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Geochronology and Geochemistry of the Changyi Banded Iron Formation in Eastern Shandong Province: Constraints on BIF Genesis and Implications for Paleoproterozoic Tectonic Evolution of the North China Craton

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1 Introduction

As the unique product in Precambrian, the deposition of banded iron formation (BIF) not only relates to the evolution of life, ocean and atmosphere, but also to the origin and growth of continents (Trendall, 2002). Paleoproterozoic BIFs were sporadically found with small scale in North China Craton (NCC), which contrast with the abundant Archean BIFs in the NCC. This distribution feature suggests that the NCC may have experienced a particular Paleoproterozoic evolutional history.

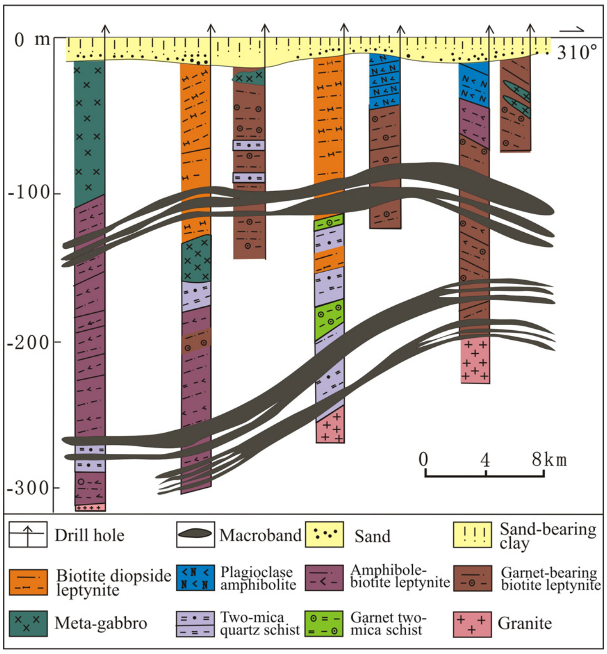

Fig.1. Profile map of drill holes along exploration line 102 from the Dongxinzhuangmining area of the Changyi BIF iron deposit (modified after Wang et al., 2007).

The Changyi BIF deposit, one of the largest Paleoproterozoic BIF deposits in eastern NCC, provides an important key to reveal the origin of the Paleoproterozoic BIFs and the Paleoproterozoic geological evolution of the eastern NCC. This BIF deposit occurs within the Paleoproterozoic Fenzishan Group, and the BIF bands are interbedded with metamorphic rocks (Fig. 1). The BIF bands can be divided into macrobands, mesobands and microbands based on their scale and occurrence (Fig. 2). The macrobands are composed of alternating quartz-rich light and magnetite-rich dark mesobands and are layered or lens-shaped with thickness of several centimeters up to thirty six meters and length of ten meters to longer than two kilometers. The mesobands

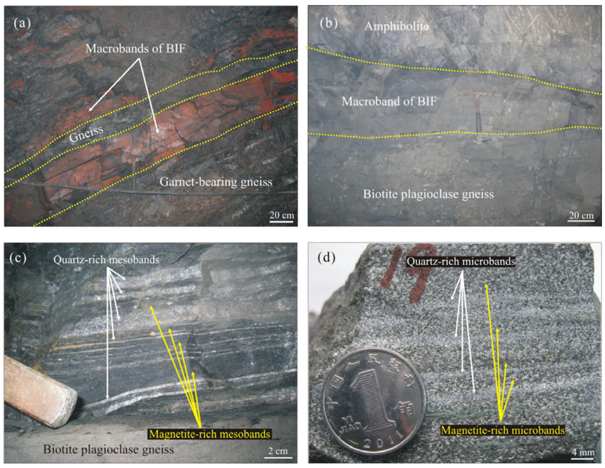

Fig. 2. (a) Layered macrobands interbedded with metamorphic rocks. (b) Lens shaped macroband thinning out along its trend. (c) Macrobands constituted by alternating quartz-rich light and magnetite-rich dark mesobands. (d) Alternating magnetite-rich and quartz-rich microbands making up the magnetite-rich mesobands.

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are constituted by alternating magnetite-rich and quartz-rich microbands. The microbands show thickness varying from 1 mm to 9 mm with major constituents of magnetite (15 to 65 vol.%), quartz (25 to 65 vol.%) and amphibole (15 to 30 vol.%). Occasionally, garnet, epidote, chlorite, calcite, biotite and pyrite occur. Three major types of metamorphic wallrocks are identified, including plagioclase gneisses and leptynites, garnet-bearing gneisses and amphibolites. These rocks are interbedded with each other and generally show gneissic structures with horizontal occurrence, although locally modified by faults and intruded by granites in the deep (Fig. 1). The BIF bands and the wallrocks have suffered amphibolite facies metamorphism.

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2 Analytical Results and Discussion

The youngest detrital zircons from the interlayered metasedimentary rock have an age range of 2240–2446 Ma, indicating that the sedimentation of the Changyi BIF occurred after 2240 Ma. In addition, an alkaline granite intruding the BIF bands and the surrounding metamorphic rocks was dated as 2193±11 Ma. These ages therefore constrain the deposition period of the Changyi BIF to be 2240–2193 Ma.

The dominant composition of SiO_2+$Fe_2O_3^T$ (average value of 92.3 wt.%) of the BIF bands suggests their formation mainly through chemical precipitation. However, the widely varying contents of major elements such as Al_2O_3 (0.58–6.99 wt.%), MgO (1.00–3.86 wt.%), CaO (0.22–4.19 wt.%) and trace elements such as Rb (2.06–40.4 ppm), Sr (9.36–42.5 ppm), Zr (0.91–23.6 ppm), Hf (0.04–0.75 ppm), Cr (89.1–341 ppm), Co (2.94–30.4 ppm), and Ni (1.43–52.0 ppm) clearly indicate the incorporation of clastics, especially continental felsic clastics, as also confirmed by the presence of Archean detrital zircons in the BIF bands. When normalized against Post Archean Average Shale (PAAS), the seawater-like signatures of REE distribution patterns, such as LREE depletion, positive La and Y anomalies, and superchondritic Y/Ho ratios (average value of 36.3) (Fig. 3), support the deposition in seawater.

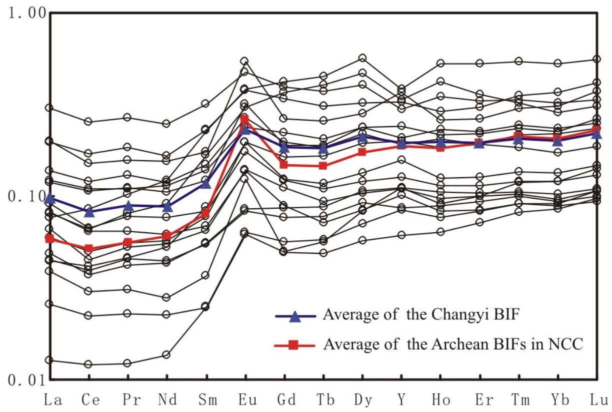

Fig. 3. PAAS-normalized REY pattern of BIF bands from the Changyi BIF iron deposit. The average value of the Archean BIFs in NCC, which are calculated from 49 samples, is shown for comparison. PAAS value is from McLennan (1989).

Strong positive Eu anomalies (Eu/Eu^*_{PAAS}=1.14–2.86) also suggest the participation of hydrothermal fluids. In addition, the sympathetic correlation between Cr, Co and Ni as well as the Co+Ni+Cu vs. ∑REE and the Al_2O_3 vs. SiO_2 relations further indicate that the iron and silica mainly originated from hydrothermal fluids. Furthermore, the appearance of negative Ce_{PAAS} anomalies in the BIF bands might suggest the influence of the Great Oxidation Event at the time of the deposition.

3 Tectonic Implications

Protolith reconstruction suggests that the protoliths of the plagioclase gneisses and leptynites are mainly graywackes with minor contribution of pelitic materials, the garnet-bearing gneisses are Fe-rich pelites

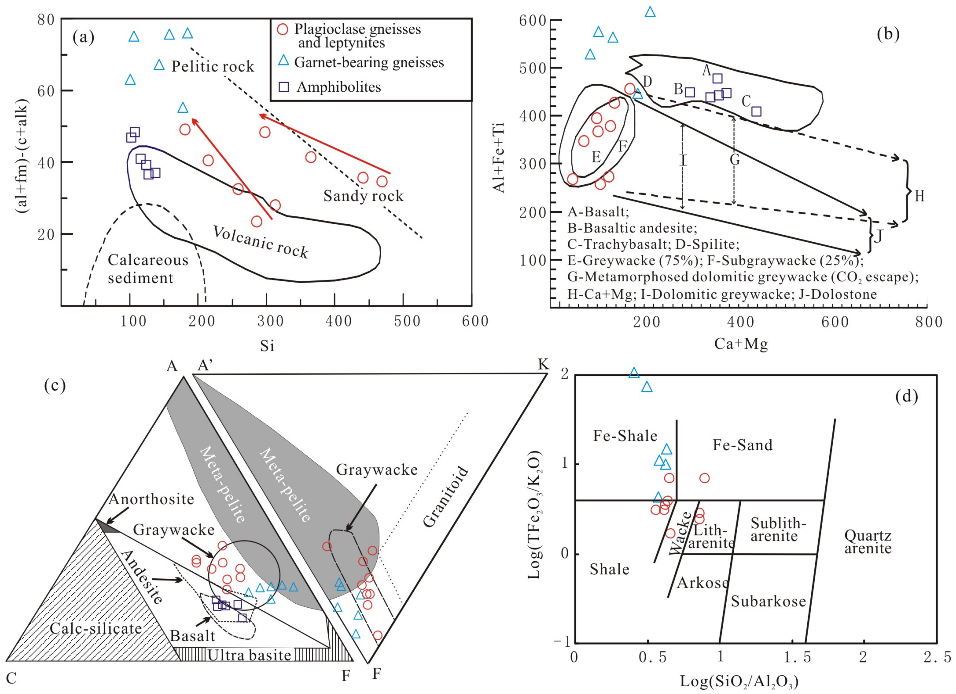

Fig. 4. Diagrams of (al + fm)-(c + alk) vs. Si (a), (Ca + Mg) vs. (Al + Ti + Fe) (b), ACF-A′KF (c) and log(SiO2/Al2O3) vs. log (TFe2O3/K2O) (d) discriminating the protoliths of metamorphic rocks. (a), (b), (c) and (d) are modified after Simonen (1953), Moine and de La Roche (1968), Winkler (1976), and Herron (988), respectively.

contaminated by clastics, and the amphibolites are tholeiitic rocks (Fig. 4). Trace elements of La, Th, Sc and Zr of the plagioclase gneisses and leptynites and the garnet-bearing gneisses support that these meta-sedimentary rocks were probably derived from recycling of Archean rocks with felsic and mafic materials differentiated into different rock types. The amphibolites show low SiO_2 (46.5 to 52.8 wt.%) and high MgO (5.68 to 10.9 wt.%) contents, crust-like trace elements features and low $\varepsilon_{Nd}(t)$ values (-4.5 to -0.3), suggesting that these ortho-metamorphic rocks were mainly derived from subcontinental lithospheric mantle with some contamination by Archean crustal materials. These rocks confine the depositional environment of the Changyi BIF to be an intra-continental rift (Fig. 5).

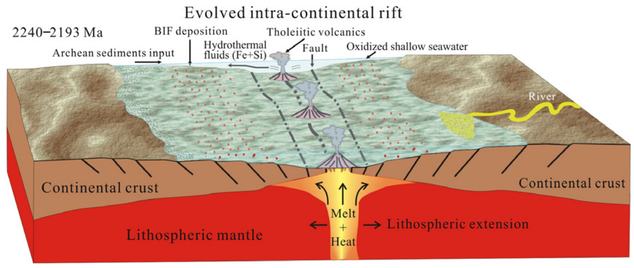

Fig. 5. Tectonic model for the formation of the Changyi BIF and its wallrocks.

Acknowledgements

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