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Thermal Fluid Geochemistry in Caldera Academy Nauk (Kamchatka, Russia)

Smyshlayeva A.A.*, Karpov G.A.*, Bortnikova S.B.**, Kuzmin D.Yu.*

*Institute of Volcanology and seismology, Piip boulevard 9, Petropavlovsk-Kamchatsky 683006, Russia

annasm@kcs.iks.ru

karpovga@kcsiks.ru devis@kcs.iks.ru

**Institute of Geology, Koptyug Pr. 3, Novosibirsk 630090, Russia

sveta@uiggm.nsc.ru

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ABSTRACT

In lake Karymskoe (Russia, Kamchatka) in 1996 has taken place underwater eruption therefore the structure of water of lake and his (its) physical and chemical parameters has essentially changed, and on his (its) coast has taken place reorganization gasgeothermal outputs (exits). The basic purpose of the works spent since 1996 on present time - studying and an estimation of consequences of underwater eruption on water object and an environment. At once after eruption outputs (exits) highly mineralized sources which part has gradually disappeared were observed, and in some there was a gradual decrease (reduction) of a mineralization. By change of the maintenance (contents) of chlorine and a pine forest having obviously deep origin, took place saturation superficial waters. And, alongside with simple saturation atmospheric waters occured and adulteration lixiviate from the fresh cast out breeds (and also ashes from be in eruption Karymsky volcano) easily mobile components, first of all sulfur, calcium, sodium, magnesium. The wide range of fluctuations of physical and chemical conditions of solutions in a modern output (exit) gasgeotherm clearly correlates with change of a chemical compound. Deep sodium chloride solutions of sources of the Academy of sciences gravitate to a field of alkaline regenerative conditions, while for solutions with the greater share of a sulfate - ion (it is obvious, formed at mixture with superficial waters) less alkaline conditions are characteristic at same variations Eh. Occurrence of a significant amount of a hydrocarbonate typically for subalkaline oxidizing conditions.

Displays endogenous fluid system in caldera Academies of sciences are characterized by the raised(increased) maintenance(contents) in waters of thermal sources of such elements, as B, Li, Sr, As, Mo, V, Ni, Ga, Ge, Zr, Cu, Zn, Br. By much sulphatic structure of water and sour lakes Karymskoe up to pH-3.2 as a result of eruption of 1996, in structure deep flying prevailed SO_2 and H_2S, that it is more typical for andesite magmas. In the volcanic centre now with the big dynamism processes of formation of new structures, volcanogenic and sedimentary formations(educations), a chemical compound of reservoirs proceed.

Now observation proceed as regime.

1. INTRODUCTION

Acidic lakes have been known in Japan (Yugama, Kusatsu-Shirane), Indonesia (Keli Mutu volcano, Crater Lakes; crater lake of Ijen Volcano, East Java), New Zealand (Ruapehu crater lake), South America (Copahue crater lake - *" Sulfur Lake "*, Andes Mountains, Neuquen Province, Argentina), on Kuriles, Kamchatka and in other regions with active volcanism. They arise in places of output of acidic volcanic gases in active volcanoes craters and exist short time between eruptions. Condensation steam-gas volcanic fluids containing acid gases HCl, HF, SO_2, H_2S cause acidity of water in these lakes. The sizes of such lakes varied in a wide range - from the first meters up to hundreds. Usually this one does not have drain, or discharge from them is very small. In paroxysmal stage activity of volcano eruption often occurs in the center of lake. In this case there are breaks of walls of crater and slop the big weights of acidic waters in a vicinity that is lead to ecological accidents.

Caldera acidic lakes take a special place among types of acid lakes of areas with active volcanism. They are exist long time and characterized by wide variations of the general mineralization, inconstancy of a chemical compound and varying acidity. These lakes arise in hollows of caldera and fix zones of tectonic breaks, on which besides high-temperature fluids from superficially deposited magmatic centers and the top parts of magmatic body not left on ground surface. On periphery this calderas often occurs active volcanoes. Usually in this calderas located large high-temperature hydrothermal systems. The salt composition of water acidic caldera lakes basically represents a mix of salts sulfuric and hydrochloric acids - as products of transformation of deep haloid-sulphurous emanations and their reaction with breeds.

The hydrothermal system of caldera Academy Nauk have special interest of various researchers after underwater phreatic-magmatic eruption in January 1-2, 1996 in northern sector Karymskoe lake filling all caldera. Consequence of this short-term but powerful eruption was formation of volcanic construction of type maar with a crater in topmost part with diameter about 600 m and depth of 56 m. The southern sector of a crater is under water. Northern, east and western boards of this construction have generated peninsula Novogodny, combined sand-scoria-bomb a material of mainly basalt composition (Figure. 1). On a rather narrow inundated terrace Karymskaya river on her new coast, in 200 m from a source was appeared the group with temperature 70-98˚C which has nameed "Piipovskye". The spring of descending thermal sources have generated groove “Goryachy” with width 2-3 m and length about 100 m. In some griffons (especially high-temperature) are observed outputs of gases. Besides thermal sources have appeared in the channel Karymskaya river (a Burlyashhy source) and a few sources on both coast of this river (sources Razlomnyi, Beregovoi) tracered on distance about 200 m a direction submeridional interstitial

трещинной a zone well shown as a powerful extended crack in a right board of a socle terrace Karymskaya river (Leonov V.L., 1998).

In the beach zone of Karymskoe lake framing from the north crater Tokareva almost on all his perimeter is observed warming zone, and in prospect-hole found thermal waters with temperature 50-96˚C (sources Plyazhnye) and in southwest sector - outputs of hydroterm with temperature to 52˚C are opened. In north-northeast sector Karymskoe lake coast in 1 km from a source Karymskaya river have appeared sources Medvezhy in 1996.

The big group of thermal sources is found in east frame of lake. The majority of sources set near shore line (Beregovoy, Serdity, Carbonatny etc.). Ushakovsky sources were appeared above 25 m higher shore line. Exact data on formation time of these sources are not present. Probably, they existed before eruption in 1996 as/since here are observed metasomatite disgraces – argillizit formation typical for the centers of discharge of modern hydrothermal systems. Apparently, they were naked after sharp downturn lake level in May, 1996. In this zone plentiful outputs of free gases from depth of 1-2 m at a coast of lake are observed also.

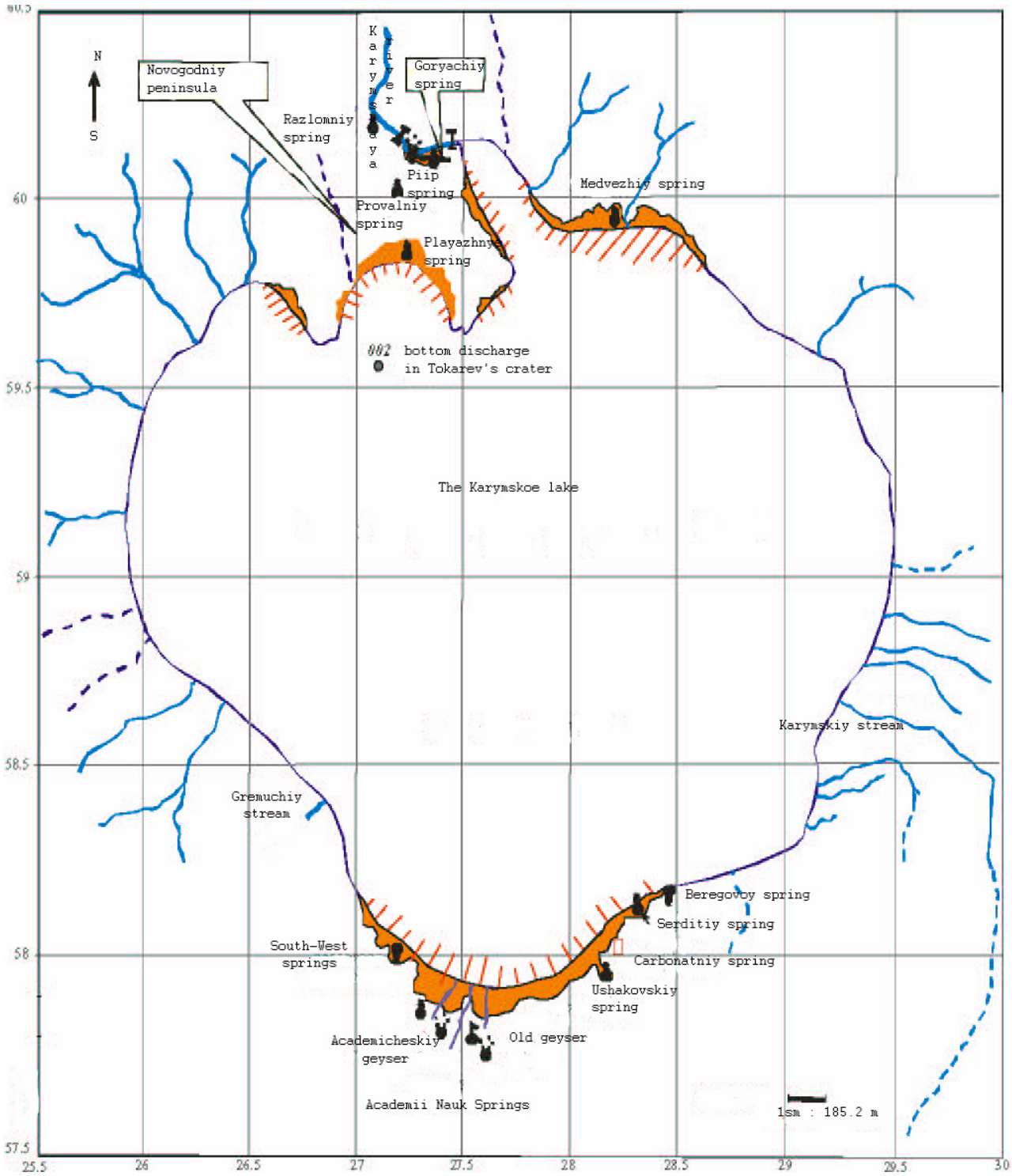

Figure 1: Location thermal springs in caldera's Academy Nauk (Kamchatka (map made by Nikolaeva A.G., Marushhak V.O., scientific editor Karpov G.A.).

Sources of the Academy Nauk were known earlier. But after eruption of 1996 there was some regrouping of outputs a hydroterm and there was found a new western group of thermal sources among with the geyser. It has received the name "Academichesky" (Vakin E.A., Pilipenko G.F., 2001).

Besides this geyser some tens outputs pair on which place pulsing sources and mud boilers with condensate water are formed here are observed. The basic purpose of hydrogeochemical studying of sources Karymskoe lake system was construction of qualitative model of their genesis on the basis of definition of physical and chemical conditions in solutions and also their basic and microelement composition. In article are used the data long-term monitoring supervision and gaugings of the specified parameters in different groups of sources and the results of their system approbation received in 2002. Detailed characteristics of the used methods are given by Bortnikova S.B., Karpov G.A., Bessonova E.P., Smyshlyaeva A.A., 2003.

2. THE SHORT CHARACTERISTIC OF A GEOLOGICAL STRUCTURE OF THE ACADEMY NAUK VOLCANO

The volcano of the Academy Nauk is allocated in structure Karymsky volcanic center and named by Vlodavets V.I. (1939). Karymsky volcanic center is one of the most active geological structures in East volcanic belt of Kamchatka. Its sizes about 50 x 35 kms. Volcanic activity began here more than 2 million years back and to present time, in this structure are allocated 21 volcanic construction, including 6 calderas. Masurenkov Yu.P. (1980) mark out four rhythms of volcanism which generated whole Karymsky volcanic center. The final (fourth) rhythm characterized by catastrophic eruptions pyroclastyc flow in the structure sector of Academy Nauk about 110-80 thousand years ago (the end of average - the beginning of top Pleistocene). It is considered, at this time was generated caldera of Odnobokiy volcano in northern sector of that subsequently has formed small stratovolcano Academy Nauk.

The Karymskoe lake is located in East Kamchatka volcanic belt in 6 kms from active volcano Karymsky and belong to Karymsky volcanic center (KVC) Hire are known two groups of thermal sources belong to calderas. Caldera Academy Nauk and Karymskaya caldera are allocated among other structures KVC with powerful modern hydrothermal activity. In caldera Academy Nauk at southern part of lake, have discharge high-temperature (boiling) hydroterms and their less hot derivatives. Karymskaya caldera, located at bottom Karymsky volcano an arrangement to the most powerful center on Kamchatka of discharge medium-temperature carbonic therms (Vakin E.A., Pilipenko G.F., 1998). Modern hydrothermal activity is concentrated near a large break submeridional direction, transversal ring structure in this western part (Vakin E.A., Pilipenko G.F., 2001).

3. METHODS OF RESEARCH

For measurements temperature on vertical structures and sampling water from depths lake were applied to overturning bathometer HYDRO-BIOS KIEL the Swedish manufacture in volume 2 litre and slamming bathometer the same firm in volume 5 litre.

At approbation of hydroterm the sample were filtered and definition, also was determined pH and Eh. Then one portion of solutions was acidified by the overtaken nitric acid to pH ~ 2 for the subsequent definition microelement composition. Another was left without fixing for definition of the basic salt composition. Field definition pH and Eh was made portable field pH-OPR-meter by HANNA.

The analysis of a chemical compound was carried out in the certificated Central chemical laboratory of IV FED Russian Academy of Science by standard techniques for the analysis of natural waters and all-Union State Standard with a mistake of definition no more than 5 %. At the analysis ardent-photometric methods calorimetric, volumetric, potentiometric were applied. The microelement structure of solutions was analyzed by method ISP on device IRIS of firm Jarell Ash Corporation (USA).

4. THE HYDROCHEMICAL CHARACTERISTIC OF THERMAL SOURCES

In group of hydroterm appear after underwater eruptions on peninsula Novogodny one year after eruption was formed failing raven with depth about 4 m at the bottom was found the output boiling hydroterm chloride-natrium composition (tab. 1). Water of this source had typical - high for this type a hydroterm contents of chlorine, sodium, potassium, a pine forest and silica acid and on the general mineralization more than twice surpassed water as old and new geyser in southern group a hydroterm. But in 1998 in crater have taken place collapse of the walls and the source has disappeared. A mineralization close to this source, had in the beginning of the existence in 1996 source #1 in Piip group of sources on the left coast Gorychy groove. But mineralization has essentially decreased after time. Similar changes were takeing place in due course with a mineralization of water and other sources of Northern group. By change of the contents chlorine and a pine forest having obviously deep origin, took place desaturation meteoric waters. With occured simple dilution by atmospheric waters and adulteration подмешивание with leachable from the fresh cast out breeds (and also ashes from be in eruption извергающегося Karymsky volcano) easily mobile components, first of all sulfur, calcium, sodium, magnesium take place.

In the modern plan of outputs hydroterms on Karymskoe lake perimeter is looked through the certain law - they are grouped in northern and southern sectors of coast. In both groups heat developable wide variations of physical and chemical parameters of solutions (fig. 2) and their hydrogeochemical composition are observed. Distinctions of oxidation-reduction conditions and acidities - alkalinity the hydroterm allows to plan trend changes of these characteristics determined, obviously, genetic features of their origin and ways of an output on a surface. Regenerative conditions of subalkaline solutions of east group of the Academy Nauk on practically linear dependence is replaced on practically neutral and further - oxidizing conditions with downturn of values pH for different groups of hydroterms (the Western group of the Academy Nauk, Piip sources, Beregovoy, Medvezhy, cold streams). Extreme values of these parameters are characterized for mud boilers of the Academy Nauk and Karymskoe lake - oxidizing conditions with subacidic- practically neutral environment.

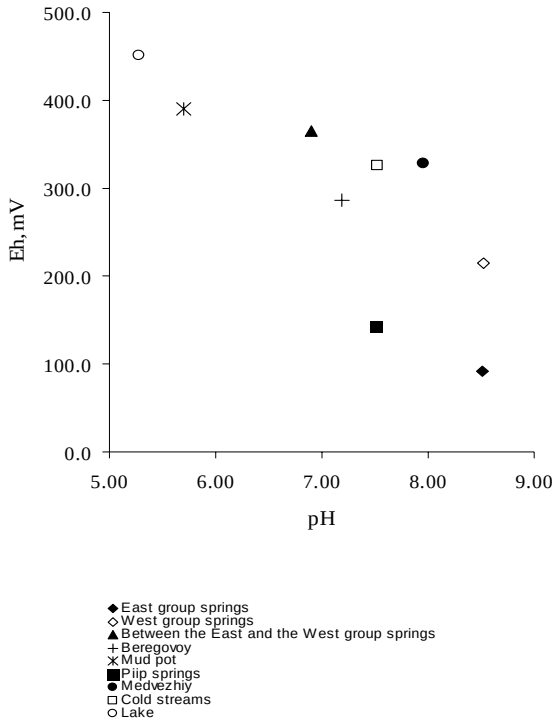

Figure 2: The pH-Eh diagram parameters springs of Karymskoe lake (The average values for different groups).

With regard to absence coarse hydrochemical ash value hydroterm, all the same, can divide sources into three groups on a ratio of the basic anions: a hydrocarbonate, chloride, sulfate. That in the majority the hydroterm the basic anion is chloride (sources of the Academii Nauk, Medvezhy, group of hydroterm in east sector of lake), in some sources (Piip, Beregovoy) the leading part plays sulfate (fig. 3). But meet the sources with composition where prevalence HCO_3-ion (except for above named Carbonatny to this type prevails concern small, but the numerous sources located on a coast of lake, between East and Western groups of geysers of the Academy Nauk). Variations in anion composition of solutions have quite distinct connection with change of physical and chemical parameters. Chloride-natrium sources occupy the right field on the diagram pH-Eh (sources from Academy Nauk, Medvezhy (fig. 4)).

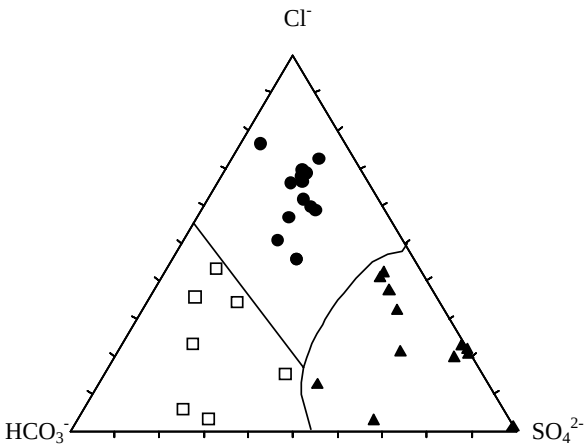

Figure 3: Relative contents of the basic anions in solutions of sources of system Karymsky lake.

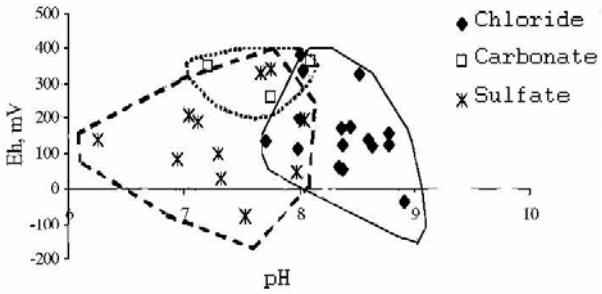

Figure 4: Values pH-Eh parameters in different hydrochemical composition.

The degree abyssal of thermal waters is well determined by the contents in them such characteristic components as Cl, B, Si. The field sulfate-natrium hydroterms shown in zones with the big capacity of a cover fresh eruptive breed, is located in regenerative, but less alkaline area (some sources near coast, Beregovye, Piip, Razlomny). In these therms always highly contents of ions Ca and Mg. And carbonate sources presented by three small hydroterms, are characterized by oxidizing conditions at subalkaline reaction. From these positions the hydrothermal system of caldera Academy Nauk in a deep zone, apparently, contains classical nitric-carbonic-acid therms chloride-natrium composition. All other types of waters arise both on peninsula Novogodny, and on other sites caldera are products of mixture chloride-natrium therm with waters of superficial formation.

Using these criteria, we can ascertain, that the most deep terms chloride-natrium composition in caldera Academy Nauk have specialization concerning such components as B, Li, Sr, As, Mo, V (tab. 2). For all types of waters high contents Cu, Zn, Br and the same Sr, Ge are characteristic. In mineral deposits of sources with these waters, except for vanadium and strontium increased contents of Ni, Ga, Zr, to a lesser degree Y is marked also.

The composition of free gases of thermal sources and centers underwater discharge in caldera Academii Nauk also has very wide variations (tab. 3). In a gas phase of a high-temperature source №1 in Piip sources group highly the contents of methane. In discharge under water in a channel Karymskaya river (source Burlyashhy) which leaves in 40 m from a source № 1, already carbonic-nitric structure of gases is observed, at the minimal contents of hydrocarbons. In a beach zone of discharge composition of gas essentially nitric, and outputs of gas directly from a bottom of Karymskoe lake (for example, on shoaliness in a Zhelaniay bay) already have carbonic structure. It is typical, that these outputs spatially gravitate to a zone of display hydrocarbonate waters (source Carbonatny). Nitric therms sources of Academy Nauk are enriched with oxygen (more than 25 % O_2), at practically normal composition of air on lake (height 624 м). Obviously, active mixture deep a term with atmospheric waters and boil-off nitrogen and to a lesser degree carbonic acids in near-surface conditions takes place.

The important information about dynamics of a stream of substance on sites of display managed hydroterm to be received according to research of a radio-activity of free gases. Pyroclastic sand-bomb material basically basalt structure composing forming Novogodny peninsula, in the first months after eruption was hot and actively degassed. In these emanations high radio-activity was marked: gamma-activity achieved 39 microroentgen per hour, and volumetric activity of radon – alpha-activity explosive and filing craters achieved 50 kilobecquerel per cubic meter. After 2 years

scale activity has decreased to 4 - 6 microroentgen per hour, and an alpha activity - to first units. Stably high alpha activity - up to 10- kilobecquerel per cubic metre - was kept only in a zone fissuring - in a channel and flood-land Karymskaya river. We explain marked changes of a volumetric radio-activity that was caused by an emanation of radon, sorbable pyroclastic material. In the magmatic products composing peninsula were few parent radioactive elements - U-238, Ra-226. Quickly finished disintegration sorbable radon was reflected by falling of a radio-activity in this site. Fissuring sites dated for zones of a stretching, apparently, drain a deep zone of hydrothermal system with an ascending stream of gases and solutions act also radioactive elements. Definitions of the contents of uranium testify to it in solutions Goryachy groove - up to 0.012 mg/*l* of uranium. In free gases of sources of the Academy Nauk volumetric activity of radon during all 6 years of supervision exceeded 100 kilobecquerel/m^3. It is indicative, that in geyserite significant maintenances of lead which can be an end-product of disintegration of uranium and thorium were determined. Hence, it is possible to believe, that in this hydrothermal system already long time rises to a surface a flow from deep substance in which structure, alongside with radioactive, act and the specific elements marked above to considered composition: B, Li, Sr, As, Mo, V, Ni, Ga, Ge, Zr, Y, Cu, Zn, Br.

5. CONCLUSIONS

1. Evolution of structure gas-hydrothermal sources after phreatic-magmatic eruption 1996 consist in natural decrease of the general mineralization of solutions and change of a ratio of the basic components aside increases of a share of the ions acting with superficial waters that was expressed in distinct reduction of contents of ions Cl and Na, but increase silica acid and a sulfate-ion.

2. The Wide range of fluctuations of physical and chemical conditions of solutions in a modern output gas-hydrotherm clearly correlates with change of a chemical compound. Deep chloride-natrium solutions of sources Academy Nauk gravitate to a field of alkaline regenerative conditions, while for solutions with the greater share of a sulfate - ion (it is obvious, formed at mixture with superficial waters) less alkaline conditions are characteristic at same variations Eh. Arising of significant amount of a hydrocarbonate typically for subalkaline oxidizing conditions.

3. Displays endogenous fluid system in caldera Academy Nauk are characterized by the increased contents in waters of thermal sources of such elements, as B, Li, Sr, As, Mo, V, Ni, Ga, Ge, Zr, Cu, Zn, Br. By much sulphatic structure of water and acidifying Karymskoe lakes to pH=3.2 as a result of eruption of 1996, in structure deep flying prevailed SO_2 and H_2S, that it is more typical for andesite magmas. The differentiation of fluid system after end eruptive expressed activity in prevalence over structure of free gases of nitrogen and carbonic acid. The question is not absolutely clear about is abnormal the high contents of metane in outputs Piip sources.

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Table 1. Change of a chemical compound of thermal sources caldera Academy Nauk.

Name of sampling	Date of sampling	T, °C	pH	Na^+	K^+	Ca^{2+}	Mg^{2+}	NH_4^+	Cl^-	SO_4^{2-}	HCO_3^-	F^-	H_3BO_3	H_4SiO_4	Σ
			mg/*l*												
Srping № 1 Piip group	Oct.1996	89	7.76	550	58	124	16.9	no data	753	509	140	no data	53.4	291	2495.3
	Apr 2001	82	7.36	390	34	42.1	9.7	no data	380	394	81.8	1.0	18.0	274	1624.6
	Jul. 2002	67	8.05	370	54	48.1	2.4	0.1	380	442	76.9	no data	28.4	410	1811.9
Provalny	Jul. 1997	96	7.80	850	85	92	2.4	0.1	1220	317	120	1.1	57.8	461	3206.4
Bottom discharge in crater Tokareva	Jul. 2002	64	7.74	98	7.5	37.7	8.3	0.2	75	230	50	no data	6.8	127	640.55
Plyazhny	Jan.1997	79	7.30	255	24	48	9.7	0.1	282	240	157	1.0	16.3	390	1423.1
	Jun.1998	72	6.50	164	15.9	46.8	11.2	0.1	122.5	300	50	0.2	8.2	204	922.9
	Jul. 1998	64	7.64	225	20	50	4.9	0.1	176	336	98.9	1.2	10.9	276	1199
	Sept. 1999	57.2	7.59	280	30.2	38.1	3.6	0.2	176	394	92.8	no data	5.2	293	1313.1
Medvezhiy	Jul. 1997	37.	7.60	79.3	8.6	20	1.4	0.1	110	28.8	65.9	1.14	8.1	167	490.34
	Sept 1999	38	7.33	115	11.9	20	1.9	0.1	146	67.2	76.9	1.14	0.4	290	730.54
	Jul. 2002	37	7.34	115	15.3	14.4	1.5	0.1	138	57.6	76.9	no data	16.7	272	707.5
Old Geyser (East group Academy Nauk springs)	1947	98	8.70	240	26	9.0	no data	no data	355	92	85	2.3	48.0	343	1150
	1974	65	8.90	300	30	2.4	1.5	0.1	347	84	74	2.3	48.0	144	1033.3
	1989	94	9,30	370	29	3.6	0.1	0.1	418	105	109	no data	52.0	512	1598.8
	1997	98	9.20	320	14	6.8	0.2	0.4	389	106	51	2.1	53.0	372	1314.5
	2002	98	9.32	310	23.5	1.6	0.12	0.1	401	106	84.8	0.3	51.9	473	1452.32
Geyser Academicheskiy (West group Academy Nauk springs)	Jul. 1997	97	9.25	360	15	6.4	0.1	0.1	453	96	115	1.93	44.9	426	1518.43
	Apr. 20.01	97	9.41	350	23.5	2.0	0.4	0.0	426	106	115	2.1	36.0	247	1308
	Jul. 2002	97	9.25	302	21.3	4.8	2.4	0.1	390	106	87.5	no.data	47.0	393	1354.1

Table 2. Geochemistry a hydroterm caldera Academy Nauk, (date of selection - July, 2002)

Name of sampling	T, ^{0}C	Mn	Fe	P	B	Ba	Li	Sr	As	Zn	Cu	Mo	V
		ppm											
Srping № 1 Piip group	67.0	0.14	0.09	0.1	3.03	0.02	0.47	0.13	0.086	0.03	0.0013	no data	no data
Razlomny	77.0	0.06	1.05	0.05	2.35	0.009	0.26	0.03	0.12	0.06	0.11	0.014	0.035
Voronka № 4	16.0	0.05	0.61	0.09	0.18	0.009	0.21	0.015	no data	0.12	0.012	no data	no data
Bottom discharge (Tokarev crater)	64	0.67	0.21	no data	1.09	0.005	0.16	0.045	0.08	0.03	no data	0.017	0.012
Medvezhiy	38.6	0.08	10.8	0.04	2.67	0.014	0.14	0.062	0.27	0.35	0.435	0.019	0.005
Beregovoy	89	0.45	0.39	0.15	0.46	0.076	0.06	0.29	no data	0.02	0.008	0.004	no data
Serditiy	79.4	0.04	0.04	no data	5.89	0.049	0.52	0.071	0.83	0.01	no data	0.014	no data
Ermakovsky	93	0.01	0.06	no data	4.32	0.004	0.68	0.310	0.70	0.02	no data	0.016	no data
Old Geyser	93.7	0.003	0.06	0.018	7.30	0.004	0.86	0.045	1.30	0.016	no data	0.041	0.009
Geyser Academicheskiy	83	0.004	0.33	0.012	7.96	0.01	095	0.021	1.48	0.057	0.012	0.048	0.013
Pulsiruyshhiy spring	76	0.16	1.14	0.21	0.89	0.06	0.06	0.06	0.14	0.014	no data	no data	0.019

Table 3: Composition of free gases of thermal sources and zones of discharge in caldera Academy Nauk (Karymskoe lake)

Name of sampling	Date	T°C	Gas composition of free gases, vol. %														N_2/Ar	N_2/O_2
			He	H_2	O_2	N_2	Ar	CO_2	CH_4	C_2H_6	C_2H_4	C_3H_8	C_3H_6	iC_4H_{10}	nC_4H_{10}			
										x10^{-6}							
Srping № 1 Piip group	Apr. 1997	83	0	0.003	0.6	23.8	0.38	31.8	41.9	3000	2140	80	20	2	1	63	40
	Jul. 1997	80	0	0	0.8	29.7	0.49	21.9	54.6	3220	2360	90	20	2	1	61	37
	Jun. 2000	no data	0.002	0.0009	1.4	36.7	0.98	9.44	51.5	0	0	0	0	23	109	37	25
	Jul. 2001	76*	0.001	0	1.2	31.8	0.82	8.69	57.4	0	0	0	17.4	6.1	7.8	39	26
	Jul. 2002	no data	0.0110	0	0.0	35.0	0.94	9.12	54.9	no data	no data	49.5	88.9	4.2	8.7	37	2059
Burlyashhiy spring in Karymskaya river–bed	Apr. 1997	92	0.004	0	0.9	20.5	0.30	78.1	0.2	1740	170	40	20	27	30	68	23
	Jul. 1997	90	0.007	0.005	1.5	39.7	0.52	58.2	0.05	700	0	50	30	71	71	76	26
	Jun. 2000	99	0.0055	0.0042	3.4	53.8	1.03	41.6	0.169	1160	49	130	25	37	33	52	16
	Jul. 2001	92.1*	0	0.0002	4.9	84.3	1.77	8.8	0.234	0	0	119.7	8.1	21.9	28	48	17
	Jul. 2002	no data	0.011	0.00	0.4	81.9	1.67	15.7	0.30	no data	809.0	101	8.6	19.6	23.90	49	197
Crater Tokareva beach	Apr. 2001	no data	0.002	0	2.0	95.8	1.51	0.63	0.079	480	20.3	44.3	4.4	10.9	10.8	63	49
	Jul. 2001	no data	0	0	2.2	95.5	1.42	0.79	0.058	0	0	32.8	4.4	6.6	6.3	67	43
Provalny	Aug. 1997	98	0	0.027	18.0	65.8	0.72	15.5	0.0039	54	32	2.2	4.2	3.5	4.1	92	4
East group Academy Nauk springs	Jun. 1984	no data	no data		14.7	62.0	1.33	21.7	0.167	0	no data	no data	no data	no data	no data	47	4
	Sent. 1995	no data	0.0016	0.002	18.9	75.3	1.57	4.20	0.03	no data	no data	no data	no data	no data	no data	48	4
	May 1996	68	0	0	18.8	78.3	1.50	1.30	0.051	1200	0	60	10	1	21	52	4
	Apr.0 2001	80	0	0	25.3	72.3	1.49	0.73	0.15	70.4	16.4	6.1	5	1.2	1.7	48	3
	Jul. 2002	82	0.00	0.00	22.2	70.2	1.13	6.48	0.0054	17.20	7.10	2.60	4.10	0.8	0.7	62	3
Outputs in lake near Academy Nauk	Apr. 2001	no data	0.001	0.003	2.5	10.4	0.29	86.0	0.902	no data	no data	6.6	14.5	1.1	1.1	37	4
	Jul. 2001	no data	0	0	2.2	14.1	0.40	82.0	1.301	no data	no data	24.6	24.6	1.1	1.6	36	6
Bottom of a Zhelannaya bay	Jul. 2002	no data	0	0	1.5	15.9	0.31	82.1	0.145	no data	no data	13.5	4.3	1.9	0.7	52	11
Medvezhiy	May 1996	37	0.002	0.0057	8.7	87.8	1.14	2.30	0.001	10	0	0	0	0	2	77	10
	Jun. 2000	no data	0.001	0	6.0	91.5	1.64	0.85	0.051	0	81	12	1.5	0.2	0.3	56	15
Air on Tokarev beach	Jul. 1998	no data	0	0	17.9	80.1	0.93	1.15	0.0006	9.4	12	2.1	26	1.8	2.2	86	4

The note: *Analyses are executed in analytical laboratory IVGG FED Russian Academy of Science, By Shapar' V.N., Gartzeva L.N;

- there are no data or were not defined