Application of big data in bauxite provenance: A case study of Yanlong area in Western Henan, China

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Abstract. The application of big data is of great significance to the quantitative study on provenance. In this paper, taking the bauxite in Yanlong area, western Henan, as an example, the detrital zircon U-Pb age big data obtained by Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) are used to study the bauxite provenance. The results show that the Caledonian and Sibao Jinning zircons are from the North Qinling Orogenic Belt (NQOB). In contrast, the Lvliang and Wutai zircons may be derived from karst insoluble of Majiagou Formation limestone.

1. Introduction

Big data was first proposed by McKinsey, a world-famous consulting company, in the research report in the 1980s. In the research report, big data is defined as the acquisition, processing and analysis of data through network technology, from which massive valuable data are extracted [1]. Big data has been widely used in various fields due to its advantages, such as fast processing efficiency, high storage security, and high analysis accuracy [2].

There are also controversies about the source of the bauxite in the southeast of the North China Block, which is based on indirect evidence such as the spatial location of the bauxite. With the in-depth development of computer technology and internet applications, wide variety of sources, fast operation, and massive amounts of information form big data, which gives birth to a new era of technology [3], so a new working model for solutions geological problems (such as provenance) comes into being.

2. Big data provenance

Zircon is widely distributed in all kinds of rocks, rich in U, Th and low in Pb, with high sealing temperature and stable minerals. It can provide accurate U-Pb age and is an ideal object for U-Pb dating [4-8]. At present, there are several methods for single-grain zircon analysis.
ID-TIMS (Isotope Dilution-Thermal Ionization Mass Spectrometry): high accuracy, time-consuming, and large sample volume.

SIMS (secondary ion mass spectrometry): in-situ analysis, expensive.

SHRIMP: in-situ, high precision, sample damage is small, expensive, and long time to test.

LA-ICP-MS: in-situ, fast, economical, large analysis volume, less accurate (meet the source requirements of a large amount of data).

LA-ICP-MS has been successfully used in the study of single-particle zircon, which has promoted provenance analysis and has become a method for U-Pb isotopic dating [9,10]. Based on zircon U-Pb dating, in-situ isotope Lu-Hf, combined with constraints of genetic mineralogy and geochemistry, LA-ICP-MS has become an effective method for studying material sources [4-8,11,12].

LA-ICP-MS U-Pb geochronology of detrital zircons is the great significance for dating constraints and provenance estimation of sedimentary strata. It is widely used to analyse paleogeography and paleoenvironment, sedimentary basin evolution and provenance research. [13-19].

3. Application examples

LA-ICP-MS was performed on two representative lithologies of pisolitic-oolitic (clastic) bauxite (sample ZK0008-43) and bauxite mudstone (sample ZK0008-44) in Benxi Formation in borehole ZK0008 in Yanlong area (figure 1) detrital zircon U-Pb age determination, two samples were tested in a total of two hundred zircons, each sample obtained Th, U, Pb, Th/U and other components, \(^{207}\text{Pb}/^{206}\text{Pb}\), \(^{206}\text{Pb}/^{238}\text{U}\), \(^{207}\text{Pb}/^{235}\text{U}\) isotopic ratios were obtained for each sample, \(^{207}\text{Pb}/^{206}\text{Pb}\), \(^{206}\text{Pb}/^{238}\text{U}\), \(^{207}\text{Pb}/^{235}\text{U}\) ages, i.e. detrital zircon U-Pb age three thousand and two hundred data [8]. The Hf isotopic data of twenty-six detrital zircons from the pisolitic-oolitic (clastic) bauxite (sample ZK0008-43) of the Benxi Formation were measured. \(^{176}\text{Yb}/^{177}\text{Hf}\), \(^{176}\text{Hf}/^{177}\text{Hf}\), \(^{176}\text{Lu}/^{177}\text{Hf}\), \(2\sigma\), \(\varepsilon_{\text{hf}}(t)\), two stage model age (TDM2), \(f(\text{Lu/Hf})\) data, that is, Hf isotopes need to analyse two hundred and thirty-four data [8].

![Figure 1](image)

Figure 1. Location of the samples of Benxi Formation in Yanshi-Longmen area.

a-Tectonic unit sketch of the study area (modified from [20]), b-Geologic column and sampling positions (modified from [8]).

LA-ICP-MS detrital zircon U-Pb dating results remove thirteen zircons whose concordance degree is less than 90% and do not participate in the age spectrum statistics. One hundred and eighty-seven
detrital zircons with concordance degree than 90% are divided into two groups: the first group contains one hundred and thirty-six zircons, whose ages range from 378 Ma to 544 Ma, accounting for 73%, with a peak value of 443 Ma (figure 2); The second group of fifty-one zircons, ranging from 629 Ma to 3116 Ma, is from Precambrian, accounting for 27%, with three age peaks: 992 Ma (accounting for 45% of the Precambrian zircons), 1817 Ma (accounting for 14% of the Precambrian zircons) and 2500 Ma (accounting for 10% of the Precambrian zircons) (Figure 2), respectively, corresponding to the age of Sibao-Jinning, Lvliang and Wutai periods.

Figure 2. Age spectrum of detrital zircons in the study area (modified from [8]).

Among twenty-six detrital zircons (sample ZK0008-43), there are fifteen Caledonian detrital zircons with peak values of ~443 Ma, and $^{176}\text{Hf} / ^{177}\text{Hf}$ is between 0.282451 and 0.282878, The $\varepsilon_{\text{Hf}}(t)$ values range from -1.8 to +13.0, and $T_{DM2}$ ranges from 600 Ma to 1500 Ma; There are eleven Precambrian detrital zircons with $^{176}\text{Hf} / ^{177}\text{Hf}$ ranging from 0.281281 to 0.282212, The $\varepsilon_{\text{Hf}}(t)$ values range from -7.7 to +3.4, and $T_{DM2}$ ranges from 1800 Ma to 2900 Ma.

According to the morphology, trace and REE characteristics of detrital zircons, the Caledonian and Sibao Jinning zircons are magmatic zircons. In contrast, the Lvliang and Wutai zircons are mainly metamorphic accretionary zircons of magmatic zircons.

According to the comparison of the age composition of detrital zircon with the U-Pb age spectrum of the NQOB, Majiagou Formation limestone, and North China Craton basement, combined with the tectonic background of the study area, zircon genetic mineralogy and Hf isotope analysis, it is believed that the Caledonian zircons and the Sibao-Jinning zircons derived from the NQOB. In contrast, the Lvliang and Wutai zircons may be derived from karst insoluble of Majiagou Formation limestone.

4. Conclusion
The detrital zircon age data of bauxite provenance obtained by LA-ICP-MS. Detrital zircon U-Pb ages are divided into two groups: the first group ages range from 378 Ma to 544 Ma, accounting for 73%, with a peak about 443 Ma; the second group ranging from 629 Ma to 3116 Ma, is from Precambrian, with three age peaks, corresponding to the age of Sibao-Jinning, Lvliang and Wutai periods.

It is proved that big data of LA-ICP-MS detrital zircon U-Pb dating and Hf isotope can quantitatively solve the problem of bauxite provenance. The Caledonian zircons and the Sibao-Jinning zircons derived from the North Qinling Orogenic Belt, while the Lvliang and Wutai zircons may be derived from karst insoluble of Majiagou Formation limestone.

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References

[1] Zhang Q X. Deep exploration technology analysis of Geology and mineral resources under the background of big data. China Metal Bulletin, 2019, 45 (11): 270-271

[2] Wang T. Application of big data in geology and mineral resources. World nonferrous metals, 2020, (17): 223-224

[3] Xu J H, Feng Q N, Chen Z R. Smart government: the advent of the era of big data governance. Beijing: CITIC Press, 2014.

[4] Sun F Y. Study on provenance and aluminum enrichment of the Benxi Formation in the southeastern part of North China Block. Doctoral dissertation of Henan Polytechnic University, 2019.

[5] Sun F Y, Cao G S, Zhou Q K. Provenance and tectonic implications of the Yanshi bauxite area in Western Henan, China. E3S Web Conf, 2021, 261: 03058.

[6] Cai S H, Wang Q F, Liu X F, et al. Petrography and detrital zircon study of late Carboniferous sequences in the southwestern North China Craton: Implications for the regional tectonic evolution and bauxite genesis. Journal of Asian Earth Sciences, 2015, 98: 421-435.

[7] Wang Q F, Deng J, Liu X F, et al. Provenance of Late Carboniferous bauxite deposits in the North China Craton: New constraints on marginal arc construction and accretion processes. Gondwana Research, 2016, 38: 86-98.

[8] Cao G S, Xing Z, Bi J H, Sun F Y, Liu L Z, Du X, Zhou H C, Chen Y C. Material Sources Analysis of the Benxi Formation Bauxite in the Yanshi-Longmen Area, Western Henan. Acta Geologica Sinica, 2018, 92(7): 1507-1523.

[9] Cawood P A, Landis C A, Nemchin A A, et al. Permian fragmentation, accretion and subsequent translation of a low-latitude Tethyan seamount to the high-latitude east Gondwana margin: evidence from detrital zircon age data. Geological Magazine, 2002, 139(2): 131-144.

[10] Hawkesworth C J, Kemp A I S. Using hafnium and oxygen isotopes in zircons to unravel the record of crustal evolution. Chemical Geology, 2006, 226(3): 144-162.

[11] Liu X F, Wang Q F, Feng Y W, et al. Genesis of the Guangou karstic bauxite deposit in western Henan, China. Ore Geology Reviews, 2013, 55: 162-175.

[12] Liu J, Zhao Y, Liu A K, et al. Origin of Late Palaeozoic bauxites in the North China Craton: Constraints from zircon U-Pb geochronology and in situ Hf isotopes. Journal of the Geological Society, 2014, 171: 695–707.

[13] Dickinson W R, Gehrels G E. Sediment delivery to the Cordilleran foreland basin: insights from U-Pb ages of detrital zircons in Upper Jurassic and Cretaceous strata of the Colorado Plateau. American Journal of Science, 2008, 308(10): 1041-1082.

[14] Mackey G N, Horton B K, Milliken K L. Provenance of the Paleocene-Eocene Wilcox group, western Gulf of Mexico basin: evidence for integrated drainage of the southern Laramide rocky mountains and cordilleran arc. Geological Society of America Bulletin, 2012, 124 (5/6): 1007-1024.

[15] Blum M, Pecha M. Mid-Cretaceous to Paleocene North American drainage reorganization from detrital zircons. Geology, 2014, 42(7): 607-610.

[16] Shi Y, Yu J H, Santosh M. Tectonic evolution of the Qinling orogenic belt, Central China: new evidence from geochemical, zircon U-Pb geochronology and Hf isotopes. Precambrian Research, 2013, 231: 19-60.

[17] Cao G S, Liu L Z, Xing Z, Sun F Y, Yu S J, Fang B B, Du X, Zhou H C, Chen Y C. Material sources analysis of Karstic bauxite of Benxi formation in Gongyi area, Henan Province:
Evidences from LA-ICP-MS U-Pb dating of detrital zircon. Journal of Henan Polytechnic University (Natural Science), 2018, 37(6): 55-65.

[18] Cao G S, Yu S J, Sun F Y, Fang B B, Xu H T. Carbon and oxygen isotopic composition palaeoenvironment analysis of lacustrine carbonate rocks in the upper member of Early Triassic Sunjiagou Formation, Yiyang Area, western Henan Province. Acta Geologica Sinica, 2019, 93(5): 1137-1153.

[19] Cao G S, Fang B B, Sun F Y, Yu S J and Xu H T. Maximum sedimentary age and provenance of Pingdingshan sandstone in the southern part of North China Block: Evidence from detrital zircon LA-ICP-MS U-Pb age. Acta Petrologica Sinica, 2019, 35(8): 2518-2544.

[20] Yang D B, Yang H T, Shi J P, Xu W L, Wang F. Sedimentary response to the paleogeographic and tectonic evolution of the southern North China Craton during the Late Paleozoic to Mesozoic. Gondwana Research, 2017, 49: 278-295.