SOLUTE FLUXES FROM THE VOLCANO-HYDROTHERMAL SYSTEM OF THE KURIL ISLAND ARC (RUSSIA).

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Eight volcanic islands of the Kuril Arc (figure) (Paramushir, Shiashkotan, Rasshua, Ushishir, Ketoy, Urup, Iturup and Kunashir) are characterized by hydrothermal activity, complementary to the fumarole activity in craters and at volcano slopes. Differences in volcanic evolution, hydrological and geological conditions have led to differences in the conditions of formation and discharge of hydrothermal systems of the region.

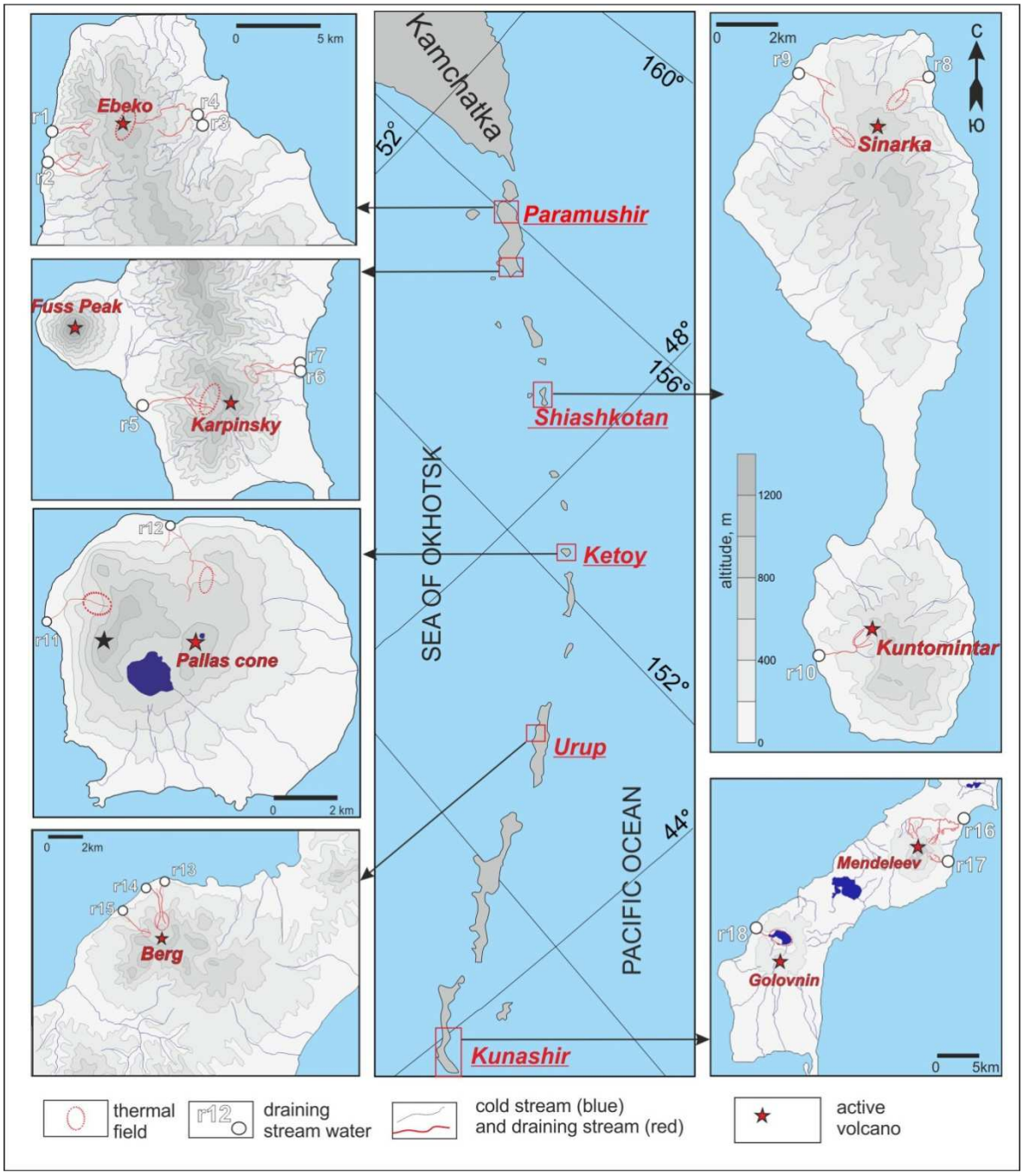

Figure. Location of the studied islands within the Kuril island arc. Numbers of points correspond to numbers in Table.

Most thermal manifestations of Paramushir, Shiashkotan, Urup, Iturup and Kunashir islands are acidic to ultra-acidic hot springs associated with hydrothermal aquifers inside volcano edifices and formed as the result of absorption of magmatic gases by ground waters. Besides, hydrothermal activity occurs as numerous coastal hot neutral springs commonly situated within the tide zone and formed by mixing of heated seawater with cold groundwater or, in contrast, by mixing of steam or conductively heated groundwater with seawater. Several groups of the above thermal manifestation were found on the western shores of Shiashkotan, Russhua, Urup, Uturup and Kunashir islands. Ushishir volcano-hydrothermal system is formed by the absorption of magmatic gases by seawater. In the crater of the Pallas cone (Ketoy island) and in a 4.2×4 km wide caldera of Golovnin volcano there are lakes with acid SO_4(Cl-SO_4) water and numerous thermal vents at the bottom and along the shores of the lakes. Ketoy volcano on the Ketoy Island and Sinarka volcano on the Shiashkotan Island host hydrothermal systems with unusual boiling near-neutral springs and steam vents.

Hydrothermal flux may be provided by the discharge of fluids generated at depth above the magma chambers and/or by acid waters formed by the absorption of the ascending volcanic vapor by shallow groundwaters. Thus, the anion composition (Cl and SO_4) of the discharging thermal waters from a volcano-hydrothermal system in many cases originates from the volcanic vapor and should be taken into account in estimations of the magmatic volatile output and volatile recycling in subduction zones. The hydrothermal fluxes of the studied areas were estimated after measuring the flow rates and water composition of streams that drain thermal fields of the islands in 2015-2017,includingParamushir (Ebeko volcanic center), Shiashkotan (Sinarka and Kuntomintar volcanoes), Ketoy (Pallas volcano), Urup (Berg volcano) and Kunashir (Mendeleev and Golovnin volcanoes).There are sixteen main solute drainages to the ocean and the Sea of Okhotsk from the islands (figure and table). Most of the rivers are acid (Table) and contain abundant dissolved Fe and Al, which causes the formation of vast visible discolored zones in the sea around the river-mouth areas.

Table.Selected features of rivers and chloride and sulfur fluxes.

code	Date of sampling	river	T,°C	pH	Q,m^3/s	TDS g/L	Type of water	Concentration, mg/l		Output, ton/day	
								Cl^-	SO_4^{2-}	SO_4	Cl
r1	17.07.17	Yurieva	14.5	1.87	2.04	2.28	Al-SO_4-Cl	480	1433	253	84
r2	16.07.17	Gorshkova	7.2	3.13	1.97	0.24	Ca-SO_4	24.8	101	17.2	3.4
r3	19.07.17	Kuz'minka	8.1	4.16	0.80	0.18	Ca-SO_4	25.1	82	5.6	1.4
r4	15.07.17	Strela		4.2	6.10	0.09	Ca-SO_4	6.9	41	21.5	
r5	17.07.17	Trudnaya	13.6	4.11	1.24	0.38	Ca-Mg-SO_4-Cl	89	147	15.8	9
r7	28.07.16	Serny	20.3	7.4	0.14	0.96	Ca-Mg-SO_4-HCO_3	118	316	3.8	1.4
r8	29.07.16	Aglomeratovy	14	3.75	0.24	2.79	Ca-Mg-SO_4-Cl	475	1640	33.7	9.7
r9	26.07.16	Kraterny	16.1	3.52	0.20	1.05	Ca-SO_4	79	721	12.6	1.3
r10	23.07.16	Gorchichny	12.8	6.79	0.12	1.18	Ca-SO_4	10.2	714	7.7	
r11	24.07.16	Vodopadny	10.4	3.99	0.63	0.92	Ca-Mg-SO_4-Cl	166	474	25.9	8.8
r12	06.08.17	Daria	13.6	3.94	0.22	1.10	Ca-Mg-SO_4-Cl	168	522	9.9	3.1
r13	05.08.17	Maria	15.1	3.46	0.24	1.43	Ca-Mg-SO_4-Cl	287	648	13.6	5.9
r14	06.08.17	Daykovy	15.5	4.48	0.20	0.93	Ca-SO_4	22.9	554	9.6	0.3
r15	18.09.15	Lesnaya	14.1	5.40	1.10	0.31	Na-Ca-Cl-SO_4	80	71	6.7	7.1
r16	21.09.15	Chetverikova		4.11	0.36	0.21	Ca-Na-SO_4	17.9	104	3.3	0.4
r17	11.09.15	Ozernaya	16.4	2.91	0.54	0.47	Na-Ca-SO_4-Cl	109	162	7.6	4.9
Total										450	140

We used a standard FP311 Global Water flow probe to measure the flow rate of the streams. Each river cross-section was divided in 7–10 vertical profiles with 3–5 flow rate measurements at each profile, depending on the water depth. The total relative error of the measured flow rate does not exceed 10%.The measured total discharges at the mouths of the rivers and concentrations of Cl and $SO_4$of stream waters are shown in the Table. The maximal hydrothermal flux of Cl and S (as SO_4) within the Kuril Chain was

measured for Ebeko volcano, Paramushir (drained by the Yurieva River). The Yurieva River drains the Yurievskie springs, flows into the Sea of Okhotsk with the flow rate of 2±0.2 m^3/s measured at the mouth, and contains480 mg/L of chloride and 1433 mg/L of sulfate (date of sampling 17/07/2017). The data provides the fluxes of the dissolved chloride and sulfate 84±8 t/d and 253±25 t/d, respectively. Shiashkotan volcanoes (Sinarka and Kuntomintar) through their hydrothermal systems emit some 11±1 t/day of Cl and 54±5 t/day of SO_4. The hydrothermal flux of the Ketoy Island is also low, 9±1 t/d of Cl and 34±3 t/d of SO_4. Berg volcano (Urup) is drained by three rivers (Daria, Maria and Daikovy) yielding 9.3±1t/d of Cl and 33±3t/d of SO_4. Thetotal discharge of Cl and $SO_4$from the Kunashir Island to the Sea of Okhotsk and the Pacific Ocean associated with magmatic activity of Mendeleev and Golovnin volcanoes is estimated as 12±1t/d and 18±2 t/d, respectively.

We don't have our own data on the hydrothermal fluxes from volcanoes of Iturup Island. There are two sites on the island with acidic Cl-SO4 systems: Chirip volcano and Baransky volcano. According to Chelnokov et al. (2014) solute flux from the hydrothermal system associated with Baransky volcano (central part of the Iturup) is ~33 t/d ± 10% of Cl and 67 t/d ± 10% of SO_4. There are no data about fluxes from Chirip volcano. Taking into account also not yet studied several sites on Urup and Ekarma islands the total fluxes can be estimated as ~180 t/d of Cl and ~550 t/d of SO_4. Taran et al. (2018 and this conference) reported data on the SO_2 flux from Kurilian passively degassing volcanoes in 2015-2017. From the measured SO_2 flux they estimated the HCl flux as ~310 t/d. This means that the hydrothermal flux of magmatic chlorine is about 2/3 of the flux provided by the direct degassing.

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