Weathering and Late Archean World Average River Water

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The interpretation of paleoenvironmental records in the late Archean (e.g. Banded Iron Formations) depends very strongly on an understanding of weathering and the resultant river water chemistry input to the oceans. Here, we report a geochemical modeling study of weathering in the late Archean atmosphere, leading to a detailed picture of world average river water (WARW) in the late Archean. We first simulated present-day chemical weathering of basalt and granite at $PO_{2,g} = 10^{-0.68}$ bar and $PCO_{2,g} = 10^{-3.5}$ bar with the addition of calcite (which has a strong effect on present-day WARW). Weathering of $10^{-4.0}$ moles of basaltic minerals (plagioclase, augite)+calcite produced hematite+kaolinite and a close match to WARW proportions of cations and anions. Results with granite (K-spar, plagioclase, biotite, muscovite)+calcite were less evolved. Quartz was suppressed owing to its lack of reactivity during weathering.

For the late Archean, we modeled weathering of basalt+komatiite and trondhjemite-tonalite-granodiorite (TTG) assuming (1) $PH_{2,g} = 10^{-5.0}$ bar and $PCO_{2,g} = 10^{-1.5}$ bar consistent with published atmospheric models; (2) Rainwater Na, K, Ca, Mg, Cl as in present-day rainwater; (3) Rainwater Fe equal to Mg; S equal to all the S from volcanic outgassing, which resulted in pH = 5.2. Weathering of $10^{-4.0}$ moles of olivine + basalt (plagioclase, augite)+calcite produced kaolinite. Weathering of $10^{-4.0}$ moles of TTG minerals (K-spar, plagioclase, biotite)+calcite produced (Fe-II, Ca)-beidellite and chalcedony. Relative to present-day WARW, predicted Archean WARW has higher Mg+Fe /Na+Ca and much higher HCO_3^-/cations + SiO_2, and the pH was 6.4. Pyrite is thermodynamically stable in the WARW, consistent with detrital mineral records.

Many trace elements can be included in the weathering model for late Archean WARW to predict their mobilities. Thus, we put chalcopyrite in the basalt-komatiite model to explore Cu mobility. Our calculations revealed trace amounts of chalcocite and bornite formed during weathering, depending on the extent of reaction. Decrease of the model $PH_{2,g}$ to $10^{-9.0}$ bar could mobilize MoO_4^{2-} to 10^{-8} m in WARW while $MoS_{2,cr}$ was still preserved. Such fluctuations of $PH_{2,g}$ could have occurred through changing volcanic outgassing rates before the GOE. Our new model enables an integrative approach to understanding riverine input to the oceans and the mineral evolution record on land during the late Archean.