

YE Chuanyong, ZHENG Mianping, WANG Zhiming, HAO Weilin, LIN Xiaobin and HAN Jun, 2014. Hydrochemistry of the Gasikule Salt Lake, Western Qaidam Basin of China. *Acta Geologica Sinica* (English Edition), 88(supp. 1): 170-172.

Hydrochemistry of the Gasikule Salt Lake, Western Qaidam Basin of China

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The Qaidam Basin is a large intermontane depression in Qinghai Province, China, which located on the northern margin of the Tibet plateau, and surrounded by the Qilian, Kunlun and Aljun mountains which rise to more than 5000m. Some 27 salt lakes occur within the basin, occupying an area of approximately 1500 km². Additionally, there are extensive areas of dry playas. Together, the playas and salt lakes cover about one quarter of the total basin area. Whereas the western region contains many playas and few high-salinity lakes, that situation is reversed in the east where there are few salt flats and many high-salinity lakes (Chen and Bowler, 1986). However, because of its remoteness and inaccessibility, few water chemistry studies have been conducted in this area. More recently, lake surveys in Qaidam Basin were conducted of enrichment of boron and lithium in the salt lakes (Tan et al., 2012), oxygen, hydrogen, chlorine isotopic geochemistry of groundwater and brine (Liu et al., 1997; Tan et al., 2009). These understanding could then contribute to paleoenvironmental change studies and mineral resources exploitation.

Gasikule Salt Lake located in the western Qaidam Basin, China, was selected as study area in these paper (Fig. 1). It is one of the most extremely arid areas in Qaidam Basin with very rare annual precipitation (less than 50mm) and high annual evaporation (more than 2,800mm). Some important salt lake

resources and all of oil or gas resources have been mined. Despite several small rivers are perennial for mountain spring water (snow melt water) and groundwater recharge,

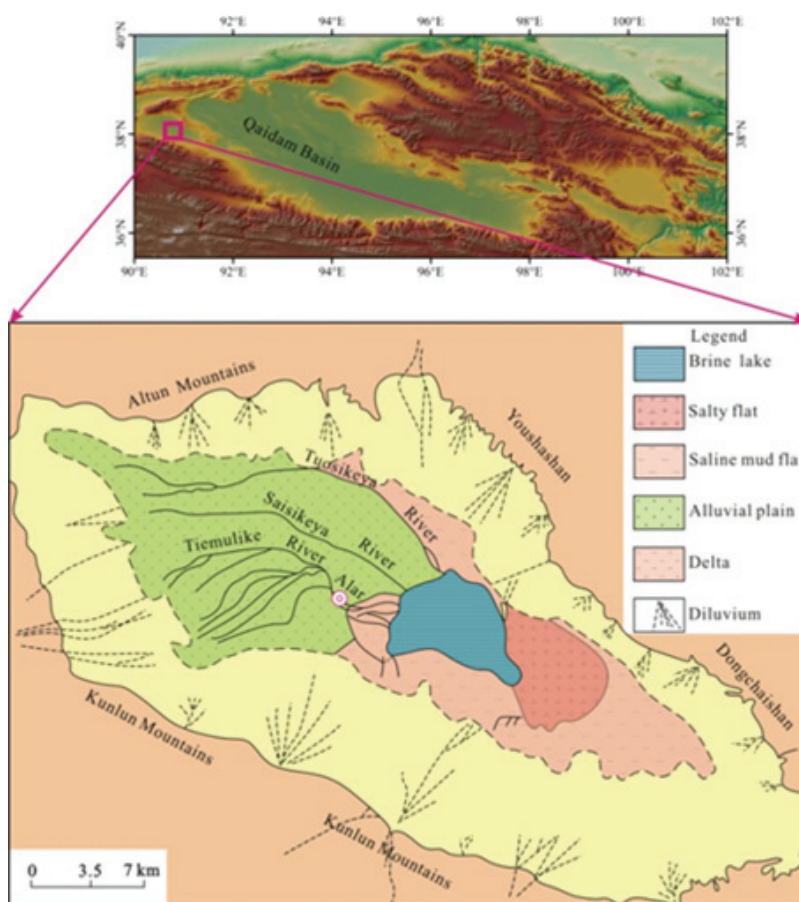


Fig. 1. Map of the Qaidam Basin and location of the Gasikule Salt Lake (Modified from Liu et al., 2013).

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they are quickly salinized by surface salts dissolved and extreme evapo-concentration once they flow the front of mountain to discharge into Gasikule Salt Lake. Gasikule Salt Lake flat plain floored by layered halite with a permanent groundwater brine located 0-1.2 m below the surface. The surface salt crust is commonly rugged and consists predominantly of a chaotic mixture of fine-grained halite crystals and mud. Vadose diagenetic features, such as dissolution pipes and cavities, and pendant cements, occur where the surface salt crust lies above the water table. Gasikule Salt Lake has a large modern saline lake in the western part of the lake, where water depth exceeds 0.5-0.8 m and the deepest point reaches 1.3 m in the south central. In contrast, the dry saline pan wide spread in the east (Chen and Bowler 1986; Zhang 1987; Cacas et al 1992). The surfaces of salt pans consist of pressure-ridges with well-developed polygonal honeycomb-shaped structures that are surrounded by a dry saline mudflat.

Brine and fresh water samples collected from Gasikule Salt Lake were analyzed for their general chemical composition and for hydrogen, oxygen and strontium isotopes in order to trace their origin, formation, and resource distribution (Fig. 2). The average contents of Ca^{2+} 、 Mg^{2+} 、 Cl^- 、 SO_4^{2-} 、 HCO_3^- existed in three types brines (salt-bond brine, intercrystalline brine and superficial brine) were all higher than those in Qaidam Basin's brines, while salt-bond brine higher than intercrystalline brine and superficial brine. However, K^+ 、 Na^+ were reversely. The trace elements' uniformity, intercrystalline brine>superficial brine>salt-bond brine; the major ions' uniformity, superficial brine>intercrystalline brine>salt-bond brine. The results showed that the brines belong to chloride type and magnesium sulphate subtype, none of sodium sulphate subtype and carbonate type. Among all of the brines, salt-bond brine belong to chloride type; intercrystalline brine belong to chloride type and magnesium sulphate subtype, magnesium sulphate subtype account for 41.7% and chloride type account for 58.33%; most of the superficial brine belong to chloride type. In a word, brines underwent relatively deep metamorphism, salt-bond brine>superficial brine>intercrystalline brine. The location of three types brines in quinary system metastable phase diagram of Na^+ 、 K^+ 、 Mg^{2+} // Cl^- 、 SO_4^{2-} - H_2O were quite differently. There existed a great difference at the evolution stages.

Hydrological, chemical and isotopic characteristics show that the groundwater in the Gasikule Salt Lake basin was recharged by meltwater from new surface snow and old bottom glaciers on the northern slope of the Kunlun Mountains and river water. In addition, the results also

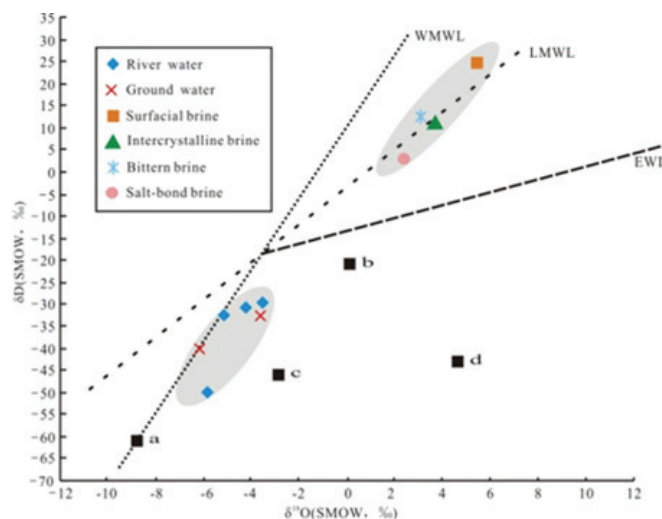


Fig. 2. A trilinear (piper) diagram for the brines and fresh water of Gasikule Salt Lake.

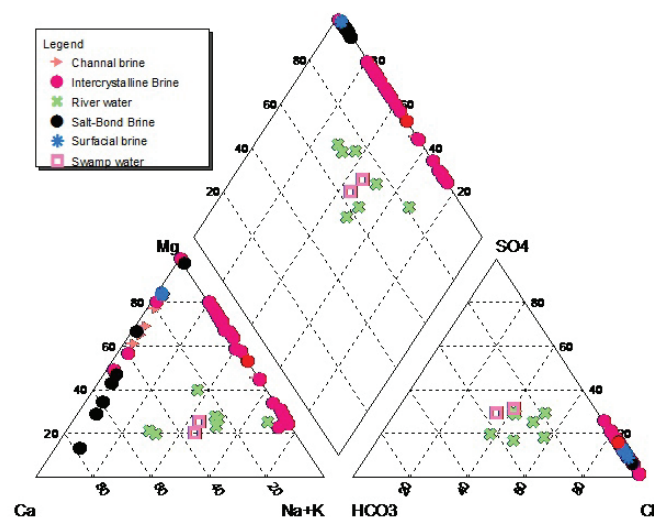


Fig. 3. Stable H and O isotopic compositions of Gasikule Salt Lake brines (surficial, intercrystalline, bittern, salt-bond) and fresh water (river and ground). Modern worldwide precipitation produces the Meteoric Water Line (WMWL), the local precipitation produces the Meteoric Water Line (LMWL) (Zhang et al., 1993), and local brine evaporated produced Evapo-concentrated Water Line (EWL) (Tan et al., 2011). Four typical types of formation brines produced in Sichuan Basin are also included: a-Average meteoric weathering water (-61‰ in δD and -8.7‰ in $\delta^{18}\text{O}$); b-Average sedimentary seawater (-21‰ in δD and 0.1‰ in $\delta^{18}\text{O}$); c-Average mixture of seawater and meteoric water (-46‰ in δD and -2.9‰ in $\delta^{18}\text{O}$); d-Average mixture of magmatic fluids and seawater (-53 to 39‰ in δD and 3.2 to 5.9‰ in $\delta^{18}\text{O}$) (Lin and Xiong, 2001).

prove that the source water is enough and stable, and the rates of the circulation and renewal of the groundwater are relatively quick. Brines in the Gasikule Salt Lake are derived from rain water through prolonged circulation. Gradual changes of stable isotopic compositions in brines and fresh waters clearly indicate the effect of evaporation on water evolution of the Gasikule Salt Lake basin (Fig.

3). According to the brine evolution and formation, we think that there has been a large and steady recharge source for the brines and the foreground of the exploration and utilization for brine resources should be well.

Key words: Gaskure Salt Lake; Brines; Fresh water; Hydrochemical composition; Hydrogen and oxygen isotopes.

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