Hydrogen, carbon, and oxygen isotope ratios from the Archean Pibara Block: constraints on geological cycles

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The Archean Pilbara Block, Western Australia, is a well-preserved ≈3.5 Gyr greenstone-granite terrain characterized by unstrained, low-grade greenstones intruded by adamellite (e.g. the North Pole Dome) and synclinorial greenstone belts of variable strain framed by batholiths (e.g. the Shaw and Coruna Downs). High strain zones with steep lineations at tectonic contacts between the granitic batholiths and the greenstone belts obscures the primary contacts between mafic and silicic rocks The stable isotope ratios of the hydrothermally–exchanged greenstone, chert, and granitic rocks are the result of Archean fluid-rock interaction. The secondary minerals provide constraints on the hydrogen, carbon and oxygen isotope ratios of Archean surface fluids.

Greenstone and granite hydrogen isotope ratios (from the core of the North Pole dome to the base of the Fortescue Group: $-84 \leq \delta D \leq -22$ (mean -64; 33 analyses) and from the North Pole, Shaw, Mt Edgar and Coruna Downs batholiths: $-87 \leq \delta D \leq -36$ (mean -66; 17 analyses)) lie within the Phanerozoic δD ranges for similar rocks. These results offer no support for the hypothesis that hydrogen loss through the upper atmosphere results in the abiotic oxidation of the Earth.

Secondary calcite in the greenstones exhibits the following range: $-3.7 \leq \delta^{13}C \leq 1.7$ (mean -0.4; 79 determinations). Hydrothermal calcite found in the pillow lava is a good proxy for the seawater inorganic carbon reservoir. These measured values are remarkably similar to Phanerozoic values suggesting that complementary reduced and oxidized carbon reservoirs existed by the early Archean. The retrograde solubility of calcite, and its abundance in greenstones of these types, insures the importance of the carbonate-silicate cycle at this time in the absence of biogenic precipitation of calcite/aragonite.

Oxygen isotope ratios on the greenstone silicate fraction (alb-chl-qtz assemblage: mean $\delta^{18}O=8.8$; 73 analyses) are ^{18}O-enriched relative to their magmatic values. Consistent with predictions of mass balance models, seawater had already evolved to the steady state value near $\delta^{18}O=0$ by this time. However, oxygen isotope buffering of the oceans requires a complementary ^{18}O-depleted reservoir, e.g. ocean layer 3 gabbros in the Phanerozoic world, a consequence of plate tectonic geometries. Low ^{18}O rocks (<+4) of any type are rare in the Archean suggesting that the greenstone belt sample may not be representative of typical Archean oceanic crust and not indicative of the predominant tectonic regime of ocean crust generation.