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LOCAL CONCEPTUAL MODEL OF THE NORTH-PARAMUSHIR HYDROTHERMAL SYSTEM (NORTH KURIL ISLAND)

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ABSTRACT

Paramushir Island is one of the largest islands in the Great Kuril Range. The northern part of the island is formed by the Vernadsky Ridge, shaped by merged structures of Quaternary volcanoes, including the Krasheninnikov volcano, and has folded-block structure. The volcano Krasheninnikov was formed by young postglacial pyroxene-andesite and andesi-basalt lavas. In the roots of the volcano, for a long time, there was a magmatic melt migration of andesi-basalt composition. A study of hydrothermal manifestations located in the north-eastern slope of the tectonic structure of the Krasheninnikov volcano was carried out as a part of an assessment of the North-Paramushir hydrothermal-magmatic system. The authors constructed a geological profile up to 1115 m depth based on data from well 4-GP, characterized the geochemistry and hydrothermal-metasomatic changes of rocks as well as the chemical composition of mineralized thermal waters discharged in Ptichya river. Moreover, the presence of high temperature chloride fluids, located in the roots of the volcano, was identified, the heat flow was evaluated and the fault zones in the area of Krasheninnikov volcano were defined. For consideration is a description of the conceptual model of North-Paramushir hydrothermal system including three main sections: the Krasheninnikov volcano (the upflow zone of hydrothermal fluids), the northeastern slope of the volcano (zone of lateral flow) and the Pacific Ocean (a discharge zone of pressurized and low-temperature hydrothermal carbonate fluid).

INTRODUCTION

Kuril Islands are located in the transition zone from continent to ocean. The islands are characterized by a high intensity magmatism, tectonic movements and sedimentation. The development of these processes determines the formation and activity of hydrothermal fluids, mostly spatially and genetically related to magmatic systems.

Paramushir Island is located in the north-east end of Big Kurile island arc (Fig. 1). The area of the island is 2042 km2. The island extends for over 100 km from the south-west to the north-east and is ca. 20 to 25 km wide. The northern part of the island is formed by the Vernadsky Ridge, which consists of quaternary volcanos. The ridge extends in submeridional direction from Vetrenaya mountain in the north to Vernadsky mountain in the south and is totally 25 km long. The ridge watershed almost coincides with the island's centerline. The highest mountains are confined to the watershed. The area is characterized by abundant rivers which are fed by abundant precipitation (rain and snow). (Lessons…1966).The existence of a long-lived hydrothermal-magmatic system in the the northern part of Paramushir Island (Vernadsky Ridge) was established (Rychagov and others, 2002). This system is unique: is located at the junction of oceanic and continental crust and it has a complex structure of its heat source. The inferred potential for electric power production is more than 100 MW (Belousov et al., 2002).

At present, the existence of a large magmatic reservoir as the heat source of the hydrothermal system in the Paramushir Island has not been well established. The presence of a multichannel magmatic system supply has been proposed (Gorshkov, 1967).

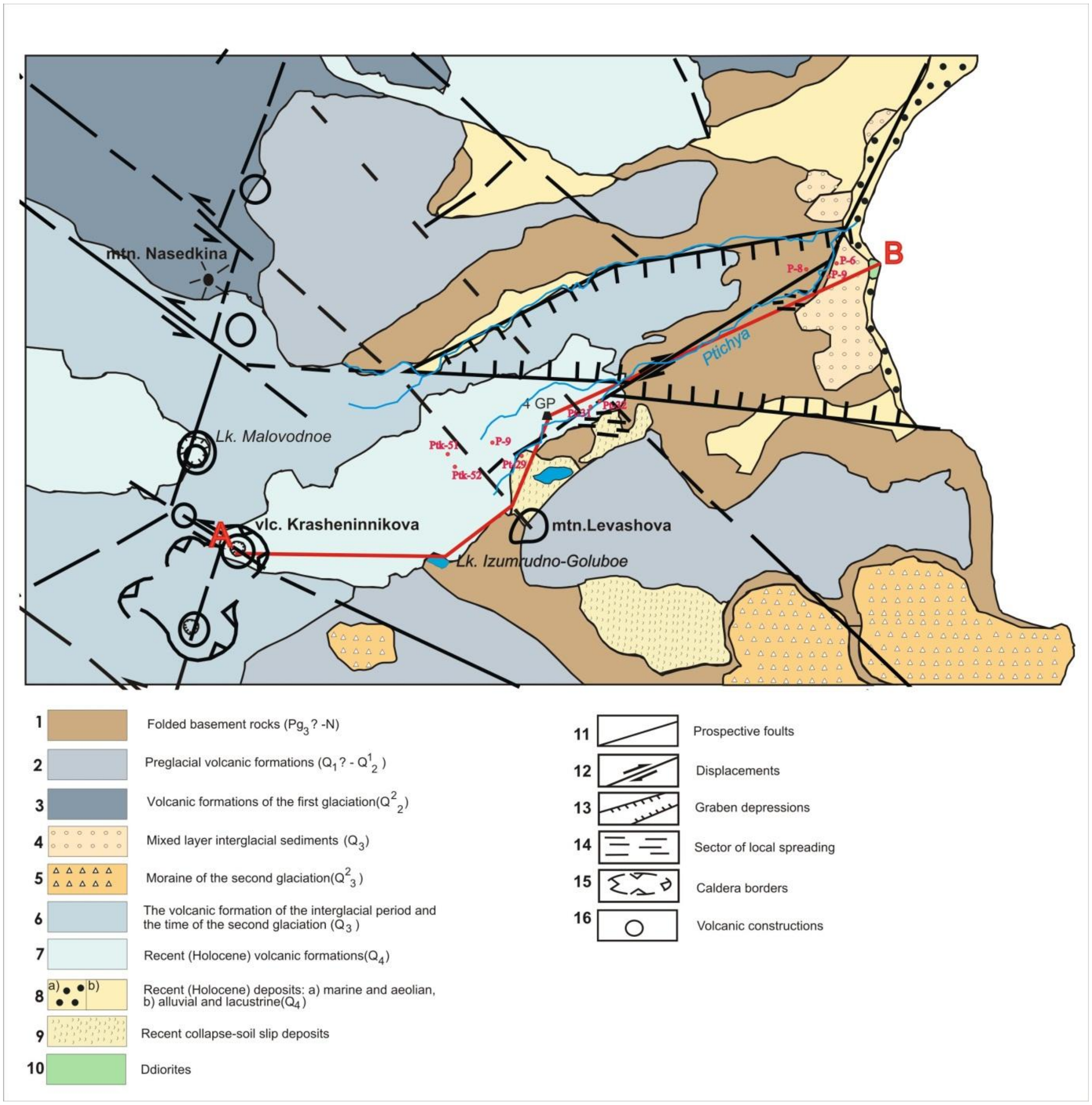

Figure 1: Shematic geological map of the Ptichya river based on FedorchenkoV.I. Leonova V., SN Rychagov

If the main characteristics (location, composition, evolution, etc.) of the heat source structure for a specific hydrothermal system are better understood, then the relation of hydrothermal and magmatic processes as well as the geothermal and ore resources can be better assessed.

GEOLOGICAL SETTING

Paramushir Island is a relatively elevated earth crustal block as is a prolongation of the coastal horst southern Kamchatka.

The northern part of Paramushir Island is composed by upper Miocene-Pliocene, Quaternary and modern rocks. The basal complex is composed of volcanogenic-sedimentary rocks of Paramushir suite – volcanomictous sandstones, tuffs, tuff-gravelites of okhotsk coset, and also poorly sorted conglomerates, breccias, coarse-grained sandstones of ocean suite. Deposits of Okhotsk and ocean suites are intruded by dykes and sills up to a few tens of meters, and by bigger subvolcanic bodies of andesite and andesite-basalt composition (Gorshkov, 1967; Fedorchenko et al., 1989). Deposits of Okhotsk and ocean suites underlie upper Pliocene age andesite lavas forming plateau in the southern part of the north Paramushir. Of the most ancient effusives lavas of basalt composition, presumably lower-middle Pleistocene in

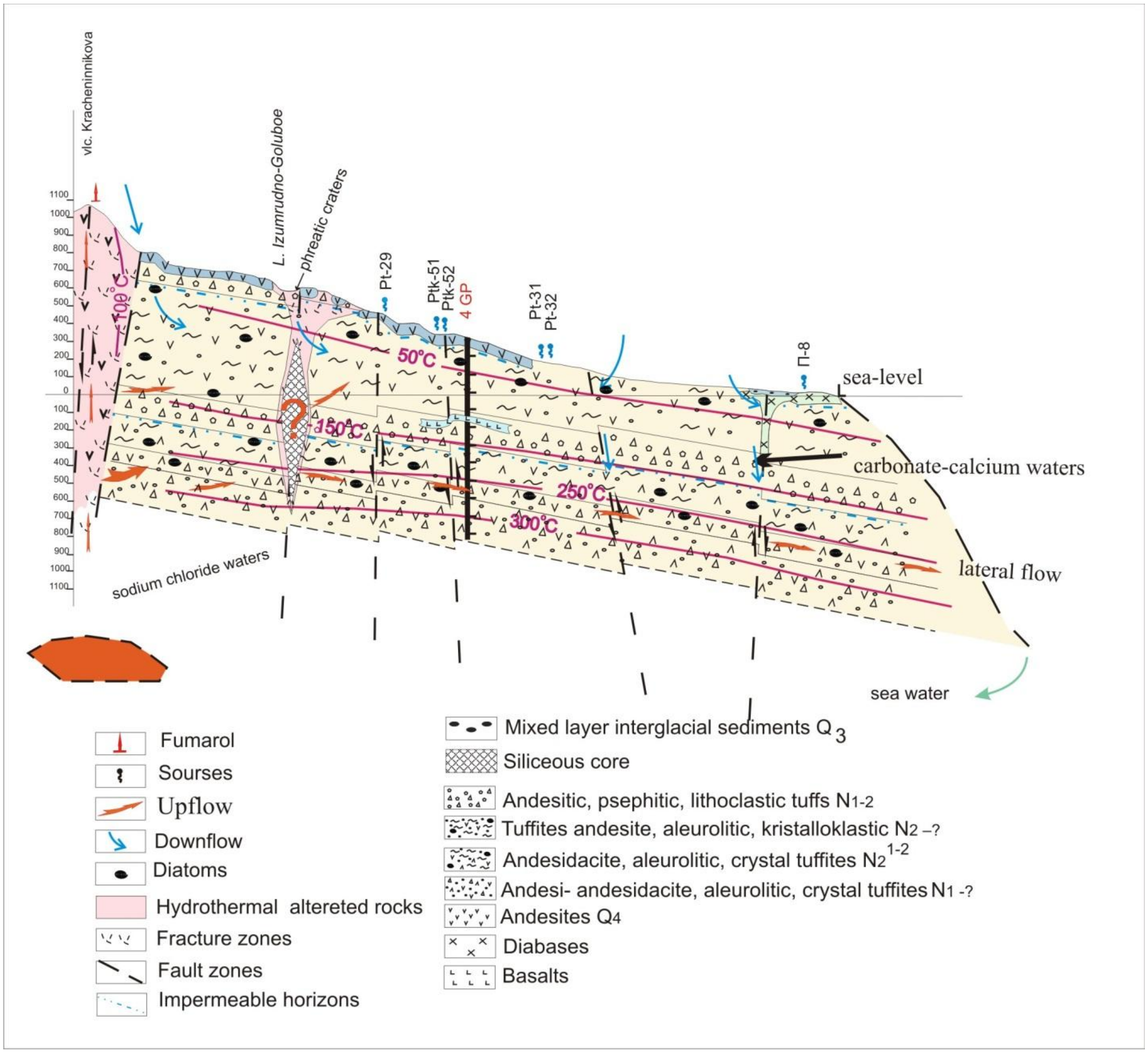

Figure 2: Scheme of the Ptichya River graben deep structure

age, are exposed. Two-pyroxene interglacial andesites are abundant. The formation of quaternary volcanites is associated with activities of several volcanoes and volcanic centers, located at the north of the island (Krasheninnikov, Bilibin, Bogdanovitch, Fersman and others).

RESULTS

Faults in the northern part of the Paramushir Island

Linear faults were identified through topographic map interpretation (scale 1:50 000). The main fault system was found to be NNE trending (Khubaeva et al., 2006).

Sub-lateral fault zones are mild in the relief, so their interpretation by topographic map is difficult. Thus, along the east coast of the island, sublatitudinal trenches system (trough valleys), which are associated with river valleys including Ptich'ya, Nasedkina etc. was interpreted. Further study of this data is recommended.

It is generally accepted that Ptichya river is confined to a large NW trending regional fault (Fig. 1), which is clearly manifested on the surface in the form of limonite slides, phreatic craters and phreato-magmatic explosions (Fig. 2) in addition to a shear zone in the North-East board of Izumrudno-goluboe lake, large fields of hydrothermally altered rocks and low-temperature surface manifestation (Fig 1,2). In Figure 1, line A-B was used to model a cross-section based on the 4-GP well cross-section. In the cross-section, rock units, hydrophilic formation, explosive crater, areas of hydrothermal altered rocks and low-degree hydrothermal manifestation are shown.

Metasomatic zonation of well-4 GP

Geological sections of the north-eastern and northern part of North Paramushir hydrothermal-magmatic system were studied. The eastern slope of the Krasheninnikov volcano, to a depth of 1115 m (based on data from borehole 4 GP), was studied. Hydrothermal-metasomatic rock alteration and the chemical composition of thermal water springs of Ptichya River were characterized. In the cross section, a succession of metasomatic zones (top - bottom): quartz - epidote - chlorite, illite-chlorite - calcite, montmorillonite – zeolite is observed. Such vertical metasomatic zonation is observed in the periphery of the main upflow zone of hydrothermal solutions, where the permeability of the rocks is low and there is an intense influx of cold meteoric water from the surface. In this case, the smooth decrease in temperature in the section (small thermal gradient), and signs of boiling fluids are missing or manifested so weak and does not determine the metasomatic zonation. This increases the thickness of montmorillonite-zeolite zone, which is associated with circulation of calcium-carbonate heated meteoric waters. Metasomatism occurs in montmorillonite-zeolite facies, where the parent rocks interact with calcium-carbonate solutions of meteoric origin, which are heated up to 150 °C, and the system becomes open to atmospheric oxygen.

Scheme of the hydrothermal-magmatic system associated with volcano Krasheninnikov

A model of the hydrothermal system is proposed for discussion: the Krasheninnikov volcano (upflow zone); the northeastern slope of the volcano (lateral flow); the Pacific Ocean (discharge zone of pressurized flow of low-temperature-carbonate hydrothermal fluids) (Fig. 2).

Fumaroles observed in the crater of Krasheninnikov volcano indicate the presence of this upflow fluid. The lateral flow is identified on a heat flux map (of the Paramushir Island) as two thermal anomalies: one in the origin of the Ptichya river and the second one in the estuaries. In addition, the chemical composition of low enthalpy sources discharging along the river represents another evidence of lateral flow in this area. Chloride-SO4 water sources (points PTC-51 PTC-52 in Fig. 1,2) contain high Cl concentrations and have a relatively low temperature (9 - 11 ° C). It is believed that the temperature of the springs, originally warm, decreases due to mixing with melt water, considering that the average water temperature in the river is 5 - 6 ° C. Thus, the sources are considered to be thermal. In addition, these sources are associated with a faulting are which may indicate the presence of a gas-hidrothermal (hydrothermal-magmatic?) fluid upflow from the lower horizons. The chemical composition of sources Pt-29, Pt-31, Pt-32, Ptk-51, Ptk-52 on the Ptichya River (Table 1) may indicate the presence of high temperature chloride (Na-CI?) deep water, located in the interior of volcano Krasheninnikov. Some of the water sources on Ptichya River are derived from condensed gas-steam of deep origin. Discharge of acidic waters affects the further composition of river waters, up to the river mouth. Surface stream flows in the eastern part of volcano have Cl-SO4 water composition. Data on the secondary mineralogy (from well 4-GP) indicate the circulation of carbonate-calcium waters in the system.

Three types of water are thought to circulate in the system: sulphate acid (Krasheninnikov volcano), carbonate-calcium (slope of the volcano) and deep sodium chloride water. This indicates that the hydrothermal system associated with the Krasheninnikov volcano is a low temperature one in the surface zone. But, the measured downhole temperature of 215 °C in addition to high Cl concentration in the thermal waters shows a high-temperature regime in the interior of the system.

Table. 1 Chemical composition of waters of the Ptichya River Note: analyses performed in the analytical center of the IVS FEB RAS, Petropavlovsk-Kamchatsky. Analyst: Shulga Olga Vasilevna													
number of samples	Date of sampling	Position of sampling	pH	T°C	Chemical composition mg/l								
					Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	Al^{3+}	Mineraliza-tion g/l
P-6	22.aug	affluent	6,78	6,0	12,3	1,0	12,8	7,9	18,4	20,7		0,121
P-8	22.aug	affluent	4,35	5,4	11,4	2,8	23,0	7,3	**45,2**	86,4	4,6	0,186
P-9	22.aug	affluent	7,08	6.0	17,8	0,6	13,2	6,6	14,2	9,6		0,133
Pt-29	22.aug	spring	4,50	2,0	5,7	1,1	12,0	2,4	**21,3**	44,2	3,2	0,092
Pt-31	22.aug	spring	4,20	3,1	9,7	4,0	26,1	9,2	43,3	105,6	10,8	0,203
Pt-32	22.aug	spring	4,30	7,1	8,1	2,3	14,4	3,9	31,9	39,2	1,1	0,105
Ptk-51	06.sept	water sources	4,12	9,0	18,5	5,6	50,1	16,4	117,0	211,2	26,4	0,445
Ptk-52	06.sept	water sources	4,16	11,0	28,3	7,1	3,5	36,2	79,1	326,4	48,6	0,529

Siliceous core at Izumrudno-Goluboe Lake.

Around the Izumrudno-goluboe Lake a lot of silica-rich, porous and brecciated big size rocks are observed. The rocks were formed by hydrothermal processes of metamorphism (under the influence of subaerial ultra-acid fluids, which are formed by condensation of magmatic gases in meteoric groundwater). Some of the rocks have a porous texture which is typical for rocks forming the core of siliceous epithermal deposits of Nansatsu type (White,1991). Development of these siliceous formations occurs at depths between 200-300 to 1000 m. Considering that in the study area the relief is young, deep erosional incisions are absent and that in the NE edge of the Izumrudno-Goluboe Lake there is an explosion crater associated to the tectonic split zone, thus, the authors consider that the emergence of big size rocks in the surface is due to explosive activity. Therefore, it is assumed that siliceous bed-rocks are located in this area in the depth interval from 200 to1000 m. The observations above indicates that at those depths was located an upflow zone of gas-steam thermal fluids, containing HCl, HF, and others, separated from a crustal magmatic reservoir (Kazahaya et al., 1991).

The presence of an explosion crater, silicified-porous-brecciated rocks near the Izumrudno-Goluboe Lake may also indicate that there is a dike at depth, which is the heat source of the hydrothermal system.

multichannel magmatic system of the Paramushir Island.

The existence of a large magmatic reservoir serving as the heat source of the hydrothermal system in the Paramushir Island has not been well established.

(Gorshkov, 1967) suggested the development of a multi-channel magmatic supply system.It is generally accepted the existence of a single long-lived hydrothermal-magmatic system in the Paramushir Island, which includes the northern part of the island (Vernadsky Ridge). Heat and material for the hydrothermal-magmatic system comes from the large solid mass of diorites and gabbro-diorites which underlay at depths from 2.5 to 3.0 km (Rychagov et al., 2002). However, geophysical and geochemical data and other type of studies do not clearly indicate the existence of a large magmatic reservoir. Given that the magmatic system feeding the island-type volcanoes has a long evolution in time, the authors suggest the existence on the Krashenninikov volcano of a complex geological structure, which has a multichannel magmatic supply system which provides heat to the hydrothermal system.

The presence of a multichannel magmatic system at the Vernadsky range has been mentioned in previous work (Fedorchenko et al., 1966). Considering that the hydrothermal system associated with the Krasheniinikov volcano is located on the slope of volcano, thus, this hydrothermal system can be referred as a hydrothermal- multichannel-magmatic system.

Within the Vernadsky range are found several dikes and explosion craters. This indicates the presence of magma with basaltic composition at the root of the system.

The characterization of the heat source of a specific hydrothermal system (location, structure, evolution, etc.) provides information of enormous help for better understanding of the relation of hydrothermal and magmatic processes as well as for further assessment of geothermal and ore resources.

CONCLUSIONS

1.Three types of water are thought to circulate in the Hidrothermal system associated with the Kracheninnikov volcano: sulphate acid (Krasheninnikov volcano), carbonate-calcium (slope of the volcano) and deep sodium chloride water.
2.Hydrothermal system associated with the Krasheninnikov volcano is a low temperature one in the surface zone and have a high-temperature regime in the interior of the system.
3.At depths between 200-300 m (under the lake. Emerald-blue) it is suggested the existence of a silica core formed by hydrothermal metomorphism processes produced by the ultra-acid fluids formed at the surface by condensation of magmatic gases in groundwater of meteoric origin.
4.It is suggested the existence, on the Krashenninikov volcano, of a complex geological structure, which has a multichannel magmatic supply system providing heat to the hydrothermal system and therefore the existence of a hydrothermal- multichannel magmatic system.

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