灾变事件引起鄂西晚元古代缺氧海洋

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〔内容提要〕 作者根据白果园银钒矿含矿系中新发现的钾长石微球粒和碳同位素亏损,提出一种新见解:该矿床成因与650Ma前的海洋环境危机有关。本文简要地介绍有关缺氧事件的重要信息,以便揭示扬子地台上前寒武纪海洋演化的奥秘。晚元古代海洋危机是由行星撞击地球或火山作用引起的灾变事件。

关键词 晚元古代 缺氧海洋 灾变事件 负$\delta^{13}C$异常 钾长石微球粒

LATE PROTEROZOIC ANOXIC OCEANS GENERATED BY CATASTROPIC EVENTS IN WESTERN HUBEI, CHINA

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The author has proposed a new explanation to link an oceanic environment crisis 650 Ma ago to the origin of the Baiguoyuan Ag-V deposit on the basis of the new findings of K-feldspar microspherules and negative carbon isotopic shift in the ore-bearing units[1,2]. In this paper, the important information about the anoxic events is presented to reveal the mystery of Precambrian oceanic evolution on the Yangtze platform.

ORE-BEARING BEDS FORMED IN ANOXIC OCEANS

The Baiguoyuan Ag-V deposit in western Hubei, China is a large-scale sedimentary deposit on the Yangtze platform. Stratigraphically, the ore-bearing units belong to the fourth member of the Upper Sinian (Late Proterozoic) Doushantuo, which is overlain by the dolostones in the Dengying Formation and underlain by the laminated algal-pelleted dolostones in the third member of the Doushantuo Formation. The ore-bearing sequence in the ore district consists chiefly of black shales (12.7—25 m thick), and can be subdivided into

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two parts: the upper member only contain a single vanadium ore bed of 2.0—7.71 m in thickness, whereas the lower one comprises a mixed Ag-V ore bed of 0.45—5.93 m in thickness and thin pelitic dolostones intercalated with banded shales or mudstones at the base. The ore deposit is interpreted as the result of sedimentary diagenesis in the oceanic anoxic environments[3,4]. According to facies analysis of sedimentary rocks, the sedimentary environment for the ore deposition is inferred as a shallow shelf lagoon in frontal zone of the western Hubei carbonate platform●. During the ore deposition, the lagoon became an anoxic reduction environment indicated by the occurrence of organic matter ($C_{org.}$ = 1.15%—4.65%) and banded pyrite (containing Ag-minerals) in the black shales.

ANOXIC OCEANS GENERATED BY CATASTROPHIC EVENTS

The author owes, in this paper, the origin of this ore deposit to the catastrophic events in the light of the depositional hiatus, basal clay layer (BCL) on the hiatal surface, the presence of K-feldspar microspherules, negative C-isotopic shift, and trace elements and REE anomalies. The remarkable evidences are listed for the unusual events as follows.

The basal clay layer (BCL)

The BCL is an essentially important marker to indicate the onset of large-scale events at the lowermost of the ore-bearing units. The BCL (10—30m thick) consist dominantly of the clay mineral illite with subordinate K-shareds, K-crystal and silty debris as well as minor amount of hematitic microspherules and glassy microspherules, suggesting the strong impact features of the explosion events. In this respect, the BCL records the paroxysmal changes from normal to anoxic reduction conditions in Late Proterozoic oceanic environments.

The K-feldspar microspherules

The K-feldspar microspherules are identified by scanning electron microscope (SEM) in the samples collected from the BCL and from Ag-V-rich black shales at the levels of 1.52 m, 3.06 m and 3.52 m above the BCL, respectively.

The K-feldspar microspherules take diverse forms of pellet, tear drop and walnut with remarkable splash surface features such as groove and gouge marks disc pits and tumour-like projections (Fig. 1). They commonly are 5—14 μm in diameter also with corrosion features to show a high-temperature melting process.

The chemical compositions of the K-microspherules using energy dispersion X-ray analytical (EDXA) technique have revealed that they may fall into the category of potassium aluminosilicates, analogous to sanidine globules and microtektite (Table 1). The SiO_2

●刘源骏等, 1996, 一个大型黑色岩系银钒矿床的成矿作用及成矿环境的讨论。第30届国际地质大会论文集(印刷中)。

contents of six samples are probably equal to those of sanidine globules (64.19%)[5] and those of tektite (63.09%)[6]. One of these samples has similar SiO_2 content (75.58%) to that of the North American microtektite and tektite (73.37%)[7]. Some samples (unlisted) chemically show no iron and MgO compounds, probably belonging to sanidine and tektite caused by the impact events 650 Ma ago. It is stated in literatures that some iron microspherules discovered in clay beds of the Ag-V ore horizons should result from the catastrophic events as well[8,9].

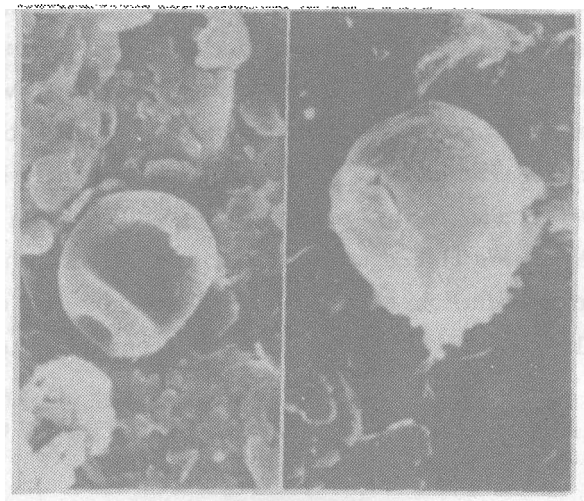

Fig. 1 Scanning electron photomicrograph showing the sizes and shapes of the K-microspherules (after Yang Zhenqiang *et al.*, 1966). (white bar=1.0 μm)

Table 1 SEM/EDXA analytical results of microspherules from the Baiguoyuan Ag-V ore district (after Yang Zhenqiang *et al.*, 1966)

	1	2	3	4	5	6	7	8	9
MgO	3.88	0.00	4.96	3.65	2.63	2.5	0.00	2.74	2.00
Al_2O_3	20.03	18.59	23.87	20.35	19.72	20.01	18.08	15.29	11.70
SiO_2	67.12	75.58	56.90	56.26	63.10	66.58	64.10	63.09	73.30
K_2O	5.29	5.83	8.13	7.02	8.08	7.65	15.67	1.59	2.30
TiO2	0.42	0.00	0.62	0.32	0.54	0.88	—	0.67	0.70
V_2O_5	0.25	0.00	2.02	0.49	4.29	0.90	—	—	—
Fe_2O_3 FeO	3.01	0.00	3.60	11.91	1.64	1.45	—	5.44	4.60
CaO							0.046	7.26	7.50
Na_2O							0.06	3.63	1.30

numbers: 1. K-microspherule, No: 92-B-13; 2. K-feldspar spherule, No: 92-B10-2; 3. K-microspherule with illite-covered surface, No: 92-B-10-3; 4. K-microspherule associated with K-feldspar, No: 92-B-18; 5. K-microspherule, No: 92-b-30; 6. teardrop-like microspherule, No: 92-B-6; 7. sanidine spherule[6]; 8. tektite[7]; 9. tektite[8]

Negative shift in C-isotopic composition

The carbonates at most boundaries of the catastrophic events are always depleted in C-isotopic composition[10—14]. The anomalies of negative $\delta^{13}C$ values are also present across the BCL in the Baigouyuan Ag-V ore-bearing units. The dolostones from the first member to the third member of the Upper Sinian Doushantuo Formation show the C-isotopic composition of positive $\delta^{13}C$ values below the BCL, but above the BCL, the $\delta^{13}C$ values of dolo-

stones suddenly drop from positive values to the minimum values ($\delta^{13}C = -8.62‰$ PDB) at the boundary between the two submembers, and then return to positive $\delta^{13}C$ values again in the overlying stromatolitic dolostones of the first member of the Upper Sinian Dengying Formation, showing C-isotopic values of normal marine dolostones ($\delta^{13}C = +3.87‰$ PDB).

The negative shift of $\delta^{13}C$ values in the black shales indicates that the marine environments on the Yangtze platform had a long period of biotic crisis in the Late Proterozoic. This crisis can be compared to that at the Precambrian/Cambrian boundary in the Yangtze Gorge section in which a negative $\delta^{13}C$ shift is indicative of the strangelove oceanic conditions as the result of the catastrophic events[12,13].

Trace elements and REE patterns

The catastrophic events always give rise to the enrichment of siderophile, precious metal and volatile elements as exemplified by the black shales at the Cretaceous/Tertiary boundary[8,9] and near the Precambrian/Cambrian boundary on the Yangtze platform[14]. Similar element enrichment and anomaly are also found in the Baiguoyuan ore beds: Au, Pt and Pd concentrate mainly in the sulfides, whereas Ni, Ti, V, Cr, Cu, Ba, Sr, As, Se and F element anomalies occur in the clay.

The REE in the BCL and black shales displays higher contents of La, Ce and Y. The chondrite-normalized REE patterns are right-leaning curves which are comparable to those of tektite[6].

DISCUSSION AND CONCLUSION

1. The presence of BCL, K-microspherules, $\delta^{13}C$ anomalies, trace element enrichment and REE patterns are also considered as the diagnostic features of terrestrial catastrophic events[12,15]. Therefore, the Ag-V-bearing black shales in the fourth member of the Upper Sinian Doushantuo Formation may be interpreted as the products of the events triggered by extraterrestrial impact or volcanic explosion during the Late Proterozoic. These events would lead to the formation of the poisonous acid rain and heavily tiny dust cloud suspended in the atmosphere. The poisonous material and acid rain might have changed the organic carbon circulation in the oceans, resulting in the formation of anoxic environments and negative $\delta^{13}C$ values.

2. The discovery of the catastrophic events in the upper part of the Doushantuo Formation is essentially helpful to explain the evolution of the Late Proterozoic algal organisms. Up to now, no big red algae have been found in the geologic records prior to the events. However the suddenly emerged gigantic red algae, i. e., the new "Miaohe biotic community"[16] has recently been recognized in the horizons corresponding to the upper submember of V-bearing beds. It is concluded that both big red algal reproduction and old fossil extinction may also be attributed to the catastrophic events.

3. A comparative study of the Proterozoic catastrophic events is highly needed and of great scientific significance. So far a Proterozoic extraterrestrial impact has been found in the Adelaide geosyncline in Australia, and this so-called Acraman impact event[11] almost corresponds to the Late Proterozoic events on the Yangtze patform which are also related to the impact events. Nevertheless, the origin of catastrophic events has been much debated world-widely[12,15,17]. More evidences for the Precambrian events related to the Ag-V enrichment will be delivered for further study.

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