Sedimentary Filling of the Pearl River Mouth Basin and Its Response to the Evolution of the Pearl River*

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Abstract

The Geochemical data of sediments from the South China Sea (SCS) provide constraints on both the composition of potential source rocks and the effects of sedimentary environments. In combination with knowledge of the regional geology, this data set allows us to decipher the tectonic implications since 32 Ma on the basis of trends and major discontinuities observed in the stratigraphic succession of geochemical sediments compositions.

According to geochemical data, the sedimentation in SCS can be subdivided into seven stages since 32 Ma: they are 32-29.5 Ma; 29.5-28.5 Ma; 26.5-23.3 Ma; 23.3-16 Ma; 16-8Ma; 8-3 Ma and 3-0 Ma, respectively. There are relatively large discontinuities between individual stratigraphic trends among these stages, and in most cases the differences of the variables among these time stages are larger than the variation within each partition, except for the samples from 26.5-23.3 Ma. The sedimentary rate and grain size has also changed on these relatively large discontinuities. There are strong deformed and slumped sediments, including some redeposits, existed from 488 mcd to 455 mcd of ODP site 1148 (26.5 to 23.3 Ma), which lead to the chemical variables strongly changed in this section.

The sediment geochemical composition between Oligocene and Miocene was different in the northern South China Sea, indicating a significant provenance change. This abrupt change coincided with a series of events including a seafloor spreading axis jump in the South China Sea and uplift of the Western Yunnan Plateau and Eastern Tibet Plateau, leading to obvious changes in drainage areas of the Pearl River and the sediment geochemical composition. The variations in Ca/Si, CIA, and Al_2O_3 reflect that the erosion areas of the Pearl River transformed from close-to- source neighboring areas in the Oligocene to the Western Yunnan Plateau and Eastern Tibet Plateau since the early Miocene, and the provenance rock types changed from silicate to carbonate, as well as the main sediment composition changed from sand-dominated to mud-dominated material. Through this tectonic event, the sedimentary environment in the Baiyun Sag area transformed from continental shelf in the late Oligocene to continental slope since the early Miocene, and the sea level rose since the early Miocene in the area. Therefore, this abrupt change event has a profound influence on the evolution of petroleum offshore in the northern South China Sea.

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1.Introduction

The South China Sea (SCS) is the largest marginal sea between west Pacific Ocean and Asia Land. Most studies on the tectonic evolution of the South China Sea are based on geophysical data and on structural evidence along the margins, since there existed no deep-sea drilling core in SCS. Therefore, there are still some dissensions about the tectonic evolutional history, the process of the seafloor spreading, as well as the detail time scale of the tectonic evolution of SCS (Briais et al., 1993; Lee et al., 1994; Yao et al., 1998), arising from a lack of detailed geological data.

ODP Leg 184 Site 1148 has taken a long time scale deep-sea sediments profile in northern South China Sea in 1999, which is best one up to now to record the tectonic evolution history of the SCS (Wang et al., 2000). Through systematic analysis of the deep-sea sediments in the SCS, it could not only reveal the tectonic evolution of SCS, but also document the influence of the collision and convergence between Indian and Eurasian Plate on SCS.

The purposes of this paper are: to examine if a long-term deep-sea record of the basin evolution is available; to use geochemical database reconstructing the tectonic evolutional history of SCS; and to reveal the provenance difference for the sediments between different periods. The main point is to answer how the geochemical variables varied with time, how the tectonic periods in SCS are subdivided, and whether any other event recorded in the deep-sea sediments after the cessation of spreading.

2. Materials and Methods

The analyzed material is collected from Site 1148 of ODP Leg 184 (18o50.17'N, 116o33.94'E, at a water depth of 3 294 m), which is located on the lowermost continental slope off southern China, near the continent/ ocean crust boundary in the South China Sea (Fig. 1), and 853 m thick ranging from the Oligocene to the Pleistocene (Wang et al., 2000).

A total of 156 samples collected from top to bottom of the core, for about every 9.5 m, were analyzed for minor and trace elements geochemistry, and 488 (for about every 1.5 m) for grain-size analysis. For geochemical analyses, each sample requires 6 run of analysis and was calibrated with international rock standards (e.g., GSR-1, JSD-1), and checked with drift control samples, duplicate samples, and blank samples. Accuracy and precision could be estimated and monitored by the control of samples and duplicates. Instrumentation and sample preparation techniques are extensively described in Garbe--Schoenberg (1993) and Rollinson (1993). The samples were analyzed in the Laboratory of Marine Geology, Tongji University and Guangzhou Institute of Geochemistry, Chinese Academy of Science. For grain-size analysis, samples were firstly removed the organic matter and authigenic components ($CaCO_3$ and SiO_2), and analyzed by Coulter Ls 230 in the Laboratory of Marine Geology, Tongji University.

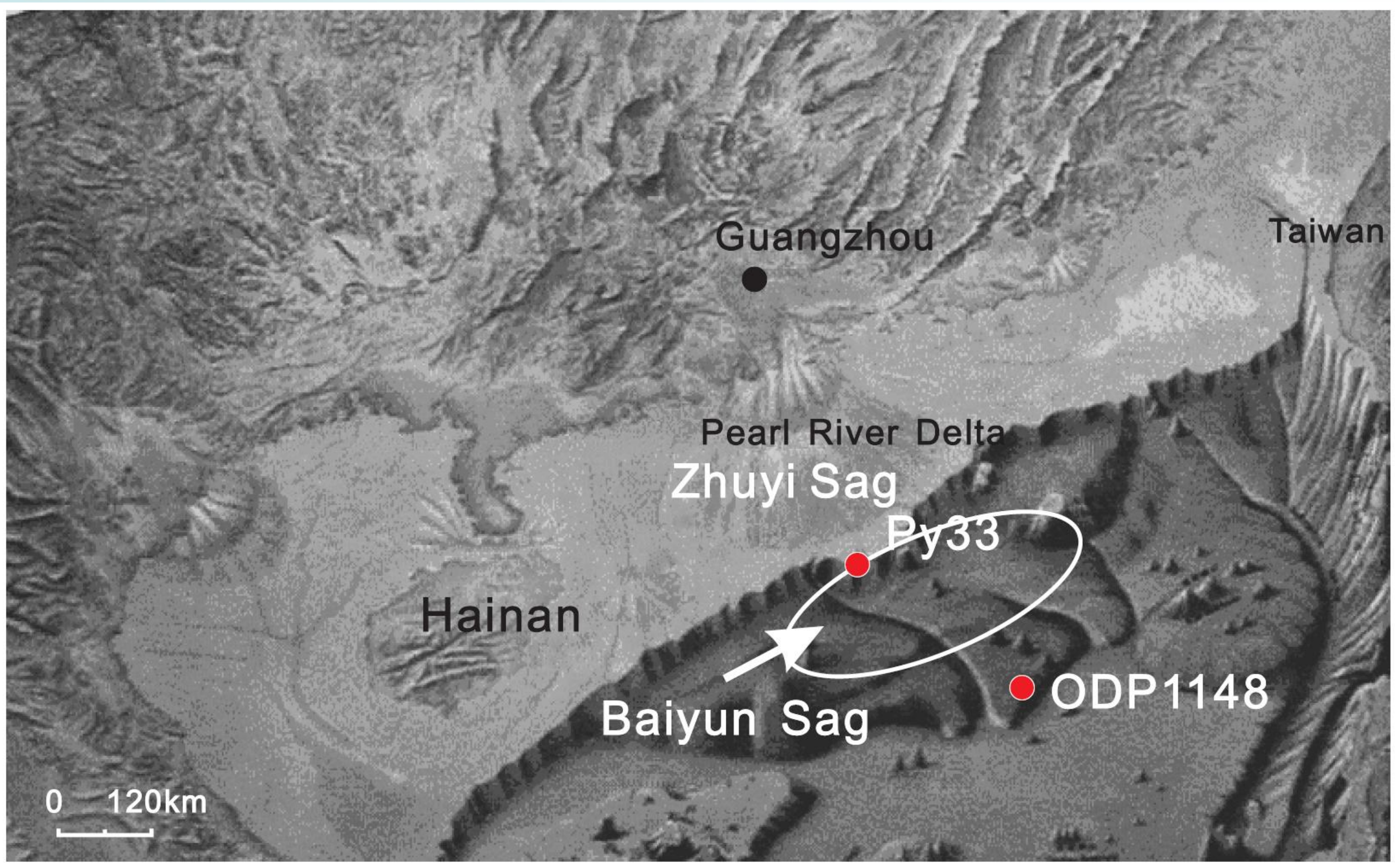

Fig. 1. Location map of the study areas and borehole sites

3.Result

Zr/Hf, Th/Sc, La/Sc, La/Sm and Nb/Ta ratios have marked stratigraphic variations and can be divided into seven periods according to the boundaries in 29.5 Ma, 28.5 Ma, 23.3 Ma, 16 Ma, 8 Ma and 3.0 Ma, those are turning points of the variables. SiO_2, Median of the sediment grain size and the sedimentary rate have also obviously changed at those points (Fig.2).

some multivariate statistical produces including discriminant analysis and cluster analysis (Davis, 1986; Stattegger, 1991) were applied to stratigraphically defined sample groups. The result of cluster data analysis in the SCS for the trace--element clearly shows that the trends of the variables can be divided into four time periods (Fig.3): 0 to 16 Ma,16-23.3 Ma, 23.3-26.5 Ma and 28.5-32 Ma.

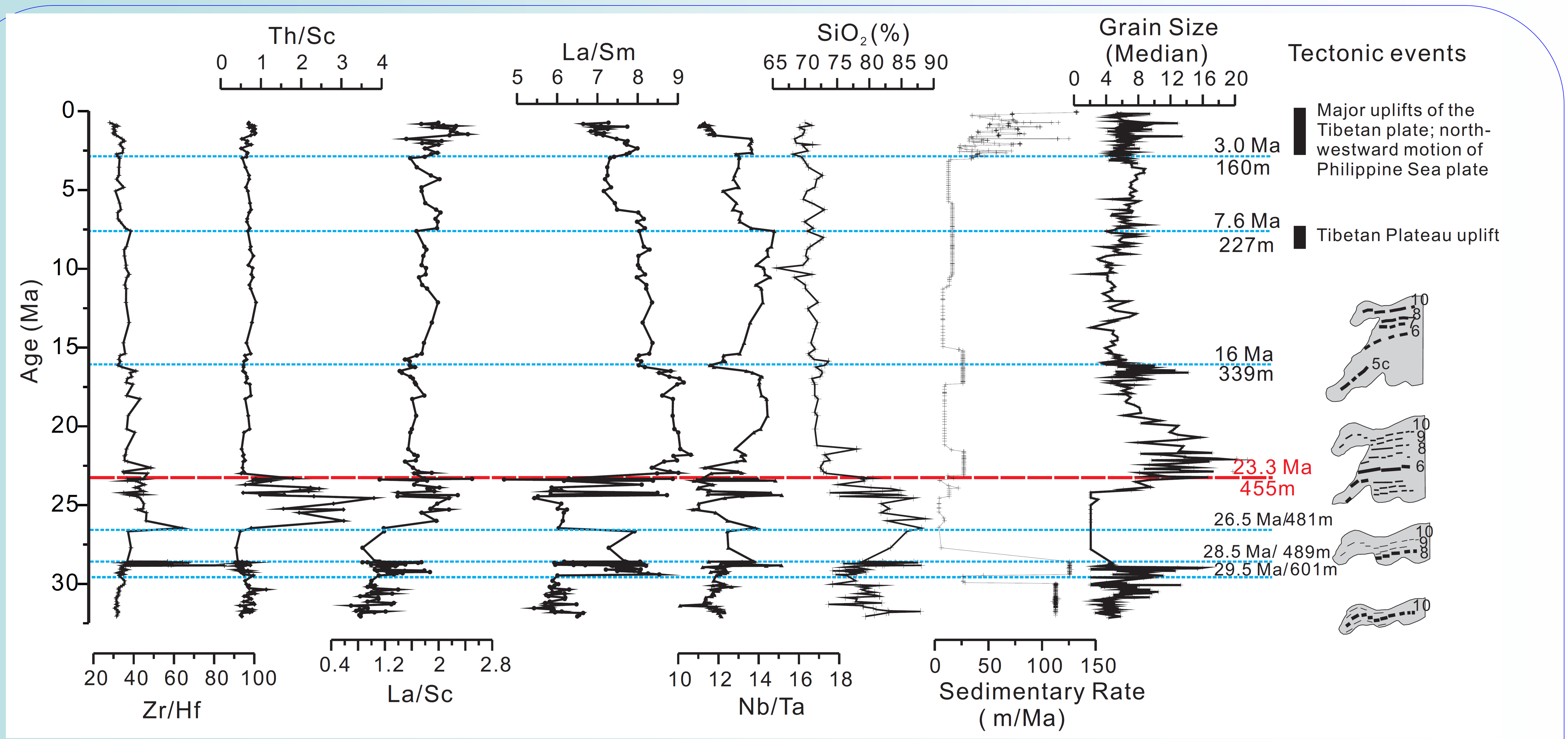

Fig. 2.Stratigraphical variations of trace elements ratios and other variables of the sediments from SCS, showing there are discontinuities at 29.5 Ma, 28.5 Ma, 26.5 Ma, 23.3 Ma, 16 Ma, 8 Ma and 3 Ma. The sedimentation can be subdivided into seven stages since 32 Ma.

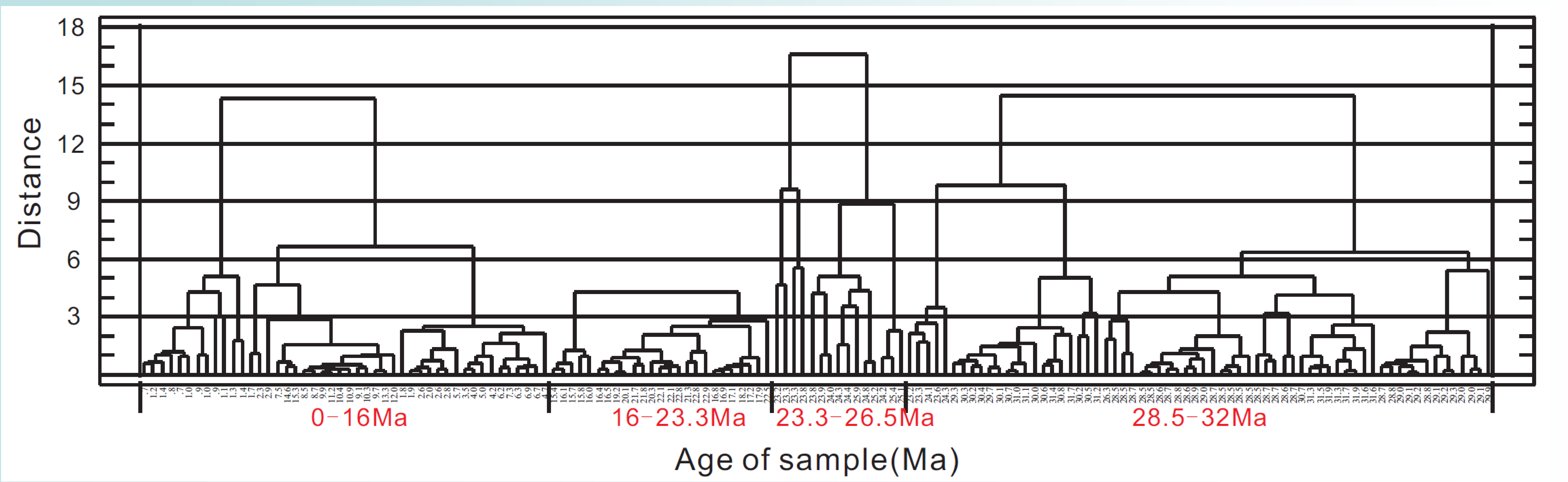

Fig. 3. Dendrogram of cluster data analysis in the SCS using nearest neighbor method. All Samples have been classed into 0-16 Ma, 16-23.3 Ma, 23.3-26.5 Ma and 28.5-32 Ma four groups. Only eight samples have been misclassified (three samples between first and second groups and five samples between third and the fourth groups).

4.Discussion

4.1Major stages of geochemical variation

The results of chemical analyses show that the sedimentation in SCS can be concluded into seven stages: 32-29.5 Ma; 29.5-28.5 Ma; 26.5-23.3 Ma; 23.3-16 Ma; 16-8Ma; 8-3 Ma and 3-0 Ma. There are clear discontinuities in chemical composition among these stages.

And in the most cases the differences of the variables among these time stages are larger than the variation within each partition, except for the samples from 26.5-23.3Ma (Fig. 2).The variables strong change from 26.5 to 23.3 Ma, for strongly deformed and slumped sediments, including some redeposits.

The discriminant and cluster analyses divided the composition of the sediments in the location of site 1148 into four groups (32-28.5 Ma; 26.5-23.3 Ma; 23.3-16Ma and 16-0Ma), indicating that the provenance of the sediments has been strongly changed among them.

The Chondrite-normalised REE plots is characterized as LREE enrichment and a flat HREE pattern (Fig. 4).

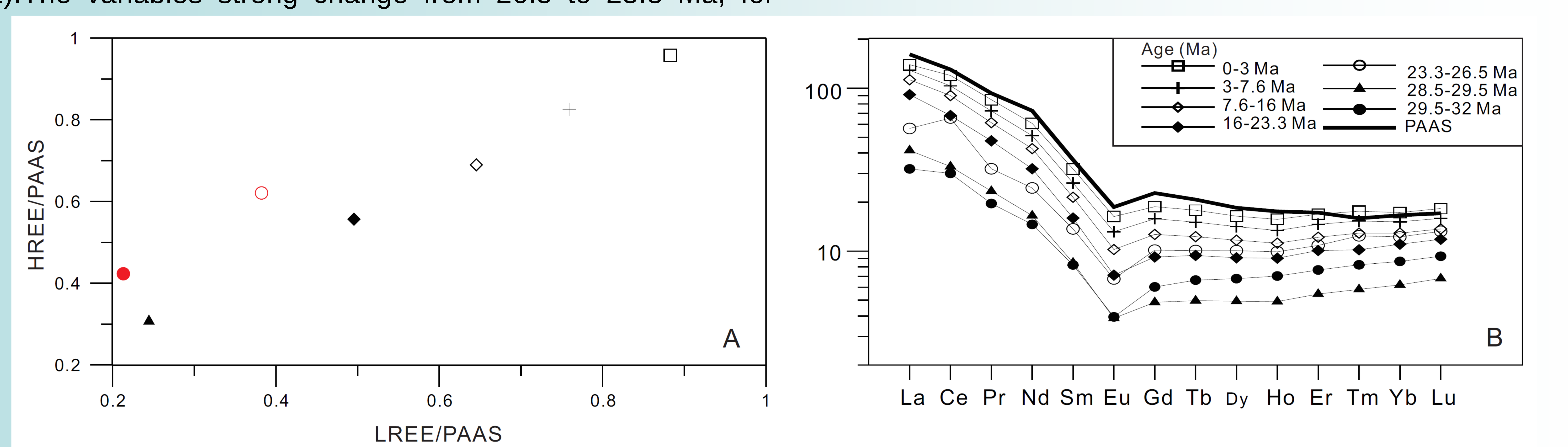

Fig. 4. Chondrite-normalised REE distribution and comparison with PAAS plots, showing the abundance of REE elements in samples is increased onwards, and similar to those of the PAAS at 3-0 Ma stage. But the content of HREE of all samples is generally higher, especially of the samples from 32-29.5 Ma and 26.5-23.3 Ma periods.

4.2 Tectonic evolutional history of SCS

There are several tectonic evens remodeled the sedimentary environment of SCS and thus left their activity trace in the sediments.

32- 29.5 Ma (anomaly 11-10): the initial seafloor spreading is very active. The seafloor spreading brought up basalt volcanic, it thus resulted in more HREE enrichmental basalt composition in sediments on the location of site 1148.

29.5-28.5 Ma (anomaly 9-8): At the time of anomaly 10, seafloor spreading stopped in the northwestern subbasin of SCS, and the spreading ridge jumped and propagated southeastward. Seafloor spreading direction was N-S. The obvious changes happened in La/Sc, La/Sm and Nb/Ta ratios at the boundary in 29.5 Ma (Fig. 2), The cluster data analyses indicates that the provenance of the sediments in this stage is more similar to the last one (Fig 3).

28.5-26.5 Ma (anomaly 8-7): Only little deposit has been received on the location of site 1148. And all physical property records are remarkably discontinuity at 488 mcd (Wang et al., 2000). Therefore, there should be a sedimentary hiatus existed in this period.

26.5-23.3 Ma (anomaly7-6b): The spreading system jumped to the south after anomaly 7, and the ridge began to propagate towards the southwest, leading to the evolution of the southwest subbasin of SCS (Briais et al., 1993). After this tectonic event, all basins along Chinese eastern and southeastern continental margin have been changed from rift basin into depressed basin. The strong volcanic activity existed in this stage, conducing to high HREE contents in sediments (Fig4).

There is a geochemical variable discontinuity at **24.5Ma**, indicating an existing boundary (Fig. 2).

23.3-16 Ma (anomaly 6b-5c) and onwards: The southwest subbasin of SCS continually spread in the direction to NNW-SSE, and stopped at 16 Ma. This is a stable evolutional period of SCS, most of the analyzed variables are uniformity except grain size, which is big at the beginning of the period and decreased late (Fig. 2).

Two main boundaries at **8 Ma** and **3 Ma** are clear, beside 16 Ma. At 8 Ma, the Tibetan plateau rapidly uplifted, and most geochemical variables of samples show discontinuities at this point. At 3 Ma , the major uplift of Tibetan plateau has taken place since last 3 Ma . The rapid uplift of Taiwan area at that time as a result of collision between the Philippine Sea plate and Eastern Asia (Li et al., 1999).

4.3 Provenance change of sediments of SCS

The results of geochemical studies of the well PY33 show that the value of the εNd(0) changed from -9 to -11 in early Oligocene to -12 to -13 in Miocene, reflacting that the sedimentary source zone in northern South China Sea had greatly changed(Li et al., 2003), which explain the consistency of sedimentary source change between the site ODP1148 and the Pearl River Mouth Basin(Fig.5).

The costal area of South China was the main provenance for site ODP1148 and the Pearl River Mouth Basin in Oligocene, and Mesozoic island arc terrace supplied mass sediments for the northern South China Sea and the Pearl River Mouth Basin, meanwhile making the value of εNd(0) at a high level.

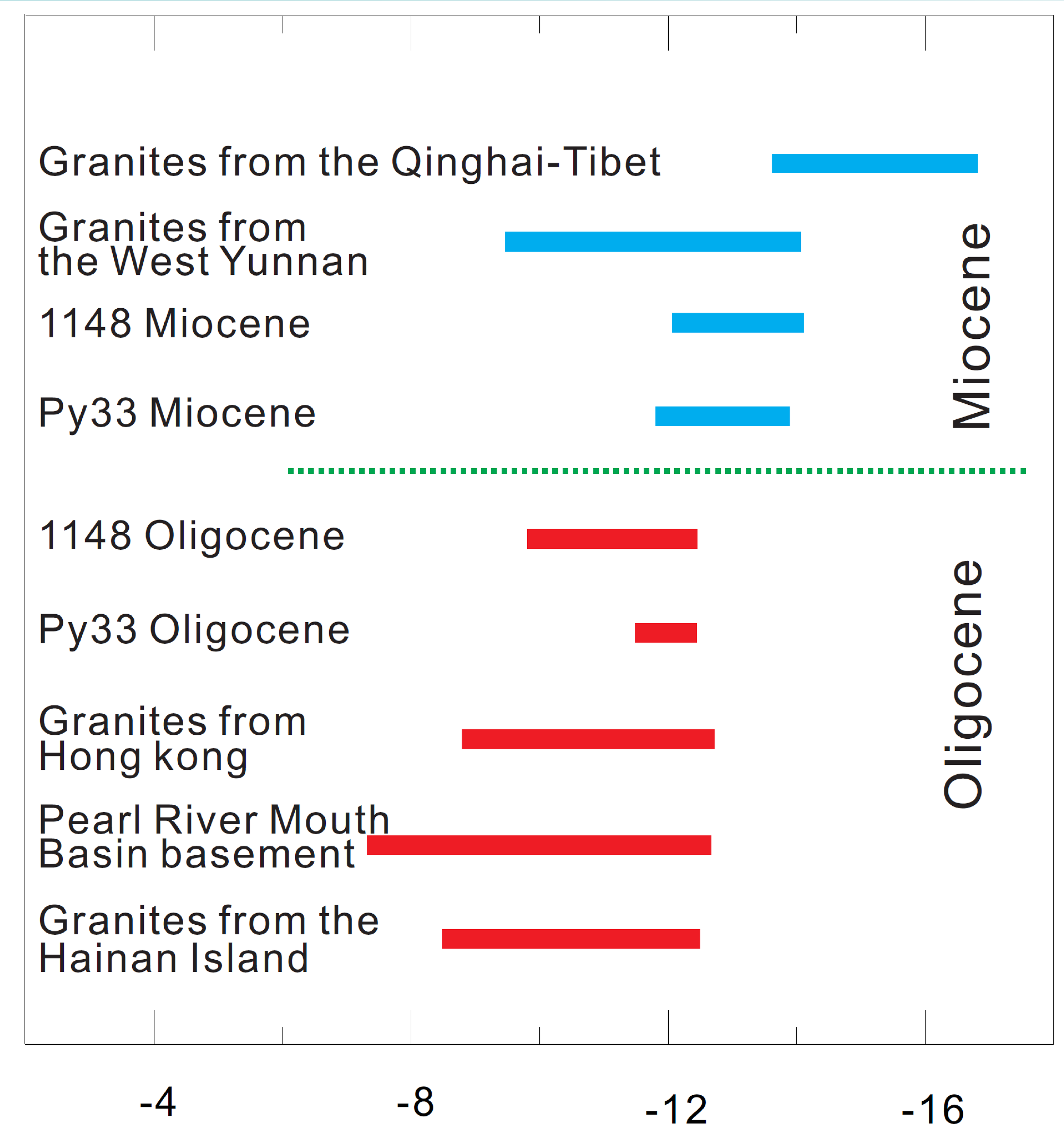

Fig. 5 Comparison of the Nd(0) values of sediments from PY33 and ODP Site 1148 with possible sources surrounding the South China Sea

5.Conclusion

The Geochemical data of sediments from SCS decipher the tectonic implications since 32 Ma on the basis of trends and major discontinuities observed in the stratigraphic succession of geochemical sediments compositions.

According to geochemical data, the sedimentation in SCS can be subdivided into seven stages since 32 Ma: they are **32-29.5 Ma; 29.5-28.5 Ma; 26.5-23.3 Ma; 23.3-16 Ma; 16-8Ma; 8-3 Ma and 3-0 Ma,** respectively. There are relatively large discontinuities between individual stratigraphic trends among these stages, and in most cases the differences of the variables among these time stages are larger than the variation within each partition, except for the samples from 26.5-23.3 Ma. The sedimentary rate and grain size has also changed on these relatively large discontinuities. There are strong deformed and slumped sediments, including some redeposits, existed from 488 mcd to 455 mcd of ODP site 1148 (26.5 to 23.3 Ma), which lead to the chemical variables strongly changed in this section.

The discontinuities between individual stratigraphic trends signify the influence of deformation within the basin and surrounding regions, and the stratigraphic trends line out detailed tectonic evolutional history of SCS since 32 Ma. The provenance of the sediments in the location of site 1148 has been strongly changed at 23.3 Ma, from neighbour areas to hinterland of the South China Block.

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