GEOCHEMISTRY AND SR-ND ISOTOPIC COMPOSITION OF KIMBERLITES, MELILITITES AND BASALTS FROM THE ARCHANGELSK REGION, RUSSIA.

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Introduction

The Letter Devonian eruptive magmatism of the Archangelsk region is represented by Group I and II kimberlites, melilitites and basaltoides that occur within the Winter Cost volcanic field situated to the north-east from the Archangelsk city and by olivine-nephiline melilitites of the Nenoksa volcanic field at the Onega peninsula. Sablukov (1990) made out two petrochemical series in the Archangelsk alkaline-ultramafic rocks: (1) an aluminum series (**AL**) consisting of richly diamondiferous mica kimberlites, olivine melilitites, olivine-nephiline melilitites; (2) a ferrous-titanium series (**Fe-Ti**) consisting of poorly diamondiferous Group I kimberlites and melilite picrites. Mahotkin et al (1993a, 1993b) noted the petrography and geochemistry similarity of the Archangelsk mica kimberlites with Group II kimberlites from South Africa and speculated that magmas of the AL and Fe-Ti series rocks were derived from old lithospheric and asthenospheric mantle, respectively.

Geological setting

The Winter Cost and Nenoksa eruptive fields are located within the Archangelsk extension tectonic zone oriented in N-E direction after Sinitsyn et al (1982) and situated to the places where this tectonic zone intersects with both the Middle Rifean buried graben flanks and Archaean greenstone belts. The Winter Cost eruptive field has zonal structure of intruding of the **AL** and **Fe-Ti** series rocks. The Fe-Ti series rocks and tholeiitic basalt pipes occur within the buried Leshukonskiy graben after Konstantinovsky (1977) mostly in its central part but AL series rocks and shoshonite pipes occur in the ring peripheral part of the Winter Cost field. The richly diamondiferous pipes making up Zolotitskiy cluster are situated to the northern shoulder of the Leshukonskiy graben close to central part of the Archaean Kola craton.

Geochemistry

Representative analyses of whole-rock and autolith chemistry from the Winter Cost (1-10) and Nenoksa (11) eruptive field pipes are presented in Tabl.1.

Mica kimberlites are ultrapotassic (K_2O/Na_2O=2-5) alkaline-ultramafic rocks (tabl.,an1,2). They are mainly feldspatoid-normative (up to 3% Ne, 2% Lc, 12% Ks). Among autolithic breccia of the Karpinskiy-I pipe there are autoliths (tabl., an.3) which are extremely enriched in K_2O (K_2O/Na_2O=12), Ba, Rb and depleted in CaO. They are perpotassic with molar K_2O/Al_2O_3=1.3 and peralkaline Lc- (up tp 10%), Ac-normative rocks with molar K_2O+Na_2O/Al_2O_3=1.5 so they should be identified as lamproites.

Olivine melilitites are subdivided into two varieties on nephiline and mica abundance. Olivine-phlogopite melilitites from Chidvia pipe and Verhotinskoiy cluster pipes are sodium-potassic (K_2O/Na_2O=~1.1), Ne-normative (up to 3-9 %) alkaline ultramafic rocks (tabl,an.4).Melilite occurs as groundmass phase (up to 30 vol%). Some of these rocks are poorly diamondiferous. In compare to typical melilitites they are depleted in CaO (up to 4-8 wt %) that is accompanied by clinopyroxene lack. Weakly crystallized clinopyroxene in the fine grain groundmass of the Chidvia pipe melilitites are established only by X-ray diffraction methods. Nephiline-olivine melilitites from Izhma and Onega peninsula pipes are sodium (K_2O/Na_2O=0.2-0.8) , Ne-normative (11-18 wt%) alkaline ultramafic rocks (tabl., an.5, 11). Nephiline and clinopyroxene occur as groundmass phases in Izhma pipe melilitites and as phenocryst and groundmass phases in the Onega peninsula pipes.

Group I kimberlites and melilite picrites of the Fe-Ti series are ultramafic rocks depleted in alkalies and CaO but having high ultrapotassic ratio as K_2O/Na_2O=2-7 (tabl, an.2,7). They have no feldspatoid norms and most of them are corundum-normative (up to 4% Co).

Basaltoides are richly glass rocks. Among them there are two series rocks : (1) Qz-normative (5-7 %) tholeiitic basalts (tabl, an.8) after of Irvine & Baragar (1971) with K_2O/Na_2O=0.7-0.9 but belonging to high K-series using diagram of K_2O vs silica after of LeMaitre et al (1989) and (2) subalkaline basalts and basaltic trahyandesites of shoshonite series (tabl., an9,10).

Compatiblle trace element concentrations (Ni,Co,Cr) in mica kimberlites and melilitites of the AL series are typical for the similar rock types but the Fe-Ti series rocks are extremely enriched in Ni (800-1800 ppm), Co (73-300 ppm) and Cr (1460-3500 ppm) that are similar to those in majmechites and

Tabl.

N	1	2	3	4	5	6	7	8	9	10	11
sample	1490	66	66	748	3002	3215	711	767	882	707	21B
	1017	247-3	395-3	120	100-1	160-1	226	387-2	302.4	A-1	45
SiO_2	35.44	40.72	44.55	46.10	40.74	35.47	43.1	48.40	50.90	55.35	38.03
TiO_2	1.08	1.19	1.30	0.97	0.88	2.18	3.54	1.61	0.96	1.49	0.86
Al_2O_3	3.10	2.80	4.20	5.40	5.80	2.07	5.65	15.15	13.74	14.16	10.86
Fe_2O3	4.50	5.10	4.55	6.35	9.25	10.08	8.29	10.30	8.23	8.36	6.23
FeO	4.16	3.01	2.42	3.15	-	-	3.59	-	-	-	3.57
MnO	0.15	0.16	0.18	0.19	0.21	0.28	0.12	0.19	0.12	0.16	0.34
MgO	31.00	25.93	28.93	19.54	21.51	34.08	22.77	9.00	11.11	7.88	15.37
CaO	6.64	5.98	1.32	8.12	9.26	1.25	3.18	8.50	1.61	1.43	8.37
Na_2O	0.41	0.68	0.43	1.36	2.41	0.10	0.16	1.70	0.60	1.90	3.65
K_2O	2.05	1.21	5.05	1.50	1.75	0.39	0.22	1.30	2.20	6.30	0.75
P_2O_5	0.65	2.05	0.53	0.82	0.47	0.34	0.94	0.14	0.17	0.53	0.49
H_2O-	0.29			4.23	1.65		3.08	0.0	0.0	0.0	
H_2O+	7.00	9.19*	7.04*	1.17	5.62	12.60**	4.22	4.60	9.74	2.8	11.38**
CO_2	2.37	0.87	0.10	0.52	0.39		0.29	<0.10	<0.10	<0.10	
Total	98.84	98.99	99.97	99.42	99.94	98.84	99.15	100.99	99.48	100.46	99.90
mg 0.15	0.884	0.874	0.899	0.811	0.839	0.884	0.806	0.663	0.755	0.682	0.772
Ni	1180	1100	940	495	646	1300	1180	69	68	75	81
Co	69	55	47	61	60	119	73	56	40	61	40
Cr	1030	630	670	855	800	2800	2330	129	159	148	174
Ba	1040	762	2225	830	200	443	970	88	20	<20	270
Sr	600	1007	675	354	492	216	254	418	224	197	310
Rb	86	55	137	46	29	20	11	8.8	11.5	62	13
Th	5.1	3.9	4.4	10	1.0	8.9	21.3	0.93	2.24	2.1	1.0
Nb	38	58	58	37	10	80	137	6	8	5	9
Ta	3.6	2.7	2.6	2.3	0.5	12.2	14.5	0.74	0.47	0.9	0.6
Zr	134	130	156	90	65	131	214	103	109	106	80
Hf	4.0	3.6	4.5	2.3	1.8	3.0	5.1	2.32	2.32	2.9	2.4
Y	19	20	23	19	16	14	24	19	21	22	15
La	51.1	49.0	54.4	44.2	11	62	32.8	7.5	13.7	20	10.3
Ce	87.1	82.2	95.9	74.4	113	73.8	14.7	14.7	28.4	59	21.9
Nd	34.8	26.9	34.4	33	9.7	33	31	9.0	32.0	53	11.0
Sm	6.3	5.7	6.9	5.8	2.03	5.7	6.7	3.33	5.6	11	2.5
Eu	1.5	1.4	1.6	1.8	0.6	1.15	1.8	0.94	1.47	3.8	0.8
Yb	1.2	1.3	1.3	1.1	1.2	0.71	1.8	1.58	1.13	2.4	1.5

*-LOI expressed as H_2O+ and H_2O- sum; **-total LOI
N 1-8, 11 alkaline-ultramafic rocks; Aluminum series (AL) : pipe N 1-Pionerskaja (mica kimberlite); 2, 3- Karpinskiy-I (2-mica kimberlite,3-lamproite); 4-Chidvia (olivine melilitite); 5-Izhma (olivine melilitite); Ferrous-titanium series (Fe-Ti) : pipe N 6-Anomaly 693 (group I kimberlite), 7-Anomaly 651 (melilite picrite); N 8-10 basaltoides: 8-Anomaly 721 (tholeiitic basalt of high K series), 9-Anomaly 753 (basalt of shoshonite series), 10-Anomaly 707 (basaltic trachyandesite of shohonite series);
N 11-Lyvozero pipe, Onega peninsula.

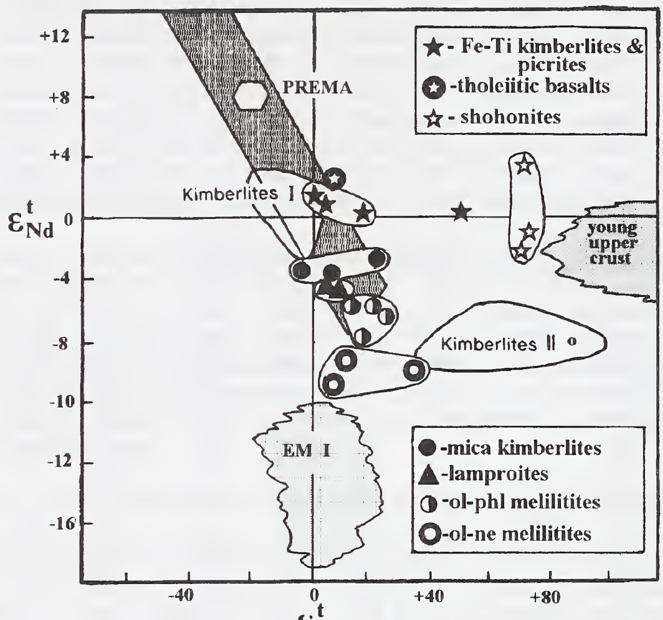
comatiites. Group I and II kimberlites, olivine melilitites and melilite picrites are strongly enriched in LREE and have similar REE patterns and variable La/Yb ratios which are equal respectively to 27-154; 21-60; 20-66; 11-87. Olivine-nephiline melilitites, shoshonoites and tholeiitic basalts are moderate enriched in LREE and their La/Yb ratios are respectively 6.1-7.5; 6.6-8.1; 3.2-4.1.

Distributions of large-ion lithophile elements (LILE) and high-field strength elements (HFSE) show that some autoliths of mica kimberlites enriched in apatite from Karpinskiy-I and Lomonosovskaja pipes are ocean-island basalts (**OIB**) -source type magmas. The mica kimberlites from Pionerskaja pipe and lamproite type autoliths from

Karpinskiy-I pipe are enriched in LILE comparatively to **OIB** and have slight HFSE/LREE negative anomalies. The olivine-phlogopite melilitites have trace element patterns which are similar to those of mica kimberlites from the Pionerskaja pipe. The olivine-nephiline melilitites and tholeiitic basalts have similar trace element patterns depleted in LILE, HFSE and LREE relative to average **OIB** after Sun (1980). Shoshonites have clearly expressed negative HFSE/LILE and HFSE/LREE anomalies that indicate the contribution of a lithosphere source component to their magmas. Group I kimberlites and melilite picrites have similar trace element patterns which are extreamly enriched in Ba,Th,Ta,Nb and LREE compared to average OIB and have negative anomalies of $(K/Nb)_N$=0.1-0.3 and $(K/Rb)_N$=0.3-0.4 relative to those of **OIB**.

Isotope composition

Sr and Nd isotope composition of the Archangelsk eruptive rocks are shown in an ENd-ESr diagram (fig.1). All rocks types have similar Sr isotopic composition which vary from 0 to +30 whereas they have variable Nd isotope composition ranging from ~0 and +3 for Group I kimberlites, melilitite picrites and tholeiitic basalts and fall down to -12 for olivine-nephiline melilitites. Zero figures of ε_{Nd}, combined with elevated La/Yb ratios, indicate that the source of Group I kimberlites and melilite picrites was either isotopicaly-homogeneous thermal layer of the lithosheric mantle or asthenosheric mantle both of which were enriched in LREE and probably HFSE shortly before magmatism. Nd model ages NdT(CHUR) of Fe-Ti series rock source regions are equal to Lower Paleozoic (0.38-0.36 B.a.). The Nd model ages for the other alkaline-ultramafic rocks range from 0.5 B.a. to 1.6. B.a. indicating that soure region of the olivine-nephiline melilitites was ancient mainly LREE enriched lithospheric mantle and its Nd model age coincides exactly with the age of Upper Proterozoic rifting and basaltic magmatism. Shohonites have elevated ε_{Sr}=~+70 and variable NdT(CHUR)= 0.299-0.855 B.a. They were contaminated by a young upper crust material.



Discussing of magma sources and primary melts.

Primary melts compositions have been calculated using appropriate olivine-melt equlibria: olivine Fo93 and Kd=0.29 for mica kimberlites and melilitites; and olivine Fo92 and Kd=0.31 for Fe-Ti series rocks and basaltoides. The mica kimberlites and olivine-phlogopite melilitites have very similar primary melts which were generated within low horizon of the mecanical layer of the old lithospheric mantle as result of low portion melting close to peritectic point of the phologlpite lherzolite under variable CO/H_2O ratio in fluids at pressure 60 and 50 kbar, respectively. Primary melts of Group I kimberlites and melilite picrites have very high MgO concentrations ranging from 20 to 27 wt%. These melts and tholeiitic basalt primary melts were generated as result of high (20%) portion melting of the free-phlogopite harzburgite in the "dry"reduced environment at the pressure 50-60 kbar and 40 kbar and probably at 1600-1700 and ~1400 °C, respectively.

Mantle sources of diamondiferous mica kimberlites and olivine-phlogopite melilitites were formed by mixing of asthenospheric and lithospheric source components with additional input of LILE and LREE shortly before magmatism as a result of plume-lithosphere interaction. Mantle plume head was incubated under the thick lithosphere of the Archangelsk region yielding erosion of the lithosphere base by thermal expansion of hot plume-generated melts and by thermal mobilization of low-temperature melt fractions within the lithosphere.