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Photo-chemical and Biologically Mediated Precipitation of Iron and Silica

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Banded iron formations (BIFs) are one of the most abundant sedimentary deposits of the Precambrian, with major accumulations having formed during the late Archean (2.7-2.5 Ga) and early Proterozoic (2.5-1.8 Ga). These thin-bedded or laminated rocks contain an anomalously high iron content, and commonly, layers of chert. After many decades of interest, the mechanisms for the formation of Precambrian BIFs still contains many areas of uncertainty. At present geological and geochemical evidence have identified that these deposits formed as marine chemical precipitates, with hydrothermal activity and continental weathering supplying the chemical constituents. However mechanisms for the removal of iron and silica from solution and the formation of the distinctive iron and silica rich banding are still problematic.

Iron, which must have been transported from its continental and marine hydrothermal sources in the ferrous state would have acted as an electron donor during a number of organic and inorganic reactions leading to iron precipitation in the form of insoluble ferric hydroxides. Although these reactions are geochemically well understood the relative contribution from photo-chemical processes, photo-dissociation of atmospheric water vapour, oxygenic and anoxygenic photosynthesis is unclear. The mechanisms for the precipitation of silica from solution are even less well constrained. Silica, in the absence of silica secreting organisms, may have been close to saturation in Precambrian oceans. Today a variety of mechanisms exist which cause silica to precipitate in an amorphous state. They include evaporation, microbial biomineralization or co-precipitation. In the case of evaporation it has been suggested that the amount of evaporation necessary to account for silica rich BIF bands would preclude this being the only process of silica precipitation (Ewers and Morris, 1981). A biological role for amorphous silica precipitation has also been considered, since bacteria are known to create favourable conditions for silicification and they provide highly reactive surfaces for silica nucleation (Konhauser and Ferris, 1996). Co-precipitation has been suggested as a means of precipitating iron and silica, but experimental studies do not appear to recreate conditions which are likely to have occurred in Precambrian oceans. As far as we are aware no study has yet linked (i) the photo-chemical precipitation of iron with silica flocculation, (ii) how the presence of silica may have affected iron precipitation and (iii) what role biomineralization had on the concomitant precipitation of iron and silica. This is despite the fact that previous studies have shown that silica affects iron mineralization, and furthermore, the presence of silica retards the transformation of amorphous ferrihydrites to more ordered forms by adsorbing to the oxides (Jones and Handreck, 1963).

This study makes use of a new approach to examine the affects of iron precipitation on silica in Precambrian oceans, taking into account the potential importance of both photochemical and microbiological reactions. Experiments were set up to mimic conditions which were likely to have predominated during Precambrian times. Free oxygen was precluded by bubbling nitrogen gas through mixed iron and silica solutions and pH was initially set to circum-neutral. These solutions were then either exposed to UV light (245 nm) to examine inorganic photo-oxidation effects or placed in contact with photosynthesizing micro-organisms which also have the ability to mineralize iron and silica. Preliminary results presented here show that in systems where ferrous iron in solution is photo-chemically oxidized to insoluble ferric hydroxides silica is also co-precipitated. Bacterially driven reactions appear to bind iron first which then allows silica to attach to bound iron on the cell surface probably via a process of cation bridging.

These findings will have important implications for Precambrian iron formations. Most models consider precipitation of iron and silica to be separate, possibly seasonal or controlled by supply of chemical constituents to the marine basin (Morris, 1993). However we suggest that iron and silica mineralization may be coupled. Additional studies will focus on the processes such as differential settling or post depositional segregation of the primary iron and silica gels, which must have occurred to yield the characteristic banding in BIFs.

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