Seasonal variations in a "greenhouse" Earth: Cretaceous coastal sea-surface temperatures inferred from $^{18}O/^{16}O$, Mg/Ca and $^{44}Ca/^{40}Ca$ ratios

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The last major episode of global greenhouse conditions began in the middle Cretaceous time and extended into the early Tertiary (~110-50 Ma). Well-constrained seasonality data for such periods, essential for climate modelling and prediction, are scarce. Temperature records of the Cretaceous sea-surface waters are mainly based on oxygen-isotope ratios from biogenic carbonate materials. The oxygen isotope proxy, however, is also sensitive to changes in freshwater input, carbonate system effects and diagenetic alteration. Thus, additional information from independent systems is needed. Here we report a combined application of $^{18}O/^{16}O$, calcium ($^{44}Ca/^{40}Ca$) and magnesium/calcium (Mg/Ca) ratios to low-Mg calcite of Late Cretaceous rudist shells. All three palaeotemperature proxies monitor seasonal variations in Cretaceous sea-surface temperatures (SST). The observed anti-correlation of $\delta^{18}O$ and $\delta^{44}Ca$ is expected for temperature dependent fractionation processes. The high degree of correlation (R=0.82) is at odds with the assumption of a significant diagenetic overprint. Yet, $\delta^{18}O$ and Mg/Ca proxies suggest high temperature seasonality (average values = 7°C and 8.5°C respectively), with $\delta^{18}O$ suggesting high and Mg/Ca rather low absolute temperatures. The $^{44}Ca/^{40}Ca$ data exhibit clear dependence on seasonal variations, demonstrating the potential of this new SST proxy. A first order calculation produces a reasonable temperature range (4.5°) for the $^{44}Ca/^{40}Ca$ proxy, pending further calibration.

With three different temperature proxies consistently indicating significant seasonal temperature changes, our data provide a detailed geochemical support for the existence of seasonal fluctuations of SST during the Late Cretaceous. Results presented here indicate that $\delta^{44}Ca$ bears the potential to become an essential tool for palaeclimatic reconstructions. The multi-proxy approach provides improved palaeotemperature estimates and, in future, may shed light on the widely debated controversy surrounding Late Cretaceous and Early Palaeogene tropical sea-surface temperatures.

Endolithic genetic record of ancient microbes in Cretaceous black shale

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A record of the history of the planet Earth is hidden in the subsurface biosphere, like the annual rings of an old tree. From limited evidences retrieved from underground, one can infer the geographical, geological and biological events that occurred throughout Earth's history. We report here the successful recovery of genetic record of ancient microbial community in mid-Cretaceous black shale. We drilled the black shale core sample from the continental margin at Serre des Castets, the southern part of France. The core contained one phosphate-accumulated strata, defined as a part of the mid-Cretaceous OAE (Oceanic Anoxic Events). Nanofossil analysis suggested that the OAE stratum was formed at 108 million years ago. Endolithic DNA was extracted from the several axis parts of the core, then bacterial ribosomal RNA genes (rDNA) was amplified by PCR. The molecular approaches such as the terminal-restriction fragment length polymorphism (T-RFLP) fingerprinting analysis, phylotype similarity analysis of rDNA clone libraries and the phylogenetic analysis of representative rDNA sequences revealed that recovered rDNA sequences were phylogenetically similar to microbial components in deep-sea sediments. T-RFLP and rDNA phylotypes analysis indicated that the rDNA structures were obviously associated with lithology. At the phosphate rich OAE stratum, the delta-subclass (sulfate reducing bacteria) of Proteobacteria class was predominantly detected, while at other sections gamma-Proteobacteria such as genera *Shewanella*, *Moritera*, and *Psychromonas* were predominant microbial components. In addition, porosity data and X-ray scanning analysis strongly supported that the extant microorganisms could not infiltrate physically into the examined black shale materials. These genetic rDNA signatures probably associated with the past microbial habitats occurring at 108 million years ago, serves as potential geomicrobiological evidence reflecting novel records of extinct life in the subseafloor paleoenvironment.