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Microtectonics of BIF – New structural insights on the origin of enigmatic banded iron formations

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Banded iron formations (BIF) are Precambrian chemical sedimentary rocks composed predominantly of alternating layers of iron oxides, iron carbonates, iron silicates and chert. It is widely accepted that the banded texture of BIF represents chemical fluctuations in the depositional environment. However, it is also well-known that the mineral assemblage is of diagenetic and/or metamorphic origin, and the mineral assemblages of BIF are unlikely to represent the primary precipitates. While the chemical transformation of the controversial iron-bearing precursor phase(s) to iron oxides has been the focus of most previous research, the genesis of the more abundant chert layers remains unclear. Additionally, despite the documentation of significant amounts of compaction, volume loss ($\sim$ 90%) and extensive deformation in BIF, the impact of differential stress and the crucial role of deformation mechanisms have been mostly disregarded.

A new microtectonic study of BIF from the Paleoproterozoic Hamersley Province (Western Australia) indicates that significant remobilisation of silica occurred during deformation, evident by significant thinning of chert bands in more deformed locations (e.g., fold limbs, shear bands) and thickening in low-pressure domains that are commonly parallel to the direction of maximum extension. Structural analysis combined with quantitative microfabric analysis (MiFA) of quartz grains in chert layers reveals strong crystallographic preferred orientations (CPOs) consistent with dissolution-precipitation creep (DPC), which has not yet been described in Hamersley Province BIF.

DPC is activated by differential stress during diagenesis and deformation under low-grade metamorphic conditions, leading to the dissolution of quartz in a present fluid phase. The dissolved solid phase is transported by diffusion and fluid flow along grain boundaries or in the available porosity and subsequently reprecipitates in low-pressure zones. This can result in significant thickness variations of chert bands and is enhanced by the electrochemical potential difference between contrasting rheological materials (e.g., quartz and hematite), which is controlled by the chemistry of the fluid phase (temperature, pH, ionic strength).

Even relatively undeformed chert bands can show strong CPOs suggesting the occurrence of non-coaxial deformation during diagenesis. Further, chert bands lacking CPOs commonly contain abundant intragranular iron oxide nanoparticles (e.g., jasper) that become liberated during deformation by DPC. These nanoparticles accumulate residually and transform into new iron oxide bands.

It is commonly assumed that only deformation by dislocation glide and not DPC is able to generate CPOs. However, our study disproves this widely held concept and illustrates that CPO patterns are able to indicate the paleo strain regimes (e.g., pure and simple shear, extension and shortening), which modified quartz aggregates by DPC. We hypothesise that deformation mechanisms have been underestimated in many aspects of BIF related research and that DPC provides a potential link between the physical and chemical processes affecting BIF since deposition. Our results suggest that ancient oceans did not need to undergo short-term cyclic chemical fluctuations to explain the origin of the banded texture of BIF. In addition, we propose that chert layers lacking a CPO show the least overprint by diagenesis and likely represent the most pristine form of BIF that should be targeted for future paleo-environmental research.