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Characteristics of Jurassic/Triassic Unconformity Structure in Ordos Basin and Its Effect on Oil and Gas

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Abstract

Longdong area is located on the southwest edge of the Ordos basin. As the Indosinian movement at the end of the Triassic led to the uplift and erosion of the Ordos basin, the pre Jurassic ancient landform in Longdong area was formed. The erosion weathering time, erosion depth, late filling, etc. of different geomorphic units are obviously different, forming the unconformity structure of different geomorphic units. After studying the logging curve, element geochemistry, physical property and other data of key well locations in the study area, It is found that the unconformity structure characteristics of different palaeogeomorphic units are different. The results show that the strata above the unconformity are mainly channel filled sandstone, and the logging curves are characterized by high resistivity and low natural gamma; Weathered clay layer is a layer with poor physical properties in unconformity structure. The lithology is mainly mudstone and sandy mudstone. The logging curve is characterized by high natural gamma and low density; The weathering leaching zone has a variety of rock types, and the reservoir connectivity is good. The logging curve is characterized by obvious sawtooth diameter curve and low resistivity, which is mainly developed on the slope of the ancient landform. The impact of unconformity structure on oil and gas accumulation is mainly reflected in that the weathering leaching zone provides a transport system for upward migration of oil. On the other hand, the distribution of weathered clay layers controls the location of oil entering Jurassic reservoirs.

Subject Areas

Geology

Keywords

Longdong Area, Unintegrated Structure, Paleomorphology, Weathering Leaching Belt, Oil and Gas Migration

1. Introduction

Unconformity is a common geological phenomenon. As one of the signs of geological development, it is believed that the occurrence of unconformity is that the stratum has experienced uplift, subsidence and other tectonic movements in a certain area. For a long time, many scholars believe that unconformity is not a simple "surface", but a complete "structural body" with a three-layer structure, which determines the close relationship between unconformity and hydrocarbon migration. Different types of unconformity structures are developed in petroleum basins in China, which affect the formation and evolution of petroleum basins. Therefore, the study of unconformity structure has always been a hot topic in the process of oil and gas exploration and development. At present, the research on unconformity mainly focuses on the identification and classification of unconformity, the vertical structural characteristics of unconformity, and the impact of unconformity on oil and gas [1]. The unconformity structure of the Triassic Jurassic system is obviously affected by the ancient landform. The unconformity structure characteristics of different palaeogeomorphic units are not clear, and the role of unconformity in oil reservoirs is rarely systematically studied. In view of these problems, on the basis of previous studies, combined with the core, seismic and logging data, field outcrop and other data in Longdong area of Ordos Basin, the unconformity structure in this area is analyzed, and the distribution law of unconformity structure and its effect on the oil reservoir are summarized to provide geological basis for further oil and gas exploration and development.

2. Regional Geology

The Ordos Basin is located in the North China Craton, bordering Yinshan Mountains in the north, Qinling Mountains in the south, Helan Mountains and Liupan Mountains in the west, and Luliang Mountains in the east, with an area of about 37×10^4 km^2, including Yimeng uplift, western margin thrust belt, Tianhuan depression, Yishan slope, western Shanxi flexure fold belt and Weibei uplift. From the profile, it is gentle in the east and steep in the west, gentle in the north and steep in the south, showing an asymmetric dustpan syncline [2]. Longdong area is located in the southwest of Ordos Basin. The structural conditions in the area are stable. It is a monoclinal structure with a low west and high east, and the average dip angle is less than 1˚. Nose shaped uplift is developed, which is controlled by the southwest and northeast provenance directions (**Figure 1**). The formation of the pre Jurassic ancient landform has gone through

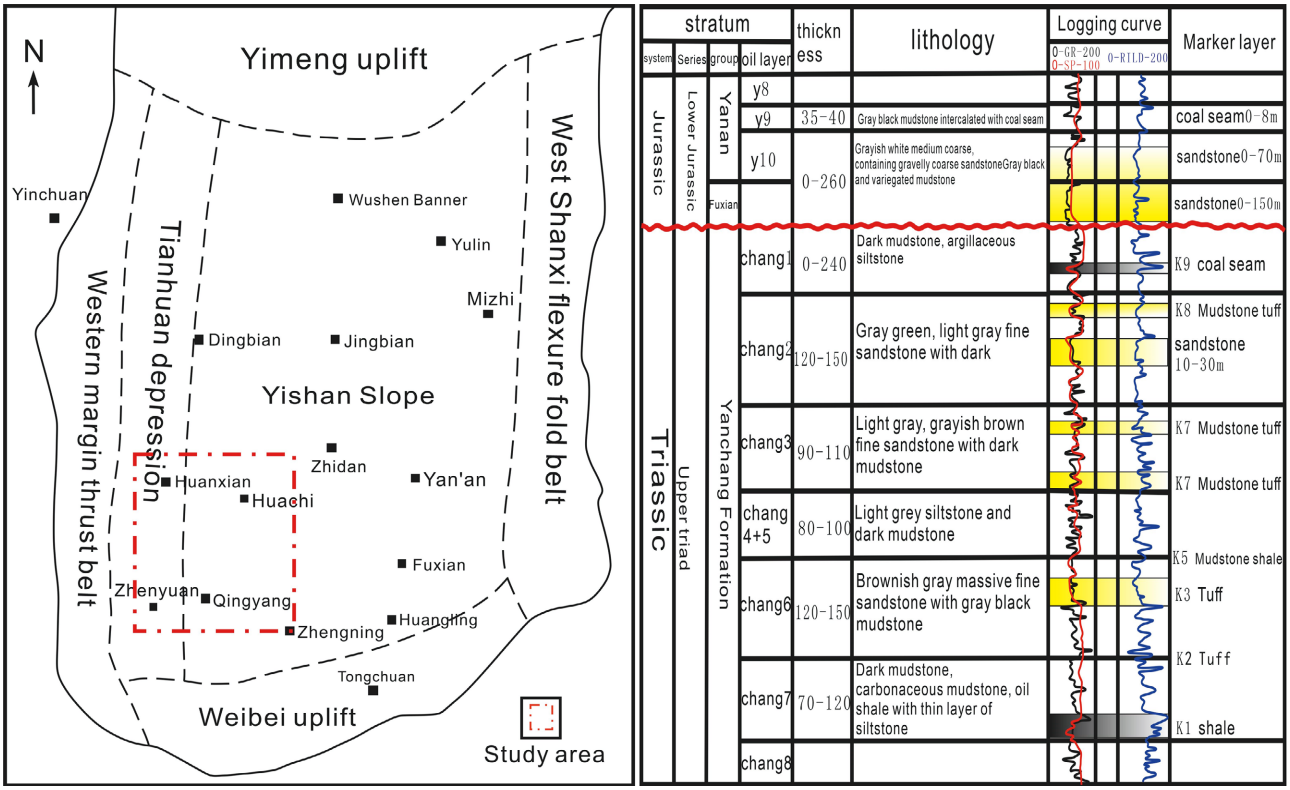

Figure 1. Study area and stratigraphic correlation map of Longdong area.

several periods of tectonic evolution, forming a wide distribution of water systems, vertical and horizontal gullies, rolling hills and ancient landform landscape [3]. The sedimentary characteristics of the upper and lower strata of the unconformity in Longdong area are jointly controlled by the denudation degree of the strata of Yanchang Formation and the characteristics of the pre Jurassic palaeogeomorphology. According to the characteristics of the sedimentary cycle and the marker bed, the Yanchang Formation and Yan'an Formation are divided into 10 oil bearing formations from top to bottom, namely, Chang 1-Chang 10 and Yan 1-Yan 10 or Fuxian Formation (**Figure 1**).

3. Division and Characteristics of Unconformity Structure

Unconformity is the product of long-term discontinuous sedimentation of the stratum. During this process, the stratum exposed to the surface has experienced a certain degree of weathering and denudation. The different depths of the exposed stratum also indicate the different degrees of weathering and denudation suffered by the stratum. The unconformity surface also shows a hierarchy in the longitudinal direction, which is the so-called unconformity structure. The unconformity structure undergoes different degrees of weathering and denudation, which has certain differences in macro and micro aspects [4] [5] [6]. To sum up, based on the analysis of field outcrops, logging data and other data, the unconformity in Longdong area is divided into three layers: rock stratum above the unconformity, weathered clay layer and weathered leaching zone (**Figure 2**).

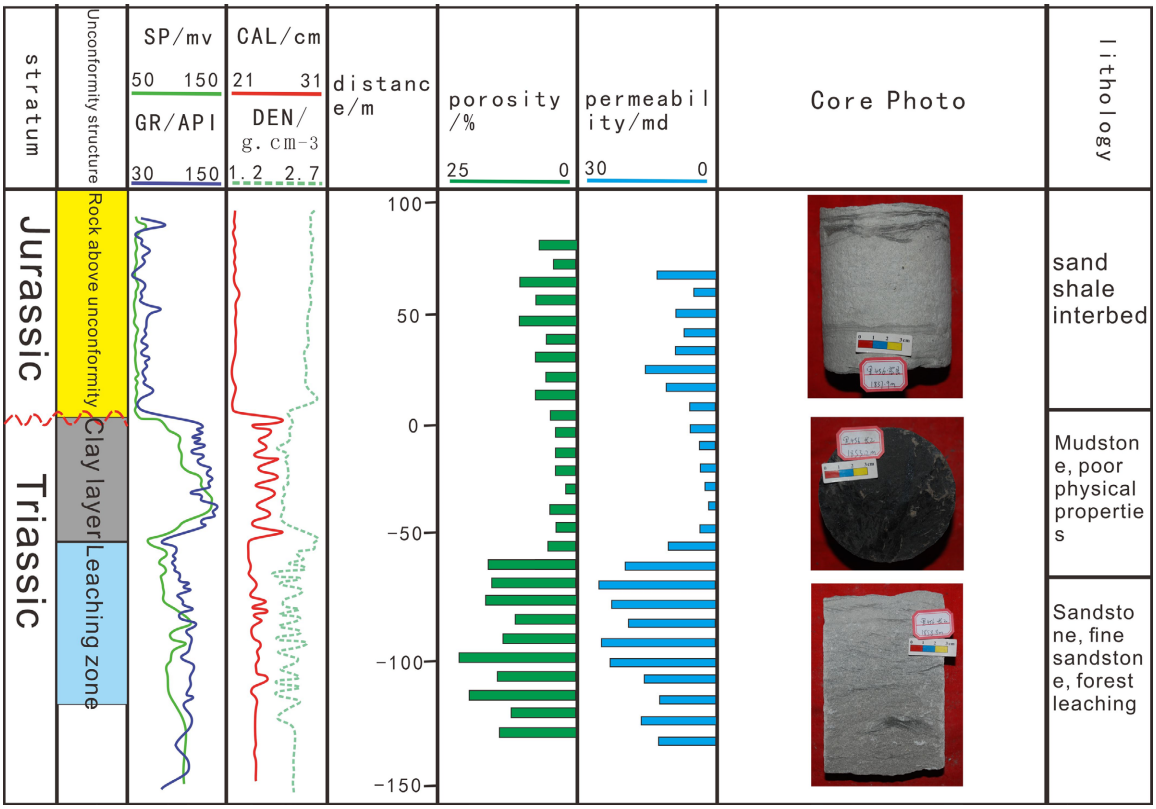

Figure 2. The basic characteristics of unconformed structure.

3.1. Structural Characteristics and Identification

1) Rock above unconformity

The rock types of the strata above the unconformity are mainly sandstone and argillaceous sandstone. It is mainly characterized by good porosity and permeability, and is a good oil and gas migration channel and reservoir. Due to the influence of strong tectonic movement, the unconformity structure of different palaeogeomorphic units in Longdong area is different. The logging curves of the strata above the unconformity are characterized by low spontaneous potential (SP), low natural gamma (GR), and low caliper curve (CAL). The thickness of rock strata above the unconformity in Longdong area is different, and the thickness of rocks above different palaeogeomorphic units is different, generally between 20 - 150 m (**Figure 3**).

2) Weathered clay layer

Weathered clay layer, located on the weathering leaching zone, is a residue mainly composed of mudstone formed by weathering and later sedimentation and compaction. Most of it is mudstone and sandy mudstone, which can be used as a good cap rock. The development degree of weathered clay layer varies in different areas, and the loss of weathered clay layer may also occur in some areas. Due to the different migration capacities of different element contents in rocks, the elements of rock minerals are decomposed and transformed during weathering. The weathered clay layer is relatively rich in aluminum, iron, manganese

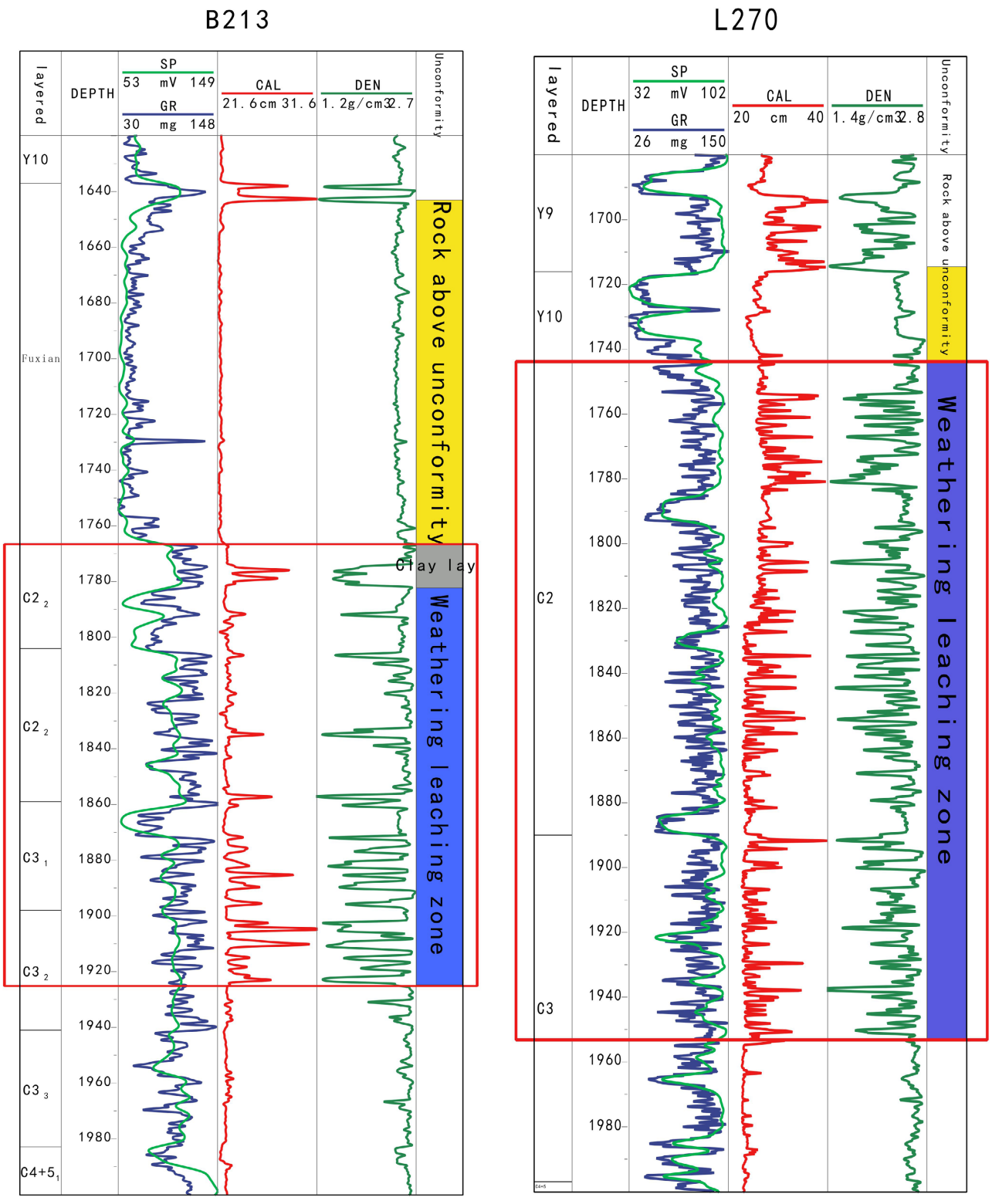

Figure 3. Logging response characteristics of unconformed longitudinal structures.

and other inert elements that are not easy to migrate, while the content of calcium, magnesium, potassium, sodium and other active elements is relatively low. The weathered clay layer can be well identified by the content table of major

elements of Well L456 (Figure 4).

The weathered clay layer in the unconformity structure of Longdong area is combined with different ancient geomorphic units. The thickness of the weathered clay layer is also different, and its development location is different. Due to the continuous scouring of ancient rivers, the weathered clay layer is missing at the ancient geomorphic river channel and at the steep slope, and developed at the highland and gentle slope, with a general thickness of 8-20m. The weathered clay layer is characterized by high natural gamma ray (GR) and low density (DEN) (Figure 3).

3) Weathering leaching zone

The weathering leaching zone is an important part of the unconformity

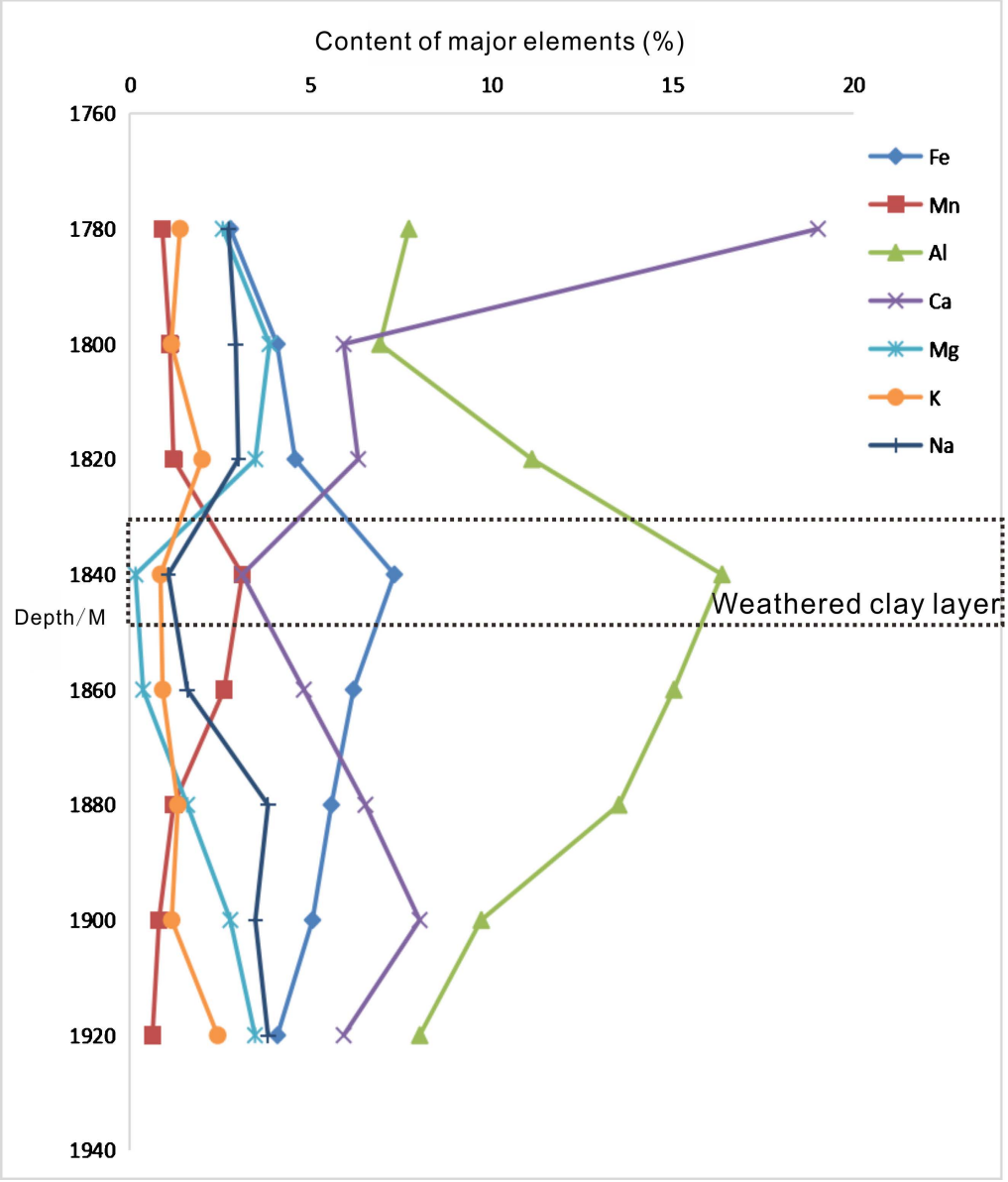

Figure 4. The relationship between the content of major and trace elements and the depth of Well L456.

structure. Because the weathering of rocks is not complete and the rocks are subject to the long-term leaching of atmospheric fresh water, the weathering leaching is mainly physical weathering and chemical action. In the process of unconformity development, atmospheric fresh water enters under the surface through cracks, so that secondary solution pores and cracks are developed in the weathering leaching zone, thus improving the rock porosity and permeability of the weathering leaching zone (Figure 5). At the same time, leaching is also accompanied by dissolution. Feldspar, rock debris and other minerals in the weathering leaching zone are subject to dissolution, generating a large number of pores and fractures, which has greatly improved the physical properties (Figure 5). The weathering leaching zone in Longdong area has a variety of rock types with good physical properties. The thickness of each well section is different. The characteristics of the logging curve are as follows: well diameter curve and acoustic time difference are sawtooth obviously, and high and low density are interbedded, which are mainly developed on the slope of the ancient landform. The thickness is generally 80 - 260 m (Figure 3).

a) Feldspar and quartz are enlarged, with intergranular pores and intergranular dissolved pores. Well M25, 2226.5 m; b) Kaolinite filled with pores, with intergranular pores and feldspar dissolution pores, well L44, 1925 m; c) Ferrite calcite is used to fill the pores, with intergranular pores, feldspar dissolution pores and intercrystalline pores. Well Z88, 1477.7 m; d) Corroded intergranular pore, well Y4, 2111.9 m.

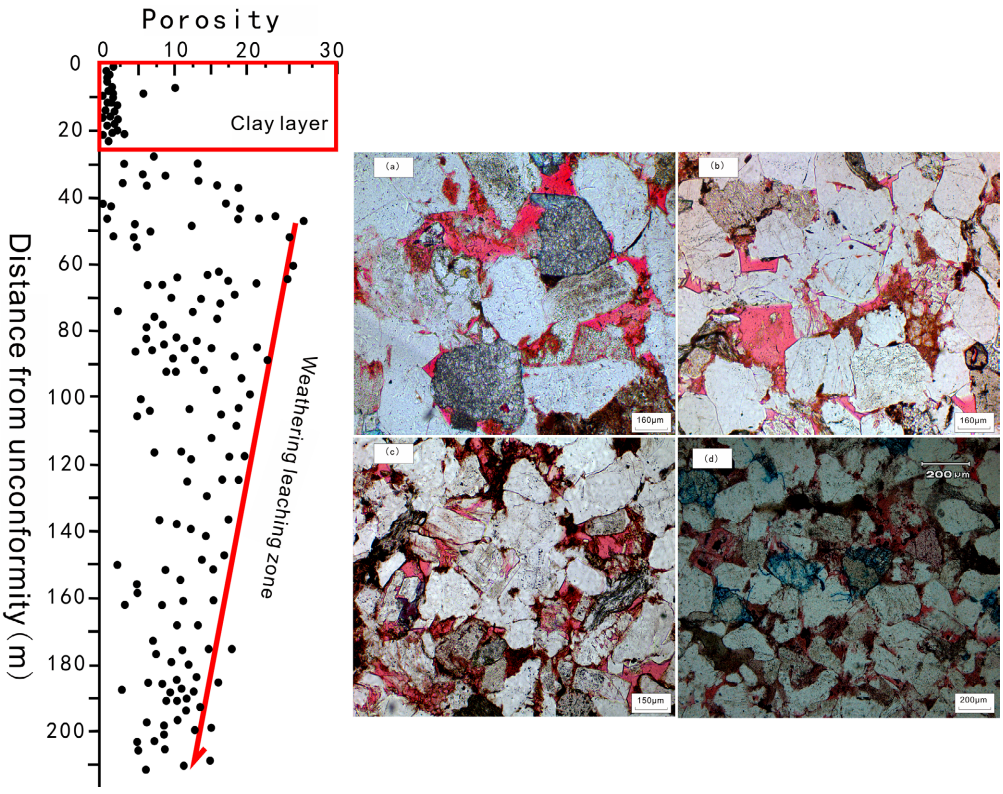

Figure 5. Physical properties and pore types of weathering leaching zone of unconformity structure.

3.2. Distribution Characteristics

1) Longitudinal distribution characteristics

It can be seen from the east-west distribution map of unconformity structure in Longdong area (Figure 6) that the continuity of rock stratum above the unconformity is good, the weathered clay layer is relatively thin, the weathered clay layer of Well X43 and Well X29 at the river channel of geomorphic unit is missing, the thickness of the weathered leaching zone is related to the ancient geomorphology and topography, and the depth of the ancient river channel is relatively large. Because of long-term water infiltration in this area, the weathered leaching effect is the best, and the overall continuity is good; It can be seen from the north-south distribution map of unconformity structure in Longdong area (Figure 7) that the rock stratum above the unconformity first thickens and then thins from north to south, and the river channel is the thickest. The weathered clay layer is relatively thick near Well Y522 and Well M89, and the weathered leaching zone is deep in the river channel and thin at the slopes on both sides. On the whole, it conforms to the characteristics of ancient landform and topography in Longdong area.

2) Layout characteristics

According to the plane distribution characteristics of the unconformity structure (Figure 8) and the ancient geomorphic characteristics of Longdong area, it is believed that the rocks above the unconformity are generally developed in this area, and the thickness of different ancient geomorphic units is different. The thickness of the rocks above the unconformity at the riverway in the study area is about 70 - 150 m, and the thickness of other places is thin. According to the characteristics of the rocks above the unconformity, the lithology is mainly sandstone and argillaceous sandstone, which is a good oil and gas transport layer; The distribution characteristics of weathered clay layer are obvious. It can be seen from the figure that the weathered clay layer is relatively developed at the highland and slope of the ancient geomorphic unit, with large thickness, less development or even missing at the river channel. The weathered clay layer is mainly composed of mudstone, with poor porosity and permeability, strong oil and gas shielding capacity, and is the main cover layer; the distribution feature of weathering leaching zone is that the slope of paleogeomorphic unit is relatively developed.

4. Oil Control Effect of Unconformity Structure

1) Oil control effect of weathered clay layer

According to the thickness of weathered clay layer at the well site in the work area, the bottom plane distribution map of weathered clay layer thickness in the study area (Figure 9) is prepared, and the proven Jurassic oil reservoir is superimposed for analysis. It can be seen from the figure that the weathered clay layer in the study area is unevenly distributed, with a thickness of 0 - 15 m generally and more than 20 m locally. The weathered clay layer on the plane is thin

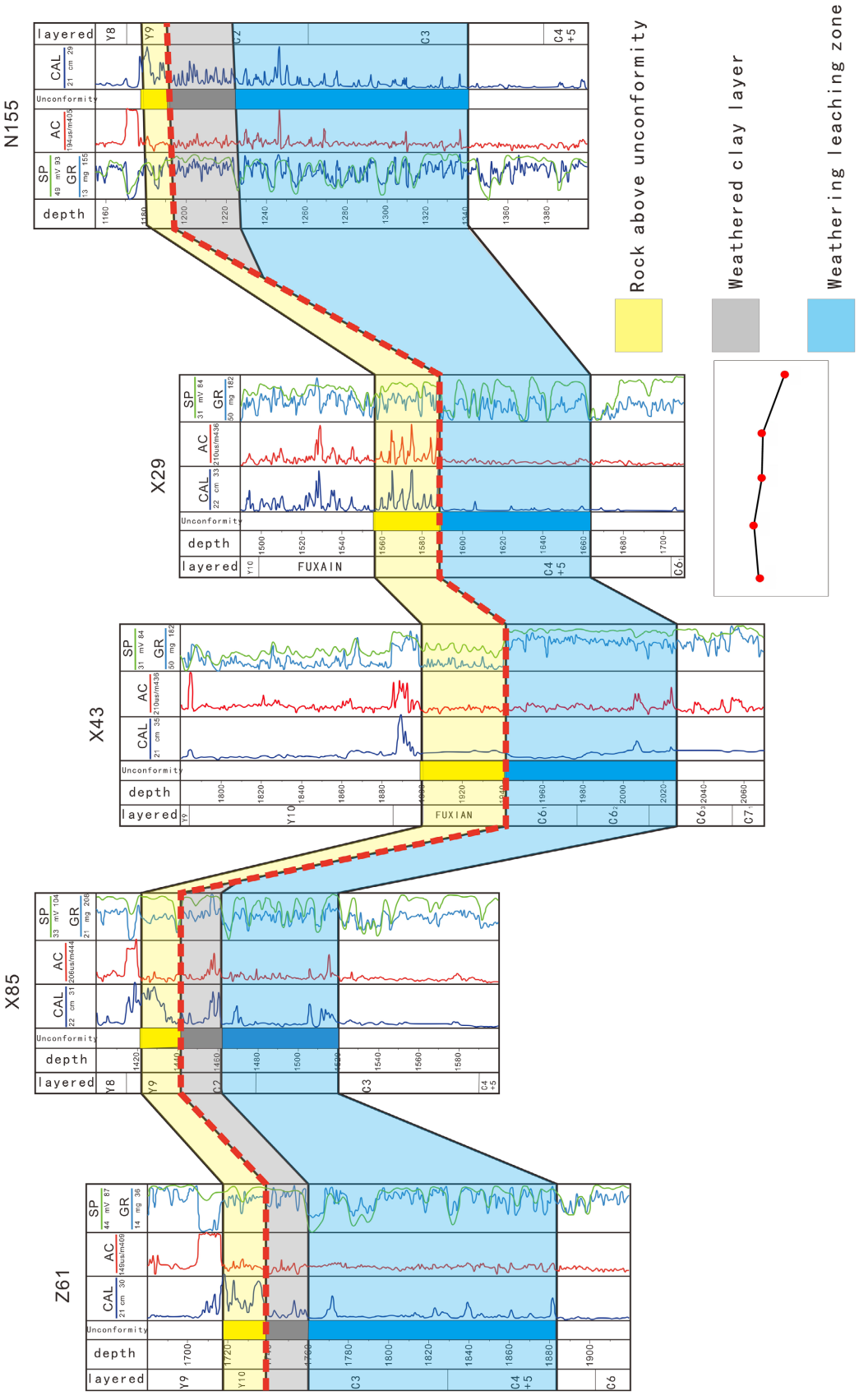

Figure 6. East-west structural characteristics of unconformed structures.

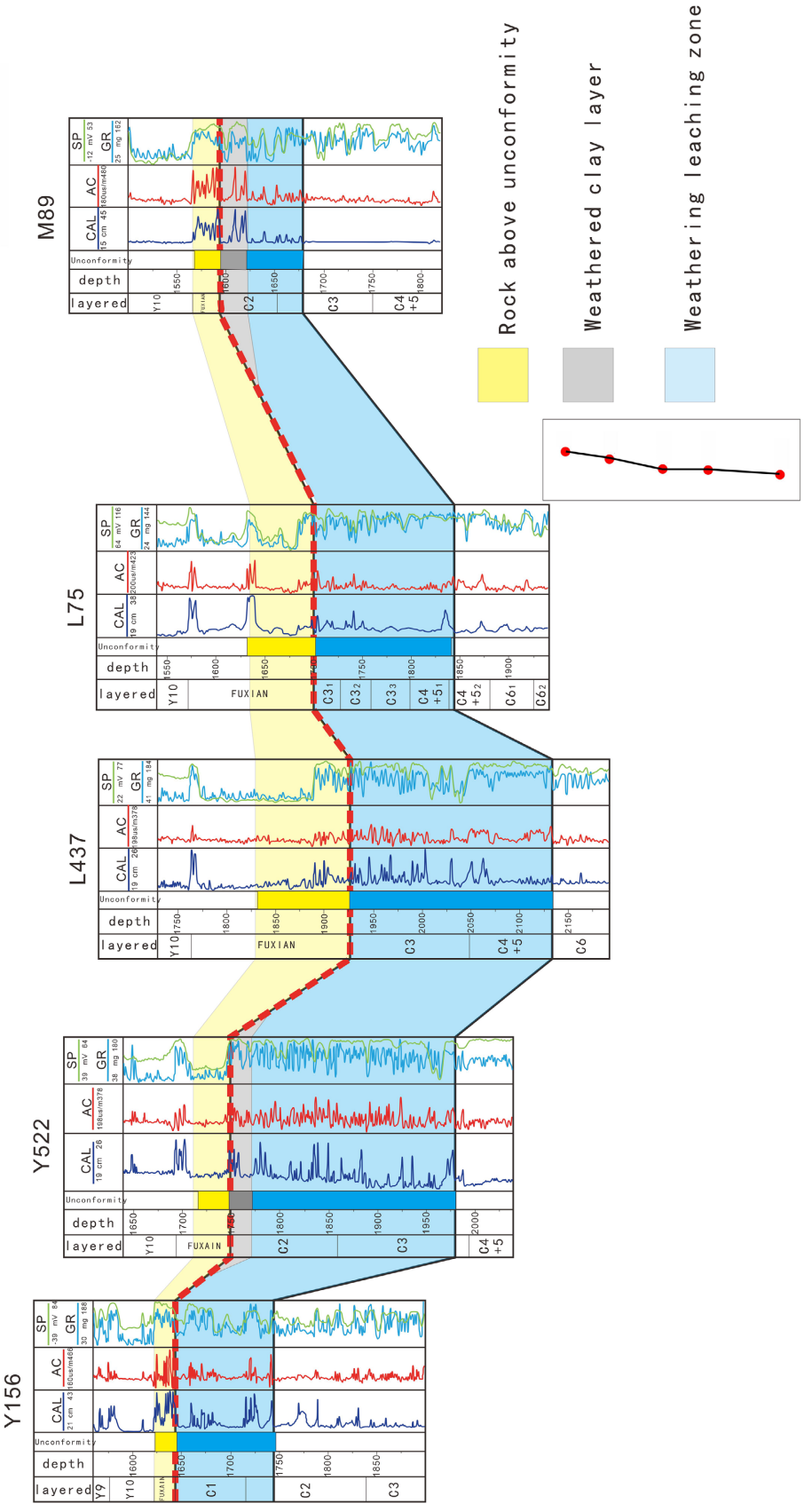

Figure 7. North-south structural characteristics of unconformity structures.

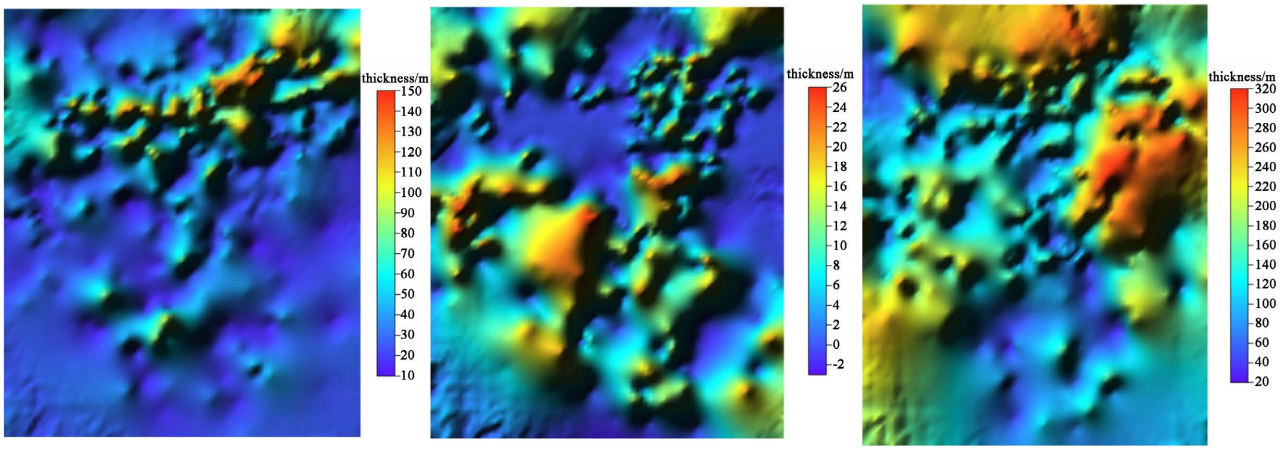

Figure 8. Unconformity structure plane distribution.

and thick and distributed in a sheet shape, which has a certain correlation with the ancient geomorphic unit. The river channel and steep slope are thin and even missing, and the gentle slope area and highland area are relatively thick, which is due to the erosion intensity of the river channel and the lithology of the underlying stratum. There is a strong current in the deep river channel for a long time, which makes the weathered clay be taken away or washed away by the water, while the gentle slope area has a gentle slope, and the weathered clay layer with weak water flow is easy to preserve. Because the lithology of unconformity upper and lower strata in this area is mostly sand mudstone interbedding, which leads to the discontinuity of weathered clay layer distribution. It can be seen from **Figure 9** that Jurassic oil reservoirs are mainly distributed in areas where weathered clay layers are not developed, and the reservoir location is affected by the thickness of weathered clay layers, which also reflects the sealing effect of weathered clay layers on Jurassic oil, providing guidance for the prediction and distribution of favorable areas in the later period.

2) Migration and accumulation model of unconformity structure reservoir

In combination with the reservoir profile, the Jurassic reservoir forming model in Ordos Basin (**Figure 10**) is finally established, which well explains the characteristics of Jurassic reservoir such as small scale, multiple strata and scattered distribution. The reservoirs in the upper part of the Yanchang Formation and Jurassic reservoirs are mainly controlled by the thickness of the source rock in the upper part of the Chang-7 Formation [7]. The reservoirs near the thick layer area are relatively developed. The reservoirs in the Yanchang Formation and Jurassic reservoirs are complementary. The early hydrocarbon expulsion was due to the abnormal pressure of the source rock, and the buoyancy played a role after entering the high permeability layer [8] [9] [10]. The fault, fracture and weathering leaching zone became effective oil transport system. Weathered clay layer plays a capping and sealing role for oil migration to the Jurassic system. Oil enters the Jurassic system from the area where the clay layer is not developed, resulting in the characteristics of scattered oil reservoirs on the plane. The oil across the un-

conformity surface forms reservoirs in the area where the sand body is developed. The main type is structural oil reservoir. After the lower oil reservoir is full

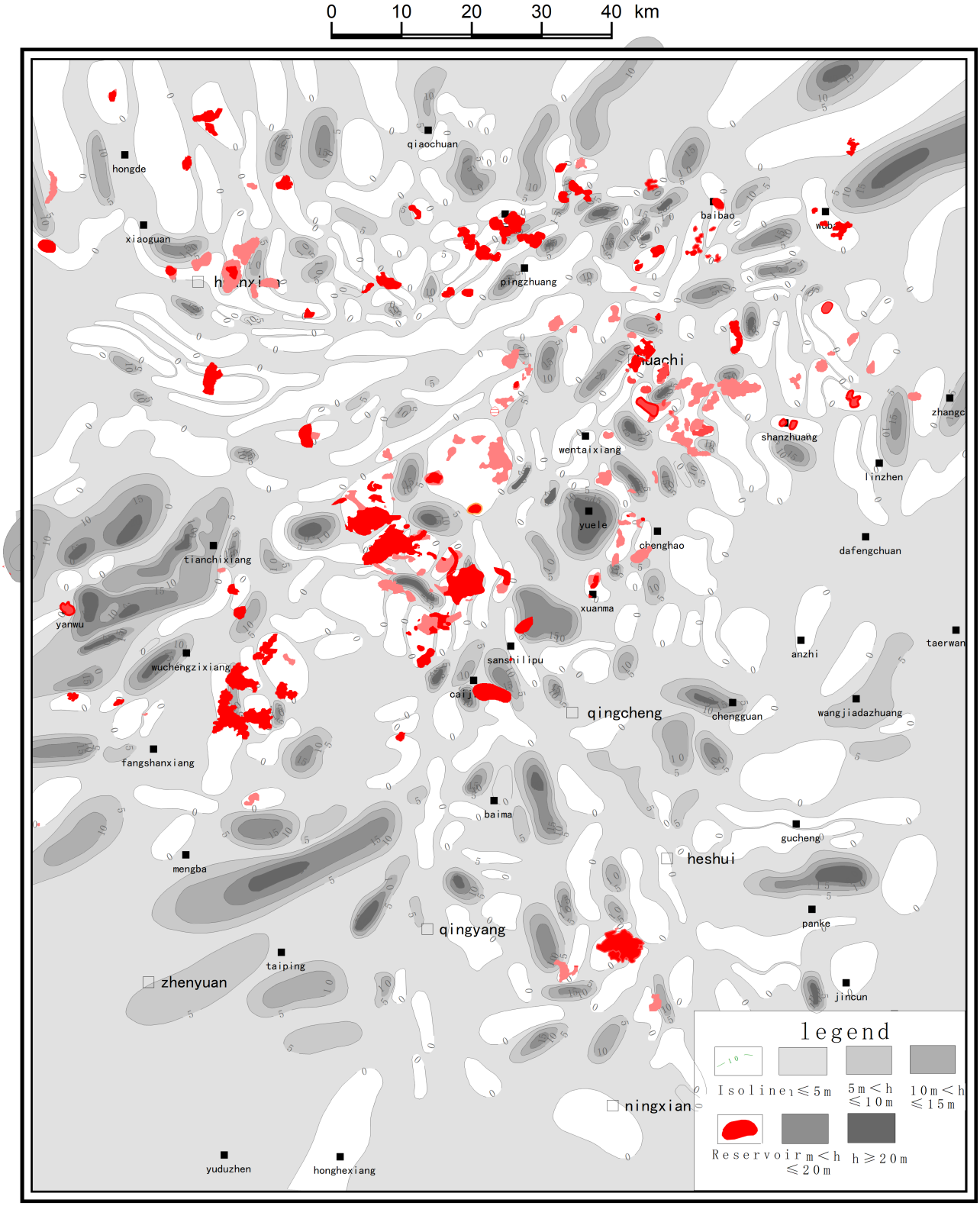

Figure 9. Thickness distribution of weathered clay layer and Jurassic reservoir distribution map.

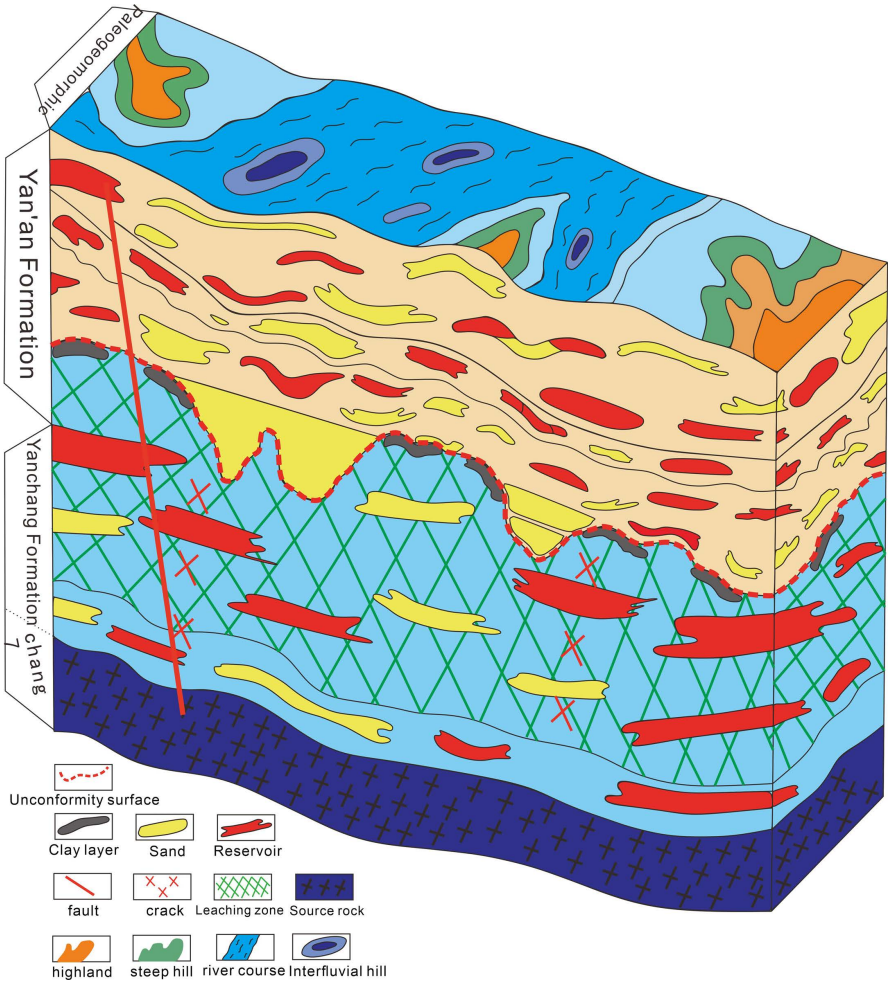

Figure 10. Unconformity structure accumulation model map.

of overflow, it continues to migrate upward or laterally for a short distance, resulting in the relatively developed Jurassic oil reservoir [11] [12] [13].

5. Conclusions

1) According to the data of well logging and the characteristics of ancient geomorphology in Longdong area, it is believed that the strata above the unconformity are generally developed in this area; The weathered clay layer is mainly developed in the highland and slope of the ancient geomorphic unit, but not in the river channel; The weathering leaching zone is mainly distributed on the slope.

2) The thickness of unconformity three-layer structure is different in different palaeogeomorphic units, but it is basically controlled by the palaeogeomorphology, which is consistent with the characteristics of the palaeogeomorphology in Longdong area; the weathering leaching zone in the unconformity structure provides the main pathway for the upward migration of oil. The distribution of weathered clay layer controls the location of oil entering Jurassic reservoir, and the reservoir forming model of Jurassic reservoir is established according to the

characteristics of palaeogeomorphic unit.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Pan, Z.X. (1983) The Importance of Unconformity for Oil and Gas Migration and Accumulation and the Search for Some Oil and Gas Reservoirs under Unconformity. *Geological Review*, 374-381.

[2] Zhao, J.X. and Chen, H.D. (2006) Evolution of Gansu Shaanxi Ancient River in Ordos Basin in Early and Middle Jurassic. *Petroleum and Natural Gas Geology*, 152-158.

[3] Fu, G. and Duan, H.F. (2005) Characteristics of Unconformity and Hydrocarbon Transport. *Daqing Petroleum Geology and Development*, 13-16+105.

[4] He, D.F. (2007) Unconformity Structure and Hydrocarbon Accumulation. *Petroleum Exploration and Development*, 142-149+201.

[5] Zhu, J., Li, W.H., Han, Y.L., *et al.* (2010) Study on Pre Jurassic Paleogeomorphology and Reservoir Formation Law in Longdong Area. *Journal of Sedimentology*, 28, 1229-1237.

[6] Yang, Y. and Meng, X.L. (2007) Types and Accumulation Rules of Stratigraphic Oil and Gas Pools. *Xinjiang Petroleum Geology*, 647-649.

[7] Guan, W. (2019) Structural Characteristics of Permian Triassic Unconformity in Luliang Uplift Belt of Junggar Basin. Master's Thesis, China University of Petroleum, Beijing.

[8] Zhang, K.Y., Ai, H.G. and Wu, Y.J. (1996) Unconformity Structural Layer at the Top of Carbonate Rock and Its Significance for Oil Control. *Petroleum Exploration and Development*, 16-19+82.

[9] Sun, X., Li, L. and Ding, C. (2016) Unconformity Structure Types and Migration Characteristics in Hangjinqi Area of Ordos Basin. *Petroleum and Natural Gas Geology*, **37**, 165-172.

[10] Li, H.Q., Pu, R.H., Qu, H.J., *et al.* (2017) Discussion on Well Logging Identification Method of Unconformity between Triassic and Jurassic in Ordos Basin. *Journal of Northwest University* (*Natural Science Edition*), **47**, 577-584.

[11] Yuan, Z., Li, W.H., Zhu, J., *et al.* (2013) Restoration of Jurassic Palaeogeomorphology in Longdong Area of Ordos Basin and Its Impact on Oil Accumulation. *Geological Bulletin*, **32**, 1806-1814.

[12] Li, Y.H., Yang, G.R., Peng, J., *et al.* (2020) Formation and Evolution of Pre Jurassic Palaeogeomorphology and Sedimentary Filling Characteristics of Ordos Basin. *World Geology*, **39**, 56-71.

[13] Fan, W. (2020) Sand Body and Unconformity Transport System in Pengyang Area and Their Impact on Oil Migration and Accumulation. Master's Thesis, Northwest University, Xi'an.