

Bottom-Water Redox and Primary Productivity of the Phosphoria Formation; A Phosphorite of Permian Age

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Rare-earth elements (REEs) in the Phosphoria Formation, a major sedimentary phosphate deposit of Permian age in SE Idaho, are partitioned into mineral components to identify the geochemistry of the formation's depositional environment. The marine fraction consists dominantly of carbonate fluorapatite, dolomite, calcite, organic matter, and chert; the detrital terrigenous fraction mostly of aluminosilicate minerals and quartz. The REEs are partitioned into apatite, with a minor amount hosted by the terrigenous fraction and a still smaller amount by carbonates and chert. REE distributions in the modern marine environment suggest that their enrichment in apatite of this deposit indicates that bottom water of the Phosphoria Basin was denitrifying. Lower concentrations in apatite from two ore zones than in apatite from waste zones suggest, however, that the bottom water was more reducing, possibly even sulfate reducing, during deposition of the ore zones, but only for very brief periods of time. In contrast to absolute concentrations, REE patterns (concentrations in individual samples, normalized to shale values on an element-by-element basis, versus atomic number) show that primary productivity, actually upwelling rate of nutrient-enriched water into the photic zone, was higher during these two episodes. Thus, the more reducing conditions are attributed to increases in the flux of organic matter into the bottom water, rather than to increases in bottom-water residence time. On average, primary productivity likely was only moderate; it seldom rose to the high level it attains in modern environments such as the Peru Shelf, even during times of deposition of the ore zones.