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Surface system response to deep Earth dynamics:A iron formation perspective

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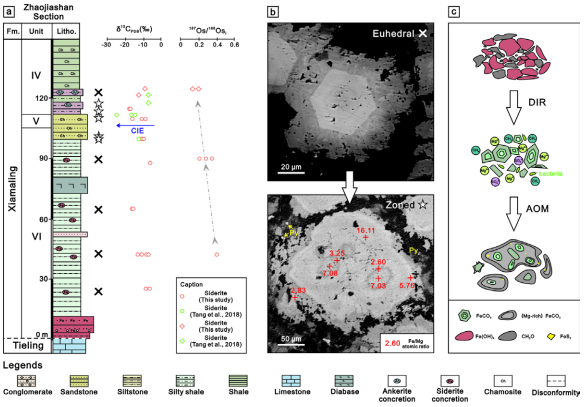
Iron formations (IFs) are Fe-enriched sedimentary rocks that are remarkably absent for the billion years of the Mesoproterozoic era. Recent studies discovered a 1,400 Ma IF containing ca. 520 gigatons of Fe in the Xiamaling Formation on the North China Craton. These IFs are primarily composed of siderite ($FeCO_3$), appearing as layers or concretions, with origins that remain unclear. This study conducted detailed petrological, C-O-Re-Os isotopic, and elemental geochemical analyses on the siderites in Units IV to VI of the Xiamaling Formation. The low thermal maturity of organic matter and clay mineral structures suggests that the layered siderites formed at burial temperatures of ≤90 °C. Microscopically, the siderites exhibit euhedral to subhedral faint rhombic and hexagonal structures, or anhedral spheroidal banded structures, with the lighter regions showing a higher Fe/Mg atomic ratio in BSE images. The average carbon isotope value ($\delta^{13}C_{PDB}$) of siderites is -8.05 ± 3.48 ‰. Considering that the $\delta^{13}C$ of seawater/porewater HCO_3^- during the same period is close to 0‰, the contribution from organic matter as a carbon source ranges from 15% to 37.5%. Additionally, there is a negative carbon isotope excursion (NCIE) of approximately ca. -12‰ in Unit V. This is also consistent with the reduction of $^{187}Os/^{188}Os_i$ to close to the mantle value (ca. 0.12). The presence of syndepositional intermittent tuff layers and significant enrichment of Cu and Zn in the siderite-hosting rocks further supports to mantle sourced carbon and iron. Coupled with other geological data, dissimilatory iron reduction (DIR) has played crucial roles in the formation of siderite during early diagenesis. In the Unit V of the Xiamaling Formation, enhanced submarine volcanic and/or hydrothermal activities associated with the final breakup of the Columbia Supercontinent disrupted the methane hydrates, leading to the anaerobic oxidation of methane (AOM). This process resulted in the formation of secondary zoned structures, while also causing the modification of the primary minerals in highly alkaline environment. This explains why zoned siderites are mainly distributed around Unit V. Obviously, the role of magmatisms in punctuating the mid-Proterozoic status quo emerges, potentially triggering shifts in biogeochemical dynamics.



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