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Research Article

Petrological Characteristics and Rock Nomenclature of Sedimentary Bauxite Gas Reservoir: A Case Study of Bauxite in Taiyuan Formation of Ordos Basin

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With the great breakthrough in natural gas exploration of Paleozoic Taiyuan formation in Longdong exploratory area in the southwestern part of Ordos Basin, it is urgent to solve the petrological nomenclature of sedimentary bauxite, so as to further study the pore formation mechanism, distribution law, and controlling factors of bauxite reservoirs. In this paper, X-ray diffraction, polarizing microscope, scanning electron microscope, and other methods are used to analyze the mineral composition and structure of bauxite rocks in the study area and give appropriate names. The results show that the sedimentary sequence of bauxite in the study area can be divided into five sections: A, B, C, D, and E. The main mineral components are diaspore (C section content can be more than 90%), illite, kaolinite, and chlorite; accessory mineral include anatase and pyrite; trace components include quartz, feldspar, rutile, hematite, and rock salt; and some of the pores are filled with calcite, siderite, and (iron) dolomite. The rock structure is mainly bedding and massive structure, and some of them have geopetal structure. The texture mainly consists of granular texture, grain (powder crystal) texture, gel texture, and algal bonding texture. Considering the special lithology of section A~C and the lack of existing nomenclature method, based on mineral composition and sedimentary fabric, a triangulation classification nomenclature method is established, which adopts structure+texture as secondary name and the main mineral components diaspore-mud-pyrite of the three end-member mineral components as primary name. It can not only highlight the mineral assemblage characteristics of sedimentary sequence of bauxite but also reflect the lithologic characteristics of reservoir development section and the influencing factors of reservoir formation, effectively reflecting the petrological characteristics of bauxite reservoir. Among them, the diaspore rocks with granular, bean-oolitic, and grain texture are the main lithologies forming the natural gas reservoir space of Taiyuan formation in Longdong area. The naming method is feasible and reliable for sedimentary bauxite rocks, which lays a good foundation for the study of natural gas reservoir, pore formation mechanism, and distribution law in Longdong area, southwest of the basin.

1. Introduction

Bauxite is a kind of chemical sedimentary rock rich in aluminum minerals. The main mineral components of the rock are diaspore, boehmite, and gibbsite, and its K_2O/Na_2O ratio is greater than 1. The appearance is similar to that of clay rock, but the lithology is dense with high hardness and density, and there is no plasticity. As an important metal mineral resource, bauxite has been extensively and deeply studied by domestic and foreign scholars [1–16] on its provenance, formation mechanism, deposit classification, mineral and chemical compositions, distribution law, deposition mechanism, and controlling factors, which has played an important guiding role in the exploration, evaluation, and utilization of metal aluminum mineral resources. According to the bedrock type, bauxite can be divided into weathering residual type (laterite type) and mechanical-chemical deposition type (karst type).

The weathering crust on the top of Ordovician system (partially the top of Cambrian system) in Ordos Basin has thick bauxite (ore) deposits and has been studied as a cap layer for a long time [17, 18]. With the increase of exploration degree and the deepening of research work, some scholars put forward the geological understanding that the bauxite of Benxi formation in Ordos Basin can be used as a potential reservoir [19]. In 2021, Changqing Oilfield will deepen the understanding of the accumulation geology of the Taiyuan formation in Longdong area, and the gas test of well L47 will yield a high-yield gas flow of 67.38×10^4 m^3/d with an open flow rate. The exploration area of bauxite gas will be 7,000 km^2, and the natural gas resources will exceed $5,000 \times 10^8$ m^3, making a major breakthrough in Paleozoic bauxite gas exploration in the basin [20]. At present, petrological studies of bauxite are mainly based on mineral and chemical compositions [12, 13, 21–23]. There are some scholars [2, 6, 16, 21] that have made classification names for bauxite mainly named based on the mineral composition of bauxite, although some scholars considered adding structure to the rock name, such as earthy, bean-oolitic, dense, coarse bauxite [24], and other naming methods in such a way that is right for bauxite. However, it cannot directly reflect the characteristics of rock sedimentary sequence, mineral assemblage, and lithologic characteristics of reservoir development segment for a natural gas reservoir, so its feasibility and practicability are not strong. The bauxite natural gas reservoir of Taiyuan formation in Ordos Basin has good reservoir performance, and its porosity is up to 28.7% with an average of 14.67% and permeability is in the range of 0.01 to 38.55×10^{-3} μm^2 with an average of 5.57 $\times 10^{-3}$ μm^2, belonging to the pore type reservoir [25]. At the same time, the pore segments of bauxite reservoir develop stably and have good continuity [25, 26]. Therefore, it is very necessary to describe and study the bauxite in detail and accurately, especially to name the bauxite in combination with its texture, structure, and characteristic mineral composition. This will have important practical guiding value and theoretical significance for gas reservoir evaluation, pore formation mechanism, distribution law, and favorable area prediction.

The sedimentary caprocks in Ordos Basin are well developed, including Neogene, Paleogene, Cretaceous, Jurassic, Triassic, Permian, Ordovician, and Cambrian. In the early Paleozoic, huge carbonate rocks were deposited. Due to the influence of Caledonian movement, weathering and denudation of 1.2 ~ 1.5 Ga occurred in the late stage. In some areas, the Ordovician strata are all denuded and the karst landforms are well developed. Thick bauxite sedimentary sequences are deposited in low-lying or negative terrain of karst landforms, with accumulative thickness up to 5 m~30 m and relatively stable distribution [25]. The genesis, sedimentary characteristics, and distribution law of Taiyuan formation bauxite in Longdong area of Ordos Basin are consistent with those of "Zunyi type" bauxite, "Xiuwen type" bauxite, "Shanxi type" bauxite, and "Pingguo type" bauxite proposed by predecessors. All of them were caused by chemical deposition, partly accompanied by the deposition of contemporaneous clasts (such as breccia, gravel clasts, and bean oolite) in the basin, namely, mechanical-chemical deposition.

2. Method

In this paper, X-ray diffraction, polarizing microscope, scanning electron microscope, and other methods are used to study the petrological characteristics of the bauxite reservoir in Taiyuan formation, Ordos Basin, and try to accurately name the rocks. Samples of this study were analyzed at the National Engineering Laboratory for Exploration and Development of Low Permeability Oil and Gas Fields, Xi'an, China. The equipment used mainly includes D8 Focus X-ray diffractometer from German Brock company, with a precision of 0.01°; Leica 4500P polarizing microscope, with a precision of 0.27 μm; and Quanta 450FEG field emission scanning electron microscope from America FEI Company with a resolution of 0.7 nm; CMS300 porosity-permeability tester from Corlab has a porosity analysis accuracy of 0.02% and permeability analysis accuracy of 0.1×10^{-3} μm^2.

3. Results

3.1. Mineral Assemblage. Sedimentary bauxite can be basically divided into five members: A, B, C, D, and E [21]. Bauxite of Ordos Basin is also can be divided into five sections from bottom to top (Figure 1), including member A (ferric bauxite) is rich in pyrite, member B (bauxitic mudstone) has a high content of clay minerals, member C (bauxite) has over 90% content of diaspore, member D (siliceous bauxite) has developed powder crystal authigenic siliceous rocks, and member E (carbonaceous mudstone or coal line) is rich in organic matter [25].

On the whole, the sedimentary sequence shows the regularities of rich iron in the bottom, the middle is high in aluminum, the upper part is much silicon, and the top contains carbon (coal line). The reservoir is mainly distributed in the middle and upper part of C, namely, the porous bauxite section. Relatively mature thin section identification methods (SY/T 5368-2016, rock thin section identification method) have been established for D and E sections, which will not be described again. The main objects of this study are sections A, B, and C. The mineral composition is relatively simple (Figure 2). The main minerals are diaspore, illite, chlorite, and kaolinite, with a small amount of anatase, pyrite, and rutile and a very small amount of quartz, feldspar, tourmaline, fluorapatite, and halite (Figure 3). The accessory mineral in late diagenetic stage is mainly ferrocalcite, dolomite, ankerite, siderite, and so on, and their occurrence is dominated by filled pores.

3.2. Rock Structure and Texture. Bauxite (ore) is a metal mineral resource, and its rock structure has been described and studied by predecessors [23, 24]. In this paper, the texture and structure of bauxite in Taiyuan formation of Ordos

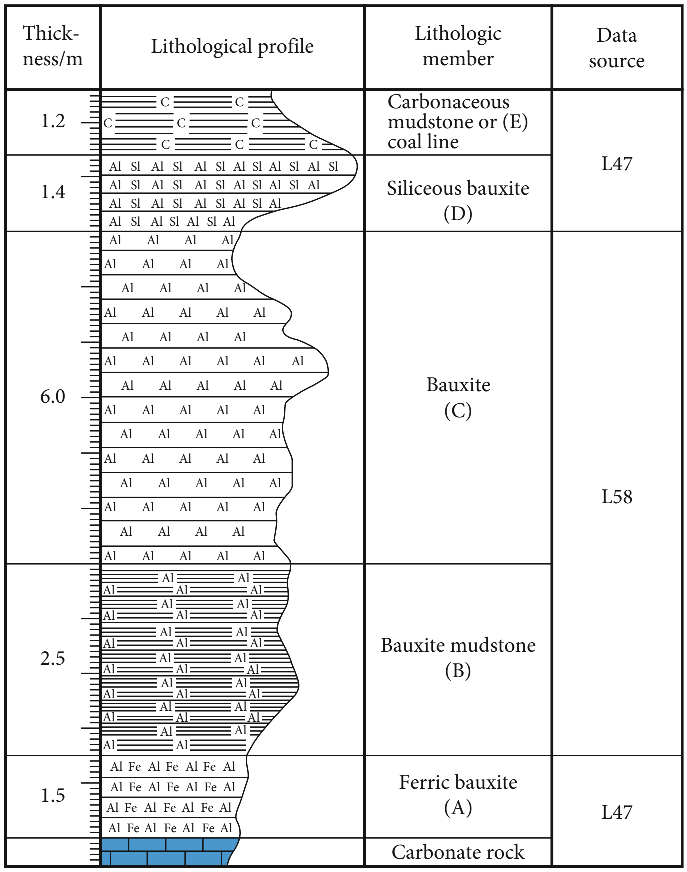

FIGURE 1: Bauxite sedimentary sequence of Taiyuan formation in Ordos Basin (modified from Nan et al. [25]).

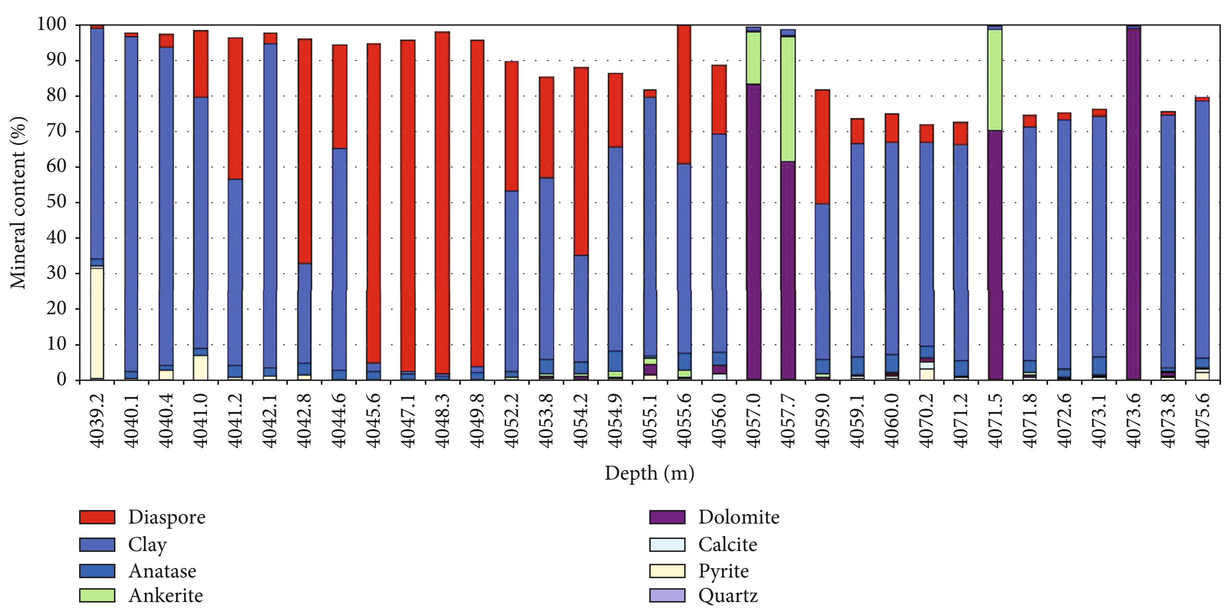

FIGURE 2: Longitudinal distribution of bauxite minerals in well L58 of Taiyuan formation.

Basin were studied and described from the perspective of natural gas reservoir.

3.2.1. Rock Structure. The bauxite structure of Taiyuan formation mainly includes massive structure, stratified structure, some geopetal structure, and rare slump structure. The massive structure has uniform lithology, porcelanous or conchoidal fracture, and uneven surface (Figures 4(a) and 4(b)). Stratified structures include laminar structures (Figure 4(c)) and bedding structures (Figure 4(d)), reflecting

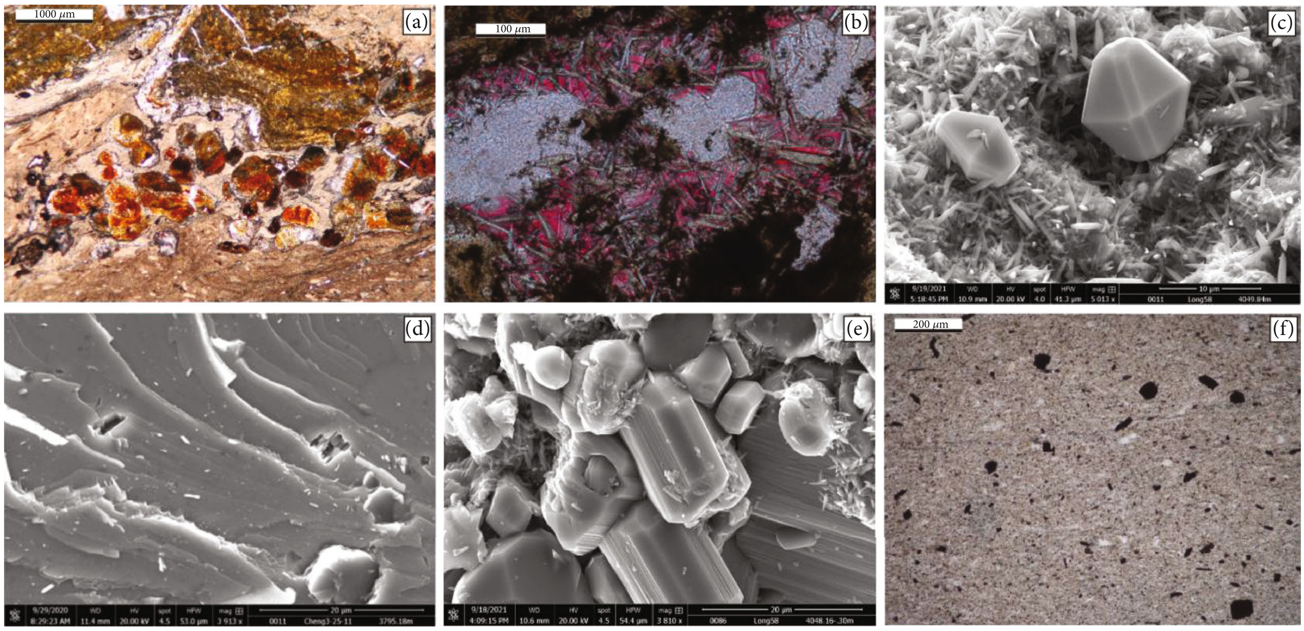

Figure 3: Mineral composition of bauxite in Taiyuan formation: (a) C3-25-11, 3812.28 m, bean-shaped and encrusted texture; the distribution of diaspore is aggregate, and clay minerals are mainly illite; (b) L47, 4119.0 m, acicular chlorite grows in dissolved pores of grains; (c) L58, 4049.84 m, idiomorphic biconical anatase; (d) C3-25-11, 3795.18 m, grey bauxite; a small part of siderite is dissolved to form micropores in grain; (e) L58, 4048.16 m, short columnar diaspore; (f) L47, 4124.00 m, pyrite in the form of cryptocrystalline aggregates is scattered.

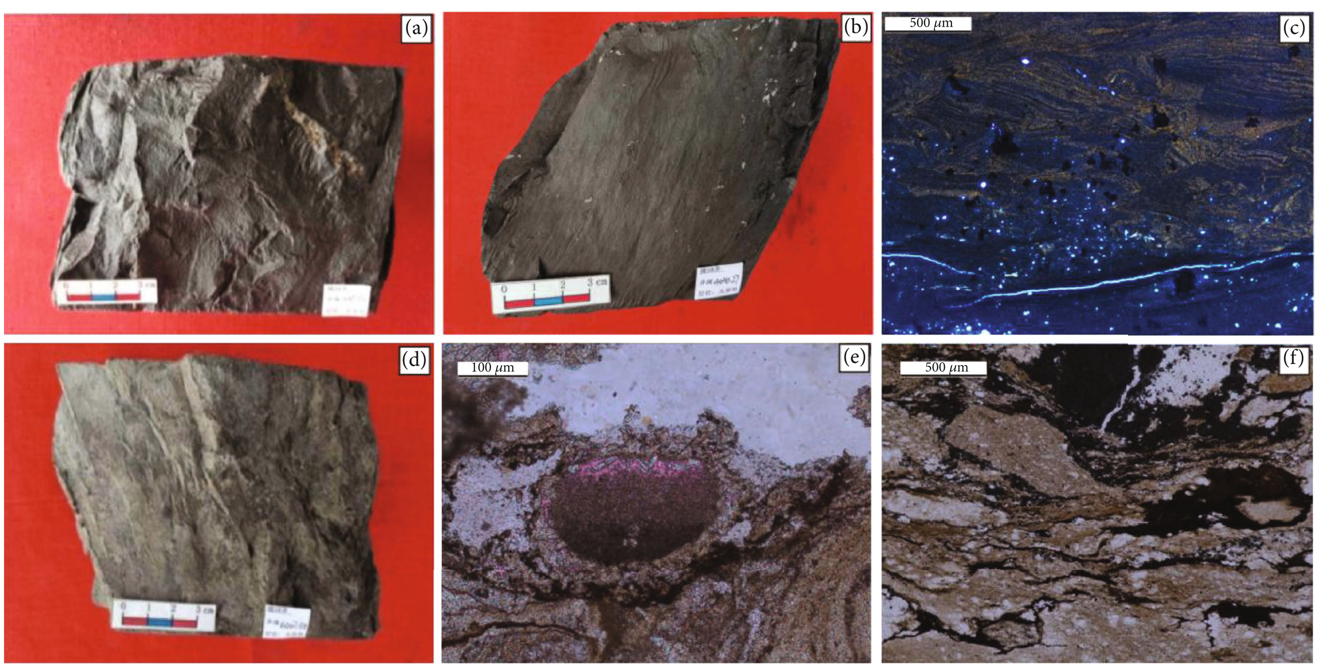

Figure 4: Sedimentary and structural characteristics of bauxite in Taiyuan formation: (a) L58, 4039.39 m, massive structure, porcelain and conch fracture (vertical), and calcite filling in the fracture; (b) L58, 4040.27 m, developed lamina; (c) Q30, 2875.22 m, developed laminar texture and plastic deformation; black mineral is pyrite (single polarization); (d) L58, 4047.40 m, well-developed bedding texture; (e) L47, 4114.00 m, bean-oolitic diaspore, bean-oolitic dissolution pore, geopetal structure, micritic diaspore at bottom, and acicular diaspore at top; (f) H2, 4612.82 m, slump structure, rock broken and deformed, and breccia form.

that the bauxite rocks were formed under certain hydrodynamic conditions. The geopetal structure appears in the bean-oolitic diaspore, in which the bottom of the bean-oolitic dissolved pores is filled with micritic diaspore and the top with acicular diaspore (Figure 4(e)). Slump structure can also be seen in bauxite (Figure 4(f)). Under the action of

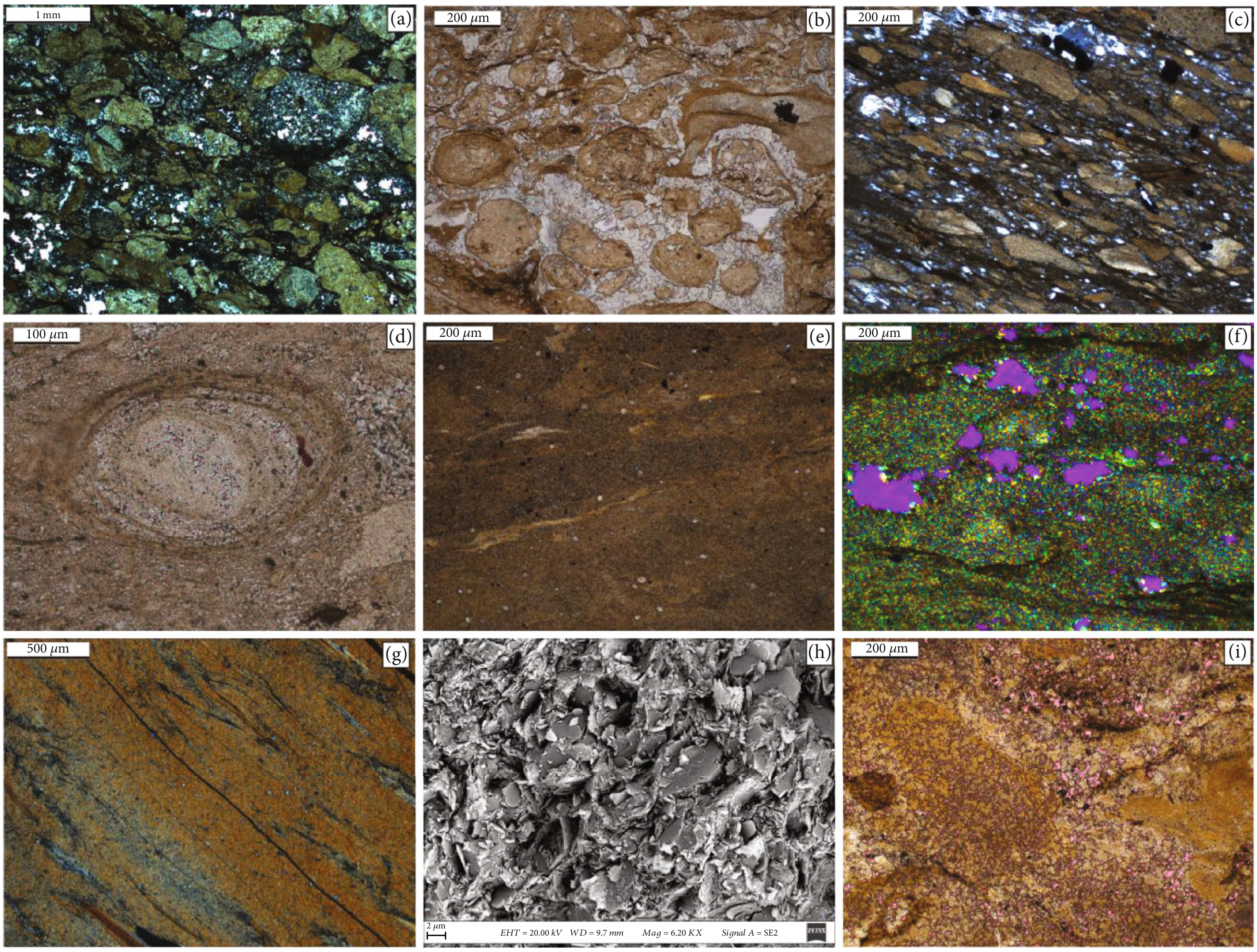

Figure 5: Thin sections and electron microscopic photographs of bauxite in Taiyuan formation: (a) S406, 4312.79 m, particle texture, poor particle sorting, and good roundness; (b) L47, 4100.00 m, particle texture; some particles suspended contact; (c) M119, 3049.64 m, particle texture and flattening and elongating along the plane; (d) L47, 4104.00 m, bean-oolitic texture and circle-layer development; (e) M11, 3048.30 m, laminar texture, grain structure, and residual gel structure; (f) M119, 3047.91 m, grain structure; dissolution pores and intergranular dissolution pores are developed; (g) T26, 3659.38 m, gel texture and characteristics of continuous wave extinction; (h) H9, 2579.15 m, micrite texture; generally, the microplate columnar shape is less than 2 μm; (i) L58, 4048.01 m, bean-oolitic microcrystalline bauxite with alga bonding texture.

gravity, the unconsolidated sediments slide, deform, and break and are breccia form with intergranular argillaceous filling.

3.2.2. Rock Texture. The bauxite rocks in the study area are rich in texture types, such as particle texture, bean-oolitic texture, grain texture, gel texture, and alga bonding texture. Particle texture includes sand texture and gravel texture, in which the particle sorting is poor with distribution in less than 0.1 mm, 0.1 mm~2.0 mm, and more than 2.0 mm (Figures 5(a) and 5(b)). Particle point-line contact is dominant (Figure 5(a)), some particles are suspended (Figure 5(b)), and some particles are flattened and elongated along the plane (Figure 5(c)), indicating that the bauxite has strong compaction after deposition. It is one of the main particles of dissolved pores formed by leaching of atmospheric fresh water. The bean-oolitic texture is usually between 0.2 and 2 mm in size, and the circle layer is developed reaching 3 to 7 layers, and 1 to 2 layers can also be seen, with local characteristics of flattening (Figure 5(d)). It is also one of the main particles of dissolved pores formed by leaching of atmospheric fresh water. The main minerals of bauxite are diaspore and boehmite, among which boehmite belongs to flake mineral and is not easy to form grain texture, while boehmite belongs to plate columnar mineral and forms grain texture by accumulation. In the study area, boehmite is rare and mainly composed of diaspore, which is generally dominated by fine powder with a particle size of more than 10 μm (Figures 5(e) and 5(f)). Intergranular pores can be formed both inside and between grains (Figures 4(b) and 4(f)). Diaspore is formed in diagenetic stage and can form a large number of intergranular pores. The gel structure is colloidal aluminite sediments deposited and crystallized into ultrafine structure of diaspore, which crystallizes along the same optical orientation and has the characteristics of continuous wave-like extinction

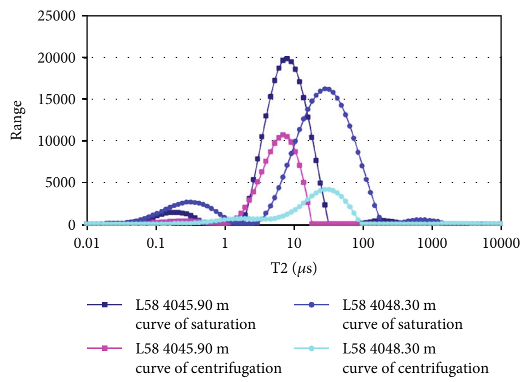

Figure 6: NMR test T2 curve of "porous bauxite section" in Ordos Basin (modified from Nan et al. [25]).

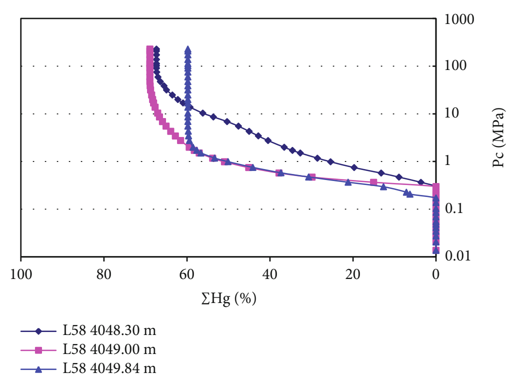

Figure 7: The capillary pressure curve of "porous bauxite section" in Ordos Basin (modified from Nan et al. [25]).

(Figure 5(g)). The gel texture is the texture of diaspore crystallized into ultrafine structure after the deposition of colloidal aluminum soil sediments. Particles in micrite texture are small with generally less than 10 μm in size, which is not easy to distinguish the crystal morphology under polarizing microscope, but only under scanning electron microscope can be observed crystal morphology (Figure 4(h)). The alga bonding texture indicates that the bauxite was influenced by algal activity to a certain extent during the deposition process (Figure 5(i)).

3.2.3. Pore Structure. The pore assemblages of bauxite are mainly composed of dissolved pores, intergranular dissolved pores, and intergranular pores, with semifilled fractures occasionally found [25]. NMR analysis showed that the bauxite (C section) exhibited high movable fluid saturation (Figure 6) above 50% at 450 psi centrifugation [25]. Constant pressure mercury injection analysis shows that the high permeability reservoir has good pore connectivity (Figure 7). The displacement pressure is generally between 0.17 and 0.37 MPa, and the maximum connected pore-throat radius is generally between 2.01 and 4.22 μm. The median pressure is generally between 5.90 and 6.72 MPa, and the average throat radius is generally between 0.11 and 0.77 μm [25]. The micron-submicron-scale pore-throat system has good connectivity, while the nanoscale pore-throat system has poor connectivity, indicating that the pore-throat connectivity of bauxite reservoir has strong heterogeneity.

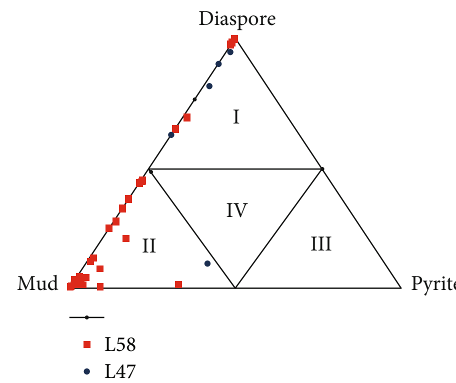

Figure 8: Classification method of three end-members of bauxite in Taiyuan formation.

4. Discussion

4.1. Classification and Nomenclature of Bauxite. Previous studies [6, 16] adopted the triangle-classification method of iron minerals, aluminum minerals+titanium minerals, and clay minerals as the three-member components for the naming of bauxite, which was established based on bauxite mineral resources and effectively solved the problem of classification and evaluation of bauxite. However, as a natural gas reservoir, its classification is too detailed, and the influence of structural characteristics of bauxite on gas reservoir performance is not considered, which is not conducive to the evaluation of natural gas reservoir. Considering the particularity of mineral assemblage in member A-C, a triangular classification method of bauxite with diaspore, clay mineral, and iron mineral (mainly pyrite) as the characteristic components of three end-members was established, supplemented by structural classification. It can not only better reflect the mineral assemblage characteristics of sedimentary sequence of bauxite but also better reflect the lithologic characteristics of reservoir development sections and the influencing factors of reservoir formation. Therefore, it is feasible and reliable to evaluate the pore formation, distribution, and controlling factors of natural gas reservoirs.

4.2. Main Rock Types. According to the three-terminal classification method, the basic lithology of the study area can be divided into four categories. Region I is diaspore rock (the pores are mainly distributed in this type), region II is mudstone, region III is pyrite rock (pyrite is missing in the analysis data due to the particularity of pyrite distribution), and region IV is mixed rock which can be called diaspore mixed rock (Figure 8). Combining structure and texture, it can be divided into sand-gravel or bean-oolitic diaspore rock (Figures 5(a), 5(b), and 5(d)), lamellar micritic diaspore rock (Figure 5(e)), laminated diaspore sand-gravel clastic mudstone (Figure 5(c)), lamellar powder diaspore rock (Figure 5(f)), gelatinous diaspore rock (Figure 5(g)), micritic diaspore rock (Figure 5(h)), and so on. And the diaspore rocks with particle, bean-oolitic, and grain texture are the main lithology of pore developed.

5. Conclusion

(1) The main mineral components of bauxite in Taiyuan formation in Ordos Basin are diaspore, clay minerals (including illite, chlorite, and kaolinite), and pyrite, with a small amount of boehmite, anatase, tourmaline, and rutile and a very small amount of hematite and halite. The accessory mineral in late diagenetic stage is mainly ferric calcite, dolomite, ankerite, siderite, and so on, and their occurrence is dominated by filled pores

(2) The rock structure of Taiyuan formation bauxite in Ordos Basin is dominated by massive structure and stratified structure, some of which show geopetal structure and few slump structures. The rock textures are characterized by particle texture, bean-oolitic texture, grain texture, gel texture, and alga bonding texture

(3) The pore assemblages of bauxite are mainly composed of dissolved pores, intergranular dissolved pores, and intergranular pores, with semifilled fractures occasionally found

(4) According to the three-terminal classification method with structures and textures as auxiliary names, the bauxite of Taiyuan formation in Ordos Basin can be divided into four categories: diaspore rock, mudstone, pyrite rock, and diaspore mixed rock. The diaspore rocks with particle, bean-oolitic, and grain texture are the main lithology of pore developed. The thin section method of bauxite rock suitable for reservoir evaluation is established in detail, which lays a foundation for the study of reservoir pore evolution and formation mechanism, pore distribution law, and favorable block prediction

Data Availability

The experimental data used to support the findings of this study are included within the manuscript.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

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References

[1] B. D'Argenio and A. Mindszenty, “Bauxites and related paleokarst: tectonic and climatic event markers at regional unconformities,” *Eclogae Geologicae Helvetiae*, vol. 88, no. 3, pp. 453–499, 1995.

[2] B. A. Bogatyrev and V. V. Zhukov, “Bauxite provinces of the world,” *Geology of Ore Deposits*, vol. 51, no. 5, pp. 339–355, 2009.

[3] A. Horbe and M. Costa, “Geochemical evolution of a lateritic Sn-Zr-Th-Nb-Y-REE-bearing ore body derived from apogranite: the case of Pitinga, Amazonas – Brazil,” *Journal of Geochemical Exploration*, vol. 66, no. 1-2, pp. 339–351, 1999.

[4] L. E. Mordberg, C. J. Stanley, and K. Germann, “Mineralogy and geochemistry of trace elements in bauxites: the Devonian Schugorsk deposit, Russia,” *Mineralogical Magazine*, vol. 65, no. 1, pp. 81–101, 2001.

[5] K. Emmerich and W. Smykatz-kloss, “Exothermic effects in soils during thermal analysis,” *Clay Minerals*, vol. 37, no. 4, pp. 575–582, 2002.

[6] G. Bardossy, *“Karst Bauxite”, Bauxite Deposits on Carbonate Rocks*, Akademiai Kiad’o Budapest, Budapest, Hungary, 1982.

[7] M. Laskou, G. Margomenou-Leonidopoulou, and V. Balek, “Thermal characterization of bauxite samples,” *Journal of Thermal Analysis and Calorimetry*, vol. 84, no. 1, pp. 141–146, 2006.

[8] R. M. Cornell and U. Schwertmann, *The Iron Oxides: Structure, Properties, Reactions, Occurrences and Uses*, Wiley-VCH, Berlin, 2006.

[9] P. Mameli, G. Mongelli, E. D. Oggiano, and E. Dinelli, “Geological, geochemical and mineralogical features of some bauxite deposits from Nurra (Western Sardinia, Italy): insights on conditions of formation and parental affinity,” *International Journal of Earth Science (Geological Rundsch)*, vol. 96, no. 5, pp. 887–902, 2007.

[10] C. L. Liu, “Classification of Chinese bauxite deposits,” *Science China: B*, vol. 5, no. 5, pp. 535–544, 1987.

[11] Z. Zhao, D. H. Wang, P. G. Li, and Z.-y. Le, “Detrital zircon U-Pb geochronology of the Dazhuyuan formation in northern Guizhou: implications for bauxitemineralization,” *Rock and Mineral Analysis*, vol. 32, no. 1, pp. 166–173, 2013.

[12] J. Q. Liu, X. L. Wang, H. R. Zhou et al., “Geochemical characteristics and material source of bauxite ores from the lower Wuchiapingian of Upper Permian in southeastern Yunnan province,” *Geology and Explorations*, vol. 48, no. 3, pp. 507–517, 2012.

[13] X. F. Liu, Q. F. Wang, Z. M. Li et al., “Mineral genesis and evolutionary sequence of the bauxite deposits in Henan province,” *Geology and Exploration*, vol. 48, no. 3, pp. 449–457, 2012.

[14] Z. G. Jin, J. X. Zhou, Z. L. Huang, J. Gu, L. Liu, and L. Dai, “Detrital zircon U-Pb dating and its geological significance for the bauxite in Wuchuan-Zheng'an-Daozhen Al metallogeic province,” *Earth Science Frontiers*, vol. 20, no. 6, 2013.

[15] W. C. Yu, Y. S. Du, Q. Zhou, Z. G. Jing, X. M. Wang, and T. Cui, “Palaeoclimate of the early Permian: evidence from characteristics of bauxite beds in Wuchuan-Zheng'an-Daozhen area,” *Journal of Paleogeography (Chinese Edition)*, vol. 16, no. 1, pp. 19–29, 2014.

[16] Y. S. Du and W. C. Yu, “Subaerial leaching process of sedimentary bauxite and the discussion on classifications of bauxite deposits,” *Journal of Palaeogeography (Chinese Edition)*, vol. 22, no. 5, pp. 813–825, 2020.

[17] Z. Yuan, F. L. Wu, and R. Feng, "The distribution rule and its geological significance of bauxite in Yanchang gasfield of Ordos basin," *Journal of Xi'an University of Science and Technology*, vol. 36, no. 6, pp. 843–848, 2016.

[18] J. J. Yang and X. G. Pei, *Natural Gas Geology of China*, Petroleum Industry Press, Beijing, China, 1996.

[19] W. H. Liu, H. P. Pan, J. W. Li, and J. Zhao, "Well logging evaluation on bauxitic mudstone reservoirs in the Daniudi gasfield, Ordos basin," *Natural Gas Industry*, vol. 35, no. 5, pp. 24–30, 2015.

[20] J. H. Fu, M. R. Li, L. Zhang, Q. Cao, and X. S. Wei, "Breakthrough in the exploration of bauxite gas reservoir in Longdong area of the Ordos basin and its petroleum geological implications," *Natural Gas Industry*, vol. 41, no. 11, pp. 1–11, 2021.

[21] T. X. Wen, "Geological characteristics of Carboniferous bauxite in Henan province," *Journal of Geology and Mineral Resources of North China*, vol. 11, no. 4, pp. 491–511, 1996.

[22] Y. C. Wang, Z. K. Li, Z. F. Zhai, R. B. Li, and X. Li, "Benxi formation bauxite mineralization condition and rule in Shanxi province," *Northwestern Geology*, vol. 44, no. 4, pp. 83–88, 2011.

[23] P. Liu and Y. C. Liao, "Regional metallogenic model and prospecting criteria of sedimentary bauxite deposits in central Guizhou-southern Chongqing region," *Geology in China*, vol. 41, no. 6, pp. 2063–2082, 2014.

[24] X. H. Meng, M. Ge, and Z. Q. Xiao, "Study on the sedimentology of the Carboniferous allite-bearing formation (sequence) of North China," *Acta Geologica Sinica*, vol. 2, pp. 182–197, 1987.

[25] J. X. Nan, N. Liu, X. Y. Wang, G. W. Xie, P. Yin, and Y. N. Yang, "Characteristics and formation mechanism of bauxite reservoir in Taiyuan formation, Longdong area, Ordos basin," *Natural Gas Geoscience*, vol. 33, no. 2, pp. 288–296, 2022.

[26] Y. N. Zhang, Y. H. Zhang, H. Wu et al., "Microscopic geochemical characteristics of oolite in oolitic bauxite ores from Wuchuan-Zheng'an-Daozhen area in the northern Guizhou province and their metallogenic significance," *Geological Science and Technology Information*, vol. 32, no. 1, pp. 63–70, 2013.