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# Geological and geochemical evolution of forming of kalium-rich brine in Sichuan Basin

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## 1 Introduction

Sichuan Basin is basically a salt brine reservoir, large closed and semi-closed artesian sedimentary basin with an area of 200,000 Km2 in southeast China. During the forming and evolution of the basin, it has been affected by numerous distinct tectonic events successively in different period: crust uplifts and depressions in Caledonian, upthrust and extension in Hercynian, differentiation and basin forming in Indosinian , evolution and overall folding in inland basin in Yanshanian-Himalayan. Locally some strata underwent strong denudation. However, considered as a whole, the strata were still stacked in sedimentary sequence(Huang Sijing , Zeng Yunfu, 1997).

The paper focus on geological and geochemical evolution of forming of kalium-rich brine.The evolution of the kalium-rich brine could be basically divided to 2 stages ( Zhang Chengjiang, et al. ,2012;Yin Guan,2008): sea water evaporation and concentration, and water rock reaction in reservoirs. Due to input, source, consumption and intensity of energy and substances varied in different stages, adding uneven energy and substances distribution, hence the evolution manner and grade of the brine obviously changed in different areas and stages. In time sequence, the brine has undergone an evolution from surface to underground, from open system to close system in principle.

## 2 Sea water evaporation and concentration

Massive Emeishan kalium-rich alkaline basalt eruption in late Permian provided considerable amount of substances enriched in K, Sr and Mg(Xiao Long,et al.,2003). With crustal uplift, Sichuan Basin was isolated from ocean and became a solitary basin. Owing to evaporation and concentration, amount of sea water sharply decreased. Both lithology and mineral sedimentary association of $T_1j^1$ and $T_2l^4$ represented some features of strong evaporation and concentration.

In early Jialingjiang Stage, small amount of evaporites occurred. In late Leikoupo Stage, marine facies evaporites gradually increased. Salt basin sediments with great thickness existed in west Sichuan, which recorded sea water evaporation and concentration were increasingly stronger. Such evaporation and concentration were significant reasons for ion concentration of sea water varied. In sea water system at ordinary temperature, precipitation and disassociation of undissolved compounds are not only related to their solubility products but also the concentration of each ion in sea water from different stages. After evaporation and concentration, content of $SO_4^{2-}$ and $CO_3^{2-}$ became higher in the sea water system. The order in which undissolved compounds were precipitated was affected by alkali metal cations (except K, Na) entering the sea water. Evaporation and concentration induced concentrations of ions in sea water ascended. Once the concentrations of ions reached or exceeded what the solubility product constant (K*sp*) of a related compound allowed, a precipitate occurred. In early Jialingjiang Stage, barite and celestite sediments existed first in some parts in east basin. In respect that solubility products constant of BaSO4 is the lowest one in such sea water system, when the solubility product of $Ba^{2+}$ and $SO_4^{2-}$ reached solubility product constant (K*sp*) of $BaSO_4$, barite precipitate occurred first. Although solubility product constant (K*sp*) of celestite was several orders of magnitude higher than that of barite, celestite precipitate was more likely to occur for universally high content of Sr in sea water in Jialingjiang Stage. Due to content of $Ca^{2+}$ was basically high in sea water and solubility product constant (K*sp*) of $CaCO_3$ was far below

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that of $CaSO_4$, so $CaCO_3$ precipitate preferentially occurred in the system in which $Ca^{2+}$, $SO_4^{2-}$ and $CO_3^{2-}$ existed. Contents of Mg and Li were lower in sea water, besides solubility product constant (K*sp*) of Mg and Li were much higher than those of other components in sea water, therefore commonly such sorts of precipitate hardly existed. Sea water is a complex ion system, in which ions interference and restrict each other, which possibly varied chemical thermodynamics and kinetics, and affected the order in which chemical precipitates occur in sea water

## 3 Geological Evidence

In the area of Huaying Mountain in eastern basin, barite and celestite mainly occurred in 4th and 2nd Members of Jialingjiang Formation. 85-150 m thick glauberite rocks, polyhalite rocks and other compound salt rocks basically existed in strata from $T_1j^5$- $T_2l^1$ in Nongle Village of Quxian County accompanied by a considerable amount of anhydrite. The sedimentary and time sequence principally indicated precipitate occurred in barite→celestite→gypsum→potassic-compound-salt order, which demonstrated, to a certain extent, the regularity in undissolved compound precipitate occurring in sea water evaporation and concentration.

In west basin, barite and celestite hardly occurred. Glauberite rocks, polyhalite rocks mainly occurred at the bottom of T2l4, which showed that the sedimentation was later than that in eastern basin.

In Xuanhan of eastern basin, kalium-rich brine (Chuan No.25 Well Drilling) bearing strata predominantly occurred in $T_2l^{1-1}$ and $T_2l^{1-2}$ at 3251.1-3251.5m, 3258.0-3261.1m and 3263.9-3269.3m deep, containing 27.68g/L $K^+$, 0.85g/L $Sr^{2+}$, 0.35g/L $Li^+$, 1.79g/L $Br^-$, 0.04g/L $I^-$ and 5.498g/L $B_2O_3$.

Represented by Pingluo No.4 Well Drilling in the western basin, Kalium-rich brine mostly occurred in T2l4 and has a concentration of the above ions that is nearly 2 times higher than that of brine from Chuan No.25 Well Drilling. Regionally it showed the forming of brine reservoir was later and concentrations of major ions were higher than that in eastern basin.

Affected by Indosinian tectonic movements, the evolution of Sichuan Basin underwent a topographic transition from higher in the west and lower in the east to lower in the west and higher in the east. Brine in western basin was formed later than one in eastern basin and more affected by long term evaporation and concentration. Besides, from early to late Triassic, the sedimentary environments were converted from marine facies to continental facies gradually. Amount of remaining sea water decreased dramatically, and evaporation and concentration became much stronger. Meanwhile, substances from adjacent areas continuously immigrated to the basin during the evolution.

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