Geochemistry of terrestrial carbonates forming within an alleged Snowball Earth glaciation

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A central feature of Snowball Earth theory is the inhibition of atmosphere-ocean exchange due to ice covering of a frigid Earth. This allowed the accumulation of volcanic volatiles in the atmosphere eventually to the point where deglaciation was triggered. Although focus has been on carbon dioxide, other volcanic volatiles should also have rained out and accumulated on the Earth's surface. This has been tested by analysis of glacilacustrine carbonates (member W2 of the Neoproterozoic Wilsonbreen Formation, Svalbard), which are analogues of lacustrine facies of the modern hyper-arid Dry Valleys area of Antarctica.

The carbonates are manganoan, implying that the precipitates formed under sub-oxic conditions, possibly under ice-covered lakes. Carbon isotope values are typically +2 to +5 $^{o}/_{oo}$, tending to become heavier as $\delta^{18}O$ increases – features that may reflect outgassing of CO_2 and equilibration with the atmosphere. Sr isotope compositions are 0.7083 to 0.7091, intermediate between the slightly more radiogenic marine dolomite underlying the Wilsonbreen Formation (0.710), and the less radiogenic pre-glacial platform carbonates (0.7063-0.707) of Svalbard and East Greenland. These compositions are consistent with a minor contribution of radiogenic Sr from silicate weathering in addition to the foregoing marine carbonate signal. Indications of hyperaridity are from evaporite traces and the exceptionally heavy $\delta^{18}O$ composition of dolocrete and laminar stromatolitic dolostone facies, invariably positive (relative to VPDB) with a maximum of +14.9 $^{o}/_{oo}$. This requires some combination of a weak hydrological cycle, hyperaridity and sub-zero temperatures of precipitation of dolomite. Fluids leached from the carbonates have Cl/Br weight ratios of 40, consistent with Br enrichment from volcanogenic sources, but sulphur isotope data are not consistent with a high S volcanogenic flux to this environment.