The 1.4 Ga Xiamaling Formation, north China: what it can and cannot tell us about the Mesoproterozoic

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The Mesoproterozoic remains an enigmatic time period in the minds of many, including the remarkable stability of the carbon isotope record, the near billion-year gap in glaciations, the seemingly early appearance but delayed diversification of eukaryotes, and the sometimes contradictory interpretations of a variety of ocean redox proxies—just to name a few reasons. This lack of understanding is, in part, due to the scarcity of continuous Mesoproterozoic sedimentary successions and their patchy temporal distribution.

In an effort to fill key data gaps, we have examined a portion of the Xiamaling Formation, specifically the black shale-rich facies of Units 2 and 3, captured in a drill core taken approximately 200 km west of Beijing. The ages of Units 2 and 3 of the Xiamaling have been well constrained by U/Pb zircon dates to ~1390 Ma.

We present a high resolution, multi-proxy approach to assess the redox structure of this Mesoproterozoic basin and, by extension, the Mesoproterozoic oceanic system as a whole. New data presented in this study include iron speciation, major and trace elemental compositions, pyrite sulfur isotopes, and molybdenum isotopes. By robustly establishing the redox conditions of the immediately overlying waters through the use of traditional sequential iron extractions, we then have a framework in which to interpret trends in both redox-sensitive trace metal concentrations and molybdenum isotopes—well established tracers of global redox.

Our results demonstrate a fundamental shift in basin hydrography near the top of Unit 3. Specifically, we suggest that the most parsimonious interpretation for the elemental relationships in Unit 3 is deposition under nonmarine conditions. If we are correct, the Unit 2/3 contact represents a marine incursion, which gives way to a richly sulfidic interval. As such, Unit 2 captures records that likely reflect global marine conditions. In this light, maximum trace metal enrichments and molybdenum isotope ratios are consistent with a low O_2 ocean/atmosphere system and a largely ferruginous deep ocean. These results corroborate our past views of the mid-Proterozoic and the environmental conditions in which the earliest complex life evolved.