Geochemistry of > 3.8 Ga banded iron formations (Isua Supracrustal Belt, Nuvvuagittuq Supracrustal Belt): implications for the chemistry of Earth's earliest oceans

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Summary

Eoarchean-aged banded iron formations (BIF) represent the oldest sedimentary rocks on Earth. In this regard, they are an invaluable tool to characterize the environmental conditions of the earliest oceans because they precipitated directly from seawater. However, these rocks have undergone several episodes of deformation and metamorphism, and thus it is important to determine which geochemical signatures are primary and which are due to post-depositional processes. Here we examine the available trace element chemistry of the two oldest BIF known to date, from Isua Supracrustal Belt in Greenland and Porpoise Cove, Quebec, We compare their geochemistry with younger, well-documented and less-altered BIF from the Dales Gorge Member, to better interpret chemical signatures associated with Earth`s earliest oceans.

Introduction

The early evolution of life on Earth is closely linked with the geochemical history of the oceans. However, the environmental conditions characterizing the earliest oceans remain largely unknown due in part to the scarcity of rocks from the first billion years of Earth's 4.5 Ga year old history. Eoarchean (4.0 Ga to 3.5 Ga) chemical sediments such as BIF are among the best sources of such information due to the fact that they precipitated directly out of seawater, retaining chemical signatures of ancient ocean geochemistry in the process. The primary iron minerals (e.g., ferric hydroxide) that comprised the initial BIF sediment are well documented sorbents for a variety of elements found in seawater, some of which are key nutrients and metals utilized in microbial metallo-enzymes (e.g., Mo, V, Co). The dissolved trace metal concentrations in seawater can be extrapolated from absolute trace metal concentrations in BIF through experimentally determined partition coefficients which can be calculated in the laboratory. Ascertaining the chemical and isotopic composition of Eoarchean BIF is not only proving extremely insightful into ancient biological activity (Bjerrum and Canfield, 2002; Konhauser et al., 2009), but it could also provide important information concerning the composition of the ancient crust and the weathering and hydrothermal processes which provided solutes to the early oceans. Only a handful of Eoarchean-aged BIF are known to exist: Tomka-Daitari Belt, India; Caozhung Complex, Northern China; the Bug Group, Belarussian-Baltic region; Nulliak Supracrustal Group, Northern Labrador, Nuuvuagittuq Greenstone Belt (Porpoise Cove), Northern Quebec , and the Isua Supracrustal Belt in Southwestern Greenland. To date, most of what we know about Eoarchean BIF comes from the extensively studied 3.8 Ga year old Isua Supracrustal Belt. The recent discovery of rocks (including BIF) in the Nuuvuagittuq Supracrustal Belt (Porpoise Cove, Northern Quebec), that may be as old as 4.28 Ga

(O'neil et al., 2008), has opened up exciting research opportunities in this regard. However, as Eoarchean BIFs have undergone several episodes of deformation and metamorphism, it is important to differentiate between elements associated with post-depositional proceeses and those associated with the primary iron minerals. This will allowing us to better interpret chemical signatures associated with Earth`s earliest oceans and perhaps even, its earliest ecosystems.

Theory and/or Method

BIF samples were collected in Porpoise Cove (Northern Quebec) in July 2009, and were subsequently cut into polished thin sections for petrographic work and chemical analyses. Mineralogy and textural relationships were assessed using a petrographic microscope. A JOEL Microprobe 8900 was used to acquire major and minor element concentrations (K, Na, Si, Fe, P, Mg, Cl, Al, Mn) from individual mineral grains, and to produce backscatter electron images and elemental distribution maps. A Quadrupole ICP-MS coupled to a laser ablation system was used to acquire in-situ trace element concentrations from individual mineral grains. Each analysis was normalized to the Fe data acquired from the electron microprobe, as an internal standard.

Petrographic work on the Porpoise Cove BIF indicates that it consist of finely laminated bands of magnetite and quartz (0.1 - 1 cm wide). Grunerite is present primarily within the oxide bands and as disseminated grains within the quartz bands, and small amounts of actinolite are also present. Both minerals have been replaced by minnesotaite (O'neil et al., 2007).

The major and trace element values of the Porpoise Cove BIF are compared to literature values of BIF from the Isua Greenstone Belt , Porpoise Cove and from the younger (~ 2.5 Ga), less altered Dales Gorge Member, previously collected by members of the Konhauser lab and others.

Conclusions

Preliminary results indicate that Eoarchean BIF from Porpoise Cove and Isua Greenstone Belt show both similarities and differences in both trace element concentration and mineralogy. Both Eoarchean BIFs have noticeably higher concentrations of "bio-essential" trace elements (Co, Cu, Mo, V, Zn) than the Dales Gorge BIF, perhaps partly due to the high hydrothermal fluxes in the early Archean (eg. Isley and Abbott, 1999). Furthermore, Porpoise Cove BIF displays slightly higher concentrations of these elements than BIF from the Isua Greenstone Belt. While the Porpoise Cove BIF displays mineral assemblages consistent with high-grade metamorphism on the order of upper-amphibolite-facies, the Dales Gorge BIF has a mineral assemblage indicative of lower grade, greenschist-facies metamoprhism (eg. hematite, siderite, ankerite, ferroan dolomite and chert) (Klein, 2005; Pecoits et al., 2009). While some of these features may surely be related to metamorphic grade, others are unlikely to be determined by post-depositional processes, and may potentially indicate the water-column geochemistry of the environment in which they were deposited.

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