1 Introduction

$^{87}\text{Sr}$ is radioactive sources in the four stable isotopes of strontium ($^{84}\text{Sr}$, $^{86}\text{Sr}$, $^{87}\text{Sr}$ and $^{88}\text{Sr}$), it is from $\beta$ decay of rubidium $^{87}\text{Rb}$. Strontium often occur in mineral containing calcium and potassium. Sialic rocks of crust-derived is with high ratio of $^{87}\text{Sr}/^{86}\text{Sr}$ (average 0.1720-0.1005), and low concentration of strontium; Mafic rocks of mantle-derived is with low ratio of $^{87}\text{Sr}/^{86}\text{Sr}$ (average 0.1704-0.1002); Marine carbonates and sulfates are with low ratio of $^{87}\text{Sr}/^{86}\text{Sr}$ (average 0.1708-0.1001), and high concentration of strontium. Although some geological processes (such as evaporation) can change the concentration of strontium isotopes, the ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ almost unchanged in the same waters and in the same geological period(Kelts et al., 1987). These characteristic of the strontium isotopes is the basis for the analysis of environmental change. (Reeder R J et al., 1983)

1.1 Geochemistry character of Strontium isotope of sea facies

The residence time of strontium in seawater is much longer than the mixing time of seawater, therefore, the global strontium element of sea facies is homogeneous in isotopic composition in every period (McArthur et al., 1992). The result is that the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio in sea water is time varying in the geological record (Wickman, 1948).

The strontium isotope in seawater is mainly determined by three sources:

(1) Weathering and denudation of the sialic rock in continent crust which possesses a high N ($^{87}\text{Sr}/^{86}\text{Sr}$) value and the average value is 0.720;
(2) Seafloor spreading or volcanism of the femic rock in the mantle, whose strontium isotope value is low to 0.704;
(3) Redissolution of carbonate rocks in older sea facies, whose value is between the former two values and the average one is 0.7080 (Montanez et al., 1996; Ruppel et al., 1996; Richter et al., 1992; DePaolo and Ingrain, 1985).

1.2 Geochemistry character of Strontium isotope of lacustrine facies

Similar to strontium isotope composition of sea facies, carbonate lacustrine carbonate strontium isotopic composition also changes in different geological periods, however, that change would be showing a relatively stable. The ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ of lacustrine carbonate strontium isotopes is higher than marine carbonate, mainly due to the lake basin is easy to be affected by the sialic rocks with high ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ than the sea basin.

The strontium isotope in lake basin is similar determined by three sources, but still a little different:

(1) The lake basin is easier to be affected by sialic rocks with high ratios of $^{87}\text{Sr}/^{86}\text{Sr}$, so the ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ of lacustrine carbonate is higher than the ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ of the marine carbonate;
(2) Be similar to the marine sea facies, the lake can also be affected by volcanic activity. That mantle-derived substances enter the lake basin make the ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ decrease;
(3) Marine carbonate re-dissolving will also affect strontium isotope composition of lake basin in different periods. So this effect will make the ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ in the lake basin reduce.

2 Geological Background

Dongpu depression is located in the southeast of the southern edge of the Bohai Bay Basin(Fig.1), which is a Cenozoic rift basin developing on Paleozoic strata. The thickness of Cenozoic strata is more than 8000m, Dongpu Depression is rich in oil and gas resources, is an important oil and gas production base in the eastern China. Cenozoic strata is the cap with basement of Paleozoic-Mesozoic strata in Dongpu depression, there are many combination of reservoir and cap strata. The Shahejie formation develop four evaporite bed which plays an important role in diagenetic evolution, the oil and gas...
generation, migration, accumulation, in the region. The predecessors has done a lot of research in these four sets of evaporite bed, but there are still some controversy of its formation mechanism and the paleoclimate. Zhang Xiaoyi (2002) holds that the evaporite bed derived from shallow water evaporation after transgression. Other geochemical data of the analysis of research also think there were transgression event in Dongpu depression during Shahejie formation depositing period. However, Chen Faliang et al. (2000), Xu Juzhen, et al. (2003) considered the cause of evaporite bed is that the brine upwell along deep fault.

3 Climate change indicative significance of Strontium isotope

The Dia (1992), Clemens, et al.(1993) found that marine strontium isotope curve shows the characteristics of the high-frequency change, and this change are synchronized with the marine oxygen isotope changes over the past 145 Ma. It proves that marine strontium isotope curve consistent with climate change.

The lake basin is easier to be affected by climate factors, so the strontium isotope reflecting the climate in lake basin is more sensitive than that in the ocean. In the climate of drought, due to reduction input of river that contain the high ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ of crust-derived silicon aluminum rock fragments to the lake basin, so during this period the ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ in the sediment is relative low; while in semiarid and semi humid climate weathering is relatively strong, while the river developed, and took rock debris weathered that contain crust-derived silicon aluminum with high ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ to the lake basin, sediment formed during this period has relative high ratios of $^{87}\text{Sr}/^{86}\text{Sr}$.

4 Discussion

The variation characteristics of ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ in different layers, Dongpu salt lake as shown in table 1. From the table we can see the ratios $^{87}\text{Sr}/^{86}\text{Sr}$ changes within small range, the highest is only 0.002178, the strontium isotope are relatively stable in the same period. The ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ in the area is generally much higher than the ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ in modern ocean (0.7092). However the ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ in modern marine is higher than the ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ of marine carbonate formed in past geological period, so Dongpu salt lake should belong to the continental salt lake, The main controlling factors affecting the strontium isotope composition should be the amount of input with high ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ crust-derived sialic rocks. Palmer et al.(1989)suggest that the average ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ of the whole global river input is 0.7119 ,that is more than the average ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ of modern seawater( 0.7092). It also confirmed this point.

<table>
<thead>
<tr>
<th>horizon</th>
<th>Max.</th>
<th>Min.</th>
<th>Max.-Min.</th>
<th>Avg. $^{87}\text{Sr}/^{86}\text{Sr}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Es1</td>
<td>0.712292</td>
<td>0.711580</td>
<td>0.000712</td>
<td>0.711894</td>
</tr>
<tr>
<td>Es2_uper</td>
<td>0.713026</td>
<td>0.711812</td>
<td>0.001214</td>
<td>0.712309</td>
</tr>
<tr>
<td>Es3_uper</td>
<td>0.717244</td>
<td>0.717244</td>
<td>0.000000</td>
<td>0.717244</td>
</tr>
<tr>
<td>Es3_mid</td>
<td>0.715179</td>
<td>0.713001</td>
<td>0.002178</td>
<td>0.714080</td>
</tr>
<tr>
<td>Es3_low</td>
<td>0.713759</td>
<td>0.711585</td>
<td>0.002174</td>
<td>0.712672</td>
</tr>
<tr>
<td>Es4_uper</td>
<td>0.713691</td>
<td>0.711877</td>
<td>0.001814</td>
<td>0.712422</td>
</tr>
</tbody>
</table>

The ratio of $^{87}\text{Sr}/^{86}\text{Sr}$ changes slightly higher in different layers, such as the difference of ratio of $^{87}\text{Sr}/^{86}\text{Sr}$ from Shahejie formation 1 to Shahejie formation 3 reach 0.005351, which shows the factors that control strontium isotope has changed in different periods, so the strontium isotope has also changed. We made the average ratio diagram of $^{87}\text{Sr}/^{86}\text{Sr}$ in different layers (Fig. 2). During the time from upper Shahejie formation 4 to upper Shahejie formation 3 the ratio of $^{87}\text{Sr}/^{86}\text{Sr}$ increased, however during the time from the upper Shahejie formation 3 to upper Shahejie formation 2 the ratio of $^{87}\text{Sr}/^{86}\text{Sr}$ suddenly reduced, but On the whole from upper Shahejie formation 3 to upper Shahejie formation 1 it shows decreasing trend. From the above analysis we can see that the basin should be an inland salt lake basin, the controlling factors of strontium isotope composition should be mainly crust-derived sialic rocks with high ratio of $^{87}\text{Sr}/^{86}\text{Sr}$ (0.720±0.005). Therefore, in this area, the ratio of $^{87}\text{Sr}/^{86}\text{Sr}$ reflects the input of terrigenous clastic. From upper Shahejie formation 4 to Shahejie formation 3 period, the ratio of $^{87}\text{Sr}/^{86}\text{Sr}$ increases gradually, rivers took more
input of terrigenous clastic to the basin during this period, it suggests that in this period the climate of this area be a semi-arid and semi-humid climate, the river took the lots of weathered silicon aluminum material with high ratio of $^{87}\text{Sr}/^{86}\text{Sr}$ to the lake, which makes strontium isotopes increase; On the contrary from upper Shahejie formation 3 to upper Shahejie formation 1 period, the ratio of $^{87}\text{Sr}/^{86}\text{Sr}$ mainly decreased, it shows that the climate in this area began to change to the arid climate, and rainfall reduced so that the supply of terrigenous clastic correspondingly decrease in the lake basin accompanying with the reduction of ratio of $^{87}\text{Sr}/^{86}\text{Sr}$. There is a sudden change between the upper Shahejie formation 3 to the upper Shahejie formation 2, so we can speculated that during the period from upper Shahejie formation 3 to upper Shahejie formation 2, the climate abruptly changes.

5 Conclusions

(1) Through strontium isotope analysis of Paleogene salt lake layers in Dongpu depression, the preliminary view is that the Dongpu salt lake is a typical inland salt lake basin and the ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ generally higher than the ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ in ocean. The main source of the strontium isotopes should be crust-derived sialic rocks with high ratios of $^{87}\text{Sr}/^{86}\text{Sr}$.

(2) To some degree, the distribution of strontium isotope in the lake reflect the current climate. The studies in Dongpu depression salt layers strontium isotope have shown that: During upper Shahejie formation 4 to upper Shahejie formation 3 period, it is semi-arid and semi-humid climate in the region and weathering strongly. During upper Shahejie formation 3 to Shahejie formation 1 period the climate in the region change from semi-arid semi-humid to more drought, reduction of terrigenous clastic make the ratios of $^{87}\text{Sr}/^{86}\text{Sr}$ lower in this period.

References


Reeder R J.Crystal chemistry of the rhombohedral carbonates[J]. Min Soc Am,Reviews in Mineralogy,1983,44:1–47


