



# Early Yanshanian sedimentary facies and implication for provenance analysis of eastern Yihezhuang Salient, Luxi Area

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**Abstract.** Early Yanshanian is a significant tectonic evolution period for Luxi Area, which is located in eastern North China Block. Analyzing the synchronous sedimentary facies and provenance is of great significance. Based on comprehensive analysis of drilling data, seismic profiles, complemented with geological background and outcrops, the sedimentary facies of early Yanshanian in eastern Yihezhuang Salient, Luxi Area, was recognized as meandering river facies. Moreover, the river flew from north to south, which implicated that the provenance area might be located in north, in accordance with the previous researchers' results.

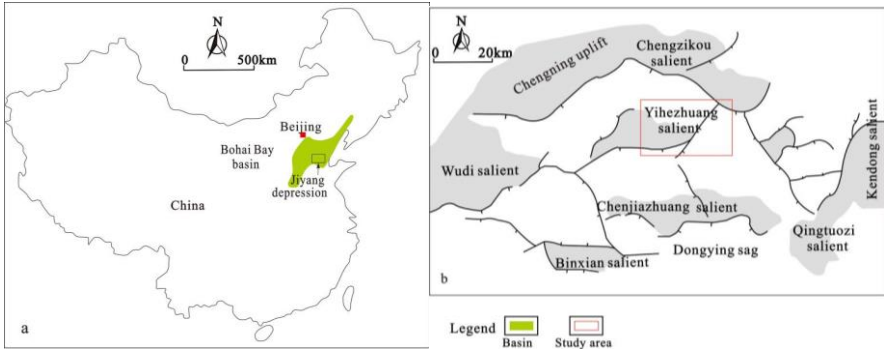
**Keywords:** provenance analysis; early Yanshanian succession; sedimentary facies; meandering river facies.

## 1 Introduction

The Early Yanshanian was an important tectonic transition period for eastern North China Block [1]. The provenance analysis of this period is helpful to determine the tectonic palaeogeographic pattern and analyze the tectonic revolution. Luxi Area is located in the eastern part of the North China Block, and the early Yanshanian strata are well preserved [2]. It is an ideal area and an important window for provenance analysis. However, the existing research results are controversial. Some scholars believed that the Luxi Area was faulted into basins during this period and the provenance mainly came from the south, while some scholars believed that the provenance came from the north [3, 4]. The above disputes caused the ambiguity of the palaeogeographic pattern. This paper takes the eastern part of Yihezhuang Uplift, where the data are relatively complete, as the research area, and carries out sedimentary facies analysis, which helps define the provenance direction from a macro perspective.

## 2 Geological background

Luxi Area is near Jiaobei Terrain and Sulu Orogenic Belt to the east with Tanlu Fault Zone. Yihezhuang Salient was located in the north of Jiyang Depression, which was an important second-order tectonic unit in Luxi Area (Figure 1). During Early Yanshanian period, the Fangzi Formation and Santai Formation were deposited in Yihezhuang Salient.



**Fig. 1.** Geographic location and regional geological settings of Dongying Sag. a: the location of Bohai Bay Basin in China; b: the location of Jiyang Depression and Dongying Sag

## 3 Material and methods

The Mesozoic strata in the eastern Yihezhuang salient are very complicated and turned to be a residual basin due to the strong alteration of late tectonic movement, so it is very difficult to research the sedimentary system [5, 6]. Based on a large number of detailed data, combined with the regional sedimentary background, according to the principle of "point-line-plane", according to the research idea of "combining point with surface, taking point with surface and advancing as a whole", the depositional system of each stratum was systematically researched, and a set of "five-in-one" research method was established for the depositional system of residual basin. "Five spots" refers to using outcrop, core, logging and seismic data to study the sedimentary characteristics of residual basins, and "one" means to study the sedimentary evolution process by using the understanding of basin properties.

## 4 Results

### 4.1 Outcrop contrast

Jiyang Depression and surrounding outcrops have a unified tectonic setting in Mesozoic period, and the lithologic assemblage, sedimentary characteristics and fossil features of the two areas can be compared. Therefore, in order to understand the characteristics of Mesozoic sedimentary distribution in the study area, the adjacent outcrop area can be investigated and studied in detail.

Figure 2a shows fluvial deposits of Early Yanshanian Fangzi Formation in Boshan area, Zibo. There are well normal cycle superposition deposits in three periods of channel, and the lower part of each period is sand body (judged as edge beach) deposition. The lithology gradually becomes fine upward and gradually becomes argillaceous deposition, which is also interbedded with coal seam, and is the product of flood plain deposition. The lower side beach and the upper floodplain constitute a good dual structure of meandering river deposits.

Figure 2b shows fluvial deposits of Early Yanshanian Santai Formation in Boshan area, Zibo. It is the channel inner sand body deposition, the large trough cross bedding well developed, and sand body is purplish red.

Figure 2 indicates that the alluvial and fluvial systems developed during the Early Yanshanian period.



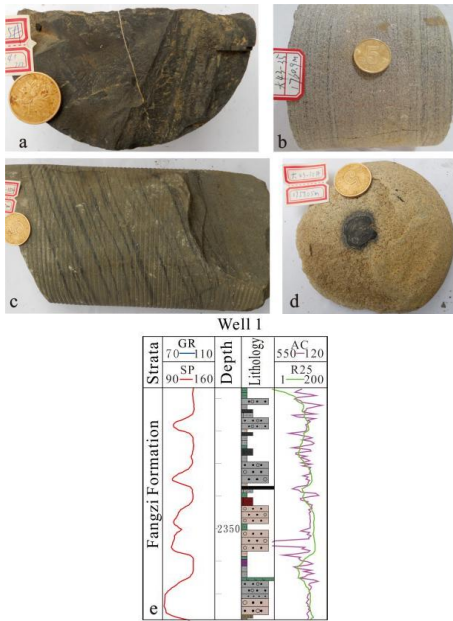
**Fig. 2.** The meandering river deposits in Boshan area, which is located in Luxi Area and near to the study area. a: three periods of channel deposits in Fangzi Formation; b: the trough cross bedding developed in Santai Formation.

## 4.2 Drilling cores

Sedimentary rock is the product of sediment source deposited in the corresponding transport mechanism and sedimentary environment. The former has a good response to the latter three, and the sediments will undergo physical and chemical changes in the process of transport, deposition and burial. By observing the grain size, sorting, grinding, structure structure of drilling cores, we can identify the sedimentary environment and process experienced by drilling cores, and then distinguish the sedimentary facies.

Drilling cores are the first physical data to research sedimentary facies and characteristics of the study area (Figure 3). By observing the grain size, lithology and structure of the core, and through grain size analysis and other tests, compared with the outcrop profile, single well phase analysis can be carried out on key coring wells in the study area, and various sedimentary subfacies and microfacies can be identified.

The Mesozoic sedimentary lithology in the east of Yihezhuang Uplift is mainly clastic rock, mainly sandstone and mudstone. The sedimentary rocks have various color types, including gray and purple red. There are plant root and stem trace fossils in the mudstones (Figure 3a), and the mudstones are dark. Moreover, in some sandstones, the parallel bedding developed (Figure 3b and c), also gravel can be found in the sandstones (Figure 3d). The above sedimentary characteristics often can be found in meandering river facies, showing the provability of meandering river facies developing.



**Fig. 3.** Drilling cores and the bell-shaped logging facies characteristics of the early Yanshanian succession in eastern Yizhehuang Salient. a: the plant root and stem trace fossils; b and c: the parallel bedding developed in sandstone; d: the gravel in sandstone; e: the “dual structure” presented vertical multi-phase superposition, forming the multistage nature of the meandering river depositional cycle.

### 4.3 Logging data

The grain size, sorting and argillaceous content of sedimentary rocks correspond well with the resistivity, natural radioactivity and natural potential of rocks. Because of the correlation between rock physical parameters and sedimentary characteristics, logging curve recording the change of rock physical parameters with depth can reflect lithology, and then reflect the change of sedimentary environment factors such as water depth and water energy, providing valuable information for the identification of sedimentary environment and sedimentation.

A particular sedimentary facies can be defined and distinguished from others by its specific geometric features, lithology, paleontology, sedimentary structure, and paleosurface. A set of logging readings taken at a particular depth in a well that evaluate the characteristics of geologic facies in terms of resistivity, density, acoustic travel time, etc. A set of logging features represents a set of logging facies, which can correspond to geological and sedimentary facies.

In the study area, the log curve showed bell-shaped obviously, and was repeated in vertical (Figure 3). Each bell-shaped curve presented one episode of “dual structure” of meandering river. The “dual structure” got superposed with each other vertically, showing the repeated bell-shaped shape in logging curve.

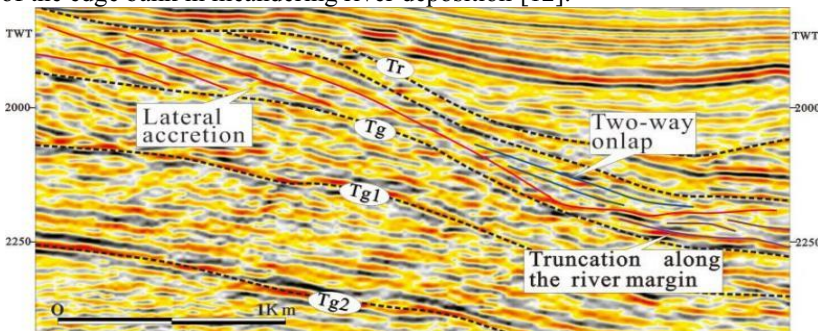
### 4.4 Seismic data

Seismic section is the seismic response of geological section. Seismic section contains a lot of geological information, and the geological phenomena involved in seismic reflection are reflected in the seismic section [7].

Seismic facies is a comprehensive reflection of various features of sedimentary body on seismic reflection profile. Seismic facies is a three-dimensional seismic reflection unit defined by seismic reflection parameters (amplitude, frequency, phase, in-phase axis and reflection structure, etc.), which is the seismic response of a specific sedimentary facies or geological body [8]. From the point of view of sedimentology, seismic facies is the sum of seismic reflection characteristics of sedimentary system or sedimentary facies. Seismic facies study is to interpret sedimentary environment and lithofacies by using sedimentary characteristics reflected in seismic data so as to predict sedimentary bodies more accurately before drilling. Seismic facies represents the geometry, lithologic assemblage, sedimentary process and lithofacies characteristics of the sedimentary bodies that generate seismic reflection [9]. The main parameters or indicators used to study sedimentary systems in seismic facies are external geometry of seismic units, internal reflection structure, amplitude, continuity of reflection in-phase axis, arrangement characteristics of in-phase axis and apparent frequency, etc. The geological significance represented by these seismic parameters is multiple.

Although the seismic parameters have a certain multi - solution, the seismic reflection characteristics of different sedimentary facies are different in certain sedimentary basins and certain tectonic background, sedimentary environment, palaeoclimate and provenance conditions. The seismic reflection characteristics can objectively reflect the sedimentary system to a certain extent [10].

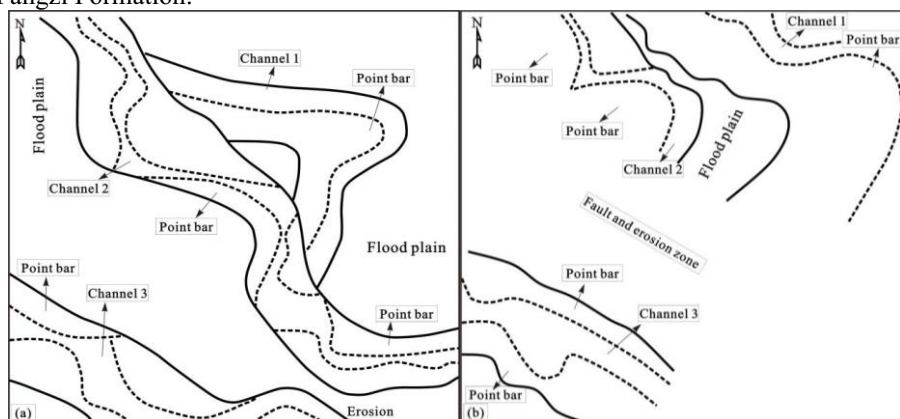
In the study area, the incised filling seismic facies and lateral accretion seismic facies mostly developed (Figure 4). The previous facies refers to the seismic facies formed by filling sediments in the depression. In the seismic profile, the reflection layer is locally concave and forms a valley, inside which, the reflectance presents onlap or progradation with strong amplitude and medium continuity. It reflects the characteristics of seismic reflection of the downstream channel [11]. Such seismic reflection characteristics can be seen in the Jurassic Fangzi Formation and Santai Formation. The lateral accretion seismic facies is the seismic reflection whose coaxial axis is nearly parallel and obliquely intersected with the coaxial axis of upper and lower strata. The coaxial amplitude is medium strong and the continuity is weak, which represents the lateral accretion of the edge bank in meandering river deposition [12].



**Fig. 4.** The incised filling and lateral accretion seismic facies of early Yanshanian succession in eastern Yihezhuang Salient

Plane seismic attributes can be used to analyze the sedimentary characteristics from plane and effectively demonstrate the distribution characteristics of sedimentary facies and provenance direction. On the basis of seismic interpretation, RMS (root mean square) amplitude attributes were extracted for the Fangzi Formation and Santai Formation of the target strata, and the distribution characteristics of attribute plane phase were analyzed, based on which, the sedimentation characteristics were analyzed (Figure 5).

In Figure 5a, the three meandering river channels and extensive flood plain can be recognized in Fangzi Formation. Inside, the meandering river channel showed the high value RMS amplitude attribute band with curved shape, and the flood plain was located on both sides of the river channel with showing mid - low RMS amplitude attribute region with spot miscellaneous shape. It is not difficult to find that river channel 2 was formed by river channel 1 through truncation and straightening, and river channel 1 was abandoned into oxbow lake, whose RMS amplitude attribute was low value curved band. In Figure 5b, three meandering channels are identified in this section from east to west. Among them, the northern channel is 300-500 m wide and the sand bandwidth is more than 2 km. It also has the characteristics of rich sand body and continuous distribution of curved strip sand body along the beach. In contrast, the southern channel is more straight. Compared with the Fangzi Formation, the number of channels decreased during this period, but the width of channels increased significantly, and the proportion of sand body distribution area increased, especially in channel 1, and the area of edge beach distribution was very extensive. It is speculated that the river at this time has strong lateral swing, indicating that the terrain at this time is flatter than the Fangzi Formation.



**Fig. 5.** The sedimentation analysis based on the RMS amplitude attribute of early Yanshanian succession in eastern Yihezhuang Salient. a: the Fangzi Formation; b: the Santai Formation.

## 5 Conclusions

The early Yanshanian succession in eastern Yihezhuang Salient, including Fangzi Formation, Santai Formation, develop meandering river sedimentary facies.

The meandering river flows from north to south, which implies that the provenance area is located in the north through the entire early Yanshanian period, i.e., Jurassic.

## Acknowledgments

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