Sr isotope of fossil foraminiferal assemblages in the Nihewan Group*

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Debate on depositional environment about foraminifera-rich strata in many Cenozoic continental basins in East China has existed for a long time. Research results achieved in recent years show that it is difficult to distinguish foraminiferal assemblages in modern salty lakes from those in weakly marine environments such as supratidal zone and lagoon[1]. However, shell geochemistry may be an outlet for this problem because of great difference in chemical and isotopic compositions between lake water and sea water. So fossils of *Nonion shansiensis* (*Evolutononion shangiensis* N. Wang), which is a sole foraminiferal species preserved in upper part of bed 27 and bed 28 in Xiaodukou section in the Nihewan Basin, were selected for Sr isotopic measurements. The sequence is larger than 12 m in length and was sampled consecutively. Because of requirement of analytical amount, the samples (25 cm × 25 cm × 20 cm) containing 300 foraminifera fossils per kilogram were chosen in this work (fig. 1).

1 Material and method

The 500 g sample was soaked in distilled water for 24 h and scattered spontaneously. By using standard sieve to grade in distilled water, grains larger than 0.09 mm in diameter were selected to be evaporated to dryness at the temperature of 80—90℃ and weighed. Then, the dry samples were floated in CCl_4 and foraminiferal fossils were concentrated.

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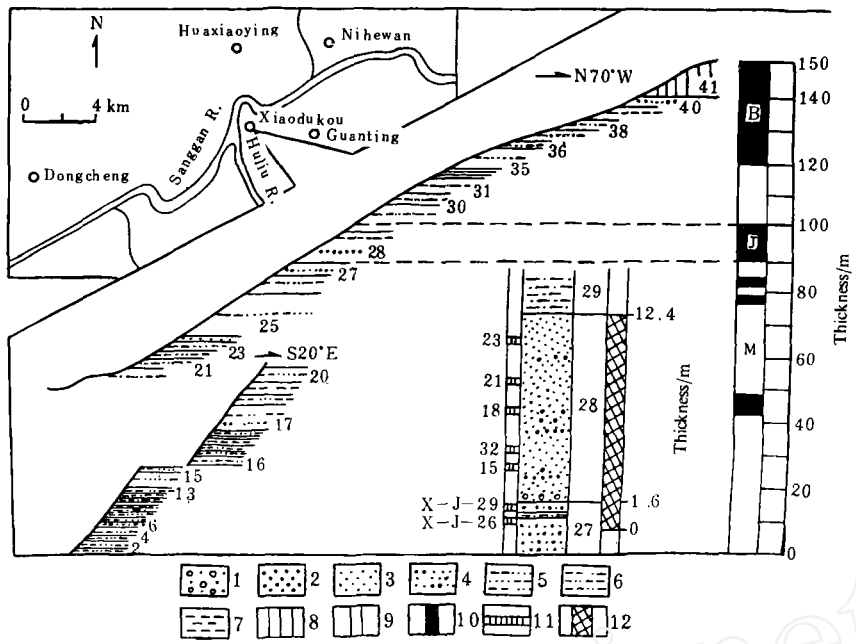

Fig. 1. Stratigraphy and sampling location of Xiaodukou section. 1, Sand and gravel; 2, coarse sand; 3, sand; 4, sandy silt; 5, muddy silt; 6, silty clay; 7, clay; 8, loess; 9, reversal of magnetic field; 10, positive magnetic pole; 11, sample point; 12, strata containing foraminifera. Data of lithology, stratigraphy and palaeomagnetism are from Chen *et al.*[7].

40 — 60 foraminifera fossils, each of which has clean external surface, about 0.20 mm and 0.10 mm in shell diameter and about 1 μg in weight, were picked out carefully under binoscopy for an analytical test. Before measurement, foraminiferal samples were immersed in H_2O_2 for 1 h, then repeatedly washed three times using deionized water and ethanol. Present chemical separate technique for Si isotopes in China requires a few more samples, about 10 mg, but the amount of microfossils usually cannot satisfy this requirement. The separate technique recently designed by us only requires a few samples, about 50 μg. Test samples were dissolved in 5% HAC. The solution was centrifuged and evaporated to dryness, then changed into chloride in 1 mol/L HCl. Chloride was dissolved in 1 mol/L HCl and directly loaded onto Dowex 50 W × 8 resion column (200 — 400 mesh). Using 1 mol/L HCl as washing liquid, the first 30 mL liquid was discarded and the following 20 mL Sr-rich liquid was collected. Sr-rich liquid was purified again by passing through Dowex-50 W × 8 resin column (100—200 mesh). The total Sr blank for this procedure is 5×10^{-9} g. Finally the collected liquid was evaporated to dryness. $^{87}Sr/^{86}Sr$ ratio was measured in a VG-354 mass spectrometer in Tianjing Institute of Geology, Ministry of Metallurgy. $^{87}Sr/^{86}Sr$ ratio measured for standard NBS 987 was 0.710229, with 2σ mean of 0.003%.

2 Analytical results and discussion

Sr deposited together with calcite minerals is not fractionated in any kind of water.

So if it does not undergo chemical alteration after deposition, Sr-bearing calcite minerals record then $^{87}Sr/^{86}Sr$ ratio of water where it deposits. Two criteria were used to evaluate diagenetic alteration. First, foraminifera with clean external surface were picked out under binoscopy; second, samples were thought to be recrystallized if examination by scanning electric microscopy (SEM) revealed dissolution or secondary enlargement in interior chamber surface and in chamber wall. Systematic examination of SEM showed that test samples did not undergo dissolution and secondary growth because it had clean surface and apparent pore structure in interior chamber surface and good column structure in chamber wall (fig. 2(b)). Compared with SEM photo (fig. 2(a)) of modern species, it is clear that original structures of foraminifera in Xiaodukou are relatively well preserved and they did not undergo apparent chemical alteration since it was buried. So the $^{87}Sr/^{86}Sr$ ratio measured for Xiaodukou foraminiferal skeleton minerals represents the then $^{87}Sr/^{86}Sr$ ratio of water where they were deposited. Also contribution of *in-situ* decay of ^{87}Rb to the concentration of ^{87}Sr could be neglected due to its low concentration in calcite minerals[3].

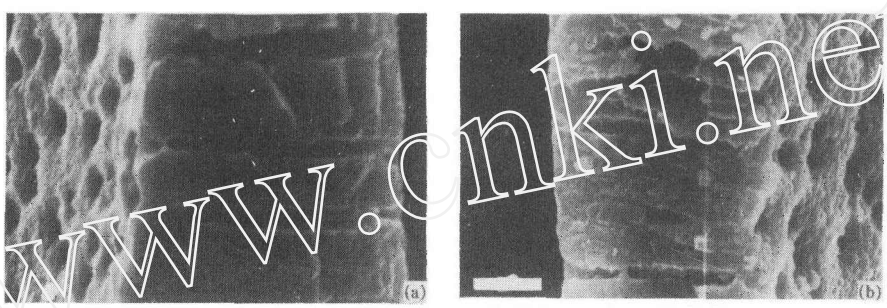

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Fig. 2. (a) Microarea SEM photo of chamber wall structure of modern *Nonion shansienses*, Luchaogang, Shanghai, ×10 000, scale bar is 2 μm; (b) microarea SEM photo of chamber wall structure of *Nonion shansienses* in Sample X-J-29, Xiaodukou section, ×8 000, scale bar is 2.5 μm.

Table 1 $^{87}Sr/^{86}Sr$ ratios of Xiaodukou foraminifera

Sample number	Bed number	$^{87}Sr/^{86}Sr$	$\Delta Sr^{b)}$
23		0.711 43±8[a)]	32.6
21		0.711 05±18	27.3
18	28	0.711 65±12	35.7
32		0.711 46±12	33
15		0.712 74±16	51.1
X-J-29	27	0.712 74±5	51.1
X-J-26		0.711 46±12	33

a) Average standard error; b) $\Delta Sr = \left[\frac{(^{87}Sr/^{86}Sr)_{sample,\ t}}{(^{87}Sr/^{86}Sr)_{seawater,\ t}} - 1 \right] \times 10^4$; when $t = 0.95$ Ma, $(^{87}Sr/^{86}Sr)$ seawater $= 0.709\ 117$[4].

$^{87}Sr/^{86}Sr$ ratios for 7 Xiaodukou samples range from 0.711 05 to 0.712 74, with a ΔSr of 33 — 51.1 (table 1), much higher than the then value of the seawater: (0.709 087 — 0.709 14 47[4]) and than the average modern value of water in the Yellow River (0.711 1[5]). It is proved that the living environment of Xiaodukou foraminifera belongs to inland lake and

the possible marine environment connected with sea can be completely excluded. In other words, regional field geologic work reported has not provided plausible evidence to explain how ancient Nihewan lake 300 km from coast line connected with the sea from the viewpoint of tectonics[2]. In the last decades some findings about modern foraminiferal species existing in inland salt and brackish lakes without any relation to the sea have been reported[1] and have demonstrated that it is possible that some foraminiferal species which can tolerate extreme environments deviated from normal sea inhabit inland lake. So it is reasonable to conclude that Xiaodukou foraminiferal assemblages belong to non-marine foraminiferal species.

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