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Factors and Mechanisms of Chemical Composition Formation of Saline Lakes in West Mongolia

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All the lakes are accumulative systems for the various chemical elements. However, the ratios of the elements in different lake types are very different. It is generally accepted that the composition of lake water determined by the degree of evaporation. However, it is proved that soda water can't be obtained by evaporation of any water (fresh, salt, marine, etc.) [Harvie et al, 1980], for which there are two main hypotheses of formation: 1) geological and 2) ion-exchange processes. Unfortunately, none of the represented hypotheses does not account the role of aluminosilicate rocks in the chemical composition of lakes. However, the problem of the genesis of soda waters can be easily solved by the «water-rock interaction» theory. In this theory, the formation of soda is considered as a stage of the system coming after calcite precipitated [Shvartsev et al, 2011].

The salt lakes of western Mongolia show a great diversity in water chemistry, TDS, pH, Eh, SiO₂ and microelements contents, and mineralogy of precipitates, including salts, carbonates, aluminosilicates, etc. These lakes have salinities up to 360 g/L, pH up to 9.9, and up to 45 mg/L SiO₂. The sulfate and chloride lakes are characterized by high TDS, while the soda lakes show high pH values.

During of our research [Isupov et al, 2011a, 2011b] there are three types of salt lakes obtained on the represented territory: soda, chloride and sulfate. Each type of lake is

formed in the conditions of a specific geochemical environment. High mineralization is typical for sulfate and chloride lakes, high alkalinity - for soda lakes.

For studying the processes controlling the concentration of elements in solution, we studied the deviation of macroelements contents of the lake waters from the simple evaporation line. To determine the degree of evaporation chlorine-ion was selected, because in the considered circumstances it does not inflow from rocks in significant quantities and is not precipitated until the aqueous solution reaches a very high salinity. Thus, any ion concentration dependence of the chlorine-ion content can show the extent of influence of evaporation process and other processes on the ion concentration, in particular, the role of the interaction of water with rocks.

As follows from Fig. 1a, calcium at a certain stage of evolution of the solution is being removed from it as a result of secondary mineral phases formation (eg calcite). However, since it forms a complex compound of the contents it is still increasing as the concentration of the solution increase, but in much smaller quantities than Na (Fig. 1b), which under these conditions is practically not generates its own mineral and continues to be concentrated in solution until the water saturates by halite. That is, the high mobility of Na compared to other cations, the equilibrium state of water with calcite and undersaturation waters regarding the primary aluminosilicates are the main factors determining the gradual increase of Na concentrations in the solution and lead to its dominance of

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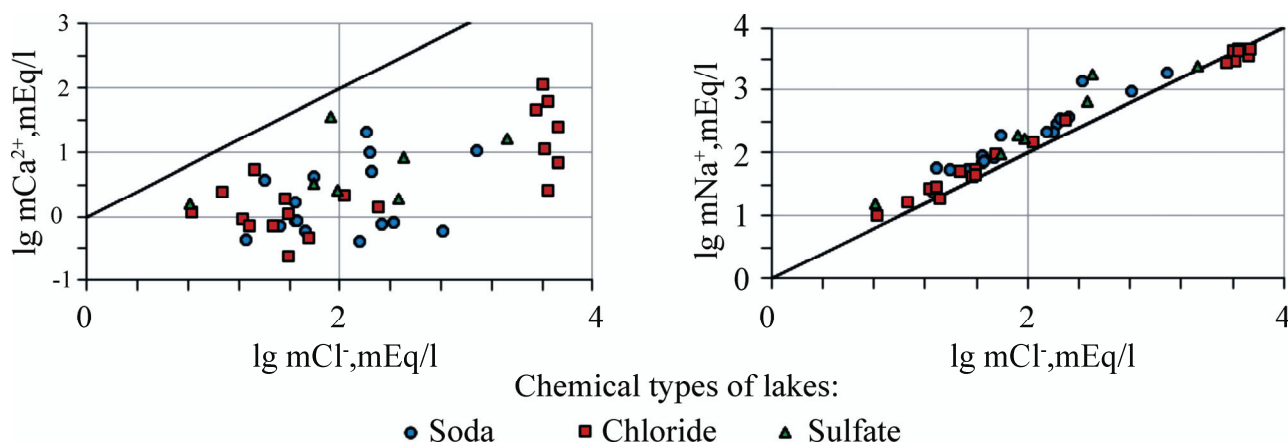


Fig. 1

Dependence of the concentration ions of calcium (a) and sodium (b) with chlorine in the waters of lakes. The solid line with a slope

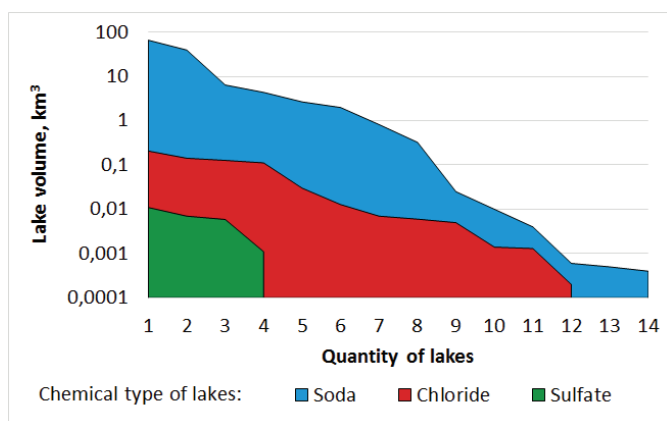


Fig. 2. Volume ratio of the lake basins for lakes soda, chloride and sulfate types

cations.

Dependence shown in Fig. 1b demonstrates the significant influence of evaporation processes on the sodium concentration in the lakes. But it doesn't point out at the low role of rocks in the water enrichment Na, because it is balanced in solution by the ions HCO_3^- and CO_3^{2-} . The process of formation soda is always accompanied by a significant increase of the pH of water due to the borrowing of chemical elements from aluminosilicate rocks: received balanced by cations in solution is OH^- , reacting primarily by reaction with CO_2 : $\text{OH}^- + \text{CO}_2 = \text{HCO}_3^-$. At the same P_{CO_2} , if activity of HCO_3^- is high, then the OH^- activity and pH of the water is higher. So soda lakes are becoming alkaline by accumulating HCO_3^- or CO_3^{2-} . The main factor in these conditions is the time of interaction of water with rocks or water exchange (Shvartsev et al, 2007), determined by the inflow and the degree of lake evaporation.

To estimate the evaporation, we studied the ratio of chlorine and TDS. Calculations showed (Table 2), the average value of Cl/TDS is for soda lakes 0,19, for chloride

– 0,34 and for sulfate – 0,16. That is, sulfate and soda lakes evaporate less than chloride. Furthermore, the volume of lakes chloride type by 3 orders of magnitude smaller volume of soda waters (Fig. 2), which also suggests a significantly less intense evaporation of the latter. That is, for the formation of lakes soda type should create the special conditions that include not only the saturation of water to carbonates, but also a certain water exchange in which evaporative concentration of salts should not suppress the dissolution of the enclosing rocks.

As water solution evaporates, it becomes saturated with all new and new secondary minerals, the formation of which leads to the transition of one type of chemical treatment to another. As the sulfate and chloride ions have a high migration ability, and only in some lakes associated with secondary minerals, then they are being accumulated in the liquid phase, and often in salt lakes hold a leading position. The role of the carbonate and bicarbonate ions progressively decreases, and the cations are mainly balanced by ions of Cl^- and SO_4^{2-} , and therefore does not increase the pH of water. Obviously, in the chemical composition of sulfate and chloride lakes processes are present formation of soda. Therefore, they are not excluded elevated concentrations of HCO_3^- or CO_3^{2-} .

So far many researchers cannot come to a common conclusion about why at some stage in the evolution of the lake in its composition is dominated by sulfates and sometimes chlorides, and what processes is governed their relationship. Our findings suggest that sulfate lake as sodas, may not only be a product of evaporative concentration, since the ratio of SO_4/Cl by simple evaporation is always close to unity. In the case that we have studied saline waters it is 1,5 – 6,9. A high ratio of these ions indicates the presence of additional sources of sulfates. The source of SO_4^{2-} is O_2 -rich groundwater in the upper hydrodynamic zone, which oxidizes pyrite and other sulfides during

infiltration through the rock and becomes sulfate-enriched., which are most often groundwater upper hydrodynamic zone that contain O_2 . The mechanism of formation of chloride lakes determined turning point when reaches saturation with gypsum, acting as a geochemical barrier to further accumulation of sulfates, which leads to the predominance of chloride ion in lake water. Thus, chloride and sulfate lakes formed under conditions of slow water exchange, when the evaporation is much higher than the inflow of the lake.

The analysis showed that in Western Mongolia are widespread lakes of different chemical types, the composition of which is defined as the degree of evaporation of water and the character of the interaction of lake water with rocks developed within their catchment area. Depending on the predominance of one or another factor will form the specific composition of the lake: soda lakes formed when the dominant role of rocks, chloride and sulfate when the dominant role of evaporation. The sulfate lakes may be formed in the presence of additional sources of ion SO_4 .

Key words: saline lakes, Mongolia, system water-rock, geochemistry, evaporation

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