Analysis of Provenance Tracıng Methods Of Bauxıte Deposıt

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Abstract. Research on provenance of bauxite deposit is a difficult topic throughout the world, based on the domestic and foreign latest researches, analysis methods of provenance of bauxite deposit are discussed here, which includes zircon provenance tracing, Harker Diagrams of major elements, trace element analysis, REE tracer and heavy minerals tracer. Bauxite deposits are of multi-sources, rare of them yielded from the single parent rock. Therefore, it should be a multi-method approaching to recognize the source of bauxite, including analysis of mineral assemblages and geochemistry, and in combination of regional paleogeographic and tectonic evolution. A comprehensive analysis of all possible sources of bauxite is necessary to avoid a one-sided consequence.

1. Introduction

Bauxite deposit is a kind of important strategic resource, which mainly yielded from 19 major metallogenic provinces around the world, one of which is China[1]. Many domestic and foreign scientists have conducted a lot of work on the bauxite deposits, including systemic research on composition of bauxite mineral, geochemistry, sedimentary environment and mineralization process [2-8]. Lateritic bauxite deposits can be divided into laterite, karst and sedimentary types[9-10], the latter two are more common, and most of the bauxite deposits in China overlie carbonate rocks. The karst type refers to the bauxite deposit overlies carbonate rocks and significantly controlled by karst depressions, and the deposit morphology is in accordance with the shape of karst depression, usually funnelform or sinkhole-shape [9]. The sedimentary type means the weathered products of parent rocks transported a certain distance and finally deposited forming stratiform bauxite ores, and paleokarst of underlying carbonate rocks is undeveloped. No matter what type of bauxite deposit, it is part of the process to experience weathering and leaching transformation, which attributes to the difficulties of provenance research of bauxite deposit. Based on extensive investigations, main research methods of bauxite resources and existing problems have been analysed, and pointed out the research direction to addressing these issues.

2. The Parent Rock Of Bauxite Deposit

Theoretically, all the sediments rich in aluminum can be the parent rocks of the bauxite deposit[9-10], and the most important parent rocks of the bauxite deposits are the aluminum silicate and carbonate rocks. Usually, aluminum silicate contains higher content of Al than carbonate units, which only contains a few percentage of Al. However, carbonate is the major source of karst type bauxite deposits, so the content of Al is not a key factor to indentify the parent rocks of bauxite deposits. Even the content of Al is very low in rocks, bauxite deposit still can be formed after a series of metallogenesis, which suggests that as long as the conditions are suitable, almost all of the rocks can be the parent rocks of the bauxite deposits.

3. Analysis Methods of Provenance of Bauxite Deposit

Zircon provenance tracing: Zircon with high closure temperature and good stability is widely used for dating, formed zircon geochronology, many scientists using zircon dating to investigate diagenetic and metallogenic ages, tectonic evolution, metallogenic process and other issues [11-15]. Zircon is not only can be used for direct dating, but also can be used to trace provenance in

sedimentary rocks. For magmatite, the age of zircon can be identified through U-Pb dating, and the characteristics of zircon can be analysed to compare with features of zircon from possible provenances[16-17]. For clasolites, various zircons reflect different provenances according to their ages and characters[18]. As for weathering residual type deposit, the basic principle is that zircon formation ages are different, consisting an age spectrum diagram. If clastic rocks have multiple sources of different ages, the age spectrum of inherited rocks should be consistent with that of clastic rocks, unless there are extreme exceptions, Wang (2010) and Rong (2012) [19-20]solved some long debated issues relating to continental strata by using detrital zircon age spectrum tracing. Yu et al. (2014)[21] also obtained good result by this method on provenance tracing of bauxite deposit of Wuchuan -Zheng'an -Daozhen area, Guizhou, and demonstrated that the underlying shales of the Hanjiadian Formation is one of the provenances of bauxite deposit.

Harker Diagrams of major elements: The metallogenesis of bauxite deposit is a process of desilication and eisenaustrag[9-10], different parent rocks have diverse evolutionary trends in the process of weathering mineralization. Harker diagrams is a study of relationship between SiO_2 and the main oxides, it is taking SiO_2 as the abscissa, and Al, Fe, Mg, Ca, Na and other elements as the ordinate. Al and Fe-Si in the bauxite is usually negatively correlated, SiO_2 and the main elements of the same parent rock is generally linear correlated. If the evolution trend is more than one line, that means it may contain a variety of parent rocks. This method is suitable for comparison with underlying strata, and for the study of phylogenetic relationship between the bauxite deposit and the underlying strata.

Trace element analysis: The trace element spider diagram: it is a method to recognize provenance by the use of combination characters of trace elements, mineral assemblage characters of bauxite deposit and features of trace elements are related with parent rocks, so the spider diagram can be applied to analyse change characteristics f trace elements. Usually the curve of trace elements of bauxite deposit shares some common characters with that of parent rocks. Some scientists have applied this method to the studies of provenances of bauxite deposit and laterite, and get favorable results in the practical applications [22-23], variations of distribution curve of the trace element from different bauxite samples indicate multiple provenances. By using this method, we should pay attention to the overall shape of the trace element curves, abnormity of few specific elements may be attributed to the impact of the metallogenetic process in special environment, therefore, it is necessary to analyse the element abnormity, especislly the morphological differences of distribution curves caused by it, and to avoid mistaking the differentiation of individual elements in special metallogenic conditions as a morphological difference of integral curve.

Triangular diagram (Zr-Cr-Ga): the content of zircon, tourmaline and rutile in sedimentary rocks are usually used as indexes for the maturity of clastic rock structures [24]. In the study of bauxite deposit, triangular diagram is also a commonly used method to analyse the characteristics of mineral assemblage and evolution process of bauxite deposit, as well as tracing provenance. Commonly used graphics include Al+Ti-clay-Fe, Kao+Gib+Al-Ca-Na, Zr-Ti-Y, Al-Si-Fe and Zr-Cr-Ga etc. Among them, the geochemical behavior of Ga is similar to Al, Zr, mainly occuring in zircon, is a relatively stable element during weathering. Zr-Cr-Ga distribution of bauxite deposit should be close to that of the parent rock, but quite different from that of non-provenance rocks.

Cr-Ni gaphic: the binary diagram of Cr and Ni can be used to tracing provenance of bauxite deposit, the values of Cr/Ni of varieties of bauxite deposits and their parent rocks are significantly different [25]. Schroll (1968) studied on the Cr-Ni relationship of typical global lateritic and karst types bauxite deposits, and proposed that their Cr/Ni value difference was distinct, different types of bauxite deposit and parent rocks have their own specific distribution areas[25]. Cr-Ni binary graphic of bauxite deposit is used to infer the parent rock types, and to study the relationship between bauxite deposit and the underlying strata, it favors to figure out the hidden provenance.

High field strength elements diagram: Zr, Hf, Nb and Ta are stable in wheathering [26-28], Zr and Hf, Nb and Ta are element pairs with similar geochemical distribution in the process of mineralization, so they are often used to trace provenance of bauxite deposits[29]. Previous work showed that the values of Zr/Hf and Nb/Ta of parent rocks and bauxite deposit exhibit a linear

correlation, Zr and Hf, Nb and Ta usually present simliar degree of enrichment or lost in metallogenesis. Zr and Hf may be enriched in zircon, while Nb and Ta are stable element pair in metallogenesis[30].

REE tracer: From previous work, it is considered that the most important factor controlling REE characteristics of sediments is provenance, which is the base of REE tracer. [31-38]. Many domestic scientists have successfully applied REE tracer in to practice: Taylor and Mclennan (1985) established a “Taylor Model” of REE to trace provenance, distinguished different provenances of river sediments, and plutonic, metamorphic and migmatite rocks in soil[35]. The REE chondrite distribution curve of karst type bauxite deposit in Guangxi is basically the same with that of the underlying carbonate rocks[30]. REE curve characteristics of bauxite deposit in Turkey not only indicate the provenance of underlying limestone, but also reflect chemical condition of mineralization environment[36].

Heavy mineral analysis: The heavy minerals can be used to trace the source of bauxite deposits [40-43]，many researchers use different heavy minerals (zircon, tourmaline, garnet, pyroxene, hornblende and spinel etc.) to analyse provenances [42-44]. Morton (1999)[45] took out P-As-Gs three endmember identification chart of garnet, based on the composition differences of sandstones from the North Sea and Tertiary sandstones from New zealand and Bangladesh. On the whole, heavy mineral tracer can be divided into three steps: 1, identifying rock types by using of traditional heavy mineral tracer, and defining prevenance location and the type of parent rock; 2, selecting one or several single grain minerals to make geochemical comparison with minerals in source area, and then obtaining further information of rocks in source area; 3, determining the age of source area through isotope dating, If it is the crust of weathering residual ore, age spectrum can be worked out. Comparing the age spectrum of rock or strata with that of potential parent rock, if the two are similar, it indicates that they have closely related, if not, they are distantly related, such as zircon age spectrum stated above. The grains of exotic zircon, rutile and tourmaline of bauxite deposit from Alpilles and Languedoc in France is one order of magnitude larger than that of the underlying limestones, some minerals (e.g. grenatite, kyanite and corundum) contained in bauxite deposit are absent in the underlying limestones, which indicates that the underlying carbonate rocks cannot be the only source of ore deposit[10].

4. Discussion

A variety of provenance analysis methods have their advantages and weakness, analysis of heavy mineral assemblages is usually better to be used to identify whether bauxite layer is a single source or "multi-source" system, especially for karst type bauxite deposit, comparing the heavy mineral assemblages between bauxite deposit and main parent rocks, can effectively identify the existence of extra provenance of bauxite deposit in addition to limestone, but contributions of various parent rocks cannot be analysed. Geochemical methods mainly include the U-Pb dating, Harker diagrams of major element and trace element analysis. Zircon age spectrum can effectively determine whether there is a relationship between the target layer and bauxite deposit, but can not determine bauxite provenance types and the contribution of each type of provenance to bauxite deposit. Cr-Ni diagram can effectively identify the type of parent rock, but it does not mean to indicate all the parent rock of bauxite deposit. The ratio of high field strength elements can be analyzed for the presence of genetic relationship of different types of parent rocks and bauxite deposits, and also can effectively distinguish the contribution degree of provenance of bauxite deposit. The REE distribution curves have positive practical application in lateritic and karst type bauxite deposits, but in the sedimentary type bauxite deposit, this method should be used with caution. Different types of bauxite deposits should be applied to different methods, and the same method on different types of bauxite deposits may obtain extremely different results, so analysis of the provenance should be combined multiple methods.

Regional palaeogeography and tectonic changes can affect the metallogenic material source supply, frequent transgression and regression usually change the bauxite metallogenetic process,

which not only change the provenance of the same deposit, but aslo make the same strata (parent rock) providedmetallogenic materials for bauxite deposit in different periods. Bauxite deposit usually present "multi-source" and "multi period" characters since paleogeographic and paleotectonic movements.

Although some methods can be applied to analyse contributions of different types of provenance, identification of different strata (rock) contributions is still lack of effective method.

5. Conclusions

Conclusions are conducted as follows: 1) Based on field geological investigation, methods to identify the source of bauxite deposit includes: Zircon provenance tracing, Harker graphic of major element, trace element analysis, REE tracing and heavy mineral tracer. 2) Different provenance analysis methods are applied to different types of bauxite deposits: each was differently qualified, among them, trace elements and REE are widely used and applicable to all types of bauxite deposits; the use of zircon provenance tracing has a good effect on sedimentary type bauxite deposit; the heavy mineral assemblage analysis is an important basis to distinguish parent rocks of bauxite deposit. 3) In the analysis of the provenance of bauxite deposit, it not only should be combined multiple methods, but also should take into full consideration of the paleogeographic and paleotectonic conditions. 4) In the future, trace elements, REE and isotope tracing are key research directions of bauxite provenance research. Quantitative analysis of the contributions of different strata (parent rock) on bauxite deposit is a challenge needed to break through.

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