Study on the influence of tectonism on bauxite mineralization and exploration: a case study of the Luoyang Yellow River Basin, China

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Abstract. With the increasing demand for mineral resources, the exploration work needs to be strengthened, and the factors affecting the layout of exploration projects need to be further studied. In this paper, the bauxite deposits in the Luoyang Yellow River Basin, Western Henan, are the research objects. According to the geological background and mining characteristics, the influence of tectonism on bauxite mineralization and exploration is comprehensively analyzed. The comprehensive exploration methods (such as geology analysis, drilling engineering, geophysical prospecting, and testing) are used to evaluate the metallogenic prospect of the study area. Through field practice, good prospecting results have been achieved.

1. Introduction
The Yellow River Basin is an economic zone, ecological barrier, and focus of coal economic recoverable capacity and production capacity in China \cite{1}. There are a large number of bauxite deposits under the coal seams of the North China Block. The Yellow River Basin in Western Henan is located in the south of the North China Block, which is the bauxite deposit belt in China. With the increasing demand for mineral resources and driven by the national "prospecting strategy breakthrough action" \cite{2-3}, the properties of bauxite have been gradually understood. However, the surface bauxite has been mined, and the mining of bauxite under coal has become inevitable. The related exploration work needs to be strengthened, and the factors affecting the layout of exploration projects also need to be further studied.

Based on the basic principles and methods of geology, this paper takes the Luoyang Yellow River Basin as an example. It makes a systematic geological and sedimentological analysis to study the influence of tectonism on bauxite mineralization and exploration to provide a scientific basis for bauxite exploration.

2. Geological background
At the end of the Early Paleozoic, the North China Block was uplifted and eroded by the subduction of the surrounding plates. During this period, the Silurian, Devonian and Early Carboniferous strata were...
missing [4-5]. The Late Carboniferous began to re-subsidence and accepted sedimentation. Due to tectonic influence, the Late Paleozoic basin generally appeared as a dustpan-like depression opening to the east [6]. The seawater intruded from east and southeast directions. The maximum transgression period was the Taiyuan period, and then the seawater gradually withdrew to the southeast direction [7]; the sedimentary environment evolves from surface sea-clastic coastal tidal flats to brackish bays filled by river deltas, and finally to offshore lakes [7].

The study area is located in the southeast of Luoyang basin, Western Henan (Figure 1). The geotectonic position belongs to the south of the North China Block, which is affected by the Qinling Orogenic Belt and eastern China Orogenic Belt.

Figure 1. The structure diagram and the location of the study area (The base map is modified from Xu Hanlin et al. [8])
F1-Jiaozuo-Shangqiu Fault; F2-Tanlu Fault; F3-Luanchuan-Gushi Fault

3. Mining area characteristics

The morphology of bauxite ore bodies in the study area is mainly layered (stratoid), lenticular and funnel-shaped [4].

The occurrence of layered (stratoid) ore bodies is consistent with that of the underlying bedrock. It extends 1-2.5Km along the strike, up to 4.2Km individually and 0.3-0.6Km along with the dip, up to about 1.1Km individually. The area of a single ore body is mostly 0.2-3.6Km², with an average of about 1.04Km², and the thickness of the ore body is 1.2-7.5m, with an average of about 3.8m. The ore grade is stable, with the content of Al₂O₃ ranging from 63% to 67% and the content of SiO₂ ranging from 8% to 15%. The size of the deposits is medium to large, and the quality of the ore is general.

Layered (stratoid), lenticular and funnel-shaped ore bodies often have a transition relationship on the plane. According to the analysis of the thickness plane contour map of the Benxi Formation made by 402 boreholes with a mesh spacing of 800m×400m in the study area, The ore bodies with a thickness of fewer than 15m in the Benxi Formation account for 79.4%, which are mainly layered (stratoid) distribution. However, there are scattered ore bodies with a thickness of more than 20m. According to the surface investigation, these orebodies with larger thickness are funnel-shaped (Figure 2a). The contact boundary between the surrounding rock and the ore body is clear, and the occurrence is steep. The carbonate rocks produce different karstification (Figure 2b). The ore layer is inclined to the funnel center, and the overlying Taiyuan Formation is in the form of a broad and gentle syncline-shaped (Figure 2c). On the southeast side of the study area, there are densely distributed ore bodies with thickness than 25m, which are generally lenticular.
Figure 2. Morphological characteristics of the bauxite ore body in the study area
a-the overall outline of the ore body; b-the steep sidewall, dissolution; c-the overlying Benxi Formation inclines to the center of the funnel, forming a syncline-shaped

4. Tectonism influence

4.1. Ore controlling factors of tectonism
The mineralization of bauxite results from the coupling of many factors, such as tectonism, sedimentation and karstification. The coupling result affects the weathering intensity, the speed of mineral element migration (leaching) and causes the difference in aluminum enrichment [4].

4.1.1. Regional distribution of bauxite
The formation of bauxite requires relatively stable geotectonic conditions. In the late Early Paleozoic, the uplift occurred in the study area and the southern part of the North China Block. Compared with the central part of the North China Block, the uplift lasted until the sedimentary period of the Benxi Formation. This tectonic setting is the main reason affecting the regional distribution of bauxite in the study area.

The distribution of different ore types in the study area has the regularity on the plane: from south to north, the thickness of aluminum-rich ore decreases and the thickness of clay ore increases.

The southeastern part of the North China Block is adjacent to the Qinling Orogenic Belt, which causes the uplift, resulting in a plateau landform with better drainage conditions for bauxite mineralization. To the north, the influence of the Qinling Orogenic Belt is gradually weakened, and the paleogeomorphology is no longer a plateau platform relatively, so the drainage conditions have deteriorated, which is not conducive to bauxite mineralization, but mainly clay minerals with incomplete chemical weathering, even clayey shale.

4.1.2. Position and thickness of bauxite
The faulting improves the mobility of groundwater and the permeability of rocks and controls the karstification. Therefore, the karstification is often along the strike of faults, especially at the intersection of faults.

Among the 43 karst funnels observed in the field, 35 have very clear sidewalls with a strike of 300°–315°. Along the northwest direction of the funnel, the ore bodies often disappear and are cut by the northeast sidewalls. Although the sidewalls in this direction also have dissolution, it is much weaker than the sidewalls in the north direction. At the intersection of the two sets of sidewalls, there
are usually thick ore bodies. Therefore, the above two sets of joints should be conjugate shear joints at
the same period when the Benxi Formation was formed. According to the sharp included angle of the
conjugate shear joint (87° in the study area), the direction (near the east-west direction) is indicated. At
the junction of joints, due to the development of structural fracture zones and cracks, it is conducive to
water flow and weathering, which makes the elements easier to hydrolyze and migrate, so the
karstification is strong. In some areas, the tracking tensional joints in the east-west direction may be
developed (Figure 3).

![Figure 3. Schematic diagram of joint control karst action in the study area](image)

4.1.3. Quality of bauxite
Due to the tectonism, the drainage conditions in the middle of the Benxi Formation are improved, and
karstification is developed. High-quality bauxite often develops in the middle of the Benxi Formation,
and poor-quality bauxite often develops in the upper and lower bauxitic mudstone. These layers have
relatively calm tectonism.

4.2. Exploration method and engineering layout
Preliminary geological work has conducted high-precision gravity measurement of the area, which
reflects the geological structure characteristics of the bedrock and explored the spatial relationship
between the gravity gradient zone and the bauxite zone, which provides a direct basis for the
determination of the target area.

Based on investigating shallow bauxite mines, the hidden bauxite deposits are predicted by
combining the production and exploration data of coal mine. According to the requirements (DZ/T
0202-2002), combined with regional mineralization characteristics and prospecting experience in
neighbouring mining areas, the work region is divided into four sub-regions. The exploration method
combining drilling engineering and geophysical prospecting is adopted to delineate the bauxite
orebody according to the chemical test and analysis results.

The layout of exploration project: the distance between exploration lines on the strike is about 800
m. The tendency is to control the drilling sparsely according to 400m engineering spacing and estimate
the predicted resource quantity of bauxite (334)? The distance between exploration lines is about
400m. The sparse drilling control is carried out according to the engineering spacing of 400m, and the
inferred resource amount of bauxite is estimated (333) [9].

4.3. Exploration effect
The comprehensive exploration methods (such as geology analysis, drilling engineering, geophysical
prospecting, and testing) are used to evaluate the metallogenic prospect of the pre-investigation area.
Sixteen bauxite ore bodies are delineated in the study area, and the bauxite resources are 249.24
million tons, a super-large mine and currently the largest bauxite in China. Also, symbiotic ore bodies
are also delineated in the study area, and the resources of refractory clay, bauxite, and pyrite are also large mine [10]. The exploration results obtained the top ten geological prospecting results in 2018.

5. Conclusion
The mineralization of bauxite results from the coupling of many factors, such as tectonism, sedimentation and karstification. The tectonism controls the regional distribution, location, thickness and quality of bauxite.

The exploration methods (such as geology analysis, drilling engineering, geophysical prospecting, and testing) are feasible, and the largest bauxite in China is proved, and the effect has been achieved.

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