EARLY PROTEROZOIC ERA

The periods which to our narrow apprehension, and compared with our ephemeral existence, appear of incalculable duration, are in all probability but trifles in the calendar of nature. It is Geology that, above all other sciences, makes us acquainted with this important, though humiliating fact. Every step we take in its pursuit forces us to make almost unlimited drafts upon antiquity. The leading idea which is present in all our researches, and which accompanies every fresh observation, the sound of which to the ear of the student of Nature seems continually echoed from every part of her works, is – Time! — Time! — Time!

—Scrope.[1]

k26 Superior-type banded ironformation

< BIF, free oxygen buildup 2.3 Ga >

Early Proterozoic upwelling bottom seawater had abundant ferrous iron, Fe(II), in solution. This is recorded by the vast quantities of Proterozoic Superior-type ironformation (of alternating layers of Fe(III) minerals and chert beds) which goes by the acronym BIF (banded ironformation) that accumulated on continental shelves 1.9-2.6 Ga (billion years ago).[2]

Described by H. L. James in 1954, BIF (commonly several hundred meters thick) is typically cherty with iron either as beds of pure magnetite and lesser ones of hematite or, more abundantly, as beds of magnetite-iron silicate or steel blue hematite-iron silicate assemblages.[3] Widely not found is any association with volcanic rocks although in some localities BIF does occur as beds in pillow lavas.[4] Discovered in 1844, the first were such. Heroic field mapping activities (before the availability of insect repellent to ward off mosquito and black fly) by USGS (United States Geological Survey) geologists coordinated by C. R. Van Hise established BIF correlations within the folded Animikie series of Wisconsin and Michigan (***Figure k26.1***).[5] Correlation was also made with the stratigraphically thinner Animikie group on the northwest side of Lake Superior. The strata there have a homoclinal south-southeast dip. Traversing opposite to the dip finds outcrops of increasing age between Cuyana range Deerwood 1.6 Gy (billion years old) ironformation and Mesabi range Biwabick 1.9-2.2 Gy ironformation. The Vermillion range and Gunflint range ironformations date 1.6-1.9 Gy. The work was aided by geophysical measurement of compass-needle deflections by the ironformation that, between rare outcrops, is otherwise concealed by covering glacial moraines.[6]

Known in detail from mining activities and geological studies (in the Mesabi and the Gogebic-Menominee ranges, Lake Superior vicinity, Morro do Urucum, western Brazil, and the Hamersley range, northwestern Australia), BIFs are shallow-sea chemical sediments.[7] BIF facies can be understood in terms of the Eh-pH conditions of chemical sediments' precipitation (***Figure k26.2***). They are: littoral and near-shore subfacies of fine-grained hematite interlayered with commonly oolitic chert or jasper (deposited under strongly oxidizing conditions) grading to deeper water offshore subfacies of hydrous ferrous silicates as greenalite, stilpnomelane, or minnesotatite interbedded with either carbonate-bearing rocks (precipitated under weakly oxidizing conditions that removed organic material but did not permit ferric compounds to form) or magnetite-bearing rocks (precipitated under moderately reducing conditions).

The absence of free oxygen (O_2) in the atmosphere, and by implication an anaerobic deep ocean, before 2.3 Ga is indicated by the absence of iron hydroxides in palaeosols older than that time.[8] Corroboration of this is a 2.5 Gy Canadian palaeosol reported by T. Murakami in 2001 to have (unoxidised) native cerium. Also, in today's atmosphere, photochemical MIF (mass-independent fractionation) of sulfur isotopes occurs but free atmospheric oxygen reacts to unscramble the isotope mix before the sulfur reaches Earth's surface. James Farquhar in 2000 pinned down atmospheric oxygen's first appearance at levels of at least 1 part per million by noting that only in rocks older than 2.4 Gy is MIF of sulfur found.[9]

For all the time of little free oxygen in the atmosphere, ultraviolet sunlight would have been strong at Earth's surface, sterilizing land and sea surfaces with its ionizing radiation.[10] Precipitation of BIF then could have been by atomic oxygen (O) and ozone (O_3), both harsh oxidizers, released from UV-dissociated water or by enzymatic Fe(II) oxidation by anoxygenic phototrophic bacteria in the photic zone below the level of killing UV.[11] ❑

Figure k26.1 Map of iron-mining districts in the Lake Superior region [12]

Key: Animikie group and series, and Huronian series (gray map areas)
Lakes (pale-gray map areas)
BIF outcrops (black map areas).

Generalized stratigraphic successions [13] of mine districts south of Lake Superior.

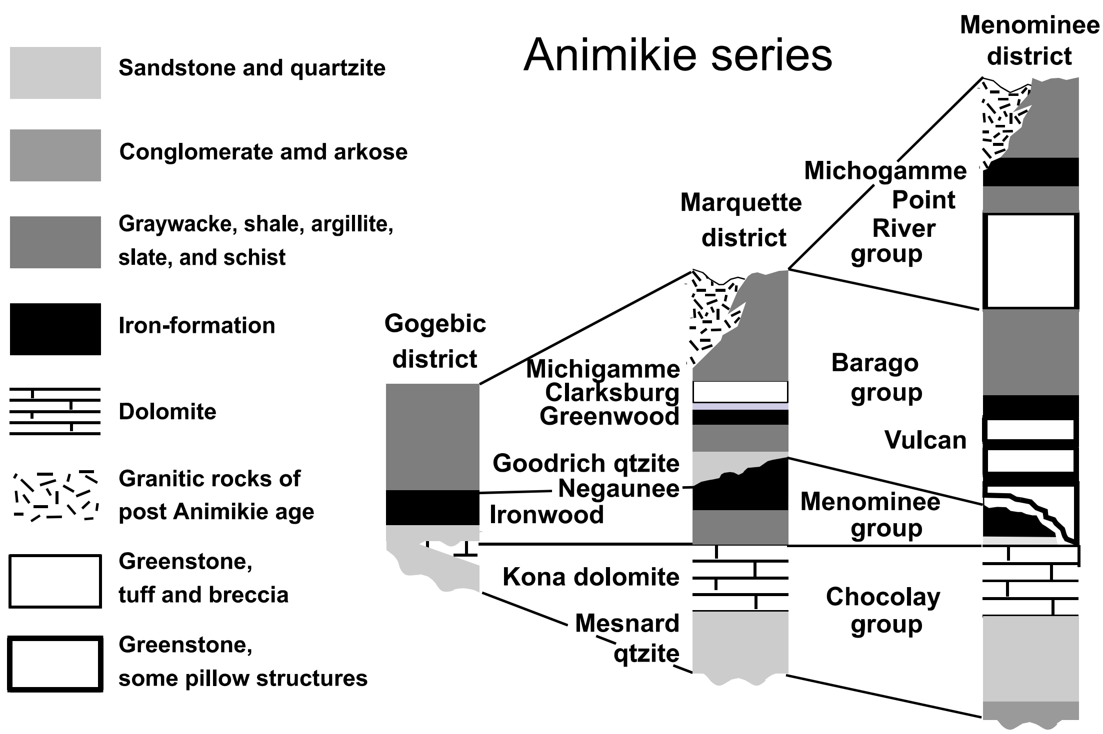

Figure k26.2 Hypothetical depositional model for the origin of Superior-type banded ironformations [14] and a plot of the upwelling precipitated chemical sediments in an Eh-pH diagram.[15]