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Apatite Weathering and the Phanerozoic Phosphorus Cycle

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Despite widespread debate in the literature, there is still considerable uncertainty concerning which nutrient ultimately controls marine net ecosystem production (NEP) over geologic time. Geochemical arguments suggest that phosphorus is the culprit. The weathering of apatite, the primary phosphorus sink in the Earth's exosphere, controls long-term phosphorus availability. If phosphorus is the ultimate controlling nutrient over geologic time scales, then long-term marine NEP is coupled to the release of phosphorus from apatite weathering. The most abundant apatite compositions found in nature are igneous fluorapatite and marine sedimentary carbonate fluorapatite. Sparse data exist on how these compositions dissolve under Earth's surface conditions. To demonstrate a need for these data and their application, we present a kinetic treatment of existing data, augmented by new results. We also present a tentative rate law for the dissolution of apatite. We then use these results in a weathering model designed to illustrate the control exerted by temperature (via activation energy) and surface area on the phosphorus flux from apatite dissolution during the Phanerozoic. Our conclusion is that activation energy, and hence temperature, and apatite surface area are important parameters governing the phosphorus flux from apatite weathering and therefore marine NEP during Phanerozoic time. Variations in these parameters over the Phanerozoic have led to a decline in the global weathering rate of apatite, and hence the flux of phosphorus to the ocean, from the Cambrian to the early Carboniferous. Since then, the flux of phosphorus to the ocean on the multimillion-year time scale has not substantially varied.