Dependence of the Chemical Composition of Thermal Waters upon Seismic Activity

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Abstract

Changes in the chemical composition of the hot springs of Mendeleev Volcano (Kunashir Island) as for Cl^-, SO_4^{2-}, CO_2, NH_4^+ and Cl^-/SO_4^{2-} are given in function of the 1965-66 and 1973 (in part) seismic activity in the South Kurile islands.

Seismic Conditions and Chemism of Thermal Waters at the Base of Mendeleyev Volcano in 1965-1966

Routine observations on the parameters of certain springs in Goriachy Pliazh and at the base of Mendeleyev volcano carried out by the Sakhalin Geological Survey in connection with a prospecting of natural thermal water and steam deposits, as well as earthquake records during many years at the near-by (at a distance of about 10 km) South-Kurile seismic station (of the Sakhalin Sci. - Res. Institute) supplied us with the first data for possible correlations between seismic activity and chemical composition of hydrothermal springs. The routine observations included a monthly collection of water samples and their more or less full standard analyses. This work proceeded systematically during 1965 and 1966.

Seismic conditions on Kunashir Island in 1965 and 1966 are given in Fig. 1, which shows clearly that the year 1966, as compared with 1965, had a higher seismic activity. In 1965 there were only 3 « intensity » earthquakes: on May 18th and 19th and on June 11th. Their total « intensity » came to 12. In 1966, « intensity » earthquakes took place 12 times: on January 2nd and 23rd; February 19th and 22nd; March 19th; April 5th; June 9th; July 29th; September 23rd; November 1-2nd and De-

cember 22nd. Their total « intensity » amounted to 52. In other words, the seismic activity on Kunashir Island in 1966 was 4-5 times higher than in 1965. Has this fact affected the chemism of hydrothermal springs there?

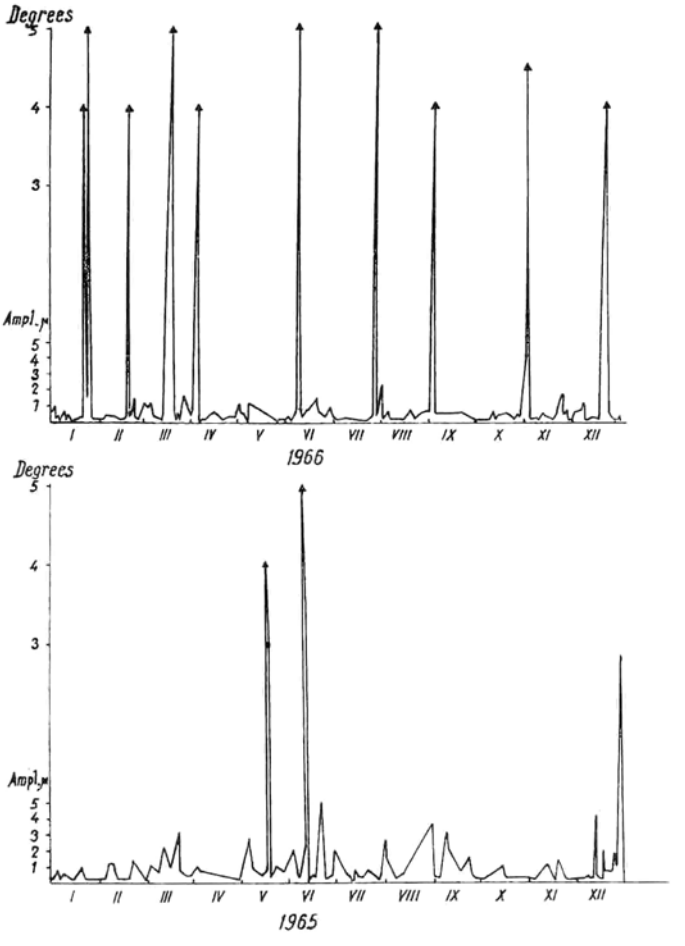

FIG. 1 - Seismic activity on Kunashir Island in 1965 and 1966.

For 1965 we had at our disposal 82 analyses of water from 10 springs and 81 analyses of water from the same springs for 1966. A comparison of these analyses indicated the following changes. The mean Cl^- content in g/l in 1966 proved to be 0.08 g/l or 10 % higher

than in 1965. The mean SO_4'' content in g/l in 1966 was 0.01 g/l or 3 % higher than in 1965. The sum of $Cl' + SO_4''$ differed in 1966 by 0.09 g/l or by about 10 %, and the Cl'/SO_4'' ratio by 0.2 or about 5 % (Table 1, Fig. 2). Of interest is the difference in the content of free carbon

TABLE 1 - Mean contents of Cl^- in g/l during 1965 and 1966.

springs	1965	*1966*
1	0,9472 (9)	0,9745 (12)
1a	1,3425 (9)	1,2468 (9)
2	1,2273 (8)	1,2808 (12)
3	0,0665 (5)	0,0571 (7)
4	0,5931 (10)	0,5966 (7)
5	0,4778 (9)	0,5950 (8)
6	0,2563 (6)	0,3508 (1)
7	0,7484 (11)	1,0613 (7)
8	2,0101 (8)	2,2436 (11)
10	0,0591 (7)	0,0612 (7)
mean	0,7728 (82)	0,8468 (81)

The number of analyses is shown in brackets.

dioxide in six springs, where it was determined. Its average for 1965 was 0.036 g/l, while in 1966 it was 0.040 or 11 % higher (Table 2, Fig. 3).

A comparison has been made between NH_4^+ and HBO_2 contents. The results of this comparison indicated that in 1966 the mean concentrations of NH_4^+ and HBO_2 were higher than in 1965 (Table 3, 4). It is worth noting that the average HBO_2 content in 1966 was substantially higher in all springs.

A correlation has been made between chemical composition of thermal waters and meteorological conditions (according to data supplied by the South-Kurile aerological station). No relation has been observed between Cl', SO_4'', NH_4^+, CO_2 and HBO_2 and the seasons and the amount of atmospheric precipitations (it is to be considered that the samples were collected on days when there were no abundant

atmospheric precipitations). The fact that the yearly precipitation in 1965 (1171 mm) was lower than in 1966 (1549 mm) warrants an assumption that lower concentrations of the components under question

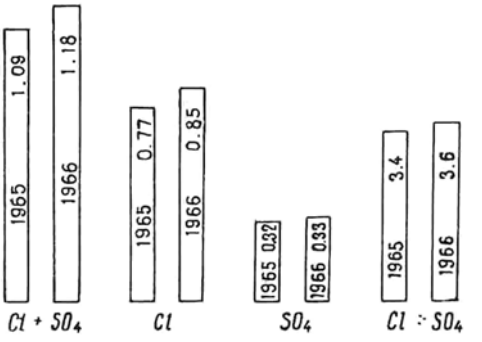

FIG. 2 - Mean annual contents in g/l of $Cl' + SO_4''$, Cl' and SO_4'' and Cl'/SO_4'' ratio in the springs of Goriachy Pliazh and of Mendeleyev volcano (82 analyses for 1965, 81 - for 1966).

in 1965 were not caused by a dilution of thermal waters by atmospheric precipitation. Therefore, the established changes in the chemical composition of thermal waters in 1965-1966 are not associated with changes is meteorological conditions.

TABLE 2 - Contents of free CO_2 in g/l in 1965 and 1966.

springs	1965	*1966*
4	0,0471 (10)	0,0644 (5)
5	0,0711 (8)	0,0729 (2)
6	0,0256 (6)	0,0264 (1)
7	0,0193 (10)	0,024 (5)
8	0,0220 (8)	0,028 (7)
10	0,0172 (6)	0,0245 (7)
mean	0,0359 (48)	0,040 (27)

The number of analyses is shown in brackets.

We think that an increase in the content of Cl', SO_4'', CO_2, NH_4^+ and HBO_2 in thermal waters around Mendeleyev volcano in 1966 as compared with 1965 was caused by a greater seismic activity.

Of interest is the behavior of free carbon dioxide in the springs during 1965. On a background of general slight seismic activity, earthquakes of about 4 in intensity took place in May-June. During the

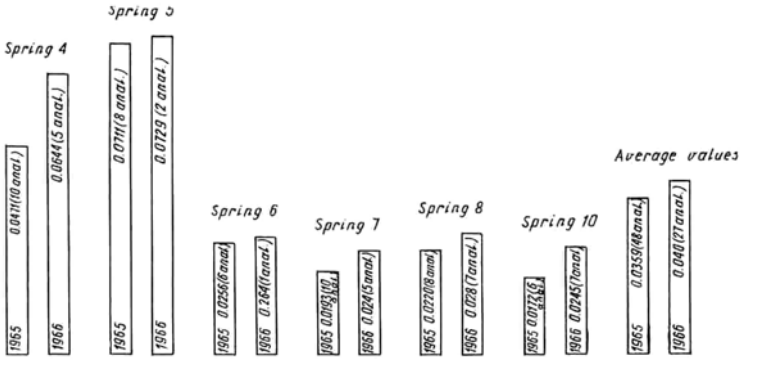

FIG. 3 - Comparison of the mean contents of free carbon dioxide in g/l in 1965-1966 in the springs of Goriachy Pliazh and of Mendeleyev volcano.

other months there were no « intensity » earthquakes. Higher contents of free carbon dioxide were recorded in April — a month preceding the May-June earthquakes — and in July — a month after

TABLE 3 - Mean contents of NH_4 in g/l

springs	1965	*1966*
1	0,0017 (9)	0,0101 (12)
1a	0,0025 (9)	0,0089 (8)
2	0,0132 (7)	0,0117 (10)
4	0,0013 (9)	0,0036 (8)
5	0,0018 (8)	0,0021 (7)
7	0,0007 (10)	0,0009 (7)
8	0,0020 (7)	0,0015 (11)
10	0,0004 (6)	0,0017 (9)

In brackets: no. of analyses.

the earthquakes. The mean values for free carbon dioxide in April-July 1965 in six springs are given in Table 5. For comparison the table gives also the mean values for all the other months. The mean value

for all six springs during April-July is 0.0432 g/l, while during the other months it is 0.0306 g/l, which is substantially lower.

TABLE 4 - Mean contents of HBO_2 in g/l.

springs	1965 *(mean)*	*1966 (mean)*
1	0,0095 (9)	0,0205 (9)
1a	0,0131 (9)	0,0189 (8)
2	0,0196 (8)	0,0275 (10)
4	0,0056 (10)	0,0095 (8)
5	0,0064 (10)	0,0113 (8)
7	0,0083 (11)	0,0097 (6)
8	0,0230 (8)	0,0350 (10)

In brackets: no. of analyses.

Changes in the H_2SiO_3 concentrations associated with earthquakes were also noticed in May-June, 1965. A much higher mean content of

TABLE 5 - Contents of free CO_2 in g/l.

springs	1965 *Months IV-VII (mean)*	*1965 Rest of the months (mean)*
4	0,0495 (4)	0,0455 (6)
5	0,0748 (3)	0,0573 (5)
6	0,0264 (4)	0,0242 (2)
7	0,0222 (3)	0,0181 (7)
8	0,0601 (3)	0,022 (5)
10	0,0264 (1)	0,0167 (5)
mean	0,0432 (18)	0,0306 (30)

In brackets: no. of analyses.

H_2SiO_3 for all the springs studied was recorded in May-June, during the earthquakes (Table 6). The mean value of H_2SiO_3 for ten springs

during May-June is 0,2275 g/l, whereas it is 0.1395 g/l during the other months, with a drop of 38.7 %.

It seems reasonable that the higher carbon dioxide contents in hot springs during April-July and the higher H_2SiO_3 contents in May-June are related to earthquakes.

The Cl'/SO_4'' ratio in equivalent percentage was analysed in connection with the earthquakes of May-June, 1965.

TABLE 6 - Contents of H_2SiO_3 in g/l in 1965.

Springs	*Months V-VI (mean)*	*Rest of the months (mean)*
1	0,2788 (2)	0,2151 (6)
1a	0,3692 (1)	0,2548 (8)
2	0,4472 (1)	0,3005 (7)
3	0,0416 (2)	0,0279 (4)
4	0,2532 (2)	0,1366 (8)
5	0,2054 (2)	0,1008 (8)
6	0,1053 (2)	0,0567 (4)
7	0,1970 (2)	0,1328 (9)
8	0,2340 (1)	0,1057 (7)
10	0,1430 (1)	0,0644 (6)
mean	0,2275 (16)	0,1395 (67)

In brackets: no. of analyses.

Apparently, these earthquakes led to a general decrease of this ratio. In one case (springs 7 and 5) this drop preceeds the earthquakes; in another case (springs 10 and 4) it accompanies them; in still another case (spring 6) this drop occurs slightly after the earthquakes.

It would be premature to recommend the use of this ratio as an indicator for predicting earthquakes. This problem needs to be studied further.

Change in the Composition of Thermal Waters at the Base of Mendeleyev Volcano in Connection with Strong Earthquakes on June 17th and 24th, 1973

On June 17th and 24th, 1973 strong earthquakes (with an intensity of about 6 took place on Kunashir Island. Their epicenters were located south-east of Shikotan Island.

A sharp increase in Cl′ content was found in the thermal water of well No. 5 after the earthquake. In April 1973 the content of chlorine was 4.85 g/l, whereas after the earthquake (in July) in 7 samples this content varied from 5.5 to 5.8 g/l.

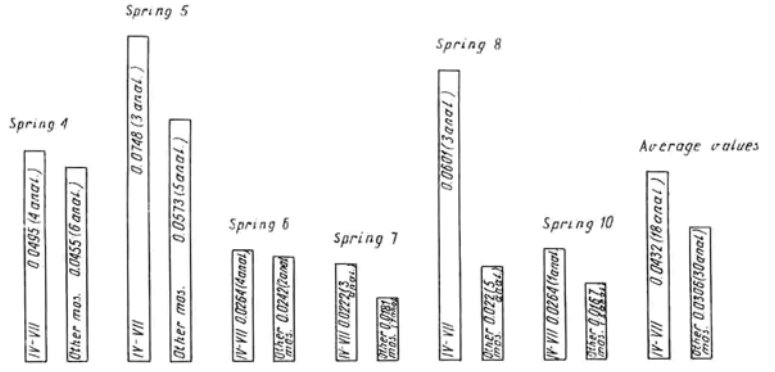

FIG. 4 - Comparison of the mean contents of free carbon dioxide in the springs during April-July and during the other months of 1965.

In spring No 6 before the earthquakes (sample taken on June 3rd) the content of Cl′ was 1.35 g/l; on the second day after the earthquake (on June 19th) it was 1.59 g/l.

In spring No 1 before the earthquake (29th of April 1973) the mg-equiv. of Cl′ was 25.4; after the earthquake (June 30, 1973) it increased to 26.4.

The data quoted would suggest a dependence of the chemical composition of thermal waters upon seismic activity. However, the relation mechanism is rather complicated and needs to be studied further in order to establish proper criteria for predicting earthquakes.

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