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# Preliminary study on water quality of lakes and rivers on the Xizang (Tibet) Plateau

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## Abstract

On the Xizang (Tibet) Plateau, we carried out limnological observations on the chemical composition of lakes and rivers in 1987.

The $\delta^{18}O$ distribution had a similar tendency between snow, rain and river waters: $^{18}O$–rich water appears in the northern part of the West Kunlun Mts. near the Taklimakan Desert and $^{18}O$–poor water in the southern part in the inland Xizang Plateau.

Hourly changes of water level (WL) and suspended substances in the river were synchronous (the same phase); however, those of WL and electric conductivity (EC) were not synchronous and the maximum of the WL lagged about a half day after that of the EC. The change of EC was similar to that of $\delta^{18}O$. The values of EC, $\delta^{18}O$, Na, Cl and $SO_4$ became lower at 18 – 20 hours Chinese Standard Time due to dilution by glacial melt water.

The lakes on the Xizang Plateau are classified into two groups ; salt lakes rich in Cl and Na+K, and fresh water lakes rich in $CO_3+HCO_3$ and Ca. In most of the salt lake waters, the contents of Na and Cl are higher than those of Ca and $HCO_3$. The contents of Ca and $HCO_3$ in the river waters are higher than those in the salt lake waters. The chemical compositions of the fresh water lakes are similar to those of river waters. In the chemical processes occurring in the lakes, Na and Cl increase, and Ca and $HCO_3$ decrease.

The age of L. Gozha is estimated to be $9\times10^3$ years, and that of L. Aksayqin $34\times10^3$ years by using the Cl budget data of the annual load and the accumulation amount. The more saline the lake is, the older its age if there are no large differences in annual Cl loads. The formation of saline lakes will be accelerated by condensation of the lake water due to the large amount of the evaporation when the salinity of the lake water become high and the lake gets hardly freeze over.

Fresh water lakes are formed in present glacial areas where a large amount of glacial melt water is continuously supplied, and the formation of salt lakes still continues in the inner part of the Xizang Plateau far from the present glacial areas.

## 1. Introduction

There are more than 1,000 lakes having surface area larger than 1 Km$^2$, including many salt lakes as well as fresh–water lakes, on the Xizang (Tibet) Plateau (Academia Sinica, 1984). The water qualities of these lakes vary greatly.

We carried out hydrological and limnological observations along River (R.) Keriya and R. Yulongkax in the northern part of the Kunlun Mts. in June, 1987, at several lakes (L. Aksayqin, L. Gozha, L. Bangdag and so on) in the southern part of the Kunlun

Mts. in August, 1987, and along the upper streams of R. Indus, R. Yarlung Zangpo and at several lakes (L. Bangong, L. Yamzhogyum and so on) on the Xizang Plateau in September, 1987.

Here, we report on the water quality of 18 lakes and 19 rivers on the Xizang Plateau (Fig.1) in relation to that of melt water from the glacial areas, the formational process of salt lakes and their ages.

## 2. $\delta^{18}O$ of precipitation and river water

Rain, snow and river-water samples were collected around the West Kunlun Mts. (Fig.2) and the oxygen-18 isotope ratios ($\delta^{18}O$ value) were determined (Table 1).

The rain and snow samples were taken from the northern side of the West Kunlun Mts. and the $\delta^{18}O$ values range from $-2$ to $-8$‰. The $^{18}O$-rich rain was found to be about $-2$‰ in the Pulu district near the Taklimakan Desert and about $-4$‰ near L. Ashikule. The $\delta^{18}O$ value dropped to about $-7$‰ in the Karatax Mts. and the West Kulun Mts.

The $\delta^{18}O$ values of the river waters were from $-7$ to $-9$‰ on the northern side of the West Kunlun Mts.; however, they dropped to $-12$ to $-16$‰ on the southern side of the West Kunlun Mts. The $\delta^{18}O$ distribution in precipitation and river water had the similarity that $^{18}O$-rich precipitation occurs in the north near the Taklimakan Desert and $^{18}O$-poor precipitation in the south in the inland part of the Xizang Plateau.

The $\delta^{18}O$ values of melt water from the Gozha Glacier and Changce Glacier were about $-16$‰, but the values became gradually $^{18}O$-rich, from $-12$ to $-14$‰, downstream about 10 km south from the glacier termini. This process is possibly caused by evaporation of river water.

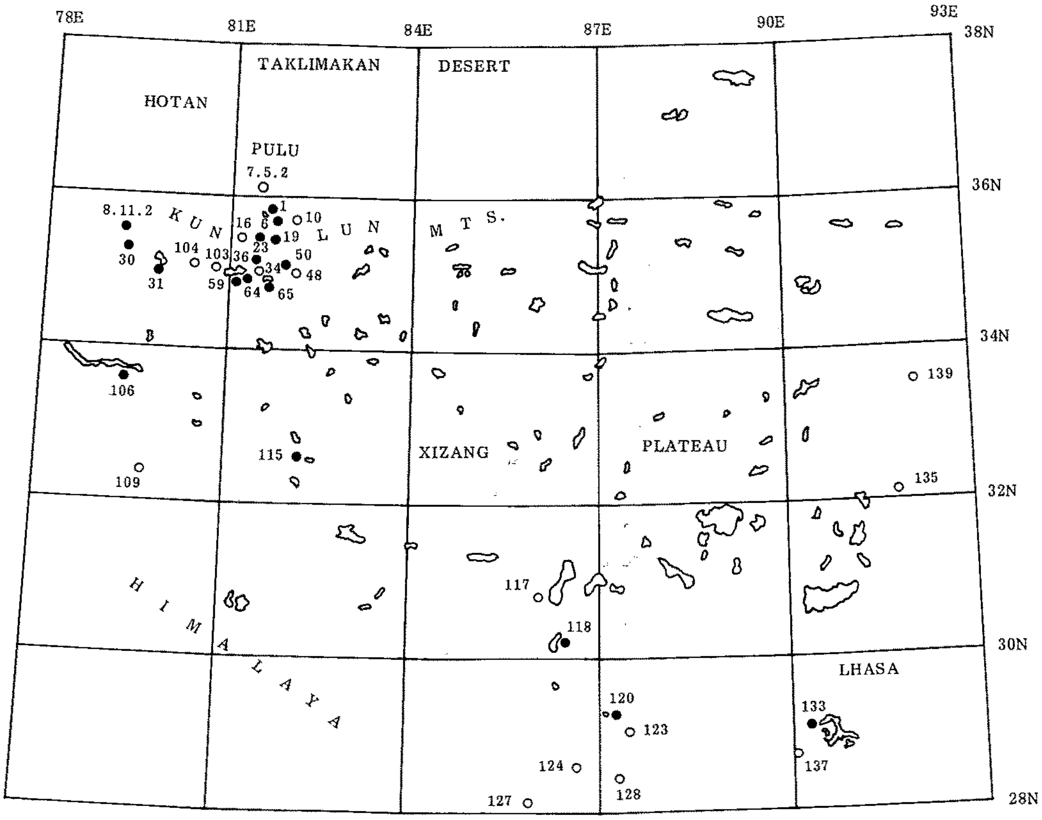


Fig. 1. Locations of lakes and rivers studied on the Xizang Plateau. Open circles show rivers and solid circles lakes with sample numbers.

Table 1. Oxygen isotope ratios of snow, rain and river water around the West Kunlun Mts.

Rain or Snow

| Sample No. | Date | Time | $\delta^{18}O$ (‰) | Remarks |
|---|---|---|---|---|
| K15 | Jul. 22 | 08 : 00 | − 6.76 | Snow on the northern side of Mt. Kunlun |
| K49 | Jul. 23 | 08 : 00 | − 7.53 | Snow on the northern side of Mt. Kunlun |
| K16 | Jul. 25 | 19 : 00 | − 3.60 | Rain in the vicinity of L. Ashikule |
| K45 | Jul. 25 | 21 : 36 | − 4.93 | Rain in the vicinity of L. Ashikule |
| 7 . 27. 1 | Jul. 27 | 07 : 20 | − 7.74 | Rain in the Karatax Mountains |
| 7 . 28 | Jul. 28 | 08 : 30 | − 1.89 | Rain in the vicinity of Pulu |
| 7 . 29 | Jul. 29 | 16 : 06 | − 2.54 | Rain in Pulu |

River water on the northern side of the Kunlun Mountains

| Sample No. | Date | Time | $\delta^{18}O$ (‰) | Remarks |
|---|---|---|---|---|
| 7 . 5 . 2 | Jul. 5 | 20 : 49 | − 7.44 | R. Keriya |
| K 1 | Jul. 6 | 07 : 47 | − 8.64 | R. Keriya |
| 10 | Jul. 12 | 16 : 30 | − 7.54 | A brook in the L. Urukekule basin |
| 16 | Jul. 13 | 20 : 30 | − 9.07 | R. Yalongkax |

River water on the southern side of the Kunlun Mountains

| Sample No. | Date | Time | $\delta^{18}O$ (‰) | Remarks |
|---|---|---|---|---|
| 27 | Aug. 12 | 12 : 43 | −12.29 | A brook south of Tienshuihai |
| 34 | Aug. 17 | 12 : 38 | −16.03 | Melt-water from the Chongce Glacier |
| 46 | Aug. 18 | 11 : 10 | −14.66 | Down-stream of R. Chongce |
| 48 | Aug. 18 | 15 : 07 | −13.77 | A brook near the Gulia Ice Cap |
| 55 | Aug. 22 | 12 : 50 | −12.44 | R. Tienshui at Base Camp |
| 57 | Aug. 22 | 16 : 16 | −16.17 | Melt-water from the Gozha Glacier |
| 103 | Sep. 1 | 11 : 55 | −13.65 | A river from the Zhongfeng Glacier |
| 104 | Sep. 1 | 16 : 05 | −13.24 | R. Qiongbingshui |

## 3. Hourly changes of river−water quality

The river−water level rapidly become high every afternoon during July and August in the West Kunlun Mts. This phenomenon is called the afternoon (summer or daily) flood (Stein, 1912) caused by melt water from glaciers.

Fig. 3 shows the hourly changes of water temperature (WT), water level (WL) and electric conductivity (EC, corrected values at 25°C) from Aug. 27 to 29, 1987. The maximum of EC appeared around 9 − 10 hours Chinese Standard Time (CST), that of WT around 16 hours CST and that of WL around 20 − 22 hours CST.

Fig. 4 indicates the hourly changes of WT, WL, EC, suspended substances (SS) and oxygen isotope ratio ($\delta^{18}O$). The changes of WL and SS were synchronous (the same phase); however, those of WL and EC were not synchronous and the maximum of WL was delayed about a half day after that of EC. The changes of EC were similar to those of $\delta^{18}O$.

Since the oxygen isotope ratio of the glacial melt water was $^{18}O$−poor, only about −16‰, a minimum in the $\delta^{18}O$ curve appeared due to dilution by glacial melt water when WL was a maximum at 20 − 22 hours CST. The maximum value of WT was observed between those of EC and WL.

Fig. 5 shows the hourly changes of EC and each ion component (Cl, $SO_4$, $NO_3$, Na, Ca, Mg and K). The concentrations of Na, Cl and $SO_4$ were high around 10 − 11 hours CST and low at 18 − 22 hours CST. The EC value become higher from 8 to 10 hours CST and lower from 16 to 20 hours CST, which corresponded to changes of $\delta^{18}O$ and WL.

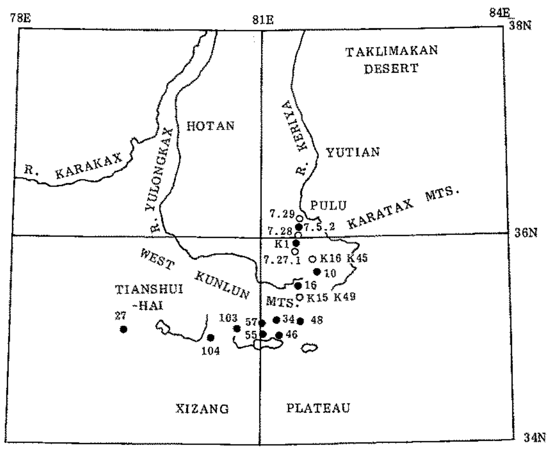


Fig. 2. Sampling points of $\delta^{18}O$ for rain/snow (○) and river waters (●) around the West Kunlun Mts.

Table 2. Chemical components of lakes on Xizang Plateau.

| Sample No. | Date | Time CST | Water Temp. C° | EC $10^3\mu s/cm$ | pH | Alk mg/ℓ | Cl mg/ℓ | $NO_3$ mg/ℓ | $SO_4$ mg/ℓ | Na mg/ℓ | K mg/ℓ | Ca mg/ℓ | Mg mg/ℓ | SS mg/ℓ | $\delta^{18}O$ ‰ | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10Jul. | 13:20 | 10.7 | 6.73 | 9.28 | 37.37 | 2222 | | 420 | 2157 | 145 | 3.9 | 418 | 0.15 | 1.40 | L. Ashikule |
| 6 | 11Jul. | 14:12 | 14.7 | | 9.22 | 117.14 | 18051 | | 1760 | 13939 | 532 | 2.2 | 620 | 1.35 | 0.38,0.95 | L. Urukekule |
| 19 | 13Jul. | 20:30 | 9.5 | 0.089 | 7.92 | 0.84 | 5.0 | | 1.1 | 2.6 | 0.50 | 14.7 | 1.5 | 4.65 | − 6.54 | |
| 23 | 15Jul. | 14:00 | 12.3 | 1.299 | 9.03 | 13 | 80.2 | | 49.2 | 414 | 11.6 | 3.2 | 13.0 | 0.15 | − 6.33 | |
| 8.11.2 | 11Aug. | 13:59 | 10.6 | | | | 2955 | | 840 | 2338 | 61.6 | 85.4 | 478 | 1.25 | | |
| 30 | 12Aug. | 13:00 | | | 7.82 | 3.2 | 600 | 2.9 | 201 | 355 | 3.3 | 20.9 | 38.9 | 0.40 | − 7.93 | L. Tianshuihai |
| 31 | 13Aug. | 16:00 | 10.0 | | 8.58 | 29.2 | 46181 | | 1838 | 24740 | 1211 | 8.6 | 359 | 2.15 | 0.71 | L. Aksayqin |
| 36 | 17Aug. | 13:56 | 7.3 | 0.070 | 7.58 | 0.72 | 2.3 | 1.3 | 5.4 | 3.0 | 0.22 | 12.3 | 2.3 | 0.70 | | |
| 50 | 18Aug. | 17:44 | 7.5 | 0.770 | 7.8 | 0.93 | 3.2 | 0.32 | 7.6 | 3.7 | 0.74 | 12.4 | 3.6 | 1.90 | −10.37 | |
| 59 | 23Aug. | 19:35 | 8.8 | 3.56 | 8.98 | 14 | 1073 | 6.0 | 265 | 955 | 47.7 | 7.7 | 162 | 0.40 | | L. Gozha |
| 64 | 24Aug. | 14:54 | 7.0 | 3.67 | 9.02 | 15.16 | 1292 | 5.5 | 258 | 1138 | 55.8 | 7.3 | 196 | 0.15 | | L. Gozha |
| 65 | 25Aug. | 15:07 | 12.3 | | | | 74424 | | 3510 | 49839 | 3167 | 10.9 | 2741 | 4.60 | | L. Bangdag |
| 106 | 2Sep. | 17:24 | 17.7 | 0.770 | 8.77 | 5.25 | 109 | | 76.1 | 117 | 7.9 | 28.0 | 47.0 | 0.40 | | L. Bangong |
| 115 | 4Sep. | 20:29 | 17.1 | | 8.38 | 9.46 | 38862 | | 5160 | 21864 | 908 | 183 | 2505 | 4.50 | | L. Yen |
| 118 | 6Sep. | 16:54 | 14.0 | 3.23 | 9.42 | 21.26 | 238 | | 911 | 1238 | 75.9 | 9.0 | 87.3 | 0.65 | | L. Dajia |
| 120 | 7Sep. | 17:46 | 18.6 | 2.69 | 9.5 | 32.22 | 199 | | 28.5 | 767 | 27.1 | 5.2 | 178 | 0.40 | | L. Lan |
| 133 | 11Sep. | 14:29 | 16.0 | 0.283 | 8.55 | 1.82 | 4.0 | | 113 | 9.9 | 0.14 | 42.2 | 19.0 | 12.30 | | L. Yamzhogyum |
| 151 | 17Sep. | 09:41 | 14.9 | 14.12 | 9.08 | 24 | 6604 | | 2522 | 5447 | 139 | 5.2 | 1518 | 5.55 | | L. Qinghai |

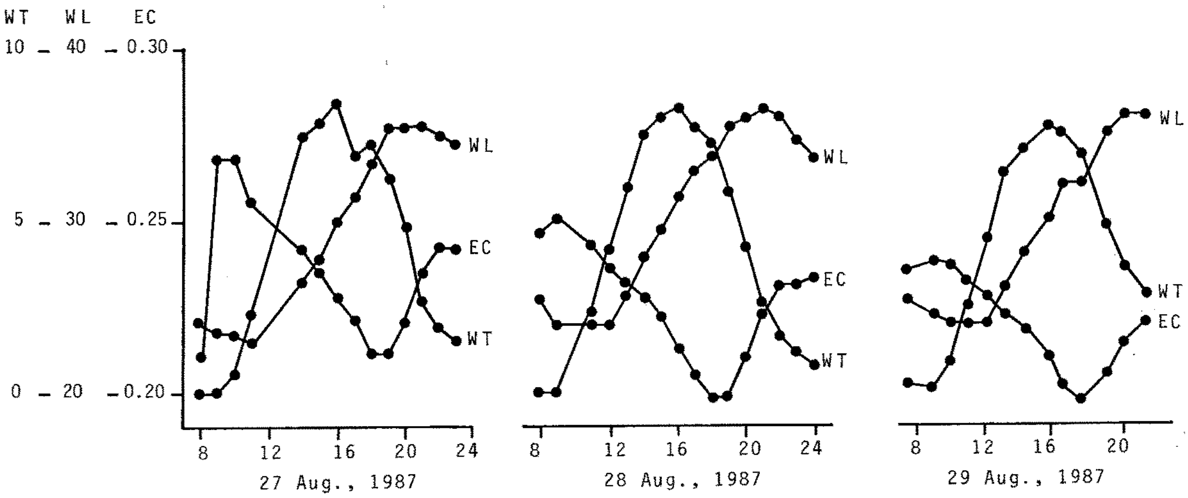


Fig. 3. Hourly changes of water temperature (WT, °C), water level (WL, cm) and electric conductivity (EC, $10^3$ $\mu$S/cm) in R. Tianshui from Aug. 27 to 29, 1987.

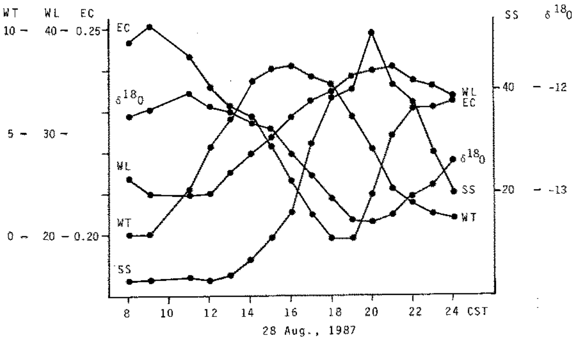


Fig. 4. Hourly changes of water temperature (WT, °C), water level (WL, cm), electric conductivity (EC, $10^3$ $\mu$S/cm), suspended substances (SS, mg/1) and oxygen isotope ratio ( $\delta^{18}$ O,‰) on Aug. 28, 1987 in R. Tianshui.

The dilution by increase of glacial melt water made the values of EC ,Na, Cl, $SO_4$ and $\delta^{18}O$ low at 18 – 22 hours CST.

The values of Na, Cl, and $SO_4$ largely changed, but those of Ca, Mg, K and $NO_3$ were rather constant. This is because considerable difference existed between the glacial melt water and basic river water in concentration of Na, Cl and $SO_4$, with less difference in the concentration of Ca, Mg, K and $NO_3$.

In the increasing ratio of glacial mëlt water, the concentrations of Ca, Mg, K and $NO_3$ were constant, while the concentration of SS increased. Here, two different processes are considered.

1. The glacial melt water had concentrations of Ca, Mg, K and $NO_3$ similar to those of river water.

2. The glacial melt water had less concentration of Ca, Mg, K and $NO_3$. Along the water circulation in the glacier and river it contained much SS, which acted to increase the concentrations of Ca, Mg, K and $NO_3$.

Further investigations are needed on those processes in glaciers and rivers.

#### 4. Water quality of lakes and rivers

Fig. 6 shows the molar ratio of main ion components, and Tables 2 and 3 the chemical components of lake and river waters, on the Xizang Plateau.

The Cl concentration in lakes ranges from 2.3 to 74,424 mg/1 (Table 2) ; however, that in rivers is from 0.49 to 123 mg/1 (Table 3). Fig. 6 indicates that lakes on the Xizang Plateau are classified into two groups ; salt lakes rich in Cl and Na+K ratios, and fresh water lakes rich in $CO_3+HCO_3$ and Ca ratios.

The chemical compositions of salt lake waters are different from those of river waters. The contents of Ca and $HCO_3$ in river waters are higher than those in salt lake waters. In most of the salt lake waters, the contents of Na and Cl are higher than those of Ca and $HCO_3$. The chemical compositions of the fresh water lakes are similar to those of the river waters.

In the process of chemical deposition occurring in the lakes, the evolution of the lake water proceeds with increase in Na and Cl contents, and decrease in Ca and $HCO_3$.

Fig. 7–1 indicates the relationship between Cl and other ions ($HCO_3$, $SO_4$, Na+K, Ca+Mg), Fig. 7–2 between $SO_4$ and other ions ($HCO_3$, Ca+Mg, Na+K) and Fig. 7–3 between $HCO_3$ and other ions (Ca+Mg, Ca/Mg, Mg/Ca).

With increase of Cl concentration, Na+K also increases, but $SO_4$ and Ca+Mg are rather constant and $HCO_3$ does not increase ( Fig. 7–1). The concentration of Ca+Mg increases, but that of $HCO_3$ does not increase with the $SO_4$ concentration (Fig. 7–2). The concentrations of Mg/Ca increase, but that of Ca/Mg decrease with the $HCO_3$ concentration (Fig. 7–3). Such a tendency is considered to reflect on the chemical evolution process in the lake waters.

The process becomes clearer by considering the chemical features of river waters. Fig. 8 shows the relationships between Cl and Na+K, Cl and Ca+Mg,

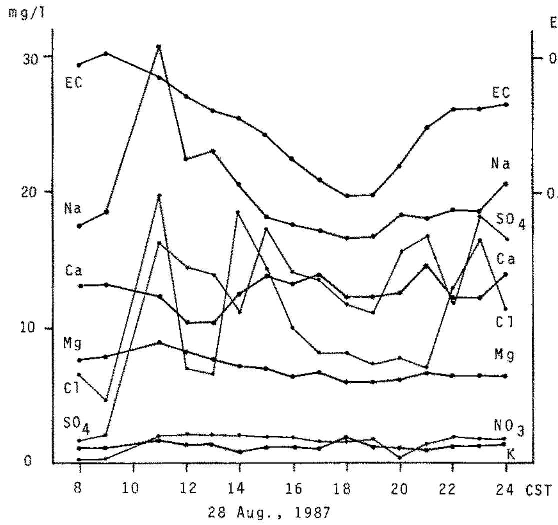


Fig. 5. Hourly changes of electric conductivity (EC, $10^3$ $\mu$S/cm), Cl, $SO_4$, $NO_3$, Na, Ca, Mg and K in R. Tianshui on Aug. 28, 1987.

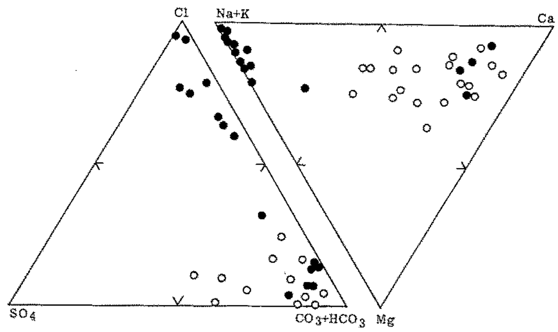


Fig. 6. Main component ratios of lakes (●) and rivers (○) in the Xizang Plateau.

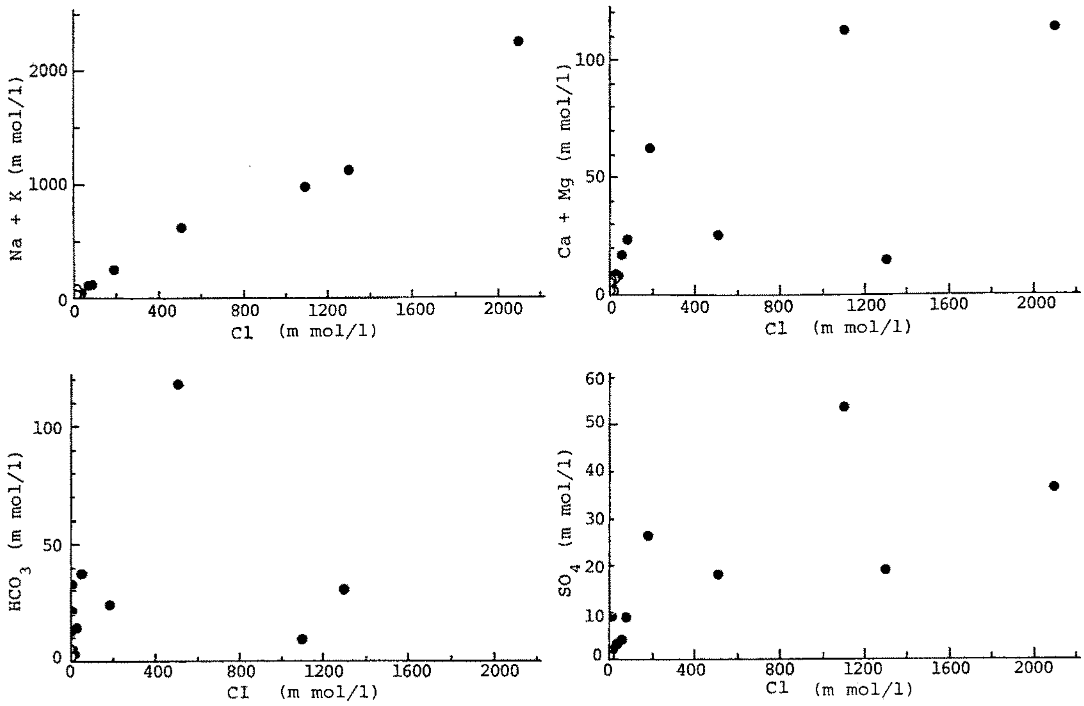


Fig. 7—1. Relationships between concentrations of Cl and other ions ($HCO_3$, $SO_4$, Na+K, Ca+Mg) in lake waters of the Xizang Plateau.

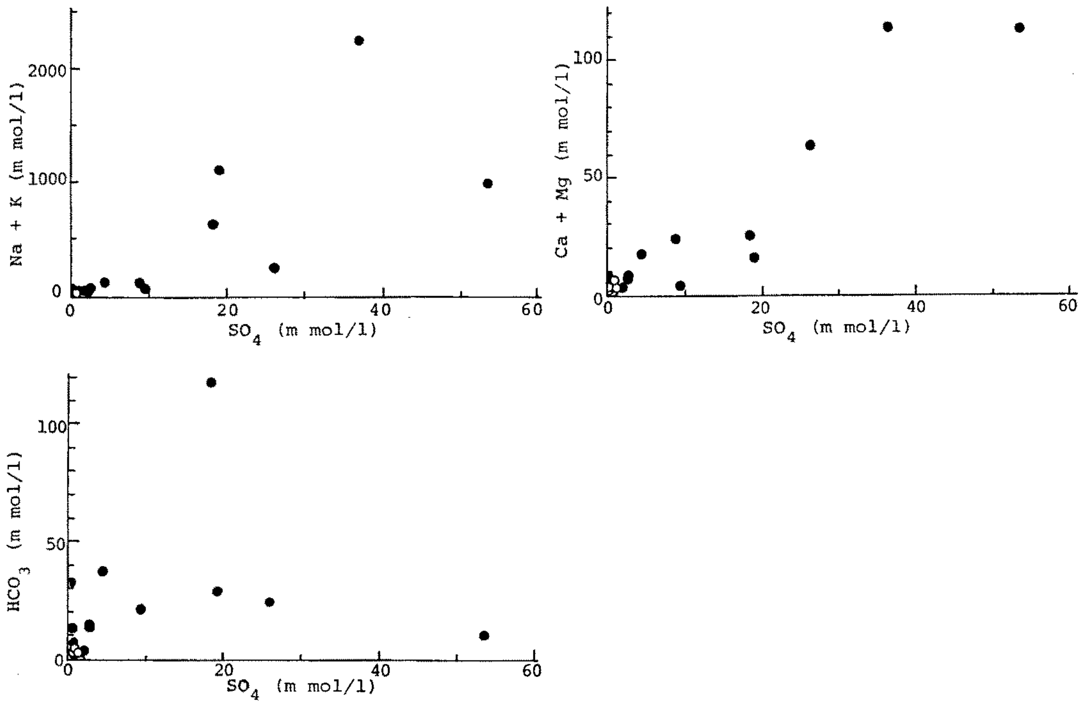


Fig. 7—2. Relationships between concentrations of $SO_4$ and those of other ions ($HCO_3$, Ca+Mg, Na+K) in lake waters of the Xizang Plateau.

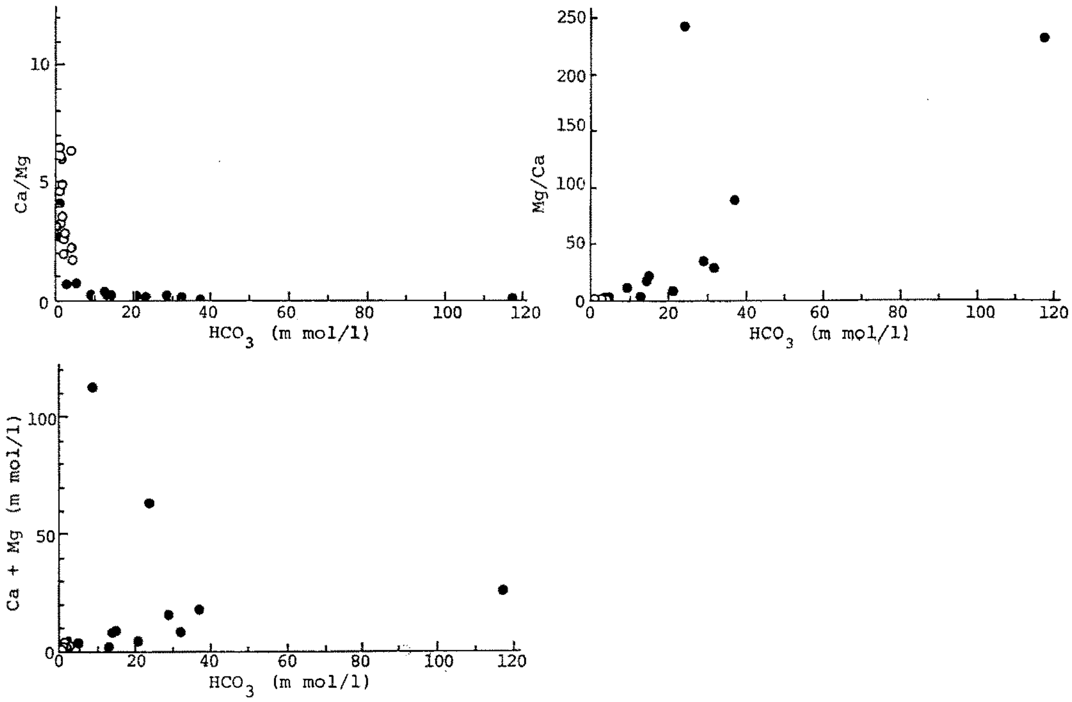


Fig. 7−3. Relationships between concentrations of $HCO_3$ and those of other ions (Ca+Mg, Ca/Mg, Mg/Ca) in lake waters of the Xizang Plateau.

Table 3. Chemical components of rivers on the Xizang Plateau.

| Sample No. | Date | Time CST | Water Temp. C° | EC $10^3\mu s/cm$ | pH | Alk mg/ℓ | Cl mg/ℓ | $NO_3$ mg/ℓ | $SO_4$ mg/ℓ | Na mg/ℓ | K mg/ℓ | Ca mg/ℓ | Mg mg/ℓ | SS mg/ℓ | $\delta^{18}O$ ‰ | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7. 5.2 | 5Jul. | 20 : 49 | 7.7 | | | | 18.6 | 3.6 | 43.1 | 21.6 | 1.3 | 12.3 | 12.0 | 40.45 | − 7.44 | R. Keriya |
| 10 | 12Jul. | 16 : 30 | | | | | 57.9 | | 53.5 | 31.7 | 0.96 | 20.7 | 10.0 | 104.55 | − 7.54 | |
| 16 | 13Jul. | 20 : 30 | 5.6 | 0.05 | | | 5.1 | 0.12 | 2.8 | 4.2 | 0.45 | 18.0 | 2.1 | 77.0 | − 9.07 | R. Yulongkax |
| 34 | 17Jul. | 12 : 38 | 2.1 | 0.941 | 7.8 | 1.08 | 1.8 | 0.73 | 12.0 | 2.9 | 0.13 | 13.3 | 4.9 | 14.0 | −16.03 | R. Chongce |
| 48 | 18Aug. | 15 : 07 | 10.9 | 0.055 | 7.82 | 0.69 | 1.4 | 0.56 | 3.7 | 1.3 | 0.28 | 9.6 | 1.9 | 2.15 | | |
| 103 | 1Sep. | 11 : 55 | 0.9 | 0.133 | 7.84 | 2.28 | 19.8 | 1.7 | 14.3 | 28.0 | 3.2 | 30.5 | 12.7 | 0.70 | −13.65 | R. Litian |
| 104 | 1Sep. | 16 : 05 | 10.3 | 0.130 | 7.44 | 1.26 | 17.4 | 1.2 | 12.8 | 19.3 | 1.6 | 22.2 | 4.5 | 1.75 | −13.24 | R. Qiongbingshui |
| 109 | 3Sep. | 21 : 00 | 15.6 | 0.239 | 7.28 | 1.56 | 14.3 | 0.48 | 28.1 | 25.7 | 1.0 | 37.8 | 12.7 | 0.50 | | R. Suqiang |
| 117 | 6Sep. | 09 : 37 | 6.6 | 0.109 | 7.56 | 1.4 | 6.6 | 0.74 | 21.3 | 12.9 | 0.38 | 32.4 | 7.9 | 1.35 | | R. Chuqinchan |
| 123 | 7Sep. | 19 : 08 | 13.9 | 0.172 | 7 | 0.47 | 3.7 | 0.72 | 38.3 | 8.6 | 0.45 | 31.0 | 11.4 | 5.35 | | R. Yarlungzangbo |
| 124 | 8Sep. | 13 : 01 | 12.3 | 0.186 | 8.01 | 0.87 | 1.0 | 0.31 | 51.6 | 4.2 | 0.54 | 43.4 | 11.3 | 3.65 | | R. Arun |
| 127 | 9Sep. | 13 : 55 | 6.3 | 0.043 | 7.86 | 3.78 | 0.49 | 0.65 | 60.1 | 1.5 | 0.59 | 4.7 | 0.9 | 1.55 | | R. Sun |
| 128 | 9Sep. | 20 : 12 | 16.8 | 0.275 | 7.62 | 2.58 | 8.7 | 1.6 | 101 | 9.4 | 0.14 | 46.1 | 21.4 | 3.05 | | R. Arun |
| 137 | 11Sep. | 12 : 47 | 6.4 | 0.143 | 8.39 | 4.7 | 0.78 | 0.81 | 49 | 1.1 | 0.18 | 2.0 | 1.4 | 0.50 | | |
| 135 | 14Sep. | 10 : 38 | 4.8 | 0.368 | 8.19 | 2.49 | 15.5 | 2.2 | 129 | 33.5 | 1.4 | 41.0 | 25.4 | 4.35 | | Amdo |
| 139 | 14Sep. | 13 : 58 | 8.6 | 0.267 | 7.79 | 4.28 | 8.8 | 1.9 | 84 | 14.0 | 0.91 | 42.0 | 23.2 | 11.55 | | Yanshiping |
| 142 | 15Sep. | 16 : 52 | 17.7 | 0.682 | | | 123 | | 120 | 90.8 | 5.4 | 69.0 | 31.8 | 25.45 | | Golmud |
| 146 | 16Sep. | 09 : 44 | 7.1 | 0.440 | | | 94.2 | 4.5 | 77.2 | 20.1 | 1.6 | 45.4 | 44.7 | 4.65 | | Nomhon |
| 147 | 16Sep. | 12 : 52 | 14.5 | 0.601 | | | 93.9 | 2.3 | 102 | 79.7 | 3.3 | 83.9 | 64.2 | 62.95 | | Xiangride |

$SO_4$ and Ca+Mg in river waters. There seem to be some weak relationships, but the correlation are apparently far from those of the lake waters. Only the relationship between Cl and Na+K in river waters appears to be an extension of that in lake waters. Therefore, it is considered that Cl and Na+K are the only quantities conserved in the evolution of lake waters. Some chemical components, such as Ca+Mg and $HCO_3$, are eliminated from the lake waters by deposition in the solid phase.

## 5. Discussion

The salt lakes are distributed around the Kunlun Mts. in the inner part of the Xizang Plateau far from the glacial areas, but the fresh water lakes are located in the south–western marginal zones of the Xizang Plateau near the Himalaya and in the West Kunlun Mts., where they are influenced by glacial melt water. The distributon of fresh water lakes reflects the regional characteristics of water circulation, especially related to glacial melt water on the Xizang Plateau.

Table 4. Main items of Cl budget for Lakes Gozha and Aksayqin.

| | L. Gozha | L. Aksayqin |
|---|---|---|
| Surface area ($km^2$) | 244 | 175 |
| Mean depth (m) | 40 | 12 |
| Volume ($km^3$) | 9.76 | 2.10 |
| Daily evaporation (mm/day) | 3.5 | 3.5 |
| Freezing period (months) | 7 | 3 |
| Annual evaporation ($m^3$/year) | $128\times10^6$ | $165\times10^6$ |
| Cl concentration of river (mg/l) | 10.4 | 17.4 |
| Cl concentration of lake (mg/l) | 1183 | 46181 |
| Cl input from rivers (gr/year) | $1.33\times10^9$ | $2.87\times10^9$ |
| Cl accumulation in lake (gr) | $1.15\times10^{13}$ | $9.70\times10^{13}$ |
| Ages for Cl accumulation (years) | $9\times10^3$ | $34\times10^3$ |

We will discuss the formation process of the salt lakes and their ages.

Since increase of Cl concentration in lake water is mainly caused by inflow of river water, we can estimate the age of the inland lakes, which have no effluent rivers, by calculating the average Cl budget.

Here, the following assumptions are made.

1) The water budget of the inland lake has been balanced, so river inflow equals evaporation from the

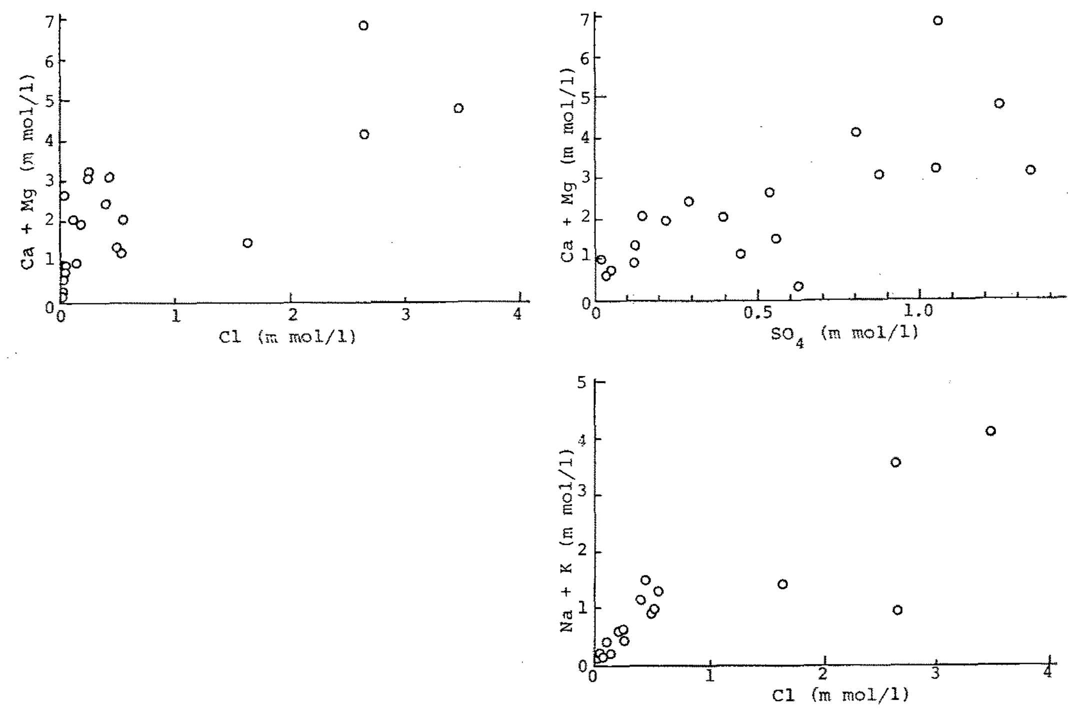


Fig. 8. Relationships between concentrations of Cl and Na+K, Cl and Ca+Mg, $SO_4$ and Ca+Mg in river waters.

lake surface. The potential evaporation measured by an evaporation pan was 5.4 mm/day (Ohata, personal communication), so the actual evaporation is thought to be 64% of the potential evaporation according to comparative measurements of an evaporation pan 20cm in diameter and a pond having $20m^2$ in area (Academia Sinica, 1984). The freezing period is estimated by analysing the series of the Landsat images.

2) The lake volume is calculated from the surface area (Academia Sinica, 1984) and the mean depth estimated from a measured topographic cross–section (Fig. 9).

3) The average Cl concentration in the inflowing

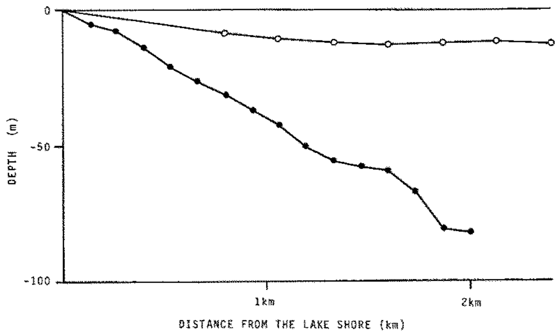


Fig. 9. Topographic cross–section of Lakes Gozha (●) and Aksayqin (○).

rivers is estimated by using data of hourly changes in R. Tianshui (Fig. 5), and that of the lake by using surface data (Table 2). In estimating the Cl load, the effect of dry fallout on the lake is neglected, as the lake surface area is less than one tenth of the catchment area.

Table 4 shows main items of the Cl budget for Lakes Gozha and Aksayqin. Since the Cl concentrations of L. Gozha and inflowing rivers are 1,183 and 10.4 mg/1 respectively as indicated in Tables 2 and 3 and Fig. 5, the annual Cl inputs from rivers and the Cl accumulation amount in L. Gozha are $1.33 \times 10^9$ gr. and $1.15 \times 10^{13}$ gr. respectively (Table 4).

There are no sub–basins with salt fields around L. Gozha and no salt layers in lake bottom cores, so deposition of Cl in the solid phase can be neglected. However, Cl accumulation in the lake is a minimum, because, it is thought, salinity increases in the deep water and so the average Cl concentration may be larger than 1,183 mg/1.

If these assumptions are reasonable, we can estimate the age of the inland lakes, which is needed for accumulating the total Cl amount, from the annual input and accumulation amount. The age of L. Gozha is estimated to be $9 \times 10^3$ years, and that of L. Aksayqin $34 \times 10^3$ years by the method mentioned above (Table 4).

As the Cl concentration of L. Gozha is 1,183 mg/1 and that of L. Aksayqin 46,181 mg/1, the former is mesohaline and the latter is saline. The more saline the lake is, the older the age is if there are no large differences in annual Cl inputs. The Cl concentrations of river waters have a narrower range than those of lake waters (Tables 2, 3), therefore the formation of salt lakes on the Xizang Plateau mainly depends on the age needed for Cl accumulation.

There is a difference in freezing period between mesohaline lakes and saline lakes (Table 4). The freezing period of salt lakes is so short that evaporation will be large. This means that the formation of salt lakes is accelerated by condensation due to the large evaporation when salinity becomes high and the lake hardly freezes over. Therefore, the lakes on the Xizang Plateau are clearly classified into two groups ; salt lakes and fresh water lakes (Fig. 6). The intermediate type is unstable.

Fresh water lakes are formed in the present glacial areas where a large amount of glacial melt water is supplied, while salt lakes still form in the inner part of the Xizang Plateau far from the present glacial areas.

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