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Study on Iron Source and Original Mineral Assemblage of Iron Formation in Paleoproterozoic Wuzhiling Formation in North China

Bin Tang*

Henan Polytechnic University, Jiaozuo, Henan, 454000, China
**Corresponding author: 13838280661@163.com*

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Abstract: The Precambrian iron formation is related to the evolution of the earth's environment and is an important record of the evolution of ancient ocean, ancient environment and atmospheric conditions. The Wuzhiling Formation iron formation at the Songshan boundary is one of the newly identified granular iron formations (GIF). Through the study of mineral characteristics and mineral morphology of iron formation in Wuzhiling Formation, it is found that its material source may be hydrothermal fluid; the original sediments may be hematite particles and ' green rust '.

1. Introduction

The iron formation (IF) formed in the Precambrian is an important part of the early crust and a product of a specific stage of Earth evolution. At the same time, iron formation is a sedimentary rock with important economic significance, which is the most common in the Precambrian sedimentary sequence. Although many questions about their origins remain unresolved, it is generally believed that long-term changes in their depositional patterns are related to the Earth's environmental and geochemical evolution [1] At the same time, iron ore from iron formation is the largest and most widely distributed iron ore resource in the world, and is the most important source of ore in the global steel industry. According to the statistics of iron deposits worldwide, this type of iron deposits account for 60% to 70% of the world's rich iron ore reserves and more than 90% of the world's iron ore production [2] In China, the proven reserves of this type of iron ore account for more than 50% of the total iron ore reserves in the country [3].

The Precambrian IF in China is dominated by Algoma type, with low ore grade, strong metamorphic deformation, few rich ore and small scale. Strengthening the study of metallogenic geological conditions of IFs in China is helpful to understand the metallogenic geological background of IF iron deposits in China. In the past few decades, there have been extensive studies on iron formation at home and abroad. However, due to its complexity and no repetition after the Precambrian, there is still a lot of controversy about its formation conditions and causes [4]. The Neoarchean and Paleoproterozoic iron formations widely distributed in the North China Craton are ideal objects for understanding the changes of ancient marine redox environment before and after the Paleoproterozoic oxidation event (GOE).

Taking the iron formation of the third member of the Wuzhiling Formation of the Songshan Group of the Paleoproterozoic as the research object, the mineralogical and petrological characteristics of the iron formation of the third member of the Wuzhiling Formation were used to study the material source and original minerals of the iron formation, in order to provide new evidence for the geological environment and evolution characteristics at that time.

2. Regional geology

As the 'iron formation' occurrence horizon of the Wuzhiling Formation, the Songshan Group is mainly exposed in the Dengfeng area of Henan Province, located in the southern section of the North China Craton, with an area of more than 60 square kilometers and a thickness of more than 1200 meters. The group is unconformably covered by the Wufoshan Group at about 1.65 Ga, mainly composed of purple sandstone [5]. It unconformably covers the Dengfeng Group at about 2.53 Ga, which is composed of metamorphic mafic volcanic rocks and Algoma-type BIFs [6]. Although the Songshan Group rocks experienced low-greenschist facies metamorphism [7], they were not significantly affected by metamorphism, and their original minerals and chemical compositions were well preserved. The Songshan Group is subdivided into Luohandong Formation, Wuzhiling Formation, Miaoposhan Formation and Huayu Formation from bottom to top. The Luohandong Formation is mainly composed of medium-coarse quartzite and basal conglomerate with a thickness of 750 meters [8]. The overlying Wuzhiling Formation can be divided into three different parts according to rock types: the lower part is composed of gray or yellow-brown quartzite, schist and a small amount of dolomite; the middle part is mainly gray sericite quartz schist and thin dolomite with thickness > 300 m. The upper part consists of GIF, schist and stromatolite-bearing dolomite lenses. The Tuomiaoposhan Formation is composed of coarse to medium-grained quartzite and sericite schist interlayer. The uppermost Huayu Formation is mainly composed of sericite phyllite and dolomite, with thin quartzite. In some cases, stromatolites also exist in dolomite. In short, the protolith of the Songshan Group is a set of shallow marine terrigenous clastic and carbonate sedimentary sequences [7].

Primitive sedimentary structures, such as ripple marks, oblique bedding and cross bedding, are widely preserved in all quartzites of the Songshan Group, indicating that the sequence of the Songshan Group is deposited on a broad and structurally stable coastal-shallow sea shelf.

3. Lithological characteristics

The first section of Wuzhiling Formation is mainly developed in the study area-Dengfengjingwan Village and its surrounding areas. The main rock types are: ' GIF ', sericite quartz schist, quartzite.

The iron formation of Wuzhiling Formation in this study is mainly exposed in the area of Jingwan Village, Dengfeng City. The overlying strata are covered by Quaternary loess. The measured total thickness is 7m, with a total of 5 layers. The first layer is mainly thick layered iron-bearing quartzite, which is light purple and pinches out to the left. There is a thin layer of sericite quartz schist interlayer between the layers, and the interlayer is gradually thickened to the left. The second layer is quartz sericite schist interlayer, which is gray green, and its schistosity is the same as the overall trend. The third layer is also a thick layer of iron-bearing quartzite, which is purple red. The layer is gradually thickened to the left and the layer is stable. The fourth layer is the quartz sericite schist interlayer, which is grayish green, with uniform thickness, and the schistosity is also the same as the overall trend. The fifth layer is mainly thick layered iron-bearing quartzite, which is black and red. According to the lithological characteristics, it is mainly sericite quartz schist and ' GIF ' interbed. The sericite quartz schist is gray-green, and the sedimentary layer of GIF

is parallel to the schistosity of the interbedded sericite quartz schist in the outcrop. At the same time, GIF is dark red, showing obvious sedimentary particle structure, and the whole is thick layered. It can be seen that the regional tectonic movement has played a great role in the metamorphism of the section.

Through the observation of hand specimens, it is found that the fresh surface of the iron construction watchbook of the Wuzhiling Formation is reddish brown, and the stripe color is cherry red, which is consistent with the characteristics of hematite, which also reflects the high hematite content in the iron construction of the Wuzhiling Formation.

4. Iron source

The source of Fe in iron formation has been controversial [4, 9, 10]. According to the physical and chemical characteristics of Fe, the sedimentary environment of iron formation, and the precambrian atmospheric-ocean redox state at the time of formation, early scholars believed that Fe in iron formation was mainly derived from continental supergene environmental weathering [11]. With the deepening role of geochemical indicators in the study of iron formation, more and more scholars believe that Fe in iron formation is mainly derived from submarine hydrothermal activity [4, 12]. Therefore, there are three main views on the source of Fe in iron formation: Fe released by continental weathering [4, 12], Fe carried by seafloor hydrothermal fluid [4] and both [13].

The hematite in the iron formation of the Wuzhiling Formation has a hexagonal iron ore and does not have a clastic structure, which excludes the input of terrestrial debris, so its iron source may be mainly hydrothermal.

5. Original sediments

There are many opinions on the composition of the original minerals in the iron formation, but the predecessors believed that the hydroxide colloid and silica of Fe^{3+} are the most important primary minerals, and the formation of hematite in the early stage of iron formation is mainly the product of the dehydration of the original Fe^{3+} hydroxide colloid deposited in the iron formation [4, 14, 15]. In discussing the genesis of IF, Beukes and Gutzmer (2008) emphasized that the earliest oxide minerals in Superior-type IF were fine-grained hematite dispersed throughout the flint [16]. Through microscopic observation, it is noted that Songshan GIF quartz contains many fine-grained hematite, which is likely to be directly formed by the dehydration of the initially deposited iron hydroxide colloid, which is wrapped by quartz to protect it from later diagenesis and metamorphism. The particle size of hematite is fine and isolated in the silica, indicating that it may be the product of the dehydration of the original trivalent iron hydroxide.

At the same time, we also observed green rust-like hexagonal hematite in the iron formation of the Wuzhiling Formation. As a metastable iron oxide, green rust is easily transformed into more stable iron oxides (such as magnetite and hematite) after sedimentation [17], and then after diagenesis to form the present hematite. Different from the green rust described by predecessors, the size of ' green rust ' in the iron formation samples of the Wuzhiling Formation is about 100μm, which is different from the green rust characteristics observed by predecessors. However, experiments have proved that the hexagonal crystal of green rust will gradually age and become larger over time [18], and the magnetite transformed from green rust is almost equilateral [19], which also excludes the biomineralization of magnetite by magnetotactic bacteria [20]. At the same time, hematite, which can appear in hexagonal form, can easily react with Fe^{2+}-containing fluids to form magnetite[21].This process often forms self-faceted magnetite crystals (usually octahedron), so it is difficult to observe hexagonal hematite particles. Therefore, the hexagonal hematite in the iron formation of the Wuzhiling Formation is likely to be transformed from early green rust.

Comprehensive analysis, the original sediments of the iron formation of the Wuzhiling Formation include hematite particles wrapped in quartz and the precursor sediment of hexagonal hematite-green rust. The hematite in the quartz particles is well preserved, and the green rust is gradually transformed into the current hexagonal hematite due to its instability.

6. Conclusion

(1) The iron source of the iron formation of Wuzhiling Formation may be hydrothermal component;

(2) The original minerals of iron formation in Wuzhiling Formation may be hematite particles and hexagonal 'green rust'.

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