

Evidence for abundant organic matter in a Neoproterozoic banded iron formation

**ZIDONG PENG^{1,2,*}, JINGBO NAN^{3,4,†}, LIANCHANG ZHANG^{2,5}, SIMON W. POULTON⁶, JUNLIE ZHOU^{7,‡},
YUAN YUAN⁸, KAIWEN TA⁹, CHANGLE WANG^{2,5,*}, AND MINGGUO ZHAI^{2,5}**

¹Institute of Mineral Resources, Chinese Academy of Geological Sciences, Beijing 100012, China

²Key Laboratory of Mineral Resources, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China

³Department of Ocean Science and Engineering, Southern University of Science and Technology, Shenzhen 518055, China

⁴Center for High Pressure Science and Technology Advanced Research (HPSTAR), Beijing 100094, China

⁵University of Chinese Academy of Sciences, Beijing 100049, China

⁶School of Earth and Environment, University of Leeds, Leeds LS2 9JT, U.K.

⁷School of Environment & Resource, Xichang University, Xichang 615000, China

⁸Key Laboratory of Shale Gas and Geoenvironment, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China

⁹Institute of Deep Sea Science and Engineering, Chinese Academy of Sciences, Sanya 572000, China

ABSTRACT

Microbial Fe(II) oxidation has been proposed as a major source of Fe minerals during deposition of banded iron formations (BIFs) in the Archean and Proterozoic Eons. The conspicuous absence of organic matter or graphitic carbon from BIFs, however, has given rise to divergent views on the importance of such a biologically mediated iron cycle. Here, we present mineral associations, major element concentrations, total carbon contents and carbon isotope compositions for a set of lower amphibolite-facies BIF samples from the Neoproterozoic Zhalingzhangzi BIF in the Qinglonghe supra-crustal sequence, Eastern Hebei, China. Graphite grains with crystallization temperatures (~470 °C) that are comparable to that predicted for the regional metamorphic grade are widely distributed, despite highly variable iron (12.9 to 54.0 wt%) and total organic carbon (0.19 to 1.10 wt%) contents. The crystalline graphite is interpreted to represent the metamorphosed product of syngenetic biomass, based on its co-occurrence with apatite rosettes and negative bulk rock $\delta^{13}\text{C}_{\text{organic}}$ values (–23.8 to –15.4‰). Moreover, the crystalline graphite is unevenly distributed between iron- and silica-rich bands. In the iron-rich bands, abundant graphite relics are closely associated with magnetite and/or are preserved within carbonate minerals (i.e., siderite, ankerite, and calcite) with highly negative bulk rock $\delta^{13}\text{C}_{\text{carb}}$ values (–16.73 to –6.33‰), indicating incomplete reduction of primary ferric (oxyhydr)oxides by organic matter. By comparison, only minor graphite grains are observed in the silica-rich bands. Normally, these grains are preserved within quartz or silicate minerals and thus did not undergo oxidation by Fe(III). In addition, the close association of graphite with iron-bearing phases indicates that ferric (oxyhydr)oxides may have exerted a first order control on the abundance of organic matter. Combined, the biological oxidation of Fe(II) in the oceanic photic zone and subsequent burial of ferric (oxyhydr)oxides and biomass in sediments to form BIFs, suggests that a BIF-dependent carbon cycle was important in the Archean Eon. Although significant re-adsorption of phosphorus to ferric (oxyhydr)oxides and the formation of authigenic phosphate minerals at the sediment-water interface would be expected, oxidation of biomass in BIFs may have recycled at least a portion of the P (and other nutrients) released from reactions between organic matter and ferric (oxyhydr)oxides to the overlying water column, potentially promoting further primary productivity.

Keywords: Organic matter, carbon isotopes, apatite, Raman spectroscopy, banded iron formation, Neoproterozoic