

ONE ASPECT OF THE EVOLUTION OF SALINE LAKES  
IN THE DRY VALLEYS OF SOUTH VICTORIA LAND,  
ANTARCTICA (EXTENDED ABSTRACT)

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In the Dry Valleys area of South Victoria Land, there are several saline lakes such as Lakes Vanda and Bonney. The waters of these lakes have been analyzed by S. NAKAYA. The concentrations and chemical compositional ratios of the lake waters are very different from each other and also from those of sea water. As to the origin of the chemical materials of lake waters, several hypotheses have been reported. This time the authors present a possible explanation for the origin and evolution of the chemical compositions of the lake waters. The working hypothesis is as follows:

1. The origin of chemical constituents was sea-salt particles sprayed from the ocean.

2. The sea-salt particles fell down on the lakes and glaciers. The melted glacier water dissolving sea-salt particles poured into the lakes, producing original very diluted lake waters whose chemical compositions and the same ratio as that of sea water.

3. During the historical age, the chemical components were concentrated by evaporation of water.

4. During the concentration, ionic exchange occurred between the water and the sediment, *i.e.*,  $(\text{Ca}, \text{Mg})\text{-rock} + 2(\text{Na}^+, \text{K}^+) \rightleftharpoons (2\text{Na}, 2\text{K})\text{-rock} + \text{Ca}^{2+} + \text{Mg}^{2+}$ . Two moles of alkali metal ions were lost from the water, and one mole of alkali earth ions was added to the water, keeping the ionic equivalent balance.

5. Since the stage of concentration, calcium sulfate, calcium carbonate and/or sodium chloride were deposited. In fact, deposits of calcium sulfate and carbonate have been found in the sediment of Lake Vanda (NAKAI *et al.*, 1975), and sodium chloride as well as calcium sulfate and calcium carbonate in east lobe of Lake Bonney (CRAIG *et al.*, 1974; WILSON and HENDY, 1974).

6. In the final stage, the concentrated saline water was covered with the fresh water of melted glacier.

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From the above hypothesis, 9 equations are derived and the amount of ion-exchange and deposition is calculated. The results are shown in Tables 1, 2 and 3 in the unit of g-equivalent/l.

Table 1. Evolutional chemical balance sheet in Lake Vanda (g-equivalent/l).

	Sea water	$\alpha$ ·sea water	Exchanged	Deposited	Calculated and present bottom water
Na <sup>+</sup>	0.480	1.961	-1.671		0.290
K <sup>+</sup>	0.0102	0.0417	-0.0167		0.0250
Ca <sup>2+</sup>	0.0212	0.0866	+1.468 <sub>7</sub>	-0.225 <sub>3</sub>	1.33
Mg <sup>2+</sup>	0.109	0.446	+0.219		0.665
SO <sub>4</sub> <sup>2-</sup>	0.0580	0.237		-0.223	0.0140
CO <sub>3</sub> <sup>2-</sup>				-0.0023	0.00946
Cl <sup>-</sup>	0.560	2.288			2.288

$\alpha$  is the concentration factor and 4.0857.

Table 2. Evolutional chemical balance sheet in west lobe of Lake Bonney (g-equivalent/l).

	Sea water	$\alpha$ ·sea water	Exchanged	Deposited	Calculated and present bottom water
Na <sup>+</sup>	0.480	2.081	-0.541		1.54
K <sup>+</sup>	0.0102	0.0442	-0.002 <sub>8</sub>		0.0414
Ca <sup>2+</sup>	0.0212	0.0919	+0.260 <sub>8</sub>	-0.271 <sub>3</sub>	0.0814
Mg <sup>2+</sup>	0.109	0.473	+0.283		0.756
SO <sub>4</sub> <sup>2-</sup>	0.0580	0.251		-0.149	0.102
CO <sub>3</sub> <sup>2-</sup>				-0.122 <sub>3</sub>	
Cl <sup>-</sup>	0.560	2.428			2.428

$\alpha$  is the concentration factor and 4.3357.

Table 3. Evolutional chemical balance sheet in east lobe of Lake Bonney (g-equivalent/l).

	Sea water	$\alpha$ ·sea water	Exchanged	Deposited	Calculated and present bottom water
Na <sup>+</sup>	0.480	4.800	-1.071	-0.119	2.98
K <sup>+</sup>	0.0102	0.102	-0.031 <sub>2</sub>		0.0708
Ca <sup>2+</sup>	0.0212	0.212	+0.674 <sub>2</sub>	-0.813 <sub>0</sub>	0.0732
Mg <sup>2+</sup>	0.109 <sub>2</sub>	1.09 <sub>2</sub>	+1.05 <sub>8</sub>		2.15
SO <sub>4</sub> <sup>2-</sup>	0.0580	0.580		-0.506 <sub>5</sub>	0.0735
CO <sub>3</sub> <sup>2-</sup>				-0.306 <sub>5</sub>	0.00740
Cl <sup>-</sup>	0.560	5.600		-0.119	5.481

$\alpha$  is tentatively chosen as 10 with a range of 9.7875-19.689.

Table 4. Ion-exchange between sea water and a rock sample collected near Lake Vanda.

Exchangeable total capacity of cations with $\text{NH}_4^+$	Capacity in milli-equivalent/100 g sample			
		11.0		
Exchangeable capacity of each element*	Na	K	Ca	Mg
	(+4.5)**	+1.1	-3.9	-1.5

\*The sign of (+) means a gain in the rock sample and a loss from the sea water, and the sign of (-) means vice versa.

\*\*The value for Na was given by the difference between the total and the sum of K, Ca and Mg.

The authors' hypothesis can quantitatively explain the present chemical compositions of Lakes Vanda and Bonney, but cannot be applied to Lake Fryxell whose constituents were not so concentrated that the ion-exchange with sediment occurred and some salts reached their saturation.

To support the idea of ion-exchange between the saline water and the sediment, exchangeable capacities between a rock sample (a kind of lamprophyre) collected near Lake Vanda and sea water were measured, according to the method proposed by SAYLES and MANGELEDORF (1977).

The result of experiment is shown in Table 4. These data also show that sodium and potassium ions are caught by the rock from a concentrated salt water such as sea water, while calcium and magnesium ions are dissolved from the rock to the water by ion-exchange.

It is assumed that during a period of time when evaporation of water was greater than input of melted glacier water and evaporation was predominant, a concentrated salt lake was formed as stated above. That was a shallow lake at the bottom of valley. Such a period was then followed by a period of a rather warm climate, so that the melted glacier water covered the concentrated salt-water layer and the gradual gradient of the salt concentration was formed by diffusion.

If a saline-water layer of  $a$  m thickness is covered with a fresh water layer of an infinite thickness at a time  $t=0$ , the concentration profile of a given ionic species along the vertical water column at time  $t$  is expressed as follows (CRANK, 1975):

$$C/C_0 = \frac{1}{2} \left\{ \operatorname{erf} \frac{a-z}{2\sqrt{Dt}} + \operatorname{erf} \frac{a+z}{2\sqrt{Dt}} \right\} \quad (1)$$

where  $C$  is the concentration of the species at a distance of  $z$  m above the bottom,  $C_0$  is the concentration in the initial saline water, and  $D$  is its diffusion coefficient ( $1.0 \times 10^{-5}$  cm<sup>2</sup>/s). Eq. (1) is re-written as follows:

$$C/C_0 = (1/2) \{ \operatorname{erf} p(1-x) + \operatorname{erf} p(1+x) \} \quad (2)$$

where  $p$  is  $a/2\sqrt{Dt}$  and  $x$  is  $z/a$ .

Then, the values of  $a$  and  $p$  are estimated for each lake by the best fitting between the observed and the calculated vertical distributions of the chloride ion concentration.

The calculated result indicates that in Lake Vanda the fresh water covered the concentrated salt water 800 to 1200 years ago, in east lobe of Lake Bonney 5000 years ago, and in west lobe 8800 years ago.

#### References

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