabbronorites. Coefficients range correlation by Spirmen were calculated firstly and then matrices these coefficients subjected to factor analysis with methodic of main components. Figure 6 show disposition points of elements between two main factors. It is possible say that these factors (F1 and F2) are have main portion of summery (89%) dispersion. On the factor diagram clearly show cauterization of elements. It is distinguished an element associations: 1) Sc-V-C typomorfic for mafic and ultramafic rocks; 2) Dy-Yb-Lu connected with subgroup of heavy REE; 3) La-Ce-Sm-Eu-Ti-Hf-Th which contents LREE and three lithofile elements; 4) K-Rb-Sr-Ba-Br-U formed by alkali and alkali-earth elements and to this connect Br and U; 5) Au-Cu-Se-Ni-Co – ore group that reflected genetic connection with Cu-Ni sulfide ores and shows a role Se in forming low sulfide PGE mineralization. Dispositions of clasters show next features of antagonisms in its conduct during reforming of the Pansky Tundra rocks. Firstly, first cluster resist to third and fourth clusters that reflect carry out Cr, Sc, V from initial rocks and accumulation lithofile elements. Secondary fifth cluster (ore elements) resist to second cluster with HREE. This indicates that bringing of ore elements in related rocks are accompanies depletion of heavy REE. So on the factor diagram presented signs of F1 which evidenced not only contamination, but also manifestation thick process bringing of K or metasomatic processes in ore bearing anorthosites. Really high negative signs F2 for Rb and Br can show in heritage of melting the geochemical features sources-rocks that possible were enrich lower crust rocks.

Table 1. *Contents of chemical elements (in ppm) in anorthosites with PGE mineralization (p) and gabbronorites (g).*

Element	ys228r	ys224r	yk221r	ma251r	ma254g	ma252g	yk216g	yk217g
Cr	6.02	24.2	2.06	20.3	159	59.1	114	64.6
Sc	1.75	7.98	5.12	13.5	21.4	18.3	35.2	-----
Ti	1010	1300	1370	680	1120	26.9	607	-----
V	26.6	54.5	43.4	52.5	80.3	941	103	111
Hf	0.296	0.633	0.986	0.391	0.413	0.287	0.1	0.436
Th	0.383	0.555	1.11	0.375	0.476	0.581	0.1	0.325
Mn	222	361	133	468	982	972	920	660
Cs	0.388	2.38	0.3	0.409	-----	-----	-----	-----
Ba	185	167	135	111	102	154	69.1	145
Rb	26	45.4	118	13.1	13.9	13.1	-----	-----
U	0.819	0.733	0.541	0.01	0.01	0.64	0.618	0
Co	107	34.5	3.77	85.1	83.6	51.4	51.8	21.5
Sr	630	597	423	507	120	220	294	373
Ga	24.5	23.2	22.3	-----	-----	-----	------	-----
Cl	160	139	281	357	0	0	0	0
Br	11.5	2.88	6.92	8.29	0.587	1.54	1.29	1.1
Ni	4840	1840	104	3330	2710	627	488	103
Ag	9.03	2.24	0	0	0	8.15	2.97	0
Ir	0.0501	0.0255	0.0139	0	0	0	0	0

Element	ys228r	ys224r	yk221r	ma251r	ma254g	ma252g	yk216g	yk217g
Se	19.5	5.25	0	6.55	2.56	6.15	0	0.07
Cu	13900	3980	602	8750	2260	9120	737	303
Au	10.7	0.699	0.0102	0.23	0.0263	0.259	0.0343	0
Te	14.5	2.58	0	0	0	0	0	0
As	-----	-----	1.57	-----	-----	-----	-----	-----
Sb	-----	-----	0.39	0.122	-----	-----	-----	-----

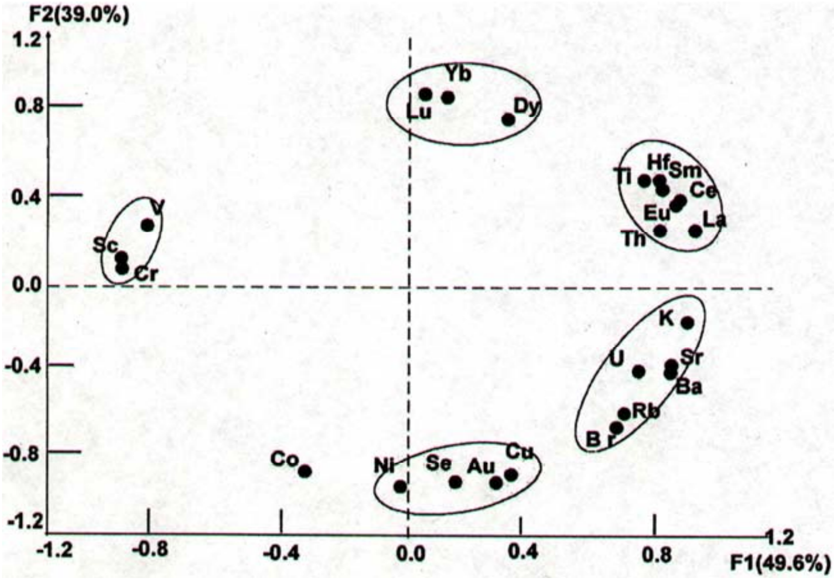

Figure 6. Diagram of factors (F1 and F2) for ore bearing and host rocks of RLH of Pansky Tundra intrusion. Black points are the elements grouped in clusters by factors.

For ore metals Co, Ni, Au, Cu peculiar grouped in the part of diagram with negative signs factor F2 and association with Se. Method INAA non allow determine in ore bearing rocks PGE and S, but close association these elements with Cu-Ni sulfides perfectly clear. The role of Se in forming PGE mineralization of Pansky Tundra intrusion determined on the first time and can be evidence about some specific sources-rock and ores. The Co on factor diagram disposal in part negative signs F1 and locate in ore bearing as well as in host rocks of intrusion. Possibly, Co is inherited geochemical from the rocks that were melted by magmatic melt of intrusion Pansky Tundra.

Elements with positive signs double main factors such as Ti, Th, Hf and LREE reflect geochemical features sources-rocks mafic intrusion. Also it is visible clear differences REE on subgroups light and heavy REE (figure 6, table 2), that connects with character disposition REE in tholeitic melts of riftogenic structures similar Petchenga and Imandra-Varsuga at north-west of Fennoscandian Shield [8]. Relation Lan/Ybn = 2.6-1.8 in anorthosites but 0.7-0.9 in gabbronorites. Origin such rocks can be connecting with melting garnet amphibolites or basic granulites and eclogites from lower crust. Distribution of REE in PGE bearing metasomatic alterated anorthosites (ore bearing rocks) of Pansky Tundra intrusion is characterized by low content of HREE in correlation with gabbronorites of RHL (figure 7, table 2) and clearly expressed positive Eu-anomaly (Eu/Eu*)n=1.7-1.8, that evidence about high degree of factionary of melt of intrusion enrichment by plagioclase component.

Table 2. Composition of REE (in ppm) in ore bearing anorthosites (r) and gabbronorites (g).

Example	La	Ce	Sm	Eu	Tb	Dy	Yb	Lu
ma251r	3.01	5.91	0.68	0.41	0.00	0.63	0.30	0.05
ys228r	3.88	6.34	0.58	0.36	0.00	0.37	0.14	0/04
yk221r	6.20	11.50	1.07	0.47	0.13	0.69	0.40	0.07
ma254g	2.71	4.67	0.63	0.29	0.00	0.39	0.39	0.07
yk216g	1.05	2.34	0.37	0.22	0.00	0.57	0.25	0.04
yk217g	3.71	7.49	0.99	0.39	0.15	0.91	0.60	0.08

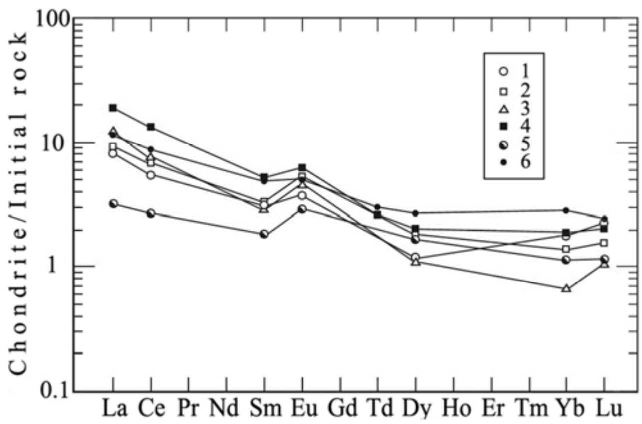

Figure 7. Distribution REE in ore bearing and host rocks of RLH intrusion Pansky Tundra. 1-ma254g - gabbronorite, 2-ma251r – ore bearing anorthosite, 3- ys228r – ore bearing anorthosite, 4-yk221r - ore bearing anorthosite, 5-yk216g – gabbronorite, 6-yk217 – gabbronorite. Positive Eu anomaly is clear visible for ore bearing anorthosites.

Peculiarity composition of fluid phases of ore bearing metasomatic altered anorthosites, non altered gabbronorites and anorthosites were investigated by method mass-spectrometric thermion emission within temperature interval 400-1200°C. Besides these, it was conducted investigation of gas-liquid inclusions (GLI) in the quartz of ore bearing anorthosites by the method homogenization that shows its low temperature genesis (near 420°C). Maximal parts of GLI consist of water fluid and CO_2 that educe thermal interval 400-600°C. The analysis of composition fluid in thermal interval 800-1200°C in ore bearing anorthosites show that its maintain N_2, CO, SO_2 and CH_4 (Table 3).

Table 3. *Maintains and composition of fluids phases in rocks of Pansky Tundra (an- anorthosites, r- ore bearing anorthosites, g- gabbronorites).*

N	Example	Bec	Maintenance of fluid phases in voluminous %					
п\п	Number and type rocks	Weight example (gram)	H_2O	CO_2	CO	N_2	SO_2	CH_4
1	MA-260 an	9.56	92.41	2.30	2.13	1.88	0.58	0.59
2	YS-228 r	14.45	92.02	1.29	1.25	2.79	2.62	0.51
3	MA-257 r	7.64	95.33	1.22	1.46	2.20	0.44	0.35
4	MA-258 r	8.24	87.50	3.92	3.85	2.85	1.50	0.38
5	MA-259 g	10.79	94.08	2.18	1.15	1.94	0.33	0.22
6	MA-252 g	16.02	96.01	1.93	0.68	1.08	0.36	0.09

In relations of fluid components PGE bearing rocks have high concentration of Br and Cl (table 1) that can be cause of peculiarities compositions high temperature fluids produced by later magmatic metasomatic reform of the rocks, what correlate with positions shown by [9].

4. Conclusion: Results of Investigation and Nature of PGE Mineralization

On the results of investigations petrology and geochemistry of host and ore bearing rocks also as fluid phases in the Pansky Tundra deposit it was become clear that anorthosites and in especially ore bearing metasomatic altered anorthosites roughly differ from other rocks of intrusion Pansky Tundra. Anorthosites located mostly within rocks RLH that it was determined by inculcation fractionated anorthosite melt into planes of nonhomogeneous RLH. Petrochemical peculiarities the rocks are shows that anorthosites are integral part of magmatic differentiation of initial mafic melt. Signs εNd from – 0.7 up to -1.7 for TDM from 2.5 to 2.47 Ga means that rocks occur from united sources, which had low Sm/Nd relation then chondrite reservoir. At the same time clearly that anorthosites and gabbronorites in the origin connect with enriched lower crust. Later inculcation anorthosites, its enrichment fluid components connect also with its saturation of metals: PGE, Cu, Ni in form chloride, florid, selenide and sulfur-bearing components. These combinations in fluids create possibilities form PGE mineralization in reef types as observe in Pansky Tundra deposit.

Analysis of fluid phases from RLH of Pansky Tundra intrusion shows presence hightemperature fluid components SO_2 и N_2, exactly in ore bearing anorthosites in which concentrated PGE mineralization. High degree restoration of fluids (CO, N_2, CH_4), association with sulfides and great contents of Cl and Br promote concentration in fluids of PGE, their transfer and deposition together with sulfides in RLH rocks of Pansky Tundra intrusion. The Sm-Nd isotope age correspond to 2427±90 Ma and εNd average –1.8 [1]. U-Pb isotope ages: gabbronorites by zircons 2470±9 Ma, anorthosites by baddeyelite 2447±12 Ma [2]. These data evidence about origin of the rocks of layered intrusion and PGE bearing rocks from united sources – enrichment subcontinental mantle activated in Palaeproterozoic sialic crust during riftogenese [10].

Acknowledgements

This article was executive by support program of fundamental investigations of Department of Earth Sciences Russian Academy of Sciences “Genetic peculiarity and conditions forming of great deposits of strategic types mineral raw and problems its complex mastering”. States contract № 10002-251/ONZ-02/182-203/090703-1035.

References

[1] Campbell I. H., Naldrett A. J., Barnes S. J. A model for the origin of the platinum-rich sulfide deposits in the Bushveld and Stillwater Complexes. J. Petrol. 1983. Vol. 24.

[2] Karpov S. M., Korchagin A. U. Geology and ores West part of Pansky Tundra massif. Gold, platinum and diamond at region Komi republic and neibourhood of RF. Syktyvkar. 1998. P. 94-95. In Rissian.

[3] Turchenko A. S., Bogomolov Eu. S., Turchenko S. I. Petrologic and Isotope Geochemical Features of PGE-bearing horizons in the Pansky Tundra layered intrusion (2. 5 Ga), Fennoscandian Shield, Russia // International Platinum (Eds. N. P. Laverov & V. V. Distler), Theophrastus Publications. St. Petersburg-Athens, 1998, p. 71-78.

[4] Baynova T. B., Mitrofanov F. P., 1999. Duration and timing of ore-bearing Palaeproterozoic intrusion of the Kola Province. Abstr. Intern. Conf. “Early Precambrian: Genesis and evolution of continental crust”, Moscow, 1999, p. 10-12.

[5] Turchenko A. S., Bogomolov E. S. Sm-Nd isotope dates of anorthosite-hosted rhythmic horizons in the Pansky Tundra layered intrusion, NW Russia. Conf. Mineral Deposits: Research and exploration where do they meet? Proc. of 4th Biennial SGA Meeting, Turku, Finland. 1997, p. 129-134.

[6] McCallum IS. The Stillwater complex // Layered intrusions. Ed. by R. G. Cawthom. South Africa. 1996. P. 441-483.

[7] Taylor S. R., McLennan S. M. The continental crust: its composition and evolution, Oxford, 1985. 380 p.

[8] Amelin Yu. A., Heaman L. M., Semenov V. S. U-Pb geochronology of layered mafic intrusions in the eastern Baltic Shield: implication for the timing and duration of Paleoproterozoic continental rifting // Precambr. Res. 1995. V. 75. №1. P. 31-46.

[9] Boudreau A. E., McCallum I. S. Concentration of platinum-group elements by magmatic fluids in layered intrusions //Econ. Geol. 1992. V. 87. P. 1830-1848.

[10] Turchenko S. I. Precambrian metallogeny related to tectonics in the eastern part of the Baltic Shield. Precambrian Research, 1992, v. 58, p. 121-141.