RIFT- AND ARC-TYPE BASALTIC VOLCANISM OF THE SREDINNY RIDGE, KAMCHATKA: CASE STUDY OF THE PAYALPAN VOLCANO-TECTONIC STRUCTURE

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Abstract: Trace element data for volcanic rocks of the Payalpan volcano-tectonic structure (Sredinny ridge, Kamchatka) allows distinguishing typical island-arc, rift and transitional series of rocks. Island-arc basaltic and differentiated magmas erupted in the Late Miocene and Pliocene. In the Late Pliocene – Early Pleistocene, there was a voluminous event dominated by the basaltic magmas of rift-type series. This event followed by voluminous eruptions of mainly basaltic andesites of transitional series. At the end of the Pleistocene and probably during the Holocene volume of eruptions diminished and composition of magmas shifted towards rift-type basaltic series. Practically in the same area in the Pleistocene and Holocene the Icha volcano produced basaltic andesite to rhyolite magmas of the island-arc and transitional series. Reasons for spatial overlapping and temporal evolution of the island-arc and rift magma types are also discussed.

Patoka and Uspensky (1977) and Volynets et al. (1984) described Pliocene to Quaternary titanium-rich (TiO_2>1.5 wt.%) alkaline basalts in the Sredinny Ridge of the Kamchatka unusual for the island-arc tectonic setting. Later, on basis of limited number of trace elements, Volynets et al. (1990a) have shown that these volcanic rocks bear geochemical features of the within plate basalts typical for intracontinental rifts (Fig. 1). Churikova et al. (2001) provided extended number of trace elements and few isotopic Sr-Nd-Pb ratios for the «within plate» (rift-type) basalts and associated basaltic andesites in vicinity of the Icha volcano. Despite the conducted studies there is a little agreement on origin of this rift-type rock series (Volynets, 1993; Churikova et al., 2001; Avdeiko et al., 2003). In part the situation is stipulated by poor knowledge of geological relations between volcanic rocks with island-arc and within plate geochemical features. Here we report results of study in the northern part of the Payalpan volcano-tectonic structure (VTS), rear part of the Sredinny Ridge (Fig. 2).

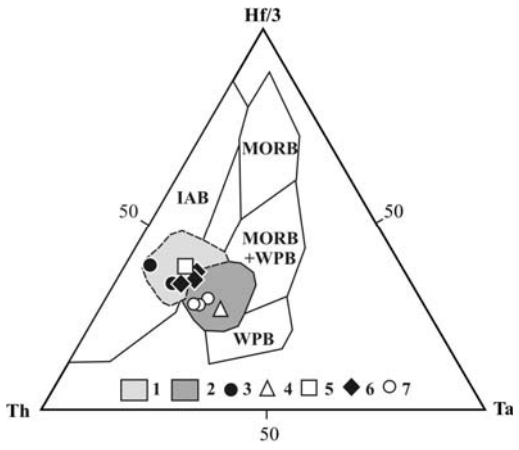

Fig. 1. Th-Ta-Hf systematics of the island-arc and riftogenic basalts of the Payalpan VTS.

1 - moderately-K island-arc basalts and 2 – rift-type and transitional basalts of the Sredinny Ridge (Volynets, 1993). Payalpan VTS: 3 – Nosichan vlc., 4 – plateau (Belogolovsky vlc.), 5 – Nyulkande vlc., 6 – Tynua vlc., 7 – cinder cones. IAB – island arc basalts, MORB – middle oceanic ridge basalts, WPB – within plate basalts (Wood, 1984).

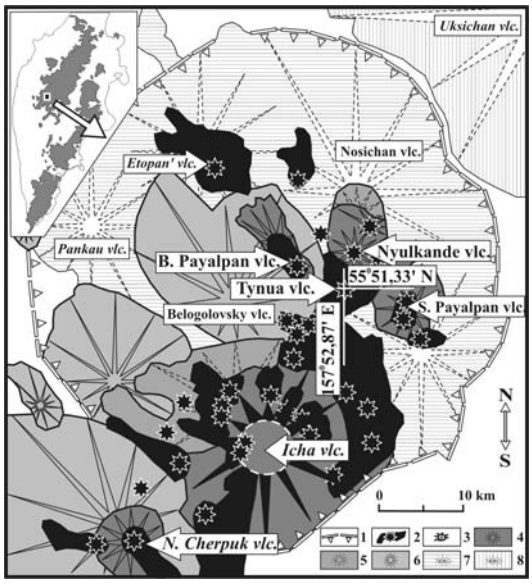

Fig. 2. Structure of the Payalpan VTS (modified after Patoka and Uspensky, 1977).

1 – structural boundary of the Payalpan VTS. Rift-type and transitional series: 2 – Q_3-Q_4, 3 – Icha volcano with summit caldera, 4 – Q_2-Q_3, 5 – Q_1-Q_2, 6 – N_2^3-Q_1. Island-arc series: 7 – N_1^3-N_2, 8 – N_1^3-Q_2 (Uksichan vlc.). Insert shows location of the Payalpan VTS within the Pliocene-Quaternary volcanic belts of the Kamchatka.

GEOLOGICAL STRUCTURE OF THE PAYALPAN VTS

The earliest volcanic activity in the studied area took place in the Nosichan volcano in the Late Miocene - Pliocene (N_1^3-N_2). This large volcano is composed mainly by andesites and dacites (after IUGS classification; Le Bas and Streckeisen, 1991). Basalts (Table 1; sample 2363) with typical island-arc trace element pattern have been found at a base of the volcano (Fig. 3). Plagiophyric basalts (Table 1; sample 2356) with less prominent depletion of high-field strengths elements (HFSE) cap this volcano.

The Late Pliocene - Early Pleistocene (N_2^3-Q_1) plateau involves typical rift-like alkaline basalts (Table 1; sample 2331) (Fig. 3).

Nyulkande, Small Payalpan and Big Payalpan volcanoes are situated on the plateau. These volcanic piles are composed mainly of basaltic andesites with subordinate andesites. The former (Table 1; sample 2340) exhibits transitional trace element pattern between the island-arc and riftogenic series (Fig. 3).

Table

Major and trace elements of representative samples from the Payalpan VTS

#	2363	2356	2331	2340	2323	2338
SiO_2	49.86	51.47	47.84	56.31	52.51	50.02
TiO_2	0.82	1.27	2.14	0.98	1.34	1.55
Al_2O_3	16.6	18.73	16.88	17.27	16.69	16.26
Fe_2O_3	5.04	3.91	5.36	3.51	3.38	4.10
FeO	4.31	5.03	5.93	3.77	5.38	5.57
MnO	0.16	0.15	0.16	0.13	0.15	0.15
MgO	7.12	3.79	6.87	4.02	6.2	7.75
CaO	11.62	9.49	8.6	7.26	7.94	8.72
Na_2O	2.34	3.39	3.66	3.73	3.6	3.45
K_2O	0.89	1.21	1.54	1.52	1.41	1.43
P_2O_5	0.23	0.28	0.47	0.48	0.56	0.47
LOI	0.98	0.41	0.53	0.89	0.66	0.30
Total	99.97	99.13	99.98	99.87	99.80	99.77
Rb	12.9	12.9	21.2	20.7	17.7	19.6
Ba	265	683	400	767	722	523
Sr	726	761	758	664	641	741
Zn	60.7	64.5	84.9	77.2	83.6	91.3
Pb	4.07	5.22	3.7	7.23	5.55	4.09
Cu	150	76.2	58.6	80.8	75.9	81.9
Co	27	25	43	14.9	27	38
Ni	48	14.4	89	30	102	133
Cr	125	18.5	85	54	117	153
V	280	280	230	180	220	240
Sc	46.4	26.4	28.4	21.6	27.7	31.3
Ta	0.08	0.31	1.56	0.47	0.69	0.94
Nb	1.67	4.78	23.2	8.42	11.6	15.3
Zr	50.4	86.9	177	193	186	152
Hf	1.54	2.3	4.36	3.98	4.1	3.5
La	10.9	10.8	23.6	22.2	21.3	19.9
Ce	23.8	24.5	50	48.3	49.3	44.3
Pr	2.86	3.43	5.9	6.23	6.3	5.71
Nd	13.5	15.4	26.2	25.8	28.6	26.7
Sm	3.16	3.99	5.58	5.71	5.98	5.68
Eu	0.94	1.32	1.8	1.6	1.86	1.55
Gd	2.9	3.43	4.86	5.04	5.34	5.18
Tb	0.45	0.6	0.75	0.79	0.82	0.71
Dy	2.71	3.48	4.32	3.92	4.44	4.17
Ho	0.56	0.66	0.81	0.82	0.83	0.79
Er	1.61	1.98	2.51	2.27	2.37	2.15
Yb	1.53	2.04	2.05	2.32	2.22	2.01
Lu	0.23	0.32	0.34	0.32	0.37	0.3
Y	17.3	21.4	24.1	25.6	25.2	23.5
Th	0.77	1.24	2.62	1.7	1.88	2.13
U	0.51	0.65	0.75	0.74	0.78	n.a.

Note: Major elements (wt. %), Co, Ni, Cr, V and other trace elements (ppm) were analyzed by XRF, AA and ICP-MS, respectively. n.a. – not analyzed. Locations of the samples see in Fig. 3.

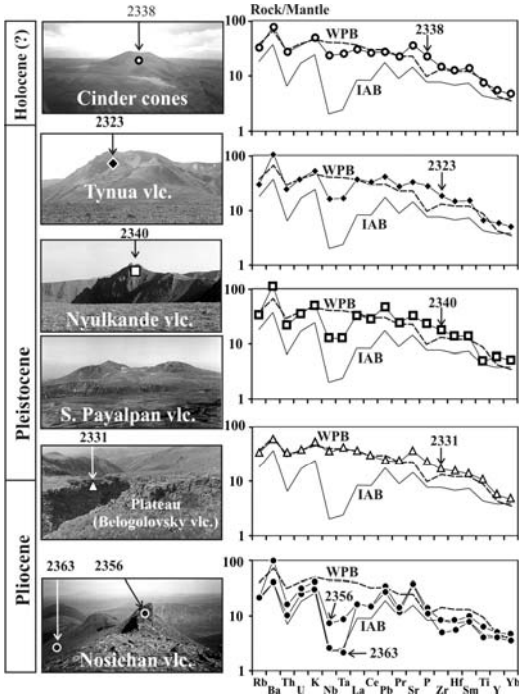

Fig. 3. Stratigraphic position of the studied volcanic units within the Payalpan VTS and primitive mantle normalized trace element diagrams for representative samples.

The primitive mantle is after (Sun, McDonough, 1989). Typical compositions of IAB as average of the high-magnesium basalt of the Klyuchevskoi volcano (Dorendorf et al., 2000) and WPB as hawaiite sample p252/2 of the Udokan volcanic field, Baikal rift system (Rasskazov et al., 1997) are shown for comparison.

Tynua volcano represents a structure with numerous 0.5-1 m thick lava flows, which lay on the lavas of the Nyulkande volcano. Basalts and basaltic andesites of remarkably uniform trace element composition compose the Tynua volcano. They are similar to the lavas of the Nyulkande volcano by trace elements, with exception of higher Ta and Nb concentrations (Table 1; sample 2323; Fig. 3).

Scattered youthful cinder cones and fissures of presumably the Late Pleistocene - Holocene age represent the latest manifestation of the volcanism. This volcanic unit is composed by rift-type basalts with only slight depletion of Ta and Nb (Table 1; sample 2338; Fig. 3; Churikova et al., 2001).

Initial eruptions of the dominated in the Payalpan VTS Icha volcano followed the formation of the plateau. Icha volcano is long living and still active. Basaltic andesites, andesites, dacites and rhyolites compose this volcano. They exhibit trace elements from typical island-arc to transitional series (Patoka and Uspensky, 1977; Churikova et al., 2001).

PLEISTOCENE ISLAND-ARC BASALTS IN THE PAYALPAN VTS PRESENT?

Basalts of the pure island-arc and rift-type series are rare in the Payalpan VTS. The former have been found at the Nosichan volcano and the latter at the plateau. Most of basaltic samples exhibit different degree of mixture between these two (Fig. 4).

Strontium isotope ratios are almost identical among different rocks of the Payalpan VTS. Rift-type series is distinguished by lower εNd in comparison to the island-arc series (Fig. 4). Rocks of the transitional series are characterized by transitional neodymium isotope ratio (Churikova et al., 2001). This supports the idea of two separate magma reservoirs (island-arc and riftogenic), which were simultaneously acting beneath the Payalpan VTS and giving transitional compositions upon the magma mixing.

COMPARISON OF THE PAYALPAN VTS WITH OTHER VTS OF THE SREDINNY RIDGE

Rift-type basaltic volcanism of the Sredinny Ridge appeared (from south to north) in Khan-

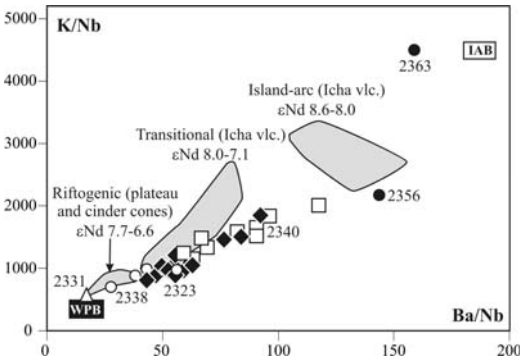

Fig. 4. K/Nb – Ba/Nb diagram for basalts and basaltic andesites of the Payalpan VTS.

Symbols as in Fig. 1. K, Nb and Ba in most samples and Nb and Ba in marked samples were analyzed by XRF and ICP-MS, respectively. Basalts and basaltic andesites of the Icha volcano and those from the area north to the Icha are shown for comparison after (Churikova et al., 2001).

gar (Golodyak plateau), Cherpuk, Payalpan, Bol'shoi-Kekuknaisky, Dol Geologov, Sedanka and Tekletunup VTS. At the present, these VTS cannot be compared at the same level of geochemical information. Detailed geological relations between rift-type and island-arc series were documented at Bol'shoi-Kekuknaisky, Khangar, Tekletunup and Payalpan VTS only (Volynets, 1994; Perepelov, 2004; this work and unpublished data of the authors). At the Khangar and Tekletunup VTS rift-type volcanism started in the Late Pleistocene, significantly later than in the Payalpan VTS. At the Bol'shoi-Kekuknaisky VTS rift-type volcanism started in the Early Pleistocene, temporary close to the Payalpan VTS. However, age estimations are based on geological and geomorphological data and not supported by radioisotope dating, yet.

DISCUSSION

Models of 1) plume-wedge interaction (Volynets, 1993), 2) lower (10 %) degree melting of wedge mantle metasomatized by water-poor HFSE-rich fluids in the rear part of the island-arc system (Churikova et al., 2001) and 3) ascending of sub-slab convective mantle through slab-window due to break down of the slab and 4) melting in front of the subducting slab (Avdeiko and Palueva, 2003) have been suggested to explain appearance of the rift-type volcanism within the Kamchatka island-arc tectonic setting. The front of the modern subducting slab in the Middle-Late Miocene was under region of rift-type volcanism of the Eastern Kamchatka (Volynets et al., 1990b) and in the Late Pliocene – Early Quaternary reached the rear part of the Sredinny Ridge (Perepelov, 2004). This can be interpreted in favor of the fourth of above-mentioned models. However, we note that in the Uksichan VTS (Fig. 2) the typical island-arc basaltic series developed since the Late Pliocene up to the Holocene (Perepelov et al., 1997), preventing application of any simple model. Rift-type volcanism of the Sredinny Ridge and Western Kamchatka was repeated since the Cretaceous - Paleogene (Koloskov et al., 2001; Perepelov et al., 2003), implying important role of the continental lithospheric structure.

To resolve the problem of the origin of the rift-type basaltic series several questions should be answered. First, precise timing of the eruptions and evolution of the magma chemistry is not yet known for all VTS of the Sredinny Ridge. Second, the tectonic structures, which control the rift-type volcanism, are not understood. These should be primary goals for the future studies.

CONCLUSIONS

The rift-type basaltic volcanism in the Payalpan VTS started at the Late Pliocene – Early Pleistocene. This event followed by voluminous eruption of transitional series of mainly basaltic andesites. At the end of the Pleistocene the volume of the eruptions diminished drastically and composition of the magma shifted towards rift-type series. Typical island-arc basalts were not found among the Pleistocene rocks in the northern part of the Payalpan VTS. Magma of such composition probably differentiated in deep magma chambers giving intermediate to acidic magmas with island-arc trace element features (i.e. Icha volcano).

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