

Migration laws of major elements of Laowashan bauxite in Zunyi area, northern Guizhou province of China

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Abstract. After exploring migration laws of major elements in Laowashan bauxite of northern Guizhou Province by geochemical methods, it was found that: 1) Si was negatively correlated to Al and Ti; Al showed significant negative correlations with Si and Fe; Al was positively correlated to Ti. 2) The content of Si and Fe was low in the middle part, high at the top and the highest at the bottom. The content of Al and Ti is the highest in the middle, followed by the content at the top and the bottom successively. 3) Karst depressions are favorable for groundwater discharge through leaching, leading to heavy loss of Fe in ZK-CS1.

1. Introduction

Zunyi area, lying in northern Guizhou Province of China, is a crucial metallogenic belt, in which lots of bauxite developed in the Carboniferous-Permian period. There have been lots of studies on bauxite of this area (Liu et al., 1990; Gao et al., 1992; Yin et al., 2011; Weng et al., 2011; Liu, 2012; Liu, 2015, 2016). Notwithstanding much relevant research, attention has been mainly paid to bauxite of other mines instead of Laowashan, and Laowashan bauxite have been rarely explored, so related research remains to be performed. In this paper, migration laws of major elements in Laowashan bauxite were studied by geochemical methods to analyze laws of vertical changes to major elements of Laowashan bauxite and correlations of various elements, thus providing much more data for examining bauxite in Zunyi area.

2. Geological setting

In Zunyi, bauxite are on the Yangtze platform. In the north, they are connected to the metallogenic belt of bauxite in the Wuchuan-Zheng'an-Daozhen Area. In Zunyi, most of the strata exposed are cambrian-triassic, among which Carboniferous Jiujialu Formation is an ore-bearing rock series (Liu et al., 1990; Gao et al., 1992), which is about 0 to dozens of meters thick. This series is covered by black muddy shale of the Liangshan Formation or limestone of the Qixia Formation. Under this series, there exist dolomites of Cambrian Loushanguan Formation or ordovician Tongzi Formation. Regional strata exposed are cambrian Loushanguan Formation, permian Liangshan-Qixia Formation, and carboniferous Jiujialu Formation, which mostly strike at 75° and incline at 15°.



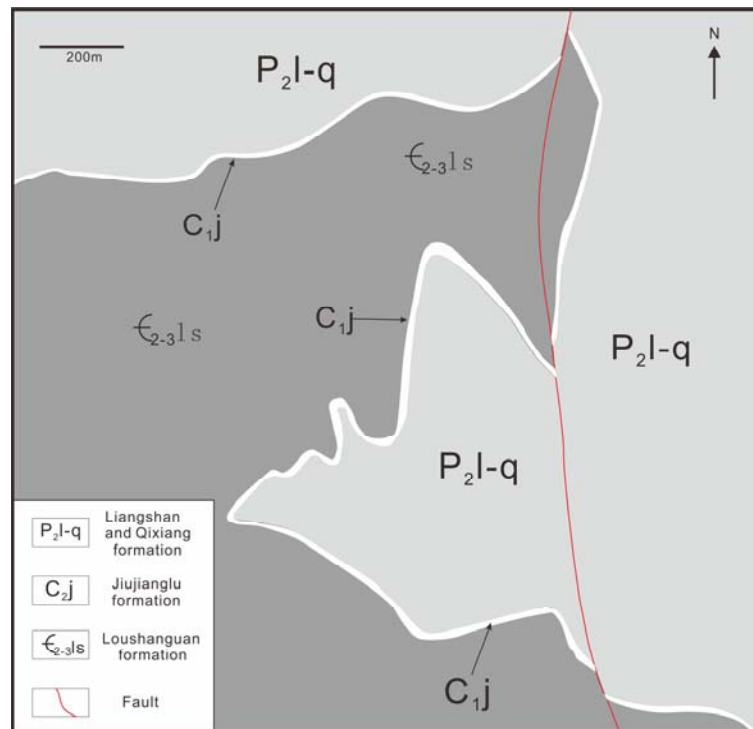


Fig.1 Geology map of the Laowashan bauxite in Zunyi area

3. Analysis and tests

6 drilled ZK-CS1 core samples (Fig. 2) in the southeast of Laowashan Mine (Fig. 1) were delivered to China Railway Langfang Geophysical Prospecting Co., Ltd for analysis and tests to obtain data about the major elements. The tests were performed based on GB/T 14506.28-2010 Methods for Chemical Analysis of Silicate Rocks. The samples were numbered from LWS-1 to LWS-6 and taken from the top to the bottom of the section of the ore-bearing rock series.

4. Features and test results of ores

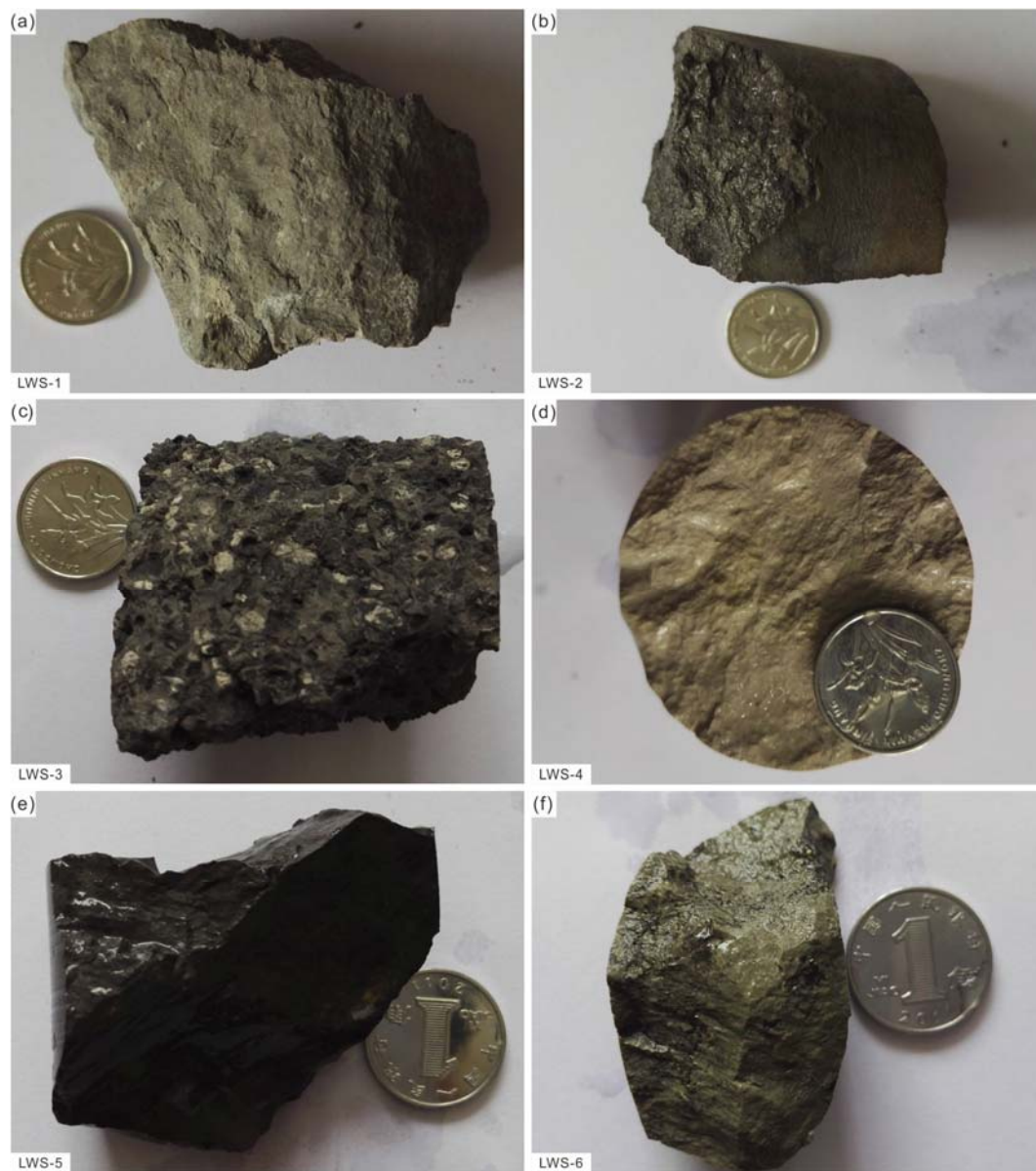
Lithological characters of the samples are shown in Table 1. According to their natural types, ores are classified into massive, clastic and oolitic ones, among which the oolitic ores are mineralized into bauxite with high content of white aluminium (Fig. 2). All core samples are relatively compact, whereas those at the top and samples of oolitic ores in the middle part are looser than other samples. According to the analysis and test results (Table 2), ZK-CS1 core samples generally present ternary structures of the ore-bearing rock series. Except that general color changes are not especially evident, the grade of ores is the highest in the middle part and lower in the lower part. Clastic and oolitic ores are in the middle part.

Table 1 Samples of ZK-CS1

Number	Code	Lithological characters
1	LWS-1	gray massive bauxite
2	LWS-2	gray clastic bauxite
3	LWS-3	gray oolitic bauxite
4	LWS-4	light yellow massive bauxite
5	LWS-5	dark gray massive bauxite
6	LWS-6	gray massive bauxite with fragment

Table 2 data of major elements

Number	SiO ₂ 10 ⁻²	Al ₂ O ₃ 10 ⁻²	TFe ₂ O ₃ 10 ⁻²	MgO 10 ⁻²	CaO 10 ⁻²	Na ₂ O 10 ⁻²	K ₂ O 10 ⁻²	MnO 10 ⁻²	TiO ₂ 10 ⁻²	P ₂ O ₅ 10 ⁻²	LOI 10 ⁻²	FeO 10 ⁻²
LWS-1	36.98	45.74	0.676	0.297	0.106	0.083	6.86	0.004	1.72	0.072	7.39	0.125
LWS-2	6.99	74.38	0.323	0.236	0.062	0.071	1.89	0.003	2.99	0.072	12.86	0.096
LWS-3	1.64	79.14	0.516	0.177	0.050	0.069	0.313	0.004	2.675	0.062	15.19	0.172
LWS-4	42.80	40.28	0.203	0.167	0.069	0.070	0.704	0.004	1.78	0.086	13.75	0.077
LWS-5	43.40	38.83	0.407	0.232	0.063	0.069	2.19	0.004	1.79	0.051	12.89	0.268
LWS-6	44.54	34.43	3.765	0.451	0.130	0.086	7.81	0.006	1.32	0.165	7.19	1.23

**Fig.2** Pictures of hand samples

5. Migration laws of elements

Distribution laws of major elements in Laowashan bauxite and their relationships were studied according to the test results. The content of SiO_2 changed a lot from 1.64% to 44.54%. It was lower in LWS-2 and LWS-3 samples, but higher (over 30%) in the remained samples. Particularly, it was high at the top, low in the middle part and the highest at the bottom. The changes to content of Si exhibit remarkable vertical migration laws. In spite of relatively great changes to the content of Al_2O_3 , the oxide accounted for more than 30% in all samples, which suggested that aluminium was relatively inert in the course of metallogenesis. Being generally low, the content of Fe_2O_3 was lower in the middle part of samples, higher at the top and the highest at the bottom. The content of alkali metals such as CaO, Na_2O and K_2O was extremely low in the ore-bearing rock series, where the content was higher at the top and bottom than that in the middle part.

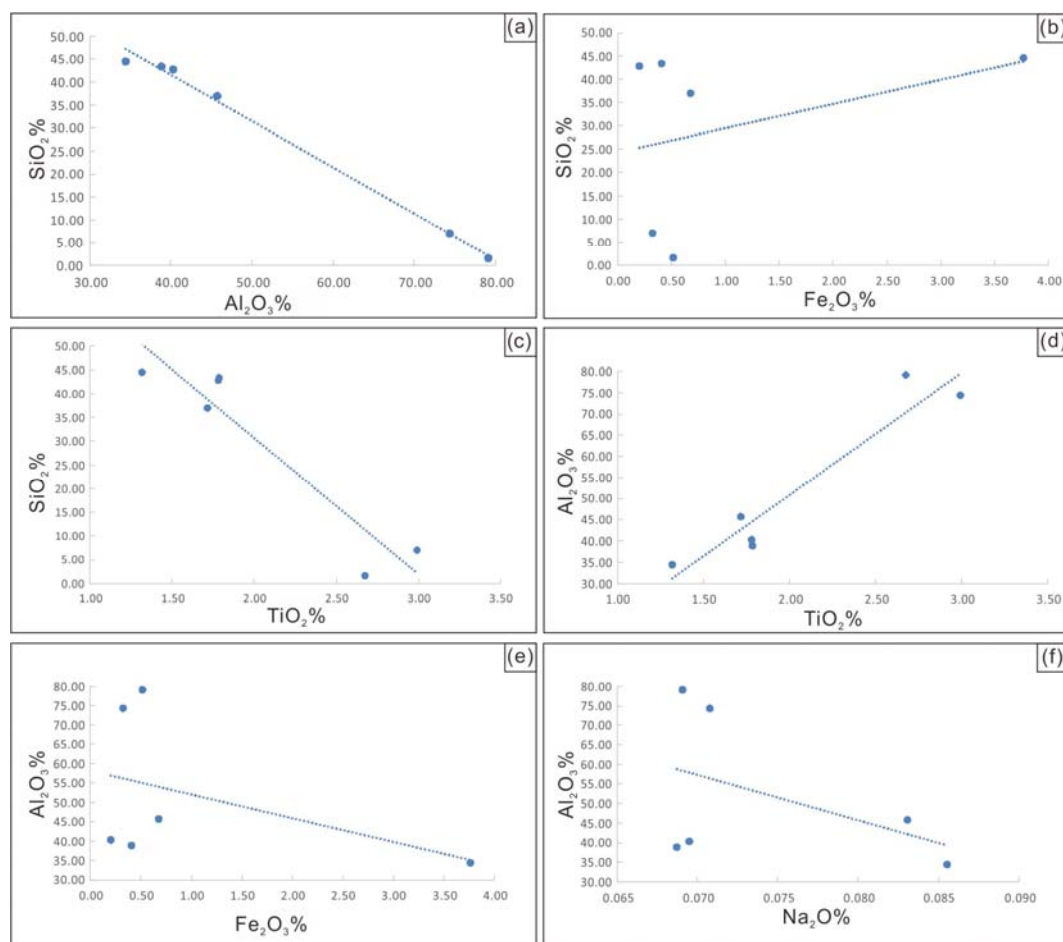


Fig.3 Plots of major elements

Correlations of major elements (Fig. 3) suggested that elements such as Si, Fe, Al and Ti were somewhat correlated to each other. Si had significant negative correlations with Al and Ti (Fig. 3, a, c), whereas the correlations between Si and Fe were insignificant. Al was significantly and positively correlated to Ti (Fig 3, d); weak negative correlations existed between Al and Fe (Fig. 3, e); there were weak negative correlations between Al and Na (Fig.3, f). The correlations of major elements suggested that Al and Ti migrated similarly and enriched during metallogenesis with relatively stable content. Both Si and Fe migrated downwards, but the extent of migration was far higher for the latter than the former. The migrations of both Si and Fe were heavily hindered at the bottom of the ore-bearing rock series. The enrichment of Si and Fe at the bottom was possibly attributable to two reasons as follows:

On one hand, Si and Fe on the upper part partially migrated to the bottom of the ore-bearing rock series. As a consequence, the content of both Si and Fe was higher at the bottom of the ore-bearing rock series than that in the upper part. On the other hand, the migration of Si and Fe was inconsistent in the ore-bearing rock series. Fe might be accumulated at the bottom to compose pyrites and suffer heavy losses. No matter Fe was accumulated in the lower part of the ore-bearing rock series to form pyrites or suffered heavy losses, its content would be always higher compared with the upper part of the series. Although Si was also lost at the bottom of the series, its losses were far smaller than iron, so there was much more Si than Fe at the bottom of the ore-bearing rock series.

Compared with normal red clay, the content of Fe was rather low in the ore-bearing rock series, which indicated that Fe was heavily lost in the process of metallogenesis. Fe was highly mobile under reduction, or acid conditions, which could be created during metallogenesis and leaching. This element migrated from the top to the bottom of the section, finally precipitating at the bottom in the form of pyrites. Pyrite deposits were common in Laowashan bauxite, which just proved this view. Under the acid environment, there was a great loss of alkali metals. No pyrite deposit formed in ZK-CS1, which showed that the groundwater discharge was smooth in this area, where Fe was heavily migrated and taken away. However, no pyrite deposit formed at the bottom. The content of Fe was extremely low from LWS-1 to LWS-6, which indicated that ZK-CS1 was intensively leached in this area.

Compared with features of major elements in the Wuchuan-Zhengan-Daozhen Area of northern Guizhou Province (Wang et al., 2013; Cui et al., 2013; Zhang et al., 2013), major elements of Laowashan bauxite in Zunyi area also presented ternary structures and reflected heavy losses of alkali metals. Al was enriched to a greater extent in bauxite of Zunyi area, where there was much heavier loss of Fe in Zunyi area compared with the loss of this element in the Wuchuan-Zhengan-Daozhen area, which suggested that leaching was more efficient and intensive during the formation of bauxite in Zunyi. This phenomenon was attributed to the fact that bauxite formed in karst depressions in Zunyi area, with underlying carbonatite depressions, which were helpful for leaching.

6. Conclusion

After analyzing major elements of Laowashan bauxite in Zunyi area, following conclusions are reached: 1) Major elements of the ore-bearing rock series were correlated to each other in Laowashan bauxite of Zunyi area. To be specific, Si was significantly and negatively correlated to Al and Ti; Al exhibited significant and negative correlations with Si and Fe; Al was positively correlated to Ti. 2) The content of Si and Fe was low in the middle part, high at the top and the highest at the bottom. The content of Al and Ti was the highest in the middle part, lower at the top and the lowest at the bottom. 3) The groundwater discharge was relatively smooth in areas where ZK-CS1 was, and the underlying carbonatite depressions were favorable for leaching. Thus, there was a much heavier loss of Fe in ZK-CS1 than that in bauxite in the Wuchuan-Zhengan-Daozhen area of northern Guizhou Province.

Acknowledgements

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