

# The Migration Pattern of Major Elements of the Bauxite in Zhangjiayuan Syncline, WZD Area, Northern Guizhou Province

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**Abstract.** Through various measures such as field geological survey, observation of hand specimens and analysis of major elements, we studied the migration pattern of major elements of the bauxite in Zhangjiayuan Syncline, Wuchuan-Zheng'an- DaoZhen(short for WZD) area of Northern Guizhou Province. The results show that: the Al element was negatively correlated with Si and Fe, but it was not completely synchronous, which indicates the complexity of the mineral transformation during the migration process and the result of superposition of multi-period migration; Al and Ti presented highly positive correlation, and both were relatively stable with certain correlation during the mineralization process; Al was enriched in the central area, Si and Fe presented the tendency of downward aggregation, but the migration scale of elements of the bauxite in Zhangjiayuan Syncline was smaller than that in the karst bauxite in Zunyi.

**Keywords:** Migration pattern, Major elements; bauxite, Zhangjiayuan syncline, Guizhou.

## 1. Introduction

There are abundant bauxite resources in WZD area of Northern Guizhou Province. Many experts and scholars have conducted related research (Du et al., 2007; Wu et al., 2008; Jin et al., 2009; Yu et al., 2013; Lei et al., 2013; Wang et al., 2013; Du et al., 2013, 2014; Huang et al., 2013; Zhang et al., 2013; Zhang et al., 2013; Cui et al., 2014), and they have in-depth recognition of the petromineralogy, geochemical characteristics, metallogenic environment and formation mechanism of bauxite deposits in WZD. Zhangjiayuan Syncline is an important part of the bauxite deposit in WZD. Previous researches mainly studied Zhangjiayuan Syncline as part of WZD, and there are very few independent researches on Zhangjiayuan Syncline. In this paper, 4 boreholes in Zhangjiayuan Syncline were selected for analysis and test. We studied the characteristics of its main elements and analyzed related migration patterns, which can provide new material to study bauxite in WZD of Northern Guizhou Province.

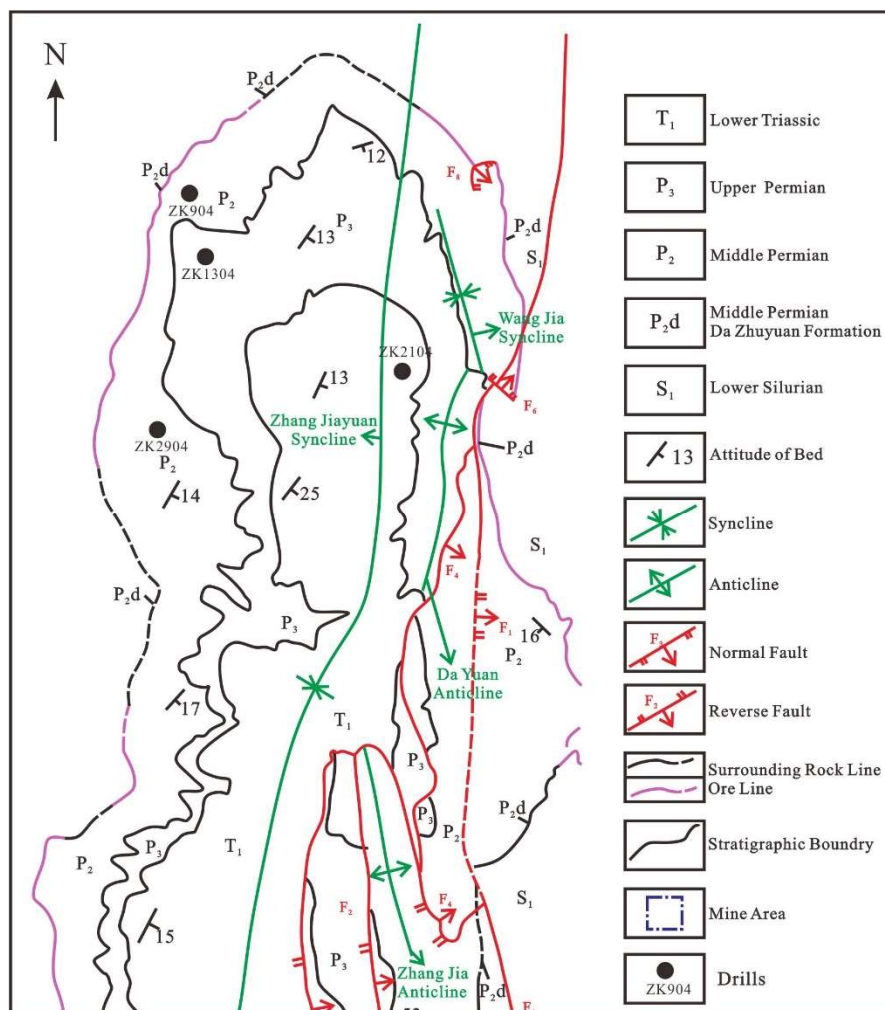
## 2. Geological Background

The bauxite mine studied in this paper is located in the Wuchuan-Zheng'an-Daozheng (WZD) area in Northern Guizhou Province, which belongs to the northern part of the Carboniferous bauxite metallogenic belt in Central Guizhou Province and Southern Chongqing, and it consists of two bauxite



belts of Zheng'an and Daozhen. The bauxite deposit was output on the mud shale of Hanjiadian Group of Lower Silurian Series and/or the limestone eroded surface of the Huanglong Formation of the Upper Carboniferous Series. The mineralogenetic epoch was considered to be the early Permian, and the rock stratum of ore-bearing rock series of bauxite deposit was determined as Dazhuyuan formation (P<sub>2</sub>d).

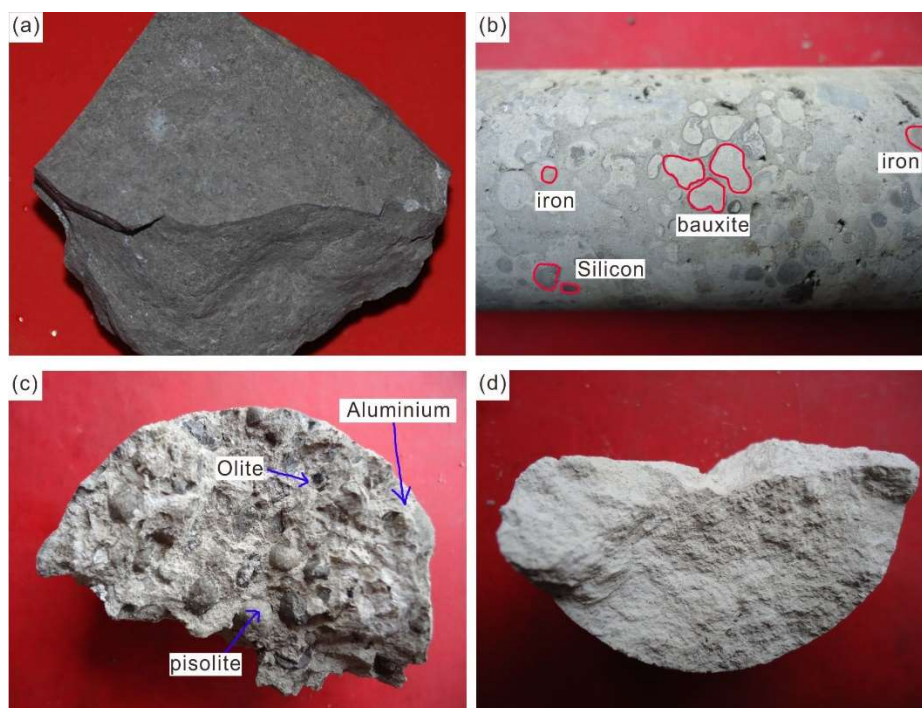
The metallogenic area of WZD bauxite is located at the Yangtze paraplatform-Tailong of Northern Guizhou Province and North of Duangong, Zunyi. The extensively exposed strata in the region include the Cambrian System, Ordovician System, Middle and Lower Series of Silurian System, Permian System and Triassic System, while lacking the Upper Series of Silurian System, Devonian System, Upper and Lower Series of Carboniferous System, and Maping Formation strata. The Cambrian is distributed in the anticline core, and the Triassic system is concentrated on the syncline core. The Liangshan Formation in the Middle Series of Permian System presented deceptive conformity contact with the Huanglong Formation stratum in the Upper Series of Carboniferous system sparsely distributed at the bottom of bauxite rock series and the Hanjiadian Formation in the underlying Silurian System. The main lithology of the ore-bearing strata and the host surrounding rock strata includes carbonaceous shale, calcareous shale and marl. The distribution of bauxite deposits (spots) is controlled by the NNE Neocathaysian synclinal folding tectonic system of Yanshanian Tectonic Period after mineralization, and they are distributed in the Liyuan-Luchi syncline, the Xinmo syncline, the Zhangjiayuan syncline, the Huanxi syncline, the Taoyuan syncline, the Datang syncline, the Daozhen syncline, and the Anchang syncline(Liu, 1993). The research object in this paper is bauxite in the Zhangjiayuan syncline (Fig.1 ).



**Fig.1** The geologicla map of Zhangjiayuan syncline

### 3. Mineral Characteristics

Similar to other synclines in the WZD Area, the minerals in Zhangjiayuan Syncline can be divided into four categories: the dense, detrital, semi-earth, pisolitic and oolitic structures (Fig.2). The dense minerals present gray and dark gray micrite structure, and the detritus content is generally smaller than 5%. The ore section is smooth with dense texture, high hardness and weak water absorption. Although the mineral composition is still mainly diaspore, there are many clay minerals. The detrital minerals generally have gray-light gray color, the detritus size is between 0.2-2mm, and the detritus shapes include: augen, lenticular, dough and other shapes. A small number of the detritus has the size between 2-5 mm, and several detritus have the size up to 10 mm. The minerals consisting of detritus include: diaspore, muddy clay, iron, silicoide, etc.; the mineral components of adglutinate mainly include: diaspore, muddy clay, iron, silicoide, etc.. The pisolitic and oolitic minerals are mainly gray. The ooid may present the sub-ellipsoidal, sub-circular, elliptic and round shapes, and the particle sizes are close. The pisolite size is generally between 2-4 mm, and some may be up to 6 mm; the ooid size is generally between 0.5-2 mm. There are more pisolites than ooids among the rocks. Most pisolites and ooids have concentric annule internal structure with varied number of annules, but the annule part is incomplete. The minerals consisting of pisolites, ooids and detritus include: muddy clay mineral, diaspore, iron, silicoide, etc.. The mineral particle has small size, generally smaller than 0.005, and they are mainly micrite or crypto-crystal. The adglutinates of pisolites and ooids include muddy clay mineral, diaspore, iron, silicoide, etc.. The semi-earth minerals present gray, light gray and yellow-gray, most minerals have detrital structure, and the detritus presents angular and sub-angular shape. The sorting is poor, and a small part presents micrite or powder crystal structure. The mineral composition is mainly diaspore, accompanied by a small amount of clay minerals, chlorite and iron minerals.



**Fig.2** Characteristics of bauxite ores in Zhangjiayuan syncline

### 4. Element Migration Pattern

We conducted analysis and test of the main components of ZK904, ZK1304, ZK2904 and ZK2912 in Guizhou Geology and Minerals Bureau(Fig.1). The results are shown in Table 1. Based on the results of Table 1, by combining the mineral characteristics and field geological characteristics, we studied the migration pattern of main elements in the bauxite of Zhangjiayuan Syncline(Table 1, Fig.3).

**Table 1.** Data of major elements of bauxite from 4 drills in Zhangjiayuan syncline

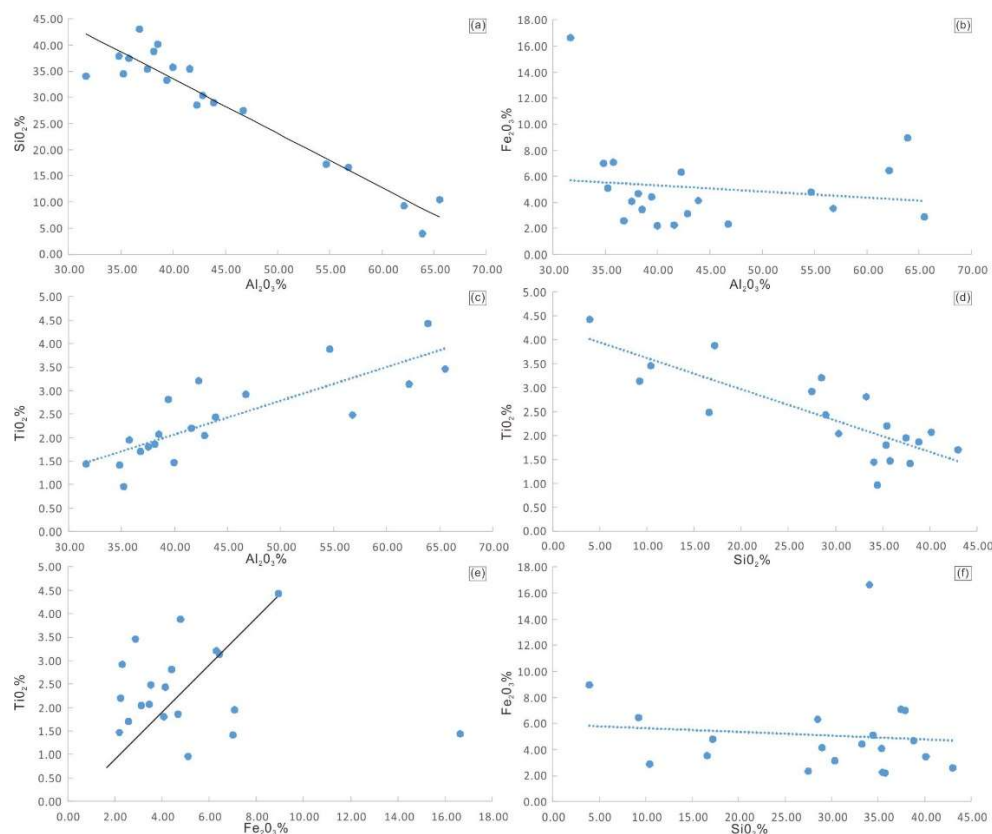
Drills	Numeber	Describe	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	S	LOI
			10 <sup>-2</sup>	10 <sup>-2</sup>	10 <sup>-2</sup>	10 <sup>-2</sup>	10 <sup>-2</sup>	10 <sup>-2</sup>
<b>ZK904</b>	ZK904-1	bauxite	35.24	34.44	5.10	0.96	13.08	2.86
	ZK904-2	bauxite	39.98	35.76	2.19	1.47	12.18	0.21
	ZK904-3	bauxite	56.78	16.60	3.53	2.48	14.04	1.76
	ZK904-4	bauxite	46.73	27.47	2.32	2.92	12.82	0.18
	ZK904-5	bauxite	41.59	35.45	2.25	2.20	11.46	0.45
	ZK904-6	bauxite	34.82	37.90	7.00	1.41	10.28	5.25
<b>ZK1304</b>	ZK1304-1	bauxite	37.53	35.36	4.08	1.80	12.79	2.59
	ZK1304-2	bauxite	42.85	30.33	3.12	2.04	12.82	0.47
	ZK1304-3	bauxite	65.51	10.41	2.87	3.46	15.04	1.10
	ZK1304-4	bauxite	43.89	28.97	4.14	2.43	13.16	1.58
	ZK1304-5	bauxite	63.88	3.95	8.94	4.43	17.26	7.43
	ZK1304-6	bauxite	38.52	40.14	3.46	2.07	12.80	2.23
<b>ZK2904</b>	ZK2904-1	bauxite	39.41	33.27	4.41	2.81	2.67	11.92
	ZK2904-2	bauxite	54.66	17.19	4.79	3.88	2.02	13.40
	ZK2904-3	bauxite	35.76	37.45	7.08	1.95	4.48	12.46
	ZK2904-4	bauxite	36.79	43.00	2.58	1.70	1.68	13.45
<b>ZK2912</b>	ZK2912-1	bauxite	42.27	28.49	6.31	3.21	4.03	13.92
	ZK2912-2	bauxite	62.12	9.22	6.44	3.14	4.43	14.92
	ZK2912-3	bauxite	38.16	38.81	4.68	1.86	2.06	12.96
	ZK2912-4	bauxite	31.68	34.06	16.64	1.44	0.53	9.95

In ZK904, all the other samples did not reach the industrial grade except for ZK904-3. In general, the variation of Al<sub>2</sub>O<sub>3</sub> was not significant. The high-grade bauxite was located in the middle; the content of Al at the top and bottom was low; from the top to the bottom of the section, the Al content increased first and then decreased. The Si content in ZK904 was generally high, with the lowest content of 16.6%. This sample had high aluminum content, and the silicon content was generally low in the middle, with little difference between the top and the bottom. In ZK904, Fe and Si had similar variations, higher at top and bottom while lower in middle, but the location with lowest Fe content was not where with highest Al content. The Ti content in ZK904 was lower at the top, higher at the middle and lower at the bottom, and the variations of Ti and Al content were generally consistent. The S content in ZK904 did not have significant change, and the highest value appeared in the sample with high Al content, and it presented a general trend of decline from top to bottom.

In ZK1304, No.3 and No.5 samples had high Al content, the difference between the top and the bottom was not large, but it presented the overall trend of decline. The high-grade bauxite was within the bauxite which only reached the boundary grade, which indicates that the high-grade bauxite was not formed at one time. Si presented an overall negative correlation with Al, and Si has a wide range of variation between 40% and 3.95%. This indicates that Si was active in the mineralization process, and the migration of elemental Si was very difficult. The migration of Si occurred through the generation and movement of clay minerals. The change of Fe content was not very regular, and the highest value was 4 times higher than the lowest value. Both the lowest value and the highest value occurred in the sample with higher aluminum content, indicating that the change of Fe and Al was not completely synchronous. The change of Ti was not significant, which presented overall positive correlation with Al, and the high value of Ti was consistent with the high value of Al. The S content in each sample was basically stable, and the high value corresponded to the sample with high Al content. The change of S in the borehole was positively correlated with Al.

In ZK2904, the Al content was generally low. Sample No.2 satisfied the industrial grade. Except for the high content of Al in the middle samples, the Al content presented the trend of decrease from the top to the bottom of the section; except for sample No. 2, the Al content didn't present significant change in this sample. The variation of Si content was higher than that of Al content, and its lowest value occurred synchronously with the highest value of Al. From the top to the bottom, the Si content presented the overall trend of increase. The Fe content was high in the middle and lower part, lower in the bottom and more stable in the upper part. The Ti content in the borehole was positively correlated with the Al content in general, and the part with highest Ti content also had the highest content of aluminum. The content of S had little variation, which was lower than the S contents in other boreholes.

In ZK2912, Sample No.2 had high aluminum content. The Al content was low in the middle and lower parts, and at the top, the aluminum content reached the boundary grade. The variation of Si was relatively large with the lowest content of only 9.22%, which was consistent with that of high-grade bauxite, indicating that Si and Al presented overall negative correlation, but they did not strictly correspond to each other. The overall content of Fe was low, which was the highest at the bottom. The lowest value Fe content was not completely synchronized with the peak value of Al, but it was near the part with the highest content of Al, and in general, Al presented a relatively significant negative correlation with Fe. From the top to the bottom, Ti presented a decreasing trend. The peak value of Ti almost occurred synchronously with the peak value of Al. Ti and Al presented a good positive correlation. The S content was the lowest at the bottom, and its content in the middle-upper part was significantly higher than that in the middle-lower part.



**Fig.3** Plots of major elements of the bauxite in Zhangjiayuan syncline

## 5. Discussion

On the plane, Al, Si, Fe, and Ti did not present any significant trend of change from north to south. However, the S content showed a clear trend of decline, which implies that the north was close to the



sea, which was consistent with the findings of previous researchs (Du Yuansheng, et al., 2013; Cui , et al., 2013). Al was negatively correlated to Si and Fe in general (Fig.3, a, b) without stringent correspondence, which indicates that the mineralization process is a process in which Al was relatively enriched, and Si and Fe were migrated, but the migration process of Si, Fe and the enrichment process Al were not a completely synchronous process. This means that the formation and migration of minerals in the process of bauxite mineralization was not a simple process, and there was mineral transformation on different layers. Bauxite had stratification, and the high-grade bauxite appeared in the middle or middle-lower part, but not at the bottom. This is because both Fe and Si had a tendency to migrate to the bottom, and Al could only be relatively enriched in the middle or middle-lower part. The distribution of Al, Si and Fe was determined by their activity. The multi-layer nature of the part with high aluminum content indicates that the migration of elements was not formed at one time during the mineralization process, but the result of repeated iterations. The latest migration result would be overlaid with previous results, and as a result, the vertical variations of Al, Si and Fe were not fully synchronized. The change of Ti and Al was basically consistent (Fig.3, c), because Ti and Al are both highly stable elements, and their migration was relatively difficult. Generally speaking, Al, Si, Fe and Ti in the bauxite all migrated during the mineralization process, but the migration ability of Al and Ti was weaker, and due to the migration of Si and Fe, Al was relatively enriched and eventually formed the industrial bauxite ore; there was a positive correlation between Al and Ti, Al and Ti were negatively correlated to Si and Fe, Al generally presented a negative correlation with Si and Fe, but they were not fully synchronized, and this may be due to the unsynchronized migration of Si and Fe and the superposition of multi-period migration; Ti and Al were highly positively correlated, and this is not because they are both stable elements, but there may be also a certain relationship between the occurrence state of Ti and Al, but the specific reasons need to be further investigated.

Compared with the karst bauxite deposits in the Zunyi Area, no pyrite deposit was found in the lower part of the ore-bearing rock series, that is, there was no significant downward migration of S. This indicates that the acidity of the mineralization environment in Zhangjiayuan Syncline was not as good as that of the Zunyi Area. Therefore, under this acid environment of this syncline, the pyrite deposit finally formed based on large-scale downward migration of sulfuric acid was not very well developed, which was consistent with the fact that the thickness of the bauxite deposit in Zhangjiayuan Syncline was much smaller than that of the bauxite deposit in the Zunyi Area. The difference in deposit thickness between Zhangjiayuan Syncline and Zunyi Area, and the lack of pyrite deposit in Zhangjiayuan Syncline may be caused by the following two reasons: 1) The karst topography of the Zhangjiayuan Syncline was not well developed, and a good karst drainage system was not formed; 2) The Zhangjiayuan area experienced frequent transgression and retreat processes, but the exposure caused by each retreat did not last long.

## 6. Conclusion

The following conclusions can be drawn according to the analysis of major elements in Zhangjiayuan Syncline: 1) On the plane, Al, Si, Fe and Ti did not present significant change pattern. From north to south, the S content presented the trend of decrease; 2) Al was negatively correlated to Si and Fe, and positively correlated with Ti. However, the correlation between Al and Si & Fe was not completely synchronous, and Al was highly correlated to the change of Ti content; 3) High-grade bauxite was located in the middle, and Si and Fe presented the trend of enrichment at the bottom, which was the result of superposition of multi-phase migration during the mineralization process; 4) Thick bauxite and pyrite deposits were not formed in the lower part of the bauxite mine in the Zhangjiayuan Area, indicating that the extent of element migration was not smaller than the Karst type bauxite in Zunyi.

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