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Research on the Development Characteristics and Stages of Cracks in Dongjiahe River Using Tilt Photogrammetry Technology

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Abstract

Cracks are important migration channels and storage spaces for oil and gas, and the peripheral cracks in the Ordos Basin have developed extensively after multiple tectonic movements. Using unmanned aerial vehicle oblique photogrammetry technology to obtain field outcrop image data and establish a three-dimensional model for observation, the NEE and NNW fractures are the most developed in the Yanchang Formation of the study area, while the NW and NNE fractures are slightly developed, all of which are high angle vertical fractures and belong to regional structural fractures. The NNW oriented cracks are restricted by the NEE oriented cracks and developed in the late stage. Combined with the analysis of regional geological background, fracture intersection relationship and tectonic stress field, it is considered that there are two stages of fractures in Dongjiahe, namely, the late Indosinian and Yanshanian.

Keywords

Tilt Photogrammetry Technology, Field Outcrop, Yanchang Formation, Crack Developing Feature, Formation Stages

1. Introduction

Yan'an area is located in the southeast of Ordos Basin. Its tectonic position is at the junction of the syncline of the Western Shanxi fold belt and the Weibei uplift belt. After multiple tectonic movements, folds and faults around the basin are widely developed, and the internal structure is simple. Fractures are the main structural features in the basin. The Yanchang Formation reservoir in the study area is a typical low porosity and low permeability reservoir (Liang et al., 2009),

which is mainly characterized by poor physical properties, tight lithology, low production and strong heterogeneity, which increases the difficulty of exploration and development. These fractures have greatly improved the reservoir performance, and the study of the development characteristics and distribution of fractures plays an important role in the exploration and development of the oilfield. Fractures in reservoirs are important migration paths and reservoir spaces for oil and gas, and their development directly affects the permeability of reservoirs (Zhang et al., 2015; Su et al., 2023). In the process of waterflooding development (Zhao et al., 2018), well pattern deployment and related technical policy-making, the occurrence and effectiveness of fractures are very important factors. Many achievements have been made in the study of natural fractures in Ordos Basin, such as: Wang Qiyu and others (Wang et al., 2011) have systematically studied the characteristics and causes of fractures in Yanchang Formation in Jiyuan area based on field profiles, drilling cores, logging data and microscopic identification data; Wang Rui and others (Wang et al., 2014) analyzed the fracture characteristics and formation mechanism of organic rich shale in Chang 7 member of Yanchang Formation of Triassic in the basin based on field outcrops and core observations; Zhang Linyan and others (Zhang et al., 2006) Quantitatively predicted the distribution of structural fractures in the Triassic Yanchang Formation in the Zhenyuan Jingchuan area of the basin based on outcrop strata, drilling cores, and rock slices.

Although there are a lot of previous research results on fracture characteristics in Ordos Basin, the research areas are generally concentrated in Jiyuan, Huangling and Yanchi areas, and the research content focuses on fracture characteristics and control factors, but the research on its genesis and formation period is less. In this paper, the fracture of Dongjiahe Yanhe section of Yanchang Formation in Yan'an area of Ordos Basin is selected as the research object. The UAV telemetry technology is introduced to obtain the high-resolution image of Dongjiahe field outcrop area. The 3D real scene model of the study area is established by using the 3D real scene modeling software, and the characteristics of fracture occurrence are extracted, in order to summarize the characteristics of structural fractures in the study area, analyze the formation period, and provide a scientific basis for oil and gas exploration and development of Yanchang formation.

2. Geologic Background

Ordos Basin is located in the west of North China Craton, which is a Mesozoic sedimentary basin formed by multiple superimposed tectonic events (Dang et al., 2005). It is the earliest sedimentary basin formed and has the longest evolution history in the Chinese mainland. The basin is composed of six major tectonic units (**Figure 1**), including Yimeng uplift, Weibei uplift, Western Shanxi fold belt, Yishan slope, Tianhuan depression and western margin thrust belt (Zhao et al., 2012; Zhao et al., 2013). The basement of the basin was inclined from west to East before the Indosinian period; During the Indosinian period, with the subduction

of the Pacific plate to the Asian continent, the eastern part of the basin was gradually uplifted by compression; During the Yanshanian period, the compressive stress was further enhanced, resulting in the significant uplift of the eastern part of the basin and the formation of a West dipping monocline. According to the stratum exposed at the eastern edge, the uplift amplitude in the East is at least more than 3 km. In the Himalayan period, the basin continued to rise and eventually evolved into a monoclinal structure with a dip of about 1˚ to the West (Zeng et al., 2007; Li et al., 2022). Under the influence of multi-stage regional tectonic movement, there are three groups of basement faults in NE, NW and EW directions in Yanchang Formation of Ordos Basin (**Figure 2**), and fractures are widely developed in sedimentary cap rocks in the basin. The Triassic Yanchang Formation in Yan'an area is mainly characterized by low porosity and low permeability reservoirs. Therefore, the fracture development horizon studied in this paper is in the Triassic Yanchang formation. The fracture characteristics of Yanchang Formation in Yan'an area are analyzed, and the parameters such as strike, dip angle and density are counted.

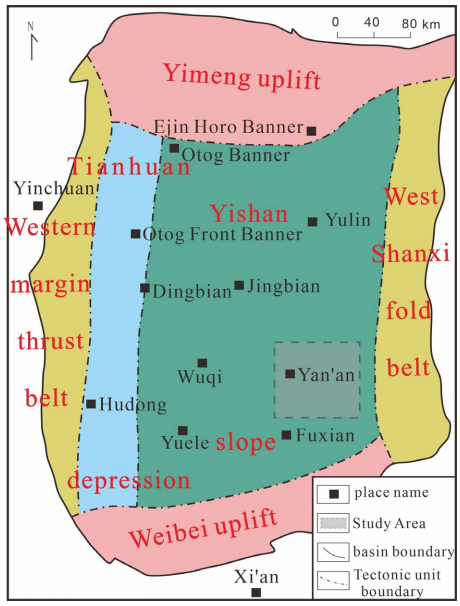

Figure 1. Structural unit map of Ordos Basin.

3. Oblique Photogrammetry Technology and Technical Route

3.1. Oblique Photogrammetry

Tilt photogrammetry technology breaks the restriction that traditional aerial survey and remote sensing can only be taken from the vertical direction. This technology uses multi rotor UAV platform equipped with multiple camera lenses to collect data from different angles (Wan et al., 2019; Yin et al., 2021). The consumer UAV is easy to operate. It can quickly obtain the field outcrop image data with the UAV Ground Station. It can not only truly reflect the high-precision ground texture information, but also realize the high-resolution and high-precision three-

dimensional measurement and modeling of the ground through advanced positioning, fusion and modeling technologies. It has the advantages of low cost, high efficiency and good security (Lian et al., 2020). At present, the oblique photogrammetry technology has been applied to the practical production process, including urban planning, land use, surveying and mapping, mine management, geological exploration and environmental protection, and has broad application prospects.

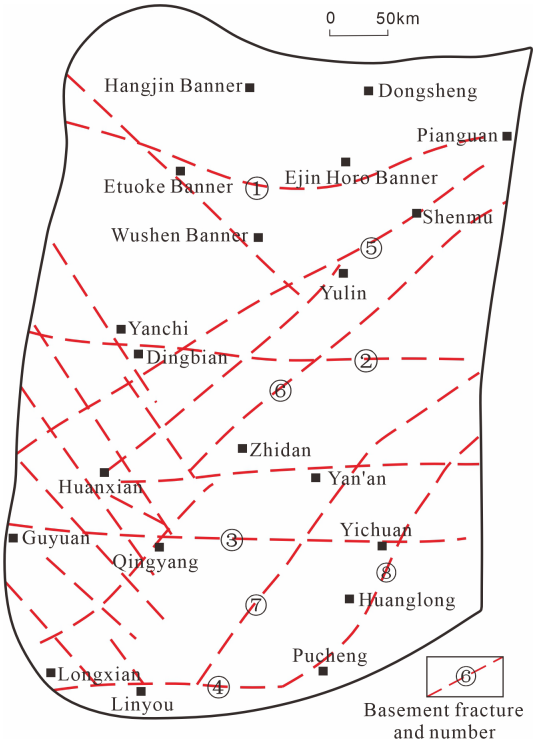

Figure 2. Fault distribution map of Yanchang Formation in Ordos Basin.

3.2. Technical Route Process

The process of building a 3D realistic model includes the following steps: selecting outcrops and conducting preliminary geological research, collecting and processing outcrop field image data, establishing a 3D realistic model, and statistical analysis of fracture occurrence data.

1) Image data acquisition

The quality of data acquisition determines the difficulty and accuracy of establishing 3D real scene model. In terms of equipment selection, UAV should be equipped with high-precision aerial camera, usually using high-resolution digital SLR or special aerial camera. Generally, five lenses are used, including one ortho pose and four tilt poses, to ensure that the facade of the building or the side of the terrain can be covered. In addition, before flying, it is necessary to lay out the ground control points for later data registration and correction, so as to improve the geographical accuracy of the three-dimensional model.

Data acquisition adopts UAV automatic flight data acquisition mode, which

has the advantages of high data quality and consistent image overlap. The specific acquisition process is as follows: 1) create the KML file of the acquisition area by using the flight software of UAV; 2) After assembling the UAV, conduct pre flight commissioning to ensure that the parameters of the flight control system are normal; 3) Formulate flight routes and set flight parameters related to tilt photography, including flight altitude, route planning and overlap.

2) Establish 3D real scene model

The image obtained by UAV tilt photography is reconstructed by context capture software. It mainly includes the following steps: image feature extraction and matching, regional adjustment, dense point cloud reconstruction, triangulation model construction, texture mapping.

The three-dimensional real scene model based on UAV tilt photography technology is shown in the following figure (Figure 3).

Figure 3. Schematic diagram of 3D model.

4. Fracture Development Characteristics

Due to the uplift of strata in the eastern Ordos Basin, the Chang 6 member in the study area is well exposed, which is a Triassic outcrop. The natural fractures of Chang 6 formation are mainly regional structural fractures, and the sandstone formation is the main fracture development formation. The fractures of the Dongjia River Yanhe section in Yanchang County were observed and measured, and the length statistics (Figure 4) and rose diagram (Figure 5) were drawn, the Dongjiahe structure features large-angle fractures, predominantly high-angle vertical fractures, all perpendicular to the rock layer. Statistical analysis reveals that the most prevalent fractures are primarily oriented in the NNW (Figure 6-Tc2) near SN and NEE (Figure 6-Tc1) near EW directions, with the NNW direction being the most prominent. However, these are mostly confined by NEE fractures, accompanied by a minor development of NWW (Figure 6-Tc3) and NNE (Figure 6-Tc4) fractures. These fractures are devoid of mineral filling and can extend up to 14.08m in length, predominantly ranging from 0.5 to 5.4 m. The spacing between fractures is between 0.1 and 0.5 m, often developing in a checkerboard pattern. Fractures oriented in the NEE direction exhibit a relatively regular distribution, characterized by straight and smooth surfaces, extensive extensions, stable orientations, and a density of 4 - 5 fractures per meter. On the other hand, NNW-oriented fractures are shorter and constrained by NEE fractures, displaying an irregular distribution and a density of 8 - 9 fractures per meter.

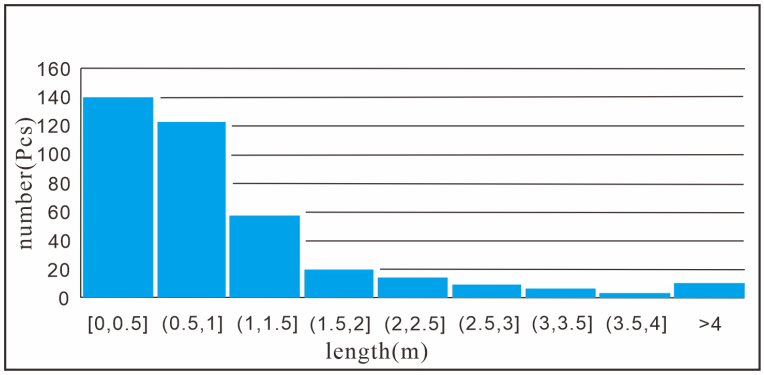

Figure 4. Histogram of crack length.

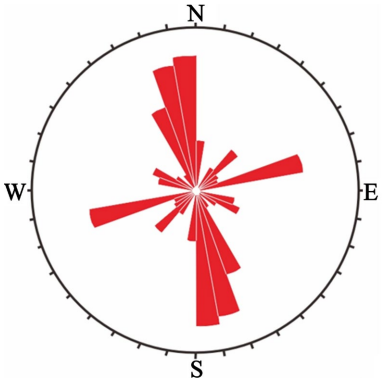

Figure 5. Rose chart.

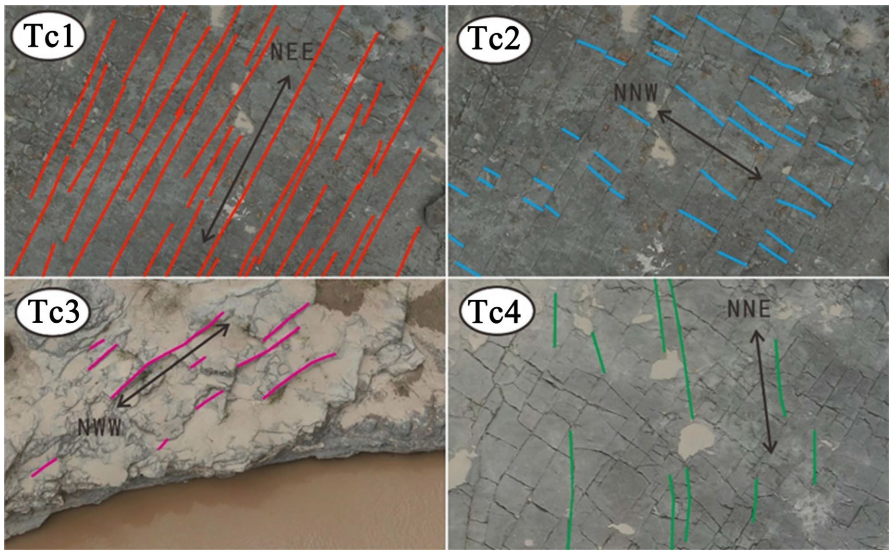

Figure 6. Characteristics of Triassic outcrop fractures in Dongjiahe Yanchang Formation.

5. Formation Period of Crack

5.1. Characteristics of Tectonic Stress Field

The formation and development of the Mesozoic Cenozoic tectonic stress field in Ordos Basin are closely related to the tectonic evolution in the eastern and western

parts of the region. The interaction between them has shaped the unique evolution process of the tectonic stress field in the transitional region of the basin. Combined with the previous research results, and analyzing the signs of tectonic deformation and regional tectonic deformation characteristics in and around the Ordos Basin, the Mesozoic Cenozoic tectonic stress field since Triassic can be divided into three stages: Indosinian, Yanshanian and Himalayan.

1) Characteristics of Indosinian tectonic stress field

The Indosinian tectonic movement resulted in angular or parallel unconformity between Jurassic and Triassic. In the southeast of the basin, the maximum principal compressive stress axis is NE; In the northwest, the stress axis tends to NW; In the northern region, the principal compressive stress axis is near the SW direction. The optimal occurrence of the maximum principal compressive stress axis in the Indosinian period in the Ordos Basin is 10˚ - 190˚∠ 2˚. Under this stress, NEE and near NS cracks are formed.

2) Characteristics of Yanshanian tectonic stress field

The Yanshanian tectonic stress field is characterized by annular compression from the edge of the basin to the inside. During this period, the Ordos Basin experienced strong tectonic movement, which led to the change of the original tectonic framework of the basin. The remote stress effect in the eastern part of the basin is the main driving force of tectonic deformation in this period. Due to the violent collision between the ancient Pacific plate and the Eurasian plate, significant tectonic deformation and uplift occurred in the eastern part of the basin. The compressive stress produced by the collision acted on the basin and formed a tectonic stress field dominated by NW-SE direction. The optimal occurrence of the maximum principal compressive stress axis is 130˚ - 310˚∠ 1˚. Under this stress environment, two groups of fractures near NW direction and EW direction were formed.

3) Characteristics of tectonic stress field in Himalayan period

The tectonic stress field in Himalayan period has changed fundamentally compared with that in Yanshanian period. In Himalayan period, with the intracontinental subduction after the collision between the Indian plate and the Eurasian plate, the thrust of the Qilian fold belt lifted the block onto the Ordos block. This tectonic movement caused the Yan'an area of the basin to be subjected to NNE-SSW compressive stress, resulting in the formation of NS and NE fractures. The preferred occurrence of the maximum principal compressive stress axis is 30˚ - 210˚∠ 2˚.

5.2. Division of Fracture Stages

Judging from the intersection relationship of cracks, NEE cracks restrict NNW cracks, which are early cracks and late cracks, so NEE cracks are formed earlier and NNW cracks are formed later. NEE and NNE fractures are mutually tangential and formed at the same time. According to the crosscutting relationship, there are at least two stages of fracture formation in this area.

The Ordos Basin has experienced three main tectonic evolution stages: Indosinian, Yanshanian and Himalayan. Although as a stable basin, the development of faults and folds is relatively limited, the tectonic stress acting on the edge of the basin will still affect the interior of the basin, and the geological instability factors caused by these stresses promote the development of extensive fractures in the basin. During the Indosinian period, the southeastern part of the basin was in the NE-SW compressive stress field (Figure 7(a)). Under this stress background, nearly NS and nee trending fractures were generated. The Yanshanian and Himalayan periods were the main formation periods of the fractures. In the Yanshanian period, the subduction, subduction and continental collision of the ancient Pacific plate and the ancient Tethys ocean plate to the North China plate caused the basin to be subjected to the compressive force with the principal compressive stress direction of NW-SE due to sinistral shear (Figure 7(b)), and the NE trending faults in the basement of the study area became active, forming two groups of shear fractures in NNW and NWW directions. During Himalayan period, affected by the NNE trending compressive and strike slip tectonic stress field caused by the collision between the Indian plate and the Eurasian plate, the NWW trending fractures were in the state of shear compression, and the NNE trending fractures continued to undergo compressive transformation, and the activity was not strong.

6. Conclusion

This paper takes the fracture of Yanchang Formation in Dongjiahe village, Yanchang County, Ordos Basin as the research object, selects observation points of Yanhe section, uses UAV tilt photography technology to capture image data and establish three-dimensional model, so as to digitize the geological section and increase the reusability of data. Compared with the traditional field survey of geological outcrop information collection, the construction of three-dimensional real scene model based on tilt photogrammetry technology has more advantages, reducing the workload of field survey, improving work efficiency, and reducing the risk of field survey. The main conclusions are as follows:

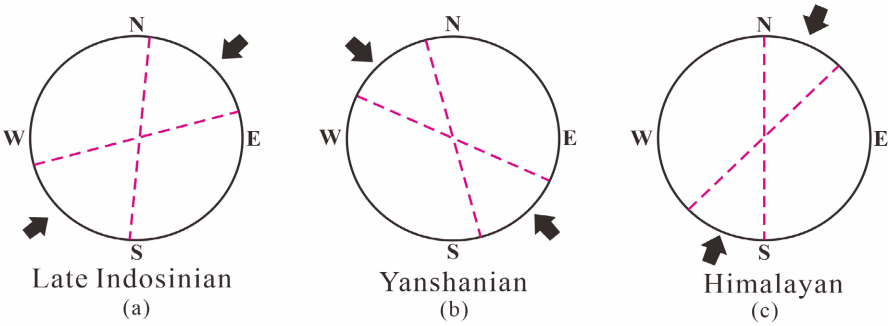

Figure 7. Model diagram of tectonic stress field.

1) The fractures of the Mesozoic Yanchang Formation in Dongjiahe village, Yan'an area, Ordos Basin are widely developed, and nee near EW and NNW near

Sn fractures are the most developed, showing a checkerboard shape. The main section of the length is 0.5 - 5.4 m, the crack spacing is mainly 0.3 - 0.5 m, and the density can reach 4 - 9 pieces/m. The fractures are straight and smooth without filling, and most of them develop vertical structural fractures.

2) According to field outcrop observation, fracture intersection relationship and comprehensive analysis of regional geological background, the formation of fractures in the Yanchang Formation in Dongjiahe village can be divided into two stages: the first stage is affected by Indosinian movement, and the second stage is affected by Yanshan movement.

3) In the early stage, the development of fractures was closely related to the NE-SW compressive stress field during the Indosinian movement, resulting in the formation of NEE and NNE fractures. In the late Mesozoic, the Yanshan movement triggered a NW-SE compressive stress field in the basin, which led to the formation of two groups of NNW and NWW fractures in the Yanchang formation. In general, the fracture development of Dongjiahe Yanhe section is strongly affected by the tectonic stress field of Indosinian and Yanshanian periods.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

Dang, Z., Zhao, H., Fu J. H. et al. (2005). Study on Structural Fracture Characteristics of Sedimentary Cap Rocks in Ordos Basin. *Natural Gas Industry, No. 7,* 12-16.

Li, Y. L., Lu, S. L., Xia, D. L. et al. (2022). Development Characteristics and Main Controlling Factors of Natural Fractures in Shale Series of Chang 7 Oil Formation in Yanchang Formation, Southern Ordos Basin. *Geological Sciences, 57,* 73-87.

Lian, H. Q., Meng, Lu., Han, R. G. et al. (2020). Geological Information Extraction Based on UAV Remote Sensing—A Case Study of Liujiang Basin. *Remote Sensing of Land and Resources, 32*, 136-142.

Liang, X. W., Han, Y. L., Wang, H. H. et al. (2009). Fracture Characteristics and Geological Significance of Yanchang Formation of Upper Triassic in Jiyuan Area, Ordos Basin. *Lithologic Reservoir, 21,* 49-53.

Su, X. C., Gong L., Fu, X. F. et al. (2023). Fracture Distribution Characteristics and Effectiveness Evaluation of Tight Sandstone Reservoir in Yanchang Formation 7 in the Trilateral Area of Ordos Basin. *Geosciences, 48,* 2601-2613.

Wan, J. H., Wang, Z., Liu, S. W. et al. (2019). Tilt Photogrammetry to Build Geological Digital Outcrop. *Geological Science and Technology Information, 38,* 258-264.

Wang, Q. Y., Zheng, R. C., Liang, X. W. et al. (2011). Fracture Characteristics and Genesis of Yanchang Formation in Jiyuan Area, Ordos Basin. *Journal of Chengdu University of Technology (NATURAL SCIENCE EDITION), 38,* 220-228.

Wang, R., Zhao, J. Z., Er, C. et al. (2014). Fracture Characteristics and Formation Mechanism of Organic Rich Shale in Chang 7 Member of Yanchang Formation of Triassic in Ordos Basin. *Journal of Xi'an Shiyou University (NATURAL SCIENCE EDITION), 29,* 43-48.

Yin, S. L., Gao, Y., Hu, Z. M. et al. (2021). Multi Point Geostatistical Simulation of Outcrop Based on UAV Tilt Photography—A Case Study of Shihezi Formation in Pingtou Township, Luliang, Shanxi. *Acta Petrologica Sinica, 42,* 198-216.

Zeng, L. B., Li, Z. X., Shi, C. E. et al. (2007). Fracture Characteristics and Genesis of Ultra-Low Permeability Sandstone Reservoir in Yanchang Formation of Upper Triassic in Ordos Basin. *Acta Geologica Sinica, No. 2,* 174-180.

Zhang, L. Y., Fan, K., Liu, J. D. et al. (2006). Quantitative Prediction of Structural Fracture Distribution of Triassic Yanchang Formation in Zhenyuan Jingchuan Area, Ordos Basin. *Journal of Geomechanics, No. 4,* 476-484.

Zhang, X. L., Liu, X., Chen, Z. B. et al. (2015). Fracture Characteristics and Formation Stages of Yanchang Formation in Huangling Area, Southeastern Ordos Basin. *Science Technology and Engineering, 15,* 10-14.

Zhao, X. Y., Zeng, L. B., Jin, B. G. et al. (2018). Characteristics and Formation Mechanism of Water Injection Induced Fractures in Low Permeability Reservoirs—Taking Chang 6 Reservoir of Ansai Oilfield in Ordos Basin as An Example. *Petroleum and Natural Gas Geology, 39,* 696-705.

Zhao, Y. G., Pan, H. P., Li, G. Q. et al. (2013). Logging Identification of Fractures in Tight Sandstone Reservoirs of Yanchang Formation in Zhenjing Oilfield, Southwestern Ordos Basin. *Modern Geology, 27,* 934-940.

Zhao, Z. Y., Guo, Y. R., Wang, Y. et al. (2012). Research Progress on Tectonic Evolution and Paleogeographic Characteristics of Ordos Basin. *Special Oil and Gas Reservoirs, 19,* 15-20, 151.