Ore Geology Reviews 73 (2016) 42–58

Contents lists available at ScienceDirect

Ore Geology Reviews

journal homepage: www.elsevier.com/locate/oregeorev

Geochronological and geochemical studies of the metasedimentary rocks and diabase from the Jingtieshan deposit, North Qilian, NW China: Constraints on the associated banded iron formations

Xiuqing Yang [a,b,*], Zuoheng Zhang [c], Shaofeng Guo [d], Jie Chen [e], Dachuan Wang [e]

[a] School of Earth and Space Sciences, Peking University, Beijing 100871, China
[b] MLR Key Laboratory of Metallogeny and Mineral Assessment, Institute of Mineral Resources, Chinese Academy of Geological Sciences, Beijing 100037, China
[c] Chinese Academy of Geological Sciences, Beijing 100037, China
[d] Research and Development Center, China Geological Survey, Beijing 100037, China
[e] State Key Laboratory of Geological Process and Mineral Resources, China University of Geosciences, Beijing 100083, China

ARTICLE INFO

Article history:
Received 16 May 2015
Received in revised form 11 October 2015
Accepted 14 October 2015
Available online 23 October 2015

Keywords:
Banded iron formations
Zircon U–Pb geochronology
Geochemistry
Jingtieshan
North Qilian

ABSTRACT

The Jingtieshan banded iron formations (JBIFs), located in the western segment of the North Qilian area, are one of the major iron deposits in NW China. The BIF occurs within the Jingtieshan Group intercalated with metasedimentary rocks which have undergone lower greenschist-facies metamorphism, and were intruded by a series of diabase sills/dykes. Here we present U–Pb data on detrital zircons from the metasedimentary rocks and the results show ages ranging from 1331 to 2919 Ma. Zircons from two diabase samples yield emplacement ages of 1236 ± 3 Ma (n = 10, MSWD = 0.26) and 1234 ± 7 Ma (n = 19, MSWD = 0.55), respectively. These new data constrain the depositional age of the JBIF at 1.23–1.33 Ga. The geochemical characteristics (e.g., CIA, PIA, Al_2O_3/TiO_2, trace element ratios and REE patterns) of the metasedimentary rocks indicate that the protolith sediments were mainly sourced from mafic and intermediate igneous rocks, followed by post-depositional K-metasomatism. The prominent age peak at 1747 Ma obtained from detrital zircons in the metasediments suggests that the zircons were mostly sourced from the underlying Zhulongguan Group in North Qilian area. The subordinate population of Early Mesoproterozoic detrital zircons was probably sourced from the North Qilian area. The minor population of zircons with Archean ages was derived from the Archean basement in the neighboring old craton. The diabase samples are characterized by slight LREE enrichment, display no distinct Eu and Ce anomalies, and show enrichment in Rb, Ba, K, and Pb and depletion in Nb, Ta, and Sr. These features suggest that the primary magmas of the diabases were likely generated by partial melting of the transitional mantle. The data presented in this study suggest that the JBIF formed in a continental margin sea within an extensional setting.

1. Introduction

Banded iron formations (BIFs) are sedimentary units deposited mostly during Archean–Paleoproterozoic (3.8–1.8 Ga) and less commonly during Neoproterozoic (0.8–0.6 Ga) (Klein, 2005; Holland, 2005; Ilyin, 2009). It is well established that the level of atmospheric oxygen was extremely low before 2.45 Ga ago. The rise of atmospheric oxygen occurred 2.4 billion years ago, and developed a stable and oxygenated atmospheric in Phanerozoic eon (less than 542 million years ago) (Bekker et al., 2004; Arnold et al., 2004; Planavsky et al., 2011; Reinhard et al., 2013; Lyons et al., 2014). However, the redox states of the mid-Proterozoic ocean are less well known. Large-scale occurrence of BIF deposits is rare during the age gap of 1.8 to 0.8 Ga, although several BIFs with VHMS and SEDEX deposits such as the Broken Hill (Richards, 1966; Lascelles, 2014) and Pecos greenstone belt in New Mexico (Slack et al., 2009) have been well documented. The absence of BIF between 1.8 and 0.8 Ga has been explained by either complete ocean oxidation (Holland, 1984, 2003) or by development of sulfidic conditions in the deep ocean (Canfield, 1998; Poulton et al., 2004). Both models also explain the redox state of the mid-Proterozoic. More recently, a new model of ferruginous (anoxic and iron-rich) conditions in the deep water during the mid-Proterozoic ocean has been proposed (Bekker et al., 2010; Planavsky et al., 2011; Poulton and Canfield, 2011; Pufahl et al., 2013; Lyons et al., 2014).

In north-western China, voluminous Mesoproterozoic Jingtieshan-type BIF deposits occur in the North Qilian area, within the Jingtieshan Group in the Gansu Province (Sun et al., 1998; Zhou and Yue, 1999; Mao et al., 2003; 2012; Zhang et al., 2014; Li et al., 2014, 2015a). The Jingtieshan BIF (JBIF), the largest and best-preserved Mesoproterozoic BIF, is hosted within meta-clastic-carbonate sedimentary formations,

* Corresponding author at: School of Earth and Space Sciences, Peking University, Beijing 100871, China.
E-mail address: xiuqing2008@126.com (X. Yang).

http://dx.doi.org/10.1016/j.oregeorev.2015.10.018
0169-1368/

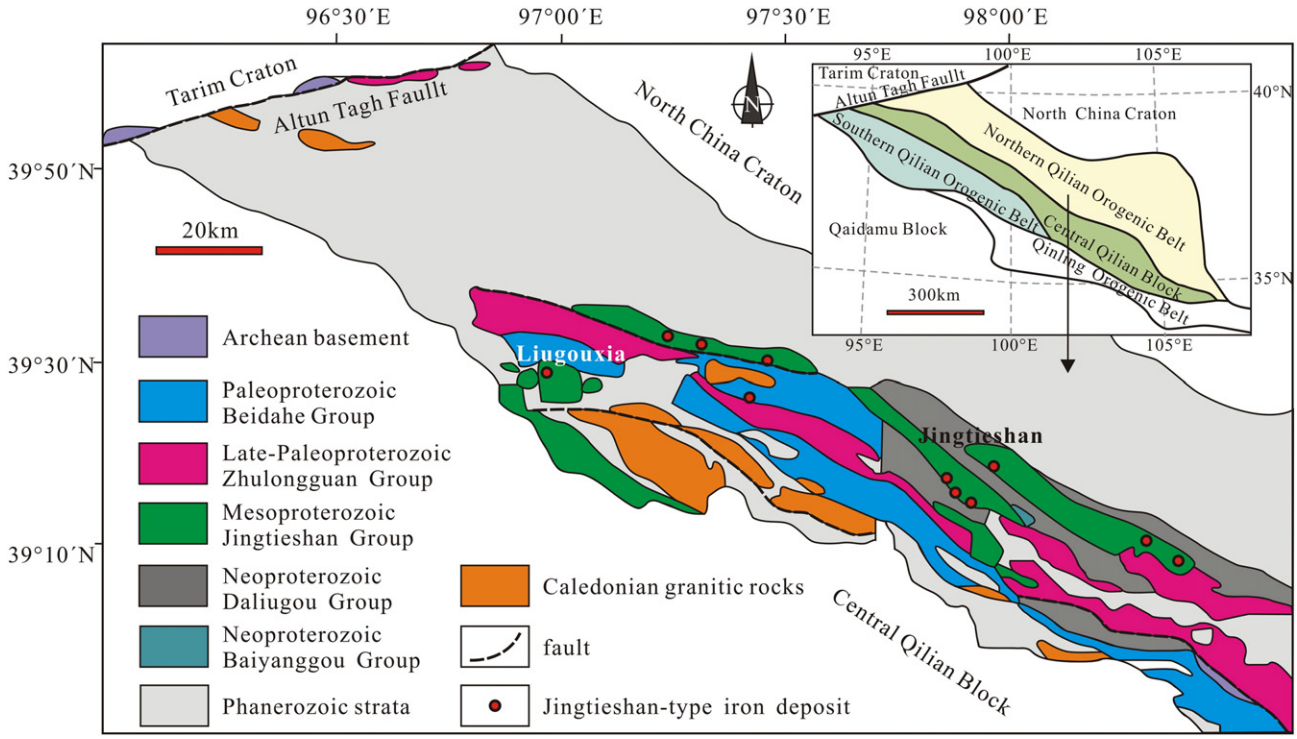

Fig. 1. Geological map of the western segment of North Qilian area, China (modified from Mao et al., 1997).

and provides a typical example to evaluate the formation of Mesoproterozoic BIF in China. The JBIF consists of alternating iron-rich (specularite/hematite and siderite), silica-rich, and barite-rich layers with high contents of $Fe_2O_3^t$, SiO_2 and BaO. The BIF also shows negative $\delta^{13}C$ values of siderite, positive Eu anomalies, and lack significant negative Ce anomalies, suggesting that the ore-forming material was derived from submarine hydrothermal solutions with weak seawater signature in anoxic deep-water (Yang et al., 2015). However, precise geochronological data are lacking for the JBIF, and the proposed Mesoproterozoic depositional age comes from relatively poor regional

Era&Period	Stratum	Histogram	Thickness (m)	Lithology	Age
Neoproterozoic	Baiyanggou Group		1075	Conglomerate rock.	
	Daliugou Group		4500	Siltstone, marlstone, dolomite, basalt, K-rich marstone, dolomite limestone, argillaceous, carbonaceous slate, motley argillaceous limestone and limestone conglomerates.	
Mesoproterozoic	Jingtieshan Group		6000	Upper lithostratigraphic units:dolomitic marble. Lower lithostratigraphic units: phyllite, BIF and quartzite.	1.23~1.33Ga This study
Paleoproterozoic	Zhulongguan Group		2055	Pillow basic lava, basic dike swarm, intermediate-mafic lava, volcanic breccia, tuff, slate, limestone, siliceous rock, sandstone and iron deposit.	1770~1840Ma Xu et al., 1996 Mao et al., 1997 Zhang et al., 2001
	Beidahe Group		>6000	Gnesis, schist, amphibolite, marble, dolostone and miner BIF.	1980±2.7 Ma Mao et al., 2003

Fig. 2. Generalized Precambrian stratigraphy of the North Qilian area, China (modified from Mao et al., 2003).