

Neoproterozoic iron formation: An evaluation of its temporal, environmental and tectonic significance



Grant M. Cox^{a,*}, Galen P. Halverson^a, William G. Minarik^a, Daniel P. Le Heron^b, Francis A. Macdonald^c, Eric J. Bellefroid^a, Justin V. Strauss^c

^a McGill University, Montreal, Quebec, Canada

^b Royal Holloway, University of London, United Kingdom

^c Harvard University, MA, USA

ARTICLE INFO

Article history:

Accepted 5 August 2013

Available online 16 August 2013

Keywords:

Iron formation
Cryogenian
Sturtian glaciation
Anoxia
Hydrothermal
Mafic volcanism

ABSTRACT

Neoproterozoic iron formation (NIF) provides evidence for the widespread return of anoxic and ferruginous basins during a time period associated with major changes in climate, tectonics and biogeochemistry of the oceans. Here we summarize the stratigraphic context of Neoproterozoic iron formation and its geographic and temporal distribution. It is evident that most NIF is associated with the earlier Cryogenian (Sturtian) glacial epoch. Although it is possible that some NIF may be Ediacaran, there is no incontrovertible evidence to support this age assignment. The paleogeographic distribution of NIF is consistent with anoxic and ferruginous conditions occurring in basins within Rodinia or in rift-basins developed on its margins. Consequently NIF does not require whole ocean anoxia. Simple calculations using modern day iron fluxes suggest that only models that invoke hydrothermal and/or detrital sources of iron are capable of supplying sufficient iron to account for the mass of the larger NIF occurrences. This conclusion is reinforced by the available geochemical data that imply NIF record is a mixture of hydrothermal and detrital components. A common thread that appears to link most if not all NIF is an association with mafic volcanics.

© 2013 Published by Elsevier B.V.

Contents

1. Introduction	233
1.1. Iron in the modern ocean	235
1.2. Broad depositional constraints	235
1.2.1. Anoxic basin waters	235
1.2.2. Hydrogen sulfide to ferrous iron ratio less than 2 ($H_2S/Fe^{2+} < 2$)	235
1.2.3. Oxidative mechanism	236
2. Geological context of Neoproterozoic iron formations	237
2.1. South Australia	237
2.2. Northwestern North America	237
2.3. Chuos–Damara–Numees iron formation, Namibia	237
2.4. Jacadigo Group, Brazil and Bolivia	238
2.5. Yermal iron formation, Uruguay	238
2.6. Chestnut Hill iron formation, United States	238
2.7. Arabian–Nubian Shield	238
2.8. Fulu Formation, South China	238
2.9. Other Neoproterozoic iron formations	239
3. Age and geographic distribution of Neoproterozoic iron formation	239
3.1. Age constraints	239
3.2. Geographic distribution	239
4. Geochemistry of Neoproterozoic iron formations	239
4.1. Major element characteristics	239
4.1.1. Major element correlation coefficients	240
4.1.2. Major element principal component analysis	241

* Corresponding author.

E-mail address: grant.cox@mail.mcgill.ca (G.M. Cox).

5.	Models for the formation of Neoproterozoic iron formation	243
5.1.	Sedimentary exhalative-rifting	243
5.2.	Snowball Earth	244
5.3.	Anoxic sub-glacial outwash	244
5.4.	Sulfur limitation	244
5.5.	Continental resurfacing	244
5.6.	Silled basins	244
6.	Discussion	245
6.1.	Depositional time constraints	245
6.2.	Major element constraints	245
6.3.	Iron isotopes	245
6.4.	Synchronicity	245
6.5.	Role of mafic magmatism and hydrothermal activity	245
7.	Conclusion	246
	Acknowledgments	246
	References	246

1. Introduction

The apparent sudden reappearance of iron formation after a ~1 billion year hiatus in the sedimentary record (Isley and Abbott, 1999; Klein, 2005) has been considered a geologically unique feature of the Neoproterozoic (~1000 Ma to 635 Ma). This last gasp of significant Precambrian iron formation (James et al., 1983; Klein, 2005) contrasts with the relatively minor abundance of Phanerozoic sedimentary iron formations, such as Clinton-type oolitic ironstones (Van Houten and Arthur, 1989; Young, 1989).

Unlike their Archean and Paleoproterozoic counterparts, which formed at a time of low atmospheric O₂ and pervasively anoxic deep oceans (Bekker et al., 2004; Canfield, 2005; Frei et al., 2009; Lyons and Reinhard, 2009), Neoproterozoic iron formation (NIF) developed at a time when pO₂ should have been significantly higher (Canfield and Teske, 1996; Canfield, 2005; Frei et al., 2009). The most significant NIFs are all associated with widespread glaciation. Thus the reappearance of iron formation during the Neoproterozoic presents a prima facie case for the apparent widespread return of anoxic and ferruginous basins or sub-basins, which is presumably linked to the extreme climate changes that dominate the middle Neoproterozoic stratigraphic record.

For the purposes of this paper we define iron formation to be a sedimentary rock containing greater than 15 wt.% Fe₂O₃ (James, 1954); however, within any given section of NIF Fe concentration can vary significantly (Fig. 1). Neoproterozoic iron formation is distinct from the extensively documented Archean and Paleoproterozoic Banded Iron Formation (BIF). For example, with some exceptions, banding is generally poorly developed (Fig. 2b) or entirely absent in most NIFs. When banding is present, it consists of layers of hematite (Fe₂O₃) and jaspilite (iron-rich chert) (Fig. 2d). Neoproterozoic iron formation more commonly occurs as ferruginous laminated siltstone (Fig. 2f) or within the matrix of diamictite (Fig. 2e). An important distinction between NIF and Archean and Paleoproterozoic BIFs is in the mineralogy: in unmetamorphosed NIF, iron resides almost exclusively in hematite (Fe³⁺₂O₃) (Klein and Beukes, 1993). Magnetite (Fe²⁺₃O₄) has also been reported, but it is never the principal iron-bearing phase (Volkert et al., 2010; Freitas et al., 2011), except in metamorphosed occurrences. Accessory minerals include chlorite, smectite, quartz and carbonate. In a few instances, most notably in the Jacadigo Group in Brazil and its equivalent in Bolivia, manganese is a significant component of NIF, typically occurring in discrete Mn-rich beds (Klein and Ladeira, 2004).

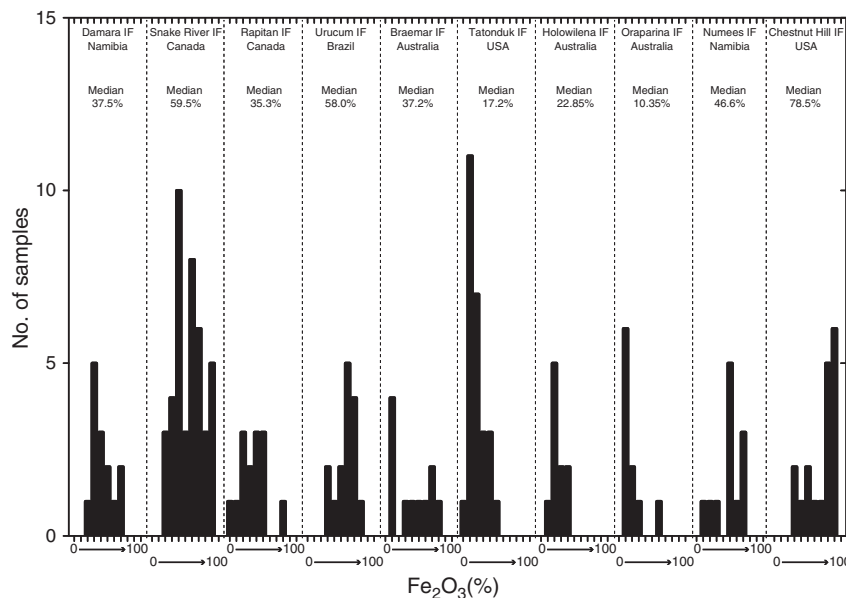


Fig. 1. Histogram of published ($n = 172$) Fe₂O₃ concentrations for NIF. For comparison, typical sedimentary rocks have Fe₂O₃ well below 10%. Data is from Lottemoser and Ashley (2000), Freitas et al. (2011), Piacentini et al. (2007), Klein and Beukes (1993), Klein and Ladeira (2004), Volkert et al. (2010), Gross (2009) and this study.

Download English Version:

<https://daneshyari.com/en/article/6436775>

Download Persian Version:

<https://daneshyari.com/article/6436775>

[Daneshyari.com](https://daneshyari.com)