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Refining the stratigraphy of the Moroccan phosphate-bearing sequences: Insights from the U-Pb dating and $\partial^{13}C$ chemostratigraphy

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Phosphorus is an essential macronutrient fertilizer for crop development. It is also a non-renewable natural resource. Morocco hosts more than 70% of the world's phosphate reserves that need to be wisely explored and exploited for sustainable development.

The Moroccan phosphate series hosts abundant species of vertebrates, ranging over a period of nearly 25 Myr from the Maastrichtian to Lutecian. However, the biostratigraphic background of some Paleocene sediments is absent or relatively unreliable. Therefore, we have explored several proxies to better constrain the stratigraphy of phosphate-rich sequences in both the western High Atlas (WHA) and Gantour Plateau of Morocco.

We first focused on the U-Pb dating of carbonate fluorapatite (CFA – $Ca_{10-x-y}Na_xMg_y(PO_4)_{6-z}(CO_3)_z(F)_{0.4z}F_2$) grains, considering the high amount of uranium in such phosphate minerals. Unfortunately, linking U-Pb phosphate ages to the age of deposition is not easy. The WHA phosphate series in Morocco yielded a mean U-Pb age of 34.5 ± 1.2 Ma, which is ~25 million years younger than the expected depositional ages. To explain such discrepancies, the highly reactive nm- to µm-sized CFA crystallites would have facilitated adsorption and desorption processes and thus long-term open system behavior over millions of years after phosphogenesis. Moreover, we have measured the carbon isotope ratios of CFA and carbonates in the WHA sediments. The results yielded $\partial^{13}C$ values as low as -12‰, suggesting a CO_2 uptake from ^{13}C-depleted porewaters rather than seawater. Finally, we explored the organic carbon isotopes ($\partial^{13}C_{org}$) of several Gantour phosphorites. A covariation was found between the global $\partial^{13}C$ trend of carbonates from deep-sea benthic foraminifera and the $\partial^{13}C_{org}$ trend of the Moroccan phosphorites, which allowed us to perform stratigraphic correlations and provide new age constraints on the world's largest phosphate accumulation. The $\partial^{13}C_{org}$ chemostratigraphy is a powerful proxy to enhance stratigraphic correlations between the various phosphate deposits of Morocco. This result will allow a better resource management in order to carry out a sustainable exploitation in front of the phosphorus demand that will increase drastically in the next decades.