Supplementary information for

A nutrient control on fluctuating oceanic redox conditions during the early Cambrian radiation of animals

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Critical assessment of P extractions

The strong correlation (r^2 = 0.98) between total P (P_{tot}) and the sum of each P extraction (P_{sum}) following the SEDEX extraction steps demonstrates that individual P extractions successfully recovered bulk P, with an average recovery of 90% (Fig. S1A). When applying P phase partitioning to ancient sedimentary rocks, it is important to consider the potential recrystallization of authigenic carbonate fluorapatite (CFA) into more crystalline P apatite during burial diagenesis and metamorphism (Thompson et al., 2019), which leads to an overestimation of the P_{det} pool to the detriment of P_{auth}. This has previously been observed

for Cambrian phosphorite deposits where P_{det} represented on average 82% of the total phosphorus content, due to additional formation of P_{det} via recrystallization of authigenic P (Creveling et al., 2014). However, many other studies of ancient rocks, including from the Cambrian and other older intervals of Earth history, have demonstrated the highly beneficial insight that can be attained from P phase partitioning extractions, even with a degree of transformation of P_{aut} to P_{det} (e.g., Guilbaud et al., 2020; Schobben et al., 2020; Alcott et al., 2022; Qiu et al., 2022; Liu et al., 2024).

For the Yurtus Formation, some samples have highly elevated detrital P contents (12-55169 ppm, av. 2379 ppm) relative to modern continental margin sediments (186 ± 21 ppm; Ruttenburg and Berner, 1993) and modern oligotrophic settings (62 – 310 ppm; Slomp et al., 2013), suggesting that for some samples, a portion of the extracted P_{det} likely represents burial recrystallisation of authigenic P (Thompson et al., 2019). However, for most samples, P_{det} does not constitute a significant proportion (~30%, 26%, and 13% on average for the SARK, SGTB and KGKT samples, respectively; Table S1), suggesting that most samples are relatively unaffected by post-early diagenetic transformations. In more detail, we observe a weak positive relationship between P_{auth} and P_{det} in the SARK section (r^2 = 0.4), while no such relationship is apparent in the KGKT and SGTB sections (Fig. S1B). This relationship in the SARK section is, however, largely driven by three samples with very high P_{det} contents (Fig. S1B), suggesting that very few of the SARK samples have been significantly affected by transformation of P_{auth} to P_{det}, with very little transformation occurring for the KGKT and SGTB sections. Nevertheless, minor transformation of P_{auth} to P_{det} means that P_{det} analyses represent maximum values, while P_{aut} (and hence P_{reac}) analyses

represent minimum values.

Given the conclusion that P_{reac} values represent minimum concentrations, we consider potential impacts on C_{org}/P_{reac} ratios, since these ratios will thus represent maximum values. In this regard, we note that samples with extremely high P_{det} and P_{det}/Al ratios all have low C_{org}/P_{reac} ratios (<106; Table S1), and since these values would be even lower without loss of P_{aut}, this confirms retention of reactive P phases in the sediment. Therefore, the potential transformation of P_{aut} to P_{det} does not affect our interpretations, and instead, the P phase partitioning analyses provide highly novel insight into the controls exerted by different redox conditions across the Yurtus Basin.

Supplementary References

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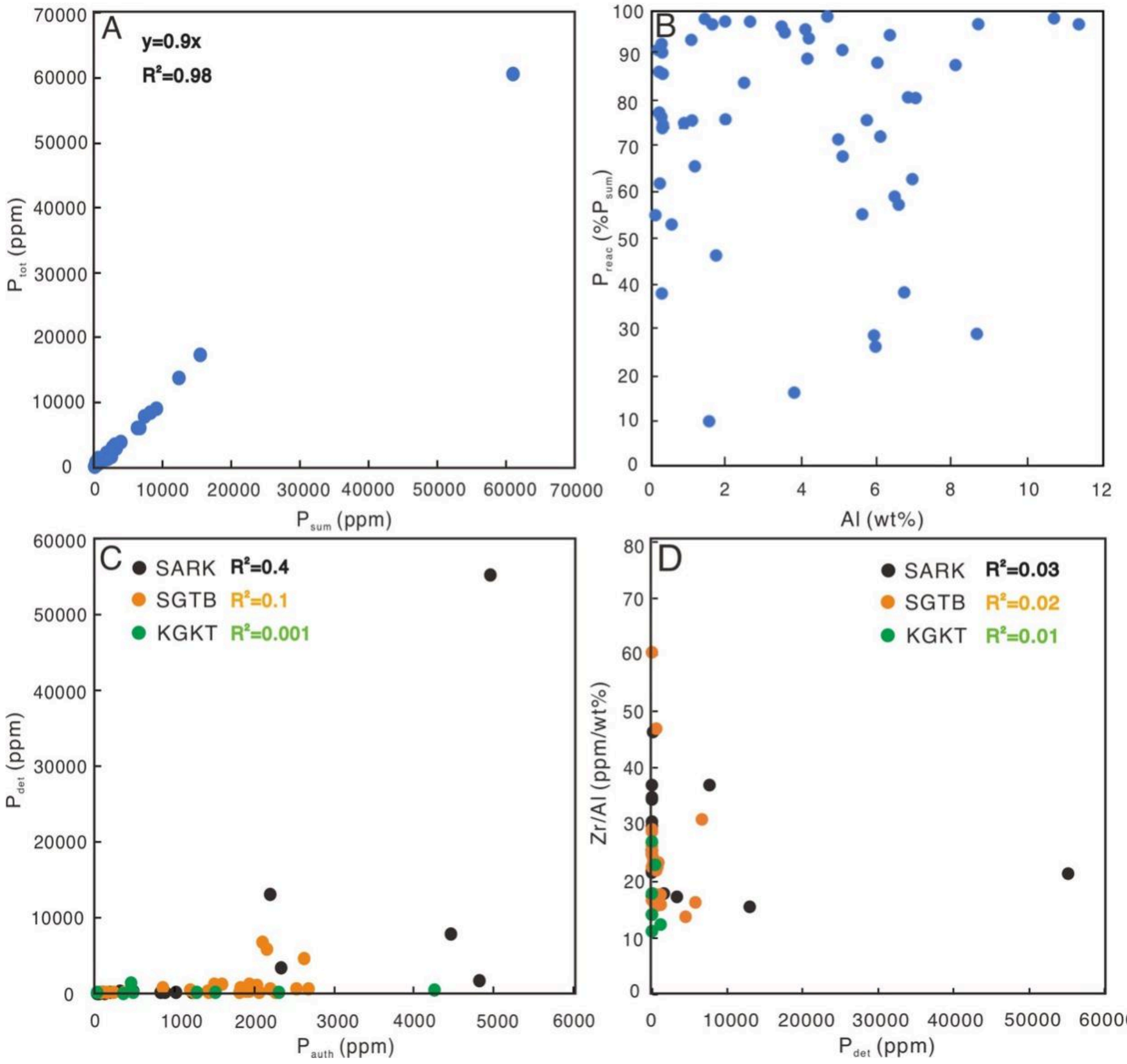

Figure S1. (A) Relationship between P_{tot} and the sum of each P extraction (P_{sum}); (B) Relationship between P_{auth} and P_{det} concentrations. SARK represents the Shiairike section, SGTB represents the Sugaitebulake section, and KGKT represents the Kungaikuotan section.

Table S1. Geochemical data, including P phase partitioning, major and trace elements.