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Early Archean Carbonate Factories - Major Carbon Sinks on the Juvenile Earth

WANLI XIANG[1], JAN-PETER DUDA[1], ANDREAS PACK[1], MATTHIAS WILLBOLD[2], WOLFGANG BACH[3] AND JOACHIM REITNER[1]

[1]University of Göttingen

[2]Georg-August-Universität Göttingen

[3]MARUM, University of Bremen

Presenting Author: wxiang@gwdg.de

Early Archean carbonates are important archives for life and environments on the early Earth. The ~3.5–3.2 Ga East Pilbara Terrane(Western Australia) encompasses a great diversity of carbonates, including interstitial carbonates between various pillow basalt units (~3.5–3.4 Ga; e.g., North Star Basalt, Mt. Ada Basalt, Apex Basalt, Euro Basalt), bedded sedimentary carbonate-chert rocks (~3.5 Ga Dresser Formation), and carbonates associated with stromatolites (~3.4 Ga Strelley Pool Formation). To better understand the geobiological significance of those early Archean carbonates, we elucidated abiotic and biological processes involved in their formation by combining analytical petrography (e.g., high-resolution microscopy, Raman spectroscopy, μ-XRF mapping) with geochemistry (REE+Y, $\delta^{13}C$, $\delta^{18}O$, $^{87}Sr/^{86}Sr$). The carbonates exhibit variable mineralogies, ranging from calcite, through dolomite to Fe/Mn-rich dolomite (ankerite), formed via the following pathways: (1) abiotic precipitation (interstitial carbonates between pillow basalts); (2) organomineralization (bedded sedimentary carbonates); (3) microbially mediated mineralization (Strelley Pool Formation stromatolites). Notably, pristine interstitial carbonates from Dresser Formation and Apex Basalt have age-corrected $^{87}Sr/^{86}Sr$ ratios of 0.700596 and 0.703094 ± 0.000979, respectively, implying precipitation from seawater and the seawater-derived hydrothermal fluid at 3.5 Ga. They share various distinct REE+Y features, most noteworthy near-chrondritic Y/Ho, LREE depletions in PAAS-normalized patterns, positive La_{SN} and Y_{SN} anomalies, and the absence of Ce_{SN} anomalies. In contrast to carbonate that abiotically precipitated from seawater, however, hydrothermal carbonates exhibit positive Eu_{SN} anomalies. Our results highlight that hydrothermal processes drove carbonate formation and, by supplying various micro-nutrients (e.g., Fe, Mn, Ca, Mg) to the biosphere, the build-up of organic matter. Hence, these processes likely influenced the global carbon cycle on the Juvenile Earth significantly.