

Strontium isotopes and metal(loid)s variations in global phosphate ores

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Phosphorus is one of the primary nutrients essential for plant growth and thus its availability is critical for sustainable agricultural development and food security. Increased utilization of P-phosphate fertilizer over the last several decades has caused eutrophication of numerous water resources. Elevated levels of metal(loid)s in phosphate rocks and P-fertilizers pose less recognized but significant potential risks to soil and water quality. While pollution of soils and water from P-fertilizer applications has been documented in several case studies, no systematic evaluation of the occurrence of metal(loid)s in global phosphate ores and the ability to detect their impact on the environment have been conducted. Here we report the data on ⁸⁷Sr/⁸⁶Sr ratios and metal(loid)s concentrations in global marine sedimentary phosphate ores (n=61) collected from Early (India; 1900 Ma) and Late (China; 770 Ma) Proterozoic, Cambrian (China), Late Cretaceous, Paleocene, Eocene (Tethys Belt including Morocco, Senegal, Togo, Algeria, Tunisia, Israel, Syria, and Jordan), and Mid-Miocene (Eastern U.S.). While the Sr isotope data of the marine phosphate rocks from the Tethys Belt and the U.S. generally mimic the secular Sr isotope variations of contemporary seawater, older marine phosphate ores from China and India show large isotopic shifts toward higher radiogenic ratios. Additionally, the younger (<100 Ma) phosphate ores exhibit higher concentrations of U, Cd, and Cr, while the older phosphate ores from China and India show significantly lower levels. The combined variations in Sr isotope ratios and metal(loid) concentrations suggest the re-equilibrium of phosphate minerals with external fluids and extensive diagenetic modification. Systematic analysis of several pairs of phosphate ore and P-fertilizer indicates minor changes in Sr isotope ratios, and yet selective enrichment of toxic metal(loid)s during P-fertilizer production. Given that 47 million metric tons of P-fertilizers are globally produced every year, we postulate large fluxes of metal(loid)s are entering the environment through P-fertilizers utilization without adequate monitoring and

evaluation of their impact. Overall, the data suggest that Sr isotope ratios can not only be used for reconstructing the geological conditions of phosphate deposition, but also for detecting the mobilization of phosphate-derived metal(loid)s in the environment.