Characteristics of chlorine isotope distribution and analysis on sylvinite deposit formation based on ancient salt rock in the western Tarim Basin

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Received February 17, 2004; revised November 2, 2004

Abstract  During formation of the Tarim Basin, there repetitively happened seawater invasion for it was ever connected with wide Paleo-mediterranean Sea. At the same time, for the application of tectonic and paleoenvironmental condition, the basin deposits many sequences of thick strata of evaporites, especially in its two largest subbasins of Kuqa in the north and Shaqa in the southwest. Therefore, the western Tarim Basin has been considered to be a favorable location to prospect ancient sylvinite deposit. But it is unfortunate that the Br×10⁻³/Cl ratio, as a common geochemical index to uncover clues of sylvinite deposit, is almost invalid to indicate the stage of ancient brine condensation for very low content of bromine in salt rock samples (less than 10⁻⁶ commonly) in the western Tarim Basin evaporites. Fortunately, we noticed recently that the values of chlorine isotope (δ³⁷Cl value) for salt rock samples follow some clear laws from place to place, which in the Shaqa subbasin, all δ³⁷Cl values of salt rock samples behaved negatively and on the contrary, they all surprisingly showed positive values in the Kuqa subbasin. Based on conclusions of previous research and referring to the ratios of Br×10⁵/Cl for salt rock or brine samples, we proved that the chlorine isotope (δ³⁷Cl) could be used as an effective index to find ancient sylvinite deposit in those evaporites rock basin with low content of Br element background, such as the Tarim Basin. Thus according to the new index of chlorine isotope, we conclude that the concentration of ancient brines formed ancient salt rocks is much more concentrated in the Shaqa subbasin than that in the Kuqa subbasin. Particularly, the δ³⁷Cl value of salt rock in Kashi depression of the western Shaqa subbasin is greatly negative (≤−1.00‰), which may predicate that the ancient brine has been concentrated to the terminal stage of salt deposit or even the later stage of sylvinite deposit. Then it is possible to find sylvinite-bearing deposits around the western region (periphery of Kashi depression) of the Shaqa subbasin if we carry out more careful exploration in later works.

Keywords: the Tarim Basin, chlorine isotope, ancient salt rock, ancient sylvinite deposit, deposit stage.

DOI: 10.1360/04yd0051
The Tarim Basin, located in Xinjiang (Fig. 1), is the largest deposit basin with an area of about 560000 km$^2$ in China. From late Triassic period to early Miocene, two huge subbasins developed, named the Kuqa subbasin at the foot of the Tianshan Mountains in the north and the Shaqa subbasin at the foot of the Kunlun Mountains in the south of the Tarim Basin. During the late Cretaceous to early Tertiary period, the Paleo-mediterranean seawater repetitively invaded into the Shaqa subbasin and again poured into the Kuqa subbasin through the Awati strait$^{[1,2]}$. At the same time, under the tectonic activities process, such as the Yan Shan movement, etc., the basin systematically depressed or upheaved and then broke up a series of more sub-depressions$^{[3]}$. Then the invaded seawater was separated into many close or half-close bays and lagoons or even salt lakes$^{[4]}$ and became an important salt rock deposit basin. At present, there appear thick sequences of salt rock outcrops or salt minerals exploitation developed in late Cretaceous (K$_2$) and Tertiary (E$_1$-E$_3$) periods here and there in middle and western regions of the Kuqa subbasin, as well as the western Shaqa subbasin, such as Kashi depression. Considering that the adjacent basin of Middle Asia, such as the Tadzhiki Basin west of the Tarim Basin, has already prospected large-scale sylvinitic deposit formed in Jurassic and Cretaceous strata$^{[5]}$. But in fact, these two basins have very similar characteristics in geology and paleo-environmental conditions since the Mesozoic period, which all are perforated by Paleo-mediterranean seawater and ever distributed just like a string of beads in landform$^{[6]}$. Therefore, the western Tarim Basin should also possess geological conditions for sylvinitic deposits$^{[7]}$: (1) Repeated seawater invasion provided rich sources for huge thick salt rock formation. (2) Several separate levels of depressions and marginal fault basins provided very favorable tectonic and reservable conditions for sylvinitic deposit. (3) Long-period arid paleoclimate provided sustainable evaporative environment for much salt precipitation and so on. They all prove that the Kuqa and Shaqa subbasins are promising areas to find ancient sylvinitic deposits. Therefore, the western region of Tarim Basin, mainly for Shaqa and Kuqa subbasins has been regarded as one of the most important regions to locate ancient sylvinitic deposit by the Chinese government. But due to the chemical properties of sylvinitic deposit—easily dissolved and eluviated by water, and also to its less scale deposit area than salt rock in a basin$^{[8]}$, it is very rich or even impossible to be discovered in the surface. So in order to lessen the range of area and find a place of sylvinitic deposit in a