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Phosphogenesis at a Cretaceous methane seep from New Zealand

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Phosphate-rich deposits have been a topic of intense research for decades. The process of phosphogenesis is mainly observed in marine sediments of coastal upwelling zones, where organic matter delivers sufficient phosphorus (P) to enable the formation of phosphorites. As P may be cycled within marine sediments on short timescales, only specific geochemical conditions allow for the precipitation and preservation of phosphate minerals. The processes that enable phosphogenesis are still a matter of debate, and not all mechanisms involved are fully understood. We expand the scope of known phosphorous-rich deposits further, with evidence of phosphogenesis at methane seeps. Cretaceous methane-seep limestones from Waipiro Bay, New Zealand, exhibit (1) a matrix composed of cryptocrystalline fluorapatite in between micritic spheroids and coated calcite grains, and (2) phosphatic spheroids within a micritic matrix. Due to the abundant spherical morphologies of phosphate and carbonate grains, and the exceptionally well preserved phosphate matrix, we suggest that their formation was associated with microbial activity. Methane seeps provide ideal conditions for chemosynthetic communities to thrive, and for the growth of bacterial mats at the sediment water interface. To understand these unique deposits, we derive a formation scenario for apatite and spheroidal carbonate, using detailed petrographical observations, X-ray diffraction, scanning electron microscopy, and electron microprobe analyses. Furthermore, it is shown that phase-specific stable carbon and oxygen isotopes confirm that both phosphate and carbonate formation occurred at a methane seep.