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## Application of Comprehensive Analysis of Multi-layered System in the Study of Sedimentary Characteristics ——take the Middle Triassic Series Zhifang Formation in the Ordos Basin as an example

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### 1 Introduction

The earth is a complex system of atmosphere, hydrosphere (includes the cryosphere), lithosphere, biosphere and solar-terrestrial space, and it is a dynamic system in which all the components are interacting. The essence of the research method of earth system science is to catch the interaction and evolution among the subsystems of the earth system. According to this understanding, this study is based on the guiding ideology of the earth system scientific research method to comprehensively consider the influence of lithosphere, hydrosphere and atmosphere on the research area, and analyze the sediment source in the research by using paleocurrent direction, paleoclimate, tectonic background analysis, clastic composition, and light and heavy mineral characteristics.

### 2 The overview of research areas

#### 2.1 Geologic aspects

Ordos basin is the earliest and longest evolutionary time sedimentary basin in China. At the same time, it is also the second largest sedimentary basin and an important energy base in China (Li Keqin, 1992). The basin starts from Yinshan mountains in the north, Qin Mountains in the south, Liupan Mountain in the west and Lvliang Mountain in the east, which stretches over Shanxi, Gansu, Shanxi, Ningxia, Neimengu five provinces and regions. The total area is about  $33 \times 10^4 \text{ km}^2$ . Except for the circumjacent basins such as

River Oxbow Basin, Liupanshan Basin, Weihe Basin and Yinchuan Basin, the area of the basin is about  $25 \times 10^4 \text{ km}^2$ . The basin is located in the middle wet of north China craton which belongs to the secondary level structure unit of the craton, and it is a whole stable subsidence, depression migration and obvious wrench movement large multicycle craton basin.

#### 2.2 Study the horizon characteristics

There are several highland denuded zones around the Middle Triassic Ordos Basin. The chief component is made up by ancient metamorphic series around the basin, which includes the north Yinshan ancient land, the northwestern margin of Alashan Goullon, the southern margin and the southwest margin of Qin – Kay fold belt, among which the Zhifang Formation underlying and Heshanggou Formation underlying are parallel unconformable or conformable contact, and are parallel unconformable contact with the group length 10 of overlying extension. In different areas of the basin, the lithologic character of Zhifang Formation is different from upper and lower strata.

#### 2.3 Structural background analysis of provenance area

Provenance refers to the source area of fragmentary material in the basin/parent area, at the same time, it also has rock types, climate and topographic implications of the parent area. Provenance analysis involves several major geological branches, such as mineralogy, geochemistry, geochronology, sedimentology, magma and metamorphic petrology

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(Houghton etc.,1991) .It can provide the most basic materials for the reconstruction of paleogeography and paleoclimate, and it also has great significance to judge the property of plate structure and regional fracture properties.

The quartz rock sedimentary source area represents the recycled orogenic belt, the interior of craton sedimentary basin and the passive continental margin. The source area is generally ancient rock series. The provenance of felsic igneous rocks represents the mature continental margin arc and the continental conversion edge and other environments.

Most of the dosage point fall into the quartz rock deposition provenance and some of them fall into the Felsic volcanic rocks provenance, which indicates that: the provenance in southern part of the basin is the ancient rock system which mainly comes from Qinling Formation in the northern Qinling Mountains area、Kuanping Formation and so on. Permian system starts, because the north China and Yangtze plate go into the frontal crash stage, the north Qinling area continuously uplifts, enhances the ability of applying the provenance to the north, and finally becomes the main sedimentary provenance of the Middle Triassic Series Zhifang Formation in the southern basin of Ordos .( Fig. 1)

At the same time,the content relationship between  $K_2O/N_2O$  and  $SiO_2$  can be used to determine the tectonic environment of sediment formation. (Rose and Korsch,1986). Three tectonic environments can be determined by the diagrams: active continental margin, passive continental margin and oceanic island arc.

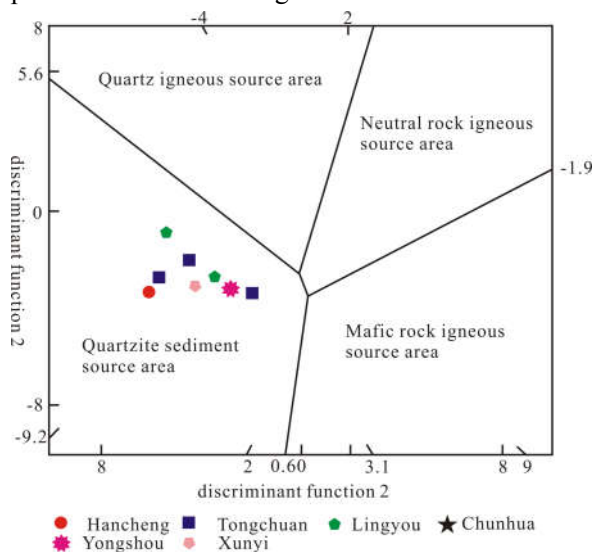


Fig.1The main element function discriminant diagram of the southern Ordos Basin Zhifang Formation Clastic Sediment Provenance characteristic (according to Roser,1988)

Discriminant function  
factor1= $1.773TiO_2+0.607Al_2O_3+0.76Fe_2O_3-1.5MgO$   
 $+0.616CaO+0.509Na_2O-1.224K_2O-9.09$

Discriminant function  
factor2= $0.445TiO_2+0.07Al_2O_3-0.25Fe_2O_3-1.142MgO$   
 $+0.438CaO+1.475Na_2O-1.426K_2O-6.861$

Most of the dosage point fall into the active continental margin, only some individual samples fall into the passive continental margin, which indicates that: when the Zhifang Formation deposits, it is mainly affected by active continental marginal provenance, and the effect of collision between the north China plate and Yangtze plate. (Fig.2)

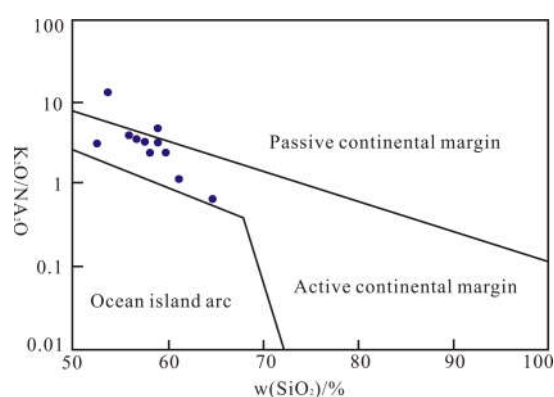


Fig.2 The structural environment discrimination diagram of the south of the basin main elements in Zhifang Formation  
 $K_2O/Na_2O-w(SiO_2)$

## 2.4 paleocurrent analysis

The paleocurrent analysis can help to determine the depositional strike, judge the provenance position, and predict the sedimentary filling distribution and sand body extension direction of the basin. It is an important content and effective method to identify depositional environment and reconstruct paleogeography.

Based on the data of the flow direction of paleocurrent which was measured by the sandstone of the Zhifang Formation in the circumferential outcrop of the basin (which can be concluded that there are two main directions of the sedimentary river system in the basin margin, that is northeast and southwest; the next one is northwestern margin outcrop (Rujigou profile、Hulustai profile) which basic paleocurrent direction is  $110^{\circ}-156^{\circ}$ ; the paleocurrent direction in southern Tongchuan (Jiangshan profile、Jinghe river profile、Liulinchuan) is  $320^{\circ}-25^{\circ}$ . These paleocurrent direction parameters indicate that the Middle Triassic Series Zhifang Formation in Ordos basin has the characteristics of multiple sources and multi-river

system injection (Fig.3).

## 2.5 mineral characteristics

The total grain size of Zhifang Formation sandstone is relatively fine, which is mostly fine sandstone and the content of feldspar and debris is higher. However, the components of clastic particles in different areas of the basin are slightly different.

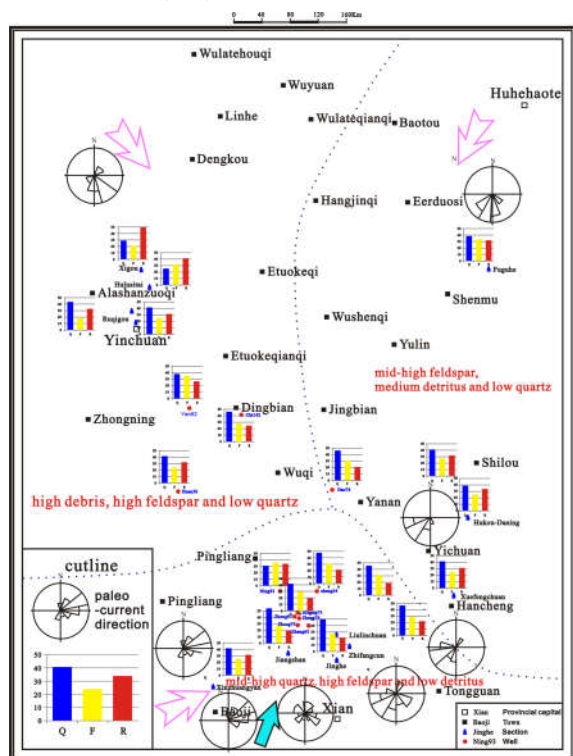


Fig.3 Comparison of light minerals and paleocurrent distribution of the Zhifang Formation in the Ordos Basin

In the northwestern part of the study region, Hulusitai and other areas are dominated by the middle coarse sandstone, which presents high debris, high feldspar and low quartz characteristics. The feldspathic lithic sandstone is the main rock type while the provenance in the south and southwest of the research area is characterized by mid-high quartz, high feldspar and low detritus. Among which the southwestern Pingliang and other areas are dominated by gritstone, and the feldspar-debris is approximately equal. The content of debris is slightly higher than feldspar and the rock types are mainly feldspar-debris sandstone; The size of the sandstone in Tongchuan, Chunhua, Liquan and other southern places is finer and is mainly the fine sandstone. The content of feldspar and quartz is relatively high, and the rock type is mainly debris feldspar sandstone; In the eastern part of the research

area like Fugu-Hancheng and other areas, the sandstone is from coarse to thin, and is mainly fine sandstone which is characterized by medium and high feldspar, medium detritus and low quartz. The content of feldspar and detritus is nearly equal, but the feldspar is slightly higher than detritus and the rock type is mainly detritus feldspar sandstone (Fig.3).

Heavy minerals refer to terrestrial clastic minerals with a density of more than 2.86g/cm<sup>3</sup> in clastic rocks, whose content in the sandstone is generally less than 1%. According to the content, combination characteristics and planar distribution of the heavy minerals, the type of parent rock and the direction of provenance can be reflected. The main heavy minerals in Zhifang Formation of Ordos basin are zircon, garnet, white titanium mine, tourmaline, rutile, epidotite, zoisite and hematite-limonite, etc. which can be inferred that the main types of parent rock affecting the basin are metamorphic rocks and acidic magmatic rocks.

The heavy minerals also show different zoning characteristics in the component of Zhifang Formation detritus. Among which the northeast provenance is characterized by high magnetite + high garnet; the northwest provenance is characterized by high epidote + high garnet; the southern and southwest provenance is characterized by high garnet + high zircon.

### 3 Paleoclimatic indicator

Paleoclimate is one of the important controlling factors for stratum development, and different climatic conditions develop different stratum. Some important sedimentary minerals such as oil, coal and salt, can only be formed in specific climatic environments. Climate is a complex reaction of physical change and action which leaves a mark (stratum) in the geological record, it includes inorganic and organic matters that form stratum. Therefore, people can use various data and information which obtained in the stratum to predict and reconstruct the paleoclimate. This paper sampled the outcrop of Zhifang Formation on the periphery of the basin, and selected typical samples for analysis, so as to infer the sedimentary geological conditions and paleoclimate characteristics at that time.

### 3.1 The element ratios reflect the paleoclimate characteristics

The microelements in sediments are affected by paleosedimentary climate, and different elements are easy to preserve in specific environments (Jin Ming

2003), which include: the humid type element is: Cr, Ni, Mn, Cu, Fe, Ba, Br, Co, Cs, Hf, Rb, Sc, Th; the dry type element is: Sr, Pb, Au, As, Ca, Na, Ta, U, Zn, Mg, Mo, B. The ratio between the dry type element (Sr) and the humid type element (Cu) can reflect the paleoclimate,  $Sr/Cu < 10$  indicates a warm and humid climate,  $Sr/Cu > 10$  indicates a dry and hot climate. Most of the ratios in the southern basin  $Sr/Cu$  are less than 10, only one ratio is greater than 10 and shows warm and moist characteristic (Fig.4).

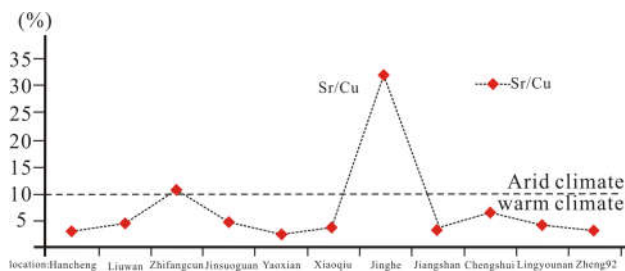


Fig.4 Comparison of light minerals and paleocurrent distribution of the Zhifang Formation in the Ordos Basin  
Basic types of logging curves in different depositional environments of Ordos basin Zhifang Formation

### 3.2 Sporo-pollen analysis

Sporo-pollen analysis is one of the methods to restore the paleoclimate and paleoenvironment. The palynological assemblage reflects the appearance of plant community, and it has a close relationship with the growth, development, prosperity and decline of plants. Therefore, the analysis of fossil sporo-pollen may be parent plant and its growing environment can infer the paleovegetation and palaeoclimate at that time.

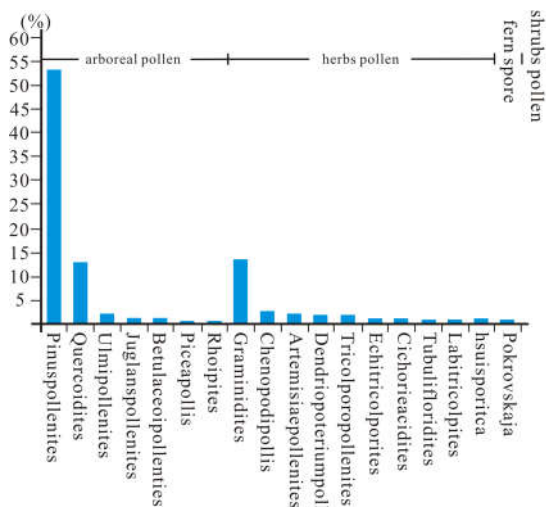


Fig.5 Sporopollen content of Zhifang Formation in Liulinchuan section of Ordos Basin

This study mainly selects two profiles about seven mudstone samples of Ordos Basin Zhifang Formation to analyze spore-pollen in the institute of hydrogeology and environmental geology of Chinese Academy of Geological Sciences. The total terrestrial plant pollen is 1865 grains, the average spore-pollen concentration was 111 grains per gram, find and identify total 40 family and genus plant pollen, which includes 15 family and genus tree plant pollen, 3 family and genus shrub plant pollen, 18 family and genus herb pollen, 4 family and genus fern spore. The arboreal plant pollen is superior in spore-pollen assemblage, the second one is herbaceous plant pollen, the shrub pollen and the fern spores appear sporadically. From the data analysis and speculation, during the Middle Triassic Series Zhifang Formation deposition, the coniferous forest which belongs to forest and spruce genus mainly distributes in mountainous area of the research and the spora lygodii and other ferns grow under it; quercus, ulmus, betula and other broadleaf forests are distributed near the low-relief terrain; The coverage rate of herbaceous plants in plain area is low which mainly grow gramineae, solanaceae, sagebrush and other herbaceous plants. The paleoclimate characteristics of Zhifang Formation have a good consistency with triassic system structural environmental evolution, which indicates that the paleoclimate has changed from the dry and hot climate of the Heshanggou Formation to hot and humid climate (Fig.5).

### Conclusion

1. Using the microelement ratio and the analysis of spore-pollen, the comprehensive judgment of Zhifang Formation depositional stage paleoclimate has changed from the dry and hot climate of the Heshanggou Formation to warm humid climate, and combines with the content of cobalt to analyze ancient bathymetric data, which explains that the water system in the most areas of Ordos basin was developed during the deposition period of Zhifang Formation.

2. According to the tectonic background and the analysis data of light and heavy mineral provenance, it reveals the characteristics of mineral component partition and divides the provenance into northeast provenance, northwest provenance and south-southwest provenance.

3. The parameters of the paleocurrent direction which is measured by sandstone in the Zhifang Formation of the outcrop of the basin shows that the middle triassic series Zhifang Formation in the Ordos

Basin has the depositional characteristics of multiple source and water injection.

4. The analysis data of each layer which includes lithosphere, biosphere, hydrosphere and atmosphere are interconnected and corroborated. Therefore, the sedimentary geological characteristics of the research area are completely presented which reflects the method of earth system scientific research. Nowadays, the earth science is developing rapidly. In the face of the topic of geological research, we should give full play to this guiding ideology.

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