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Invited review

Steep Rock Lake: Sedimentology and geochemistry of an Archean carbonate platform

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ABSTRACT

The ~2800 Ma Mosher Carbonate Formation at Steep Rock Lake in south central Canada is one of Earth's oldest limestone deposits. It is both thick (up to 500 m) and relatively well-preserved, and was one of the first Precambrian successions to be noted for evidence of early life. It continues to provide information on the antiquity of such processes as photosynthesis. The carbonate contains a variety of fabrics and facies, from apparently fine-grained, bedded limestones with domal and columnar stromatolites, atikokania radial fans, and sheet-cracks, to closely packed metric-scale hybrid domes of originally aragonite seafloor crust interlayered with fenestral fabric. Here we review previous work, provide new observations concerning these sediments and their geochemistry, and discuss the inception, overall development and ultimate demise of the Steep Rock platform. We divide the Mosher Carbonate into the lower Hogarth Member and upper Elbow Point Member. These units constitute a shallow-water carbonate platform succession. The Hogarth Member overlies eroded ~3000 Ma tonalite and is at least 120 m thick. Thin horizons of domal, pseudocolumnar, columnar and fenestral stratiform stromatolites, and occasional layers of 'atikokania' radial crystal fans, occur within relatively fine-grained, thin-bedded limestone with iron-carbonate horizons. In the upper part, meter-scale domes occur locally, with sheet cracks and stromatactis. The irregular laminae that build the small domal and columnar stromatolites are interpreted to be lithified mats and biofilms, presumably cyanobacteria-dominated. Fine-grained, well-bedded facies of the lower Hogarth Member and its varied association of small stromatolites is interpreted to have accumulated in a relatively protected inner platform environment. Numerous very thin horizons of iron-carbonate in the lower and upper parts of the Hogarth Member suggest temporally limited influence of iron-rich offshore waters. Vertical trends in Fe, Mn, Ba, Sr, Ce and $\delta^{13}C$ probably reflect progressive restriction of circulation with at least one abrupt, but short lived, change back to more open seawater conditions. The upper Hogarth Member with large banded domes and fenestral crusts and stromatolites is interpreted as back margin facies. The overlying Elbow Point Member is at least 70 m thick and appears to be entirely composed of innumerable juxtaposed, elongate, smooth and thickly layered domes lacking intervening sediment. Each dome is typically several meters across and composed of centimetric alternations of cuspate fenestral fabric, possibly microbial, and crystal fan fabric that is probably abiotic seafloor aragonite precipitate. Adjacent cuspate fenestral and crystal fan fabric show significant differences in concentration of $\delta^{13}C$, Sr, Ba, Fe and Mn. This 'Giant Dome' facies is interpreted as a platform margin deposit in which alternating calcite–aragonite mineralogies within each dome reflect a laterally fluctuating offshore redox boundary. Negative Ce anomalies, positive Gd anomalies and reduced positive Eu anomalies, relative to laterally correlative deep-water iron formation, occur in the majority of crystal fan samples and in some cuspate fenestral fabric samples. Ca-carbonate precipitation at the margin of an anoxic iron-rich sea would have been promoted by oxygenic removal of iron from seawater; otherwise Fe-carbonate would have been favored over Ca-carbonate precipitation. The Mosher Carbonate Formation is interpreted as an early marine oxygen oasis: a shallow-platform that favored cyanobacterial productivity, was sufficiently isolated from open marine circulation for the seawater to become relatively oxygenated, and where carbonate sediment aggradation was a positive feedback that sustained these shallow-water conditions. Limestone accumulation terminated as transgressive suboxic and anoxic seawater deposited first manganese oxide-rich and then manganese oxide-poor iron formation sediments.

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