DILUTION AND CONCENTRATION OF SALINE WATER IN DON JUAN POND IN 1974

Kikuo KATO,

Water Research Institute, Nagoya University, Chikusa-ku, Nagoya 464

Tetsuya TORII

Chiba Institute of Technology, Tsudanuma, Narashino 275

and

Nobuyuki NAKAI

Department of Earth Sciences, Nagoya University, Chikusa-ku, Nagoya 464

***Abstract*:** Remarkable dilution and concentration of saline water in Don Juan Pond were found in 1974, in the winter of which Don Juan Pond was found to be frozen for the first time since its discovery.

Don Juan Pond was supplied with a large amount of water during summer to winter of 1974. The supplied water probably originated from the same source as that of water of Lake Vanda.

Concentration of saline water in Don Juan Pond was very rapid even under low temperatures. Rapid evaporation of saline water caused large oxygen isotope fractionation between saline water and water vapor under low temperatures.

1. Introduction

Don Juan Pond was discovered in October 1961 (MAYER *et al.*, 1962). Since then, the pond had known to remain unfrozen throughout the year. In the winter of 1974, however, it was found for the first time that Don Juan Pond was frozen (S. TREVES, 1974, personal communication). We took this good opportunity to study the origin of water and the concentration of saline water in the pond.

Don Juan Pond is situated in the South Fork of the Wright Valley of Victoria Land, Antarctica and about 13 km west of Lake Vanda. The sequential annual variations in the chemical compositions of saline water in the pond have been observed since 1961 (TORII *et al.*, 1977). The salt content of the pond water varies fairly from year to year depending on the water supply, but it is the highest among the Antarctic saline lakes. Most of the water samples were collected only in mid-summer except for 1974.

In 1974 water samples were fortunately collected in all seasons by the help of the investigators of New Zealand and the United States of America. Chemical and oxygen isotopic compositions of these water samples were determined to study the origin of pond water and the evaporation processes.

2. Oxygen Isotope Determination

The experimental procedures for the oxygen isotope determination of water samples are essentially the same as those described by EPSTEIN and MAYEDA (1953). After equlibrating isotopically 4 cm^3 (STP) of CO_2 with 2 ml of a water sample at 25°C, the $^{18}O/^{16}O$ ratio of CO_2 was measured with a double collector mass spectrometer (Varian Mat CH-7) at Department of Earth Sciences, Nagoya University. Analytical results are given in $\delta\,^{18}O$ notation (CRAIG, 1961) as follows,

$$\delta\,^{18}O=\frac{(^{18}O/^{16}O)_{sample}-(^{18}O/^{16}O)_{SMOW}}{(^{18}O/^{16}O)_{SMOW}}\times 1000\ (‰)$$

SMOW: Standard Mean Ocean Water
and analytical error is $\pm 0.2‰$.

The oxygen isotope ratio determined in the above procedures provides the oxygen isotope activity ratio of the water sample. The time required for the equilibration between CO_2 and a water sample varies according to the contents and the kinds of salts in the water sample. So, the change with time was determined in $\delta\,^{18}O$ of a puddle water, which was sampled on 7 December 1974 and was then

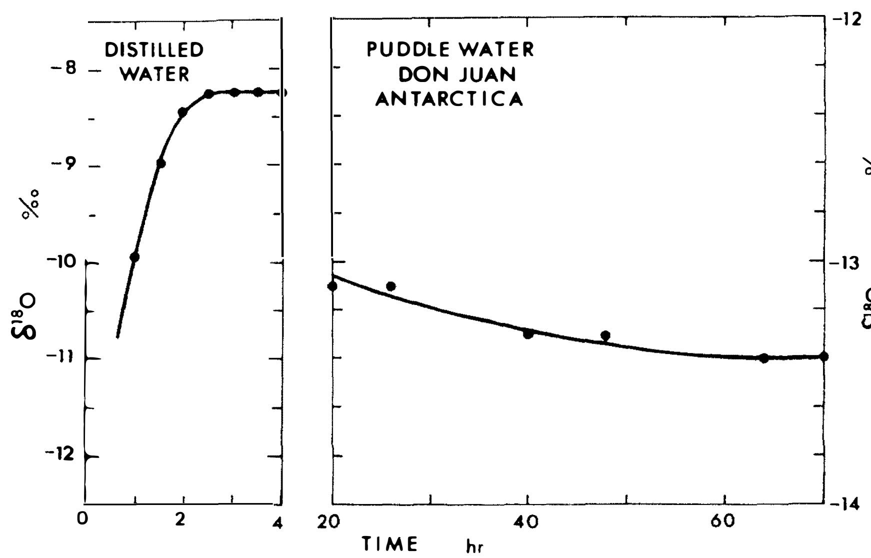

Fig. 1. Change with time in $\delta\,^{18}O$ of a water sample at 25°C. Left: distilled water. Right: puddle water, Don Juan Pond, Wright Valley, Antarctica, which was sampled on 7 December 1974 and was then with antarcticite.

Table 1. Chemical and oxygen isotopic compositions of pond water and puddle water.

Sampling date	Specific gravity	Na	K	Ca (g/kg)	Mg	Cl	$\delta^{18}O$ (‰)
Pond water							
17 Nov. 1973	1.324	6.7	0.14	112.7	1.6	215.7	−16.5
25 Apr. 1974	1.224	6.2	0.10	81.1	1.1	157.9	−19.7
9 July 1974	1.208	8.1	0.08	74.1	1.1	147.6	−20.3
1 Nov. 1974	1.171*	7.3*	0.07*	61.7*	0.8*	123.7*	−19.0
7 Dec. 1974	1.233	9.0	0.09	81.9	1.1	162.8	−13.4
〃	1.245*	9.4*	0.09*	84.8*	1.2*	170.6*	−12.9
14 Dec. 1974	1.255	9.8	0.11	88.4	1.2	175.5	−12.3
9 Jan. 1975	1.265	9.9	0.12	91.5	1.2	182.0	−10.6
Puddle water							
9 July 1974	1.134	6.8	0.05	48.2	0.70	98.7	—
7 Dec. 1974	1.364*	2.4*	0.15*	129.4*	2.1*	243.1*	−13.4

*Determined by Microanalysis Section, Water Research Institute, Nagoya University.

with antarcticite (TORII and OSSAKA, 1965). The results are shown in Fig. 1. The chemical compositions of the puddle water are given in Table 1. The change with time in $\delta\,^{18}O$ of distilled water is also shown in Fig. 1.

$\delta\,^{18}O$ of distilled water becomes constant after only 2.5 hr, whereas $\delta\,^{18}O$ of puddle water becomes constant after 60 hr. Therefore, the time required for the equilibration between CO_2 and a saline water sample was over 60 hr at 25°C in this study.

3. Results and Discussions

3.1. Seasonal variation of the salt content of pond water

The chemical and oxygen isotopic compositions of pond water and puddle water samples collected during a period from November 1973 to January 1975 are given in Table 1. The main chemical components are chloride and calcium, whose contents show obvious seasonal variations but the ratio of calcium to chloride is fairly constant. $\delta\,^{18}O$ of pond water also shows an obvious seasonal variation.

Fig. 2 shows the variation of the chloride content of pond water from November 1973 to January 1975, which presents also that of the salt content of pond water. It is seen from the figure that the salt content decreased from (austral) summer to spring and then increased rapidly toward summer in 1974.

Usually, the salt content of pond water was known to show the minimal seasonal variation in midsummer. This is because Don Juan Pond was usually fed by inflow water from the west of the pond only in midsummer and the pond water remained unfrozen even in midwinter. Then the seasonal variation of the salt content

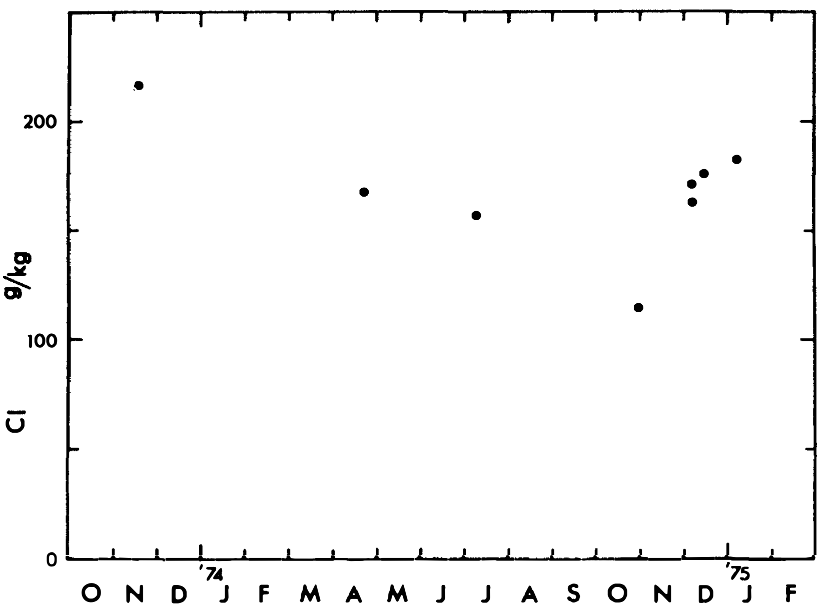

Fig. 2. Variation of chloride content of Don Juan Pond water during the period from November 1973 to January 1975.

shown in Fig. 2 indicates that there was an unusual water supply to Don Juan Pond in 1974.

3.2. *Water supply to Don Juan Pond in 1974*

The sequential variation of the salt content of pond water in 1961–1976 is the minimum in the midsummer of 1970 to 1971 (TORII *et al.*, 1977). In this summer, much run off is known to have resulted in a rise of the water level of Lake Vanda by 2 m. Inflow to Don Juan Pond also increased and the maximum water depth of the pond was 22 cm in contrast to about 10 cm in ordinary summer. The variation of the salt content may reflect the variation of water supply to the pond.

The salt content of pond water in midsummer shows the smallest value in the midsummer of 1974 to 1975 (TORII *et al.*, 1977). However, a large amount of inflow to Don Juan Pond was not observed in this summer. The salt content of pond water sampled on 1 November 1974 is smaller than any others sampled in 1961–1976. This fact means that a large amount of water was supplied to the pond in the seasons other than summer in 1974.

The gradual decrease in the salt content from November 1973 to November 1974 shown in Fig. 2 indicates a gradual water supply to the pond during this period.

A relation between $\delta\,^{18}O$ and the chloride content of pond water is shown in Fig. 3. It is seen from the figure that $\delta\,^{18}O$ of pond water decreased with a decrease in its salt content from November 1973 to July 1974 and increased with an increase in its salt content from November 1974 to January 1975. $\delta\,^{18}O$ of saline

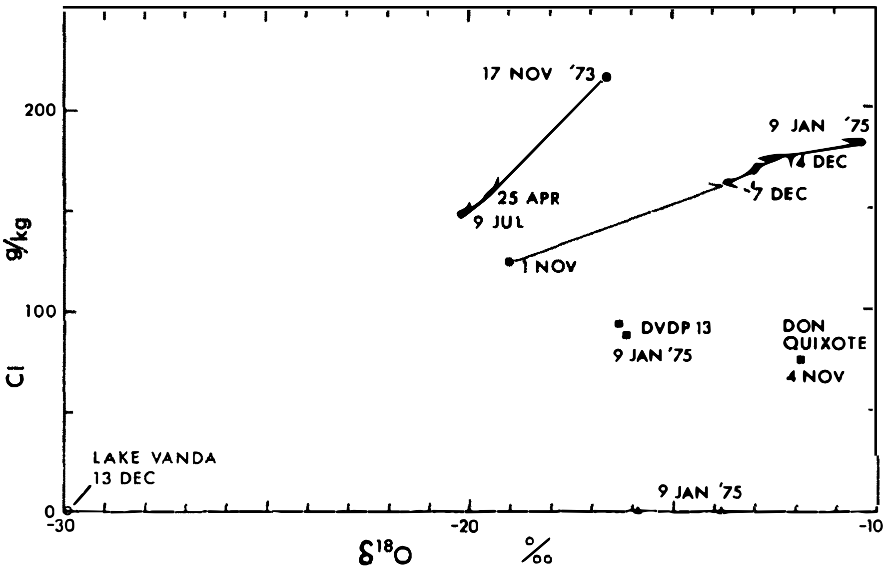

Fig. 3. Relation between δ 18O and chloride content of Don Juan Pond water, inflow water from the west of Don Juan Pond, ground water from borehole DVDP 13 and from Don Quixote, and lake water of Lake Vanda, which were sampled during the period from November 1973 to January 1975.

water sampled on 1 November 1974 was larger than those sampled on 25 April and 9 July 1974. These facts indicate that the salt content of pond water was smaller in August to October than that of pond water sampled on 1 November 1974. Don Juan Pond is considered to have been supplied with a large amount of water during these months.

A puddle water sample was collected on 9 July 1974 on the east side of the pond. Its salt content is smaller than that of pond water sampled on 1 November 1974, as seen in Table 1. When dissolution of salt deposits into supplied water is taken into consideration, this fact means that Don Juan Pond was supplied with a large amount of water with a salt content much smaller than that of puddle water sampled on 9 July 1974.

In order to confirm that Don Juan Pond was frozen in the winter of 1974, the freezing point of pond water sampled on 1 November was determined in the cold room of the National Institute of Polar Research. The value determined is -21°C. This result confirms that Don Juan Pond was frozen in the winter of 1974.

3.3. Origin of water supplied to Don Juan Pond in 1974

Fig. 3 shows the relation between δ ^{18}O and chloride content of inflow water from the west of Don Juan Pond, ground water from borehole DVDP 13 and from Don Quixote, and lake water of Lake Vanda together with Don Juan Pond water.

δ ^{18}O of the pond water decreased with a decrease in its salt content. Therefore,

$\delta\ ^{18}O$ of water supplied to Don Juan Pond is considered to have been fairly smaller than $-20‰$. Accordingly, the supplied water is clearly different from inflow water from the west of the pond and ground water from borehole DVDP 13 (MUDREY *et al.*, 1975; TORII *et al.*, 1977) and from Don Quixote in North Fork of the Wright Valley. As seen from Fig. 3, the supplied water probably originated from the same source as that of water of Lake Vanda.

The salt content of puddle water sampled on 9 July 1974 on the east side of the pond was much smaller than that of pond water sampled on the same day, as seen in Table 1. This is contrary to the ordinary relation between the salt contents of pond water and puddle water, as shown by those sampled on 7 December 1974. These facts show that water was supplied from the east of the pond. These facts also support the above idea on origin of water supplied to Don Juan Pond.

3.4. Concentration of saline water in Don Juan Pond

As seen from Fig. 2, the salt content of pond water remarkably increased from spring to summer of 1974. This fact shows that concentration of saline water in Don Juan Pond was terribly rapid even under fairly low temperatures.

It is seen from Fig. 3 that $\delta\ ^{18}O$ of pond water increased remarkably with a remarkable increase in its salt content. This fact shows that rapid evaporation of saline water caused large oxygen isotope fractionation between saline water and water vapor under low temperatures.

It is noticeable in Fig. 3 that the water samples collected from 1 November to 14 December 1974 fall on one straight line but the water sample collected on 9 January 1975 is off the straight line. These facts show that both the supply of inflow water from the west of the pond and the rapid evaporation of pond water caused a larger increase in $\delta\ ^{18}O$ of saline water in the pond than by rapid evaporation alone, as seen from Fig. 3.

4. Concluding Remarks

Remarkable dilution and concentration of saline water in Don Juan Pond were found in 1974, in the winter of which Don Juan Pond was found to be frozen for the first time since its discovery.

Don Juan Pond was supplied with a large amount of water during summer to winter of 1974. The water supplied to Don Juan Pond is different from inflow water from the west of the pond, which has been seen in every midsummer. The supplied water is also different from ground water from borehole DVDP 13 and from Don Quixote. The supplied water probably originated from the same source as that of water of Lake Vanda.

Concentration of saline water in Don Juan Pond was very rapid even under fairly low temperatures. Rapid evaporation of saline water caused large oxygen isotope fractionation between saline water and water vapor under low temperatures.

Acknowledgments

The authors are greatly indebted to Dr. A. M. BROMLEY of DSIR, New Zealand and Dr. K. CARTWRIGHT of Illinois State Geological Survey, U.S.A. for collection of the samples. Thanks are also due to the National Institute of Polar Research, Japan, to the Antarctic Division, DSIR, New Zealand and to the National Science Foundation, U.S.A. for their supports.

References

CRAIG, H. (1961): Standard for reporting concentrations of deuterium and oxygen-18 in natural waters. Science, **133**, 1833–1834.

EPSTEIN, S. and MAYEDA, T. (1965): Variation of O^{18} content of water from natural sources. Geochim. Cosmochim. Acta, **4**, 213–224.

MAYER, G. H., MORROW, M. B., WYSS, O., BERG, T. E. and LITTLEPAGE, J. L. (1962): Antarctica: The microbiology of an unfrozen saline pond. Science, **138**, 1103–1104.

MUDREY, M. G., Jr., TORII, T. and HARRIS, H. (1975): Geology of DVDP 13—Don Juan Pond, Wright Valley, Antarctica. DVDP Bull., **5**, 78–93.

TORII, T. and OSSAKA, J. (1965): Antarcticite: A new mineral, calcium chloride hexahydrate, discovered in Antarctica. Science, **149**, 975–977.

TORII, T., YAMAGATA, N., OSSAKA, J. and MURATA, S. (1977): Salt balance in the Don Juan basin. Nankyoku Shiryô (Antarct. Rec.), **58**, 116–130.

(Received September 18, 1978; Revised manuscript received April 16, 1979)