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Structural Subsidence Characteristics of Ordovician Bottom Interface in the Middle and Eastern Ordos Basin

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Abstract

In order to analyze the structural subsidence characteristics of the Ordovician bottom in the central and eastern Ordo Basin, based on the 25 wells in the central and eastern part of the basin that drilling through the Ordovician, based on the backstripping method, and combined with the previous denudation thickness data, Paleo-water depth data and average density data, the subsidence characteristics of single well and subsidence cycles were studied. The subsidence process of the basin was mainly composed of two rapid subsidence stages and four slow subsidence stages since the Ordovician. The subsidence process could also be divided into three subsidence cycles, which were the Lower Paleozoic subsidence cycle and the Permian-Triassic subsidence cycle, and the Jurassic-Cretaceous subsidence cycle.

Keywords

Ordos Basin; Bottom of the Ordovician; Structural Subsidence Characteristics.

1. Introduction

Since the 1990s, sedimentary basin dynamics analysis has become the main trend of basin analysis, and structural subsidence was an important part of sedimentary basin dynamics analysis. Research on its characteristics can quantitatively restore the construction process of sedimentary basins and discuss the driving mechanism of structural subsidence, exploring the formation mechanism of basins. The research on the characteristics of structural subsidence is mainly based on the backstripping method, after correcting parameters such as ancient water depth, ancient sea level height, denudation thickness, etc., removing the influence of sedimentary material loads to obtain the structural subsidence characteristics of the basin [1].

Previous studies on the structural subsidence of the Ordos Basin were mainly concentrated in the southern part of the basin, the northwestern edge of the basin, and the southwestern edge of the basin[2-4]. The Ordovician salt depression zone in the central and eastern part of the basin lacked a bottom-up and systematic study on structural subsidence. In order to quantitatively restore the sedimentation and construction process of the Ordovician bottom in the central and eastern part of the basin, 25 exploratory wells were used. On the basis of determining the relationship between different lithological porosity and depth, the backstripping method was applied. Combined with the ancient water depth, denudation thickness and other data , the burial history of the basement in the central and eastern part of the basin was quantitatively restored. Combined with the density data of the sedimentary layer of the basin, the structural subsidence history of the central and eastern part of the basin in different periods was finally obtained, the basin subsidence cycle was divided.

2. Regional Geological Background

The Ordos Basin refers to the basin area surrounded by five mountain ranges including Luliang Mountain, Yinshan Mountain, Helan Mountain, Liupan Mountain and Qinling Mountain. It was

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a typical multi-cycle superimposed basin which was developed on the North China Craton [5]. The basin can be divided into six first-level structural units, which are the Yimeng Uplift, Weibei Uplift, West Margin Thrust Belt, Tianhuan Depression, Yishan Slope, and Western Shanxi flexural fold belt (Fig. 1a).

It could be seen from the superficial geological map of the study area and the comprehensive column chart of the stratigraphy that the sedimentary caprocks in the study area were mainly the Lower Paleozoic, Upper Paleozoic and Mesozoic Cenozoic, among which Silurian, Devonian, Lower Carboniferous Some stratums were missing sediments in the ancient and Mesozoic (Fig. 1c). At the same time, affected by the regional uplift of the Late Cretaceous, from west to east, the Cretaceous to Ordovician strata emerge from the new to the old one (Fig. 1b).

There were four unconformities in the study area: the unconformity contact between Lower Paleozoic and Upper Paleozoic, the unconformity contact between Middle Jurassic and lower middle Triassic, the unconformity contact between Jurassic and Cretaceous, and the unconformity contact between Cretaceous and overlying strata(Fig. 1c).

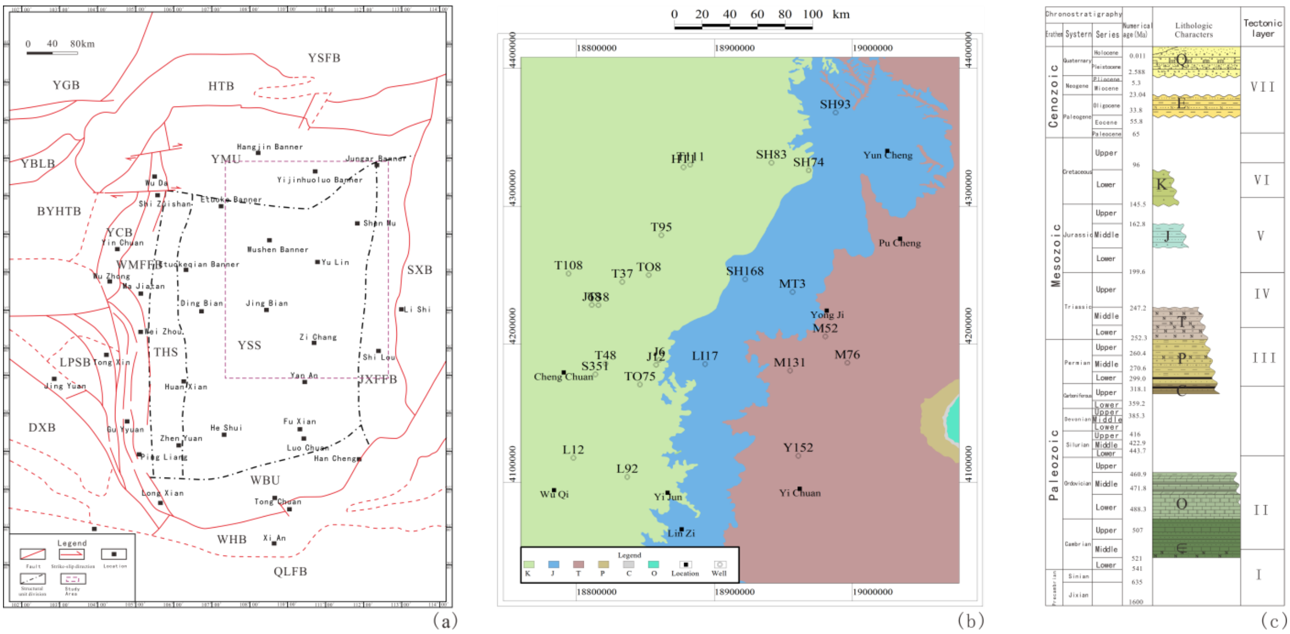

Figure 1. The regional geological background, superficial geological map and comprehensive stratigraphic histogram of study area

3. Main Method

Basin subsidence is mainly composed of two parts: structural subsidence and non-structural subsidence. Non-structural subsidence mainly refers to the subsidence caused by the sedimentary material load and the relative change of the global sea level. The research on subsidence characteristics is mainly based on the stratum stripping method. Based on the invariant model of rock skeleton thickness, under the premise of determining the relationship between the porosity of various lithologies and the depth, and combining the ancient water depth and the erosion thickness correction, the basement subsidence characteristics of the basin were extracted. Then removing the influence caused by the sedimentary material load , the structural subsidence curve was finally obtained. In the actual research process, the research accuracy of structural subsidence was controlled by various lithological porosity changes with depth, ancient water depth, erosion thickness, average density and other parameters. In order to restore the history of structural subsidence in the study area , all the parameters were discussed separately.

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3.1. The relationship between porosity and depth

Based on the measured porosity curve, the relationships between the actual porosity and the sonic time difference curve of various lithologies were established. Then the corresponding porosity curve was obtained from the sonic time difference curve. Based on the porosity data, the initial porosity data and compaction coefficient data of different lithologies could be solved (Fig. 2). It is finally determined that the initial porosity of sandstone is 39.358%, and the compaction coefficient is 0.532. The initial porosity of mudstone is 37.697%, and the compaction coefficient is 0.534. The compaction parameters of limestone and dolomite are empirical parameters. Initial porosity of limestone is 36.94% and the compaction coefficient is 0.672. Initial porosity of dolomite is 42% and the compaction coefficient is 0.59.

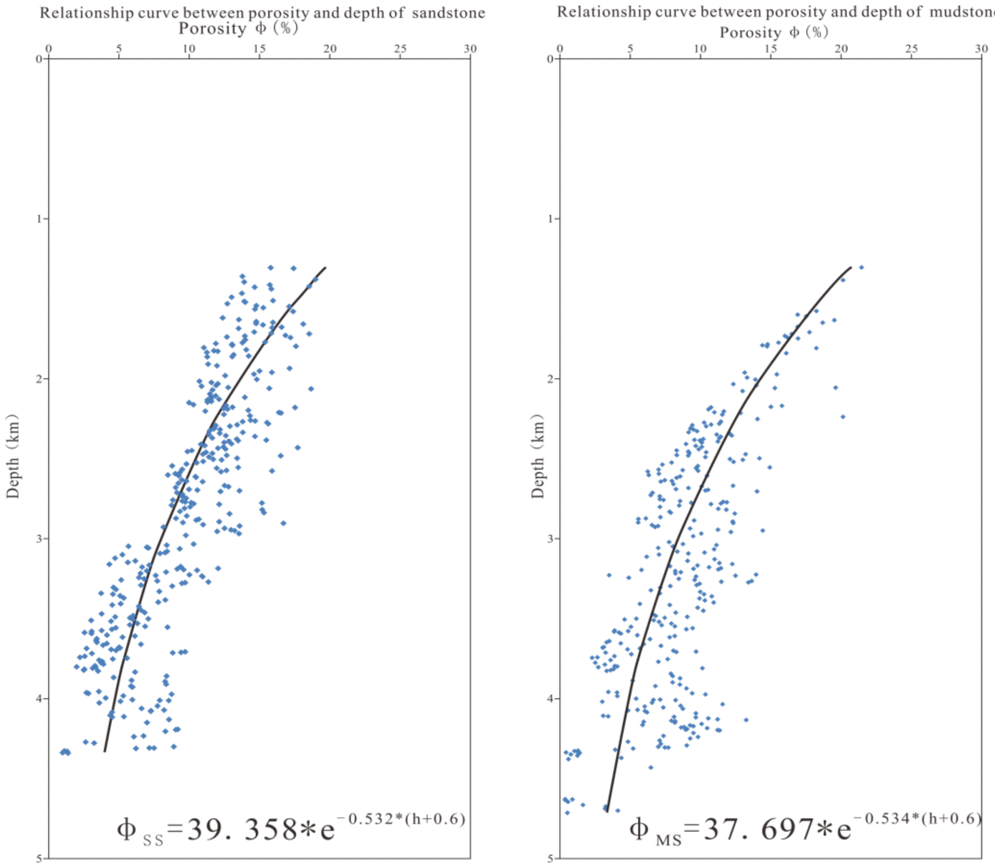

Figure 2. Relation curve between porosity and depth of sandstone and mudstone of Study Area

3.2. Ancient water depth

Paleo-water depth is one of the important factors that affect the accuracy of structural subsidence research. The sedimentary facies was used to limit the water depth this time. From the Cambrian to the Ordovician, marine carbonate rocks were mainly developed, and the depth of paleo-water was 30-50m. The Carboniferous to Permian were marine-terrestrial transitional facies, and the depth of paleo-water bodies was 25-30m. The Mesozoic and Cenozoic were terrigenous clastic deposits, and the depth of paleo-water bodies was 0-25m.

3.3. Erosion thickness

The recovery methods of denudation thickness mainly include geological comparison method, geothermal index method, logging technique method, deposition rate method and other methods [6]. In the study area, the basin-wide large-scale erosion since the end of the Early Cretaceous should applie the combination of mudstone acoustic time difference extrapolation

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and mudstone vitrinite reflectance method to restore the erosion thickness. Periodic denudation during the Yan'an period and the Middle Jurassic period should be restored by geological analysis and comparison method and denudation thickness. Chen Ruiyin's research results was used to control this parameter [7].

3.4. Average density and age of top and bottom interface

Based on the rock skeleton density of different lithologies, combined with the previously calculated porosity vs. depth curve, the average density of each formations were calculated. The age of the top and bottom of the strata mainly adopts the corresponding parameters in the International Year of Stratigraphy (2020).

4. Result

4.1. Typical single well structural subsidence characteristics

After all the parameters were confirmed, the subsidence inversion study of the structural subsidence history could be carried out. In this study, the LI 17 well in the central part of the study area was taken as an example to analyze the structural subsidence characteristics of a single well. Well Li 17 is located 100km east of Chengchuan. According to the superficial geological map, after the Paleogene, Neogene and Quaternary strata were removed, the Jurassic strata was mainly exposed in this area. Judging from the structural subsidence curve, LI 17 has mainly experienced 5 subsidences and 4 uplifts since the Middle Ordovician. The study area during the Middle Ordovician Majiagou period belonged to slow subsidence, with a structural subsidence rate of 7 m/Ma. Later, it was affected by the Caledonian movement and lacked the sediment from the Upper Ordovician to the Lower Carboniferous. The study area during the Permian was in a period of slow subsidence, but the structural subsidence was a tendency of gradual acceleration, from 1 m/Ma in the early stage of subsidence to 5 m/Ma during the early Late Permian. Late Permian period and the early Triassic Liujiagou period were the accelerated subsidence period, and the structural subsidence rate was 22-37 m/Ma. The study area during Middle-Late Triassic was in a period of slow subsidence, with a structural subsidence rate of 10.1 m/Ma. During the Jurassic , only the Anding Formation and Zhiluo Formation were deposited, and the structural subsidence rate was 5 m/Ma. The Early Cretaceous was a period of slow subsidence, with a structural subsidence rate of 7 m/Ma (Fig. 3).

4.2. Subsidence stage division

Through calculation of the corresponding subsidence t inversion parameters, the structural subsidence curve of the Ordovician bottom of 25 wells could be simulated. Based on the structural subsidence curve, the entire settlement process in the study area is divided into three subsidence cycles.

Cambrian-Ordovician subsidence cycle: Due to the limited depth of exploratory wells in the study area, from the perspective of the structural subsidence curve, this cycle was dominated by slow Ordovician subsidence. This cycle included two subsidence phases, a period of subsidence and the period of lack of sedimentation. The rate of structural subsidence in the Majiagou period was 3-12 m/Ma, and there were no deposits from the Late Ordovician to the Early Carboniferous.

Permian-Triassic subsidence cycle: This cycle consisted of two slow subsidence periods and one rapid subsidence period. The subsidence rate of the Permian period was relatively slow during the subsidence period. The structural subsidence rate in the Early Permian was 1-2 m/Ma, then gradually accelerated to 4-6 m/Ma in the Middle Permian. The study area from the Late Permian to the Early Triassic was in a period of rapid subsidence, with a peak structural subsidence of 48 m/Ma. The Middle-Late Triassic was a period of slow subsidence, with a structural subsidence rate of 5-10 m / Ma.

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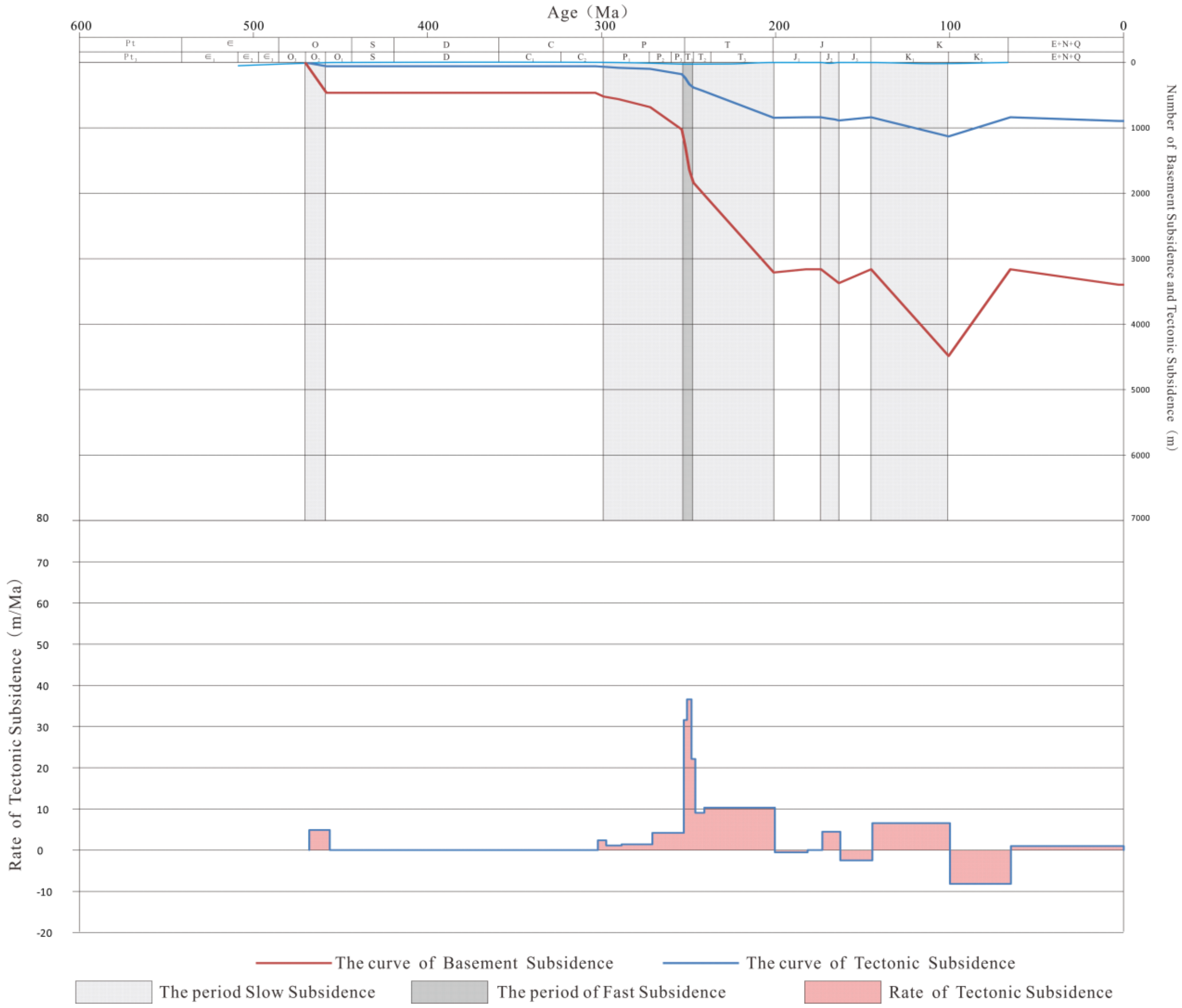

Figure 3. The subsidence's characteristic curve of LI 17

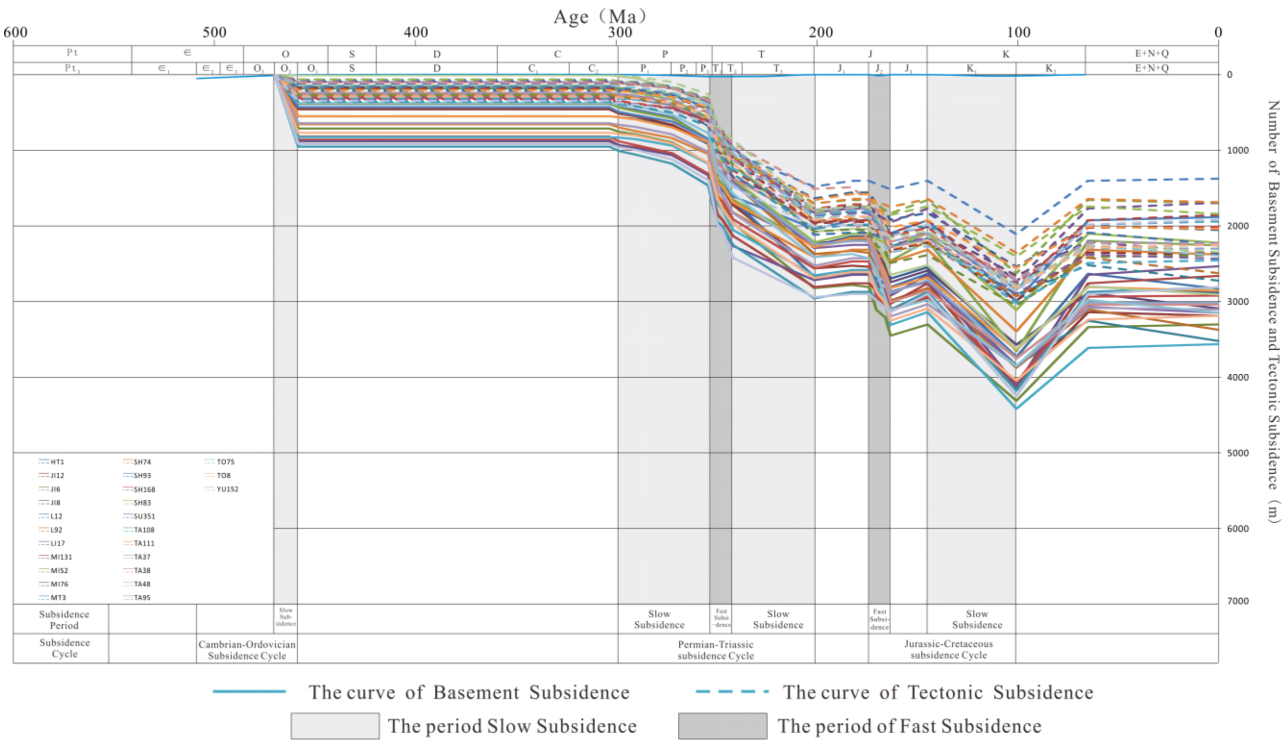

Figure 4. Scheme for division of structural subsidence cycles

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Jurassic-Cretaceous structural cycle: This cycle consisted of a slow subsidence period and an accelerated subsidence period. the Middle Jurassic was the accelerated subsidence period, and the structural subsidence rate was 10-32 m/Ma. The Early Cretaceous was a period of slow subsidence, with a structural subsidence rate of 5-8 m/Ma (Fig. 4).

5. Conclusion

The central and eastern Ordos Basin had mainly experienced 4 slow subsidence stages and 2 rapid subsidence stages from the Middle Ordovician to the present. With the unconformity surface as the boundary, the subsidence could be divided into the Lower Paleozoic subsidence cycle, Permian-Triassic subsidence cycle, and Jurassic-Cretaceous subsidence cycle. The Lower Paleozoic subsidence cycle was dominated by the Ordovician slow subsidence, the Permian-Triassic subsidence cycle consisted of two slow subsidence and one accelerated subsidence. The Jurassic-Cretaceous subsidence cycle had one accelerated subsidence and one slow subsidence.

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