Discovery of Ni-Fe phosphides in the 3.46 Ga-old Apex Basalt: Implications on the phosphate budget of the Archean oceans

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We have discovered Ni-Fe phosphides in the 3.46 Ga Apex Basalt in the ABDP #1 drill core from Pilbara, Western Australia. Their compositions are Ni=86.1±1.4, Fe=1.6±1.1 and P=12.3±1.2 wt%, or $Ni_{3.74\pm0.37}Fe_{0.13\pm0.05}P_{1.0}$. They are mixtures of Ni-rich schreibersite ($(Ni, Fe)_3P$) and Ni-rich melliniite ($(Ni, Fe)_4P$). Because these Ni-Fe phosphides are associated with various meteoritic minerals that apparently condensed from the very reducing Solar Nebular gas (Ohmoto et al., 2017, Goldschmidt Abst.), and because organic-C-rich sediments necessary to reduce the basalts were absent in the region, these Ni-Fe phosphides most likely represent the pieces of an asteroid body that impacted the Marble Bar area 3.46 Ga ago.

The average bulk-P content of the Apex Meteorites is ~0.01 wt%, which is ≤ ~1/10 of the average P contents of carbonaceous-, enstatite- and ordinary chondrites and Fe-meteorites. Our calculation suggests that the total P flux by asteroids to the Earth at ~3.5 Ga was ~$4x10^{10}$ to ~$4x10^{11}$ g/yr. Because most of the asteroid bodies would have been buried in the oceanic crust and mantle upon impact, the P flux to the oceans by the dissolution of meteoric Ni-Fe phosphides would have been <10^{10} g/yr, compared to the present-day riverine P flux (~$2x10^{12}$ g/yr). Our computations on the solubility of apatite (± calcite) in seawater as a function of T, pH, pCO_2, $m\sum Ca$, and $m\sum Cl$ suggest that the P fluxes to the oceans by low- and high-temperature alteration of phosphate-bearing submarine volcanic rocks were comparable to or higher than the present-day riverine-P flux; this would have created a flourishing biosphere in the Archean oceans.