Why did globally distributed ironstones reappear in the Neoproterozoic after a one-billion-year hiatus?

Amanda Smith

Neoproterozoic ironstones mark the reappearance of iron deposits after about a one-billion-year hiatus. However, the mechanisms responsible for disappearance and reappearance of these deposits is debated. Three separate deep ocean redox states (euxinic, aerobic, and anoxic) have been proposed to generate conditions for ironstone deposition. These theories influence our understanding of eukaryote evolution and paleo-atmospheric conditions. The first widely accepted theory explains the deposition of ironstones by a change in deep ocean chemistry from anoxic to aerobic. However, this model does not fully address the mechanism of returning the deep ocean to anoxic conditions following Archean ironstone deposition. In contrast, a deep ocean change to euxinic conditions has been argued as the mechanism of Archean deposition, based on evidence of sulfide isotope fractionation trends in iron formations. It has been proposed that iron was able to build up in the Neoproterozoic through ocean stagnation during “snowball Earth” glaciations. Neoproterozoic ironstone deposition thus marks the termination of deep ocean euxinia and the development of aerobic conditions. However, nearly all evidence for euxinic conditions can be explained by locally developed redox conditions on intracratonic basins, rather than deep ocean basins. Building on this idea, another theory has proposed that deep oceans were fully aerobic by the Neoproterozoic. Glacial coverage of silled basins limited ocean circulation and generated anoxic ferruginous conditions, which then precipitated ironstones following glacial retreat. Evidence for this theory includes rare earth element anomalies and the distinctive redox behaviours of Mo and U. Conversely, Fe speciation ratios provide evidence that widespread anoxic ferruginous conditions were also common below mean storm wave base and in outer shelf environments, leading to a fourth theory that widespread ferruginous anoxic redox state generated conditions for Neoproterozoic ironstone deposition. Supporting evidence for all three paleo-ocean redox states has been found, indicating that ocean redox conditions were heterogeneous during the Proterozoic era.