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Some Precambrian banded iron-formations (BIFs) from around the world: Their age, geologic setting, mineralogy, metamorphism, geochemistry, and origin

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ABSTRACT

Banded iron-formations (BIFs) occur in the Precambrian geologic record over a wide time span. Beginning at 3.8 Ga (Isua, West Greenland), they are part of Archean cratons and range in age from about 3.5 until 2.5 Ga. Their overall volume reaches a maximum at about 2.5 Ga (iron-formations in the Hamersley Basin of Western Australia) and they disappear from the geologic record at about 1.8 Ga, only to reappear between 0.8 and 0.6 Ga.

The stratigraphic sequences in which BIFs occur are highly variable. Most Archean iron-formations are part of greenstone belts that have been deformed, metamorphosed, and dismembered. This makes reconstruction of the basinal setting of such BIFs very difficult. The general lack of metamorphism and deformation of extensive BIFs of the Hamersley Range of Western Australia and the Transvaal Supergroup of South Africa allow for much better evaluations of original basinal settings. Most Archean iron-formations show fine laminations and/or microbanding. Such microbanding is especially well developed in the Brockman Iron Formation of Western Australia, where it has been interpreted as chemical varves, or annual layers of sedimentation. BIFs ranging in age from 2.2 Ga to about 1.8 Ga (e.g., those of the Lake Superior region, U.S.A., Labrador Trough, Canada, and the Nabberu Basin of Western Australia) commonly exhibit granular textures and lack microbanding.

The mineralogy of the least metamorphosed BIFs consists of combinations of the following minerals: chert, magnetite, hematite, carbonates (most commonly siderite and members of the dolomite-ankerite series), greenalite, stilpnomelane, and riebeckite, and locally pyrite. Minnesotaite is a common, very low-grade metamorphic reaction product. The Eh-pH stability fields of the above minerals (and/or their precursors) indicate anoxic conditions for the original depositional environment.

The average bulk chemistry of BIFs, from 3.8 through 1.8 Ga in age, is very similar. They are rich in total Fe (ranging from about 20 to 40 wt%) and SiO_2 (ranging from 43 to 56 wt%). CaO and MgO contents range from 1.75 to 9.0 and from 1.20 to 6.7 wt%, respectively. Al_2O_3 contents are very low, ranging from 0.09 to 1.8 wt%. These chemical values show that they are clean chemical sediments devoid of detrital input. Only the Neoproterozoic iron-formations (of 0.8 to 0.6 Ga in age) have very different mineralogical and chemical make-ups. They consist mainly of chert and hematite, with minor carbonates.

The rare-earth element profiles of almost all BIFs,with generally pronounced positive Eu anomalies, indicate that the source of Fe and Si was the result of deep ocean hydrothermal activity admixed with sea water.

The prograde metamorphism of iron-formations produces sequentially Fe-amphiboles, then Fe-pyroxenes, and finally (at highest grade) Fe-olivine-containing assemblages. Such metamorphic reactions are isochemical except for decarbonation and dehydration.

The common fine lamination (and/or microbanding) as well as the lack of detrital components in most BIFs suggest that such are the result of deposition, below wave base, in the deeper parts of ocean basins. Those with granular textures are regarded as the result of deposition in shallow water, platformal areas. Carbon isotope data suggest that for a long period of time (from Archean to Early Proterozoic) the ocean basins were stratified with respect to $\delta^{13}C$ (in carbonates) as well as organic carbon content. In Middle Proterozoic time (when granular BIFs appear) this stratification diminishes and is lost.

The Neoproterozoic BIFs occur in stratigraphic sequences with glaciomarine deposits. These BIFs are the result of anoxic conditions that resulted from the stagnation in the oceans beneath a near-global ice cover, referred to as "Snowball Earth."

All of the most "primary" mineral assemblages appear to be the result of chemical precipitation under anoxic conditions. There are, as yet, no data to support that BIF precipitation was linked directly to microbial activity. The relative abundance of BIF throughout the Precambrian record is correlated with a possible curve for the evolution of the O_2 content in the Precambrian atmosphere.