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Unusual very positive enrichment of ^{13}C in carbonate sediments deposited in modern hypersaline environment, Lagoa Salgada, Brazil: Indicator of salinity controlled metabolic processes

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In the geologic record, prolonged intervals of intense $\delta^{13}C$ enrichment (>10‰) in carbonate deposits occurred, in particular during the mid-Palaeoproterozoic (2.3-1.9 Ga) and the mid-Neoproterozoic (0.8-0.6 Ga) [1]. These anomalously high $\delta^{13}C$ values have been interpreted as a global effect due to enhanced burial of organic matter with depleted $\delta^{13}C$ values [2]. However, an alternate interpretation has been proposed whereby the metabolic activity of specific microbial communities, such as methanogens, may have been the source of the strong carbon isotope fractionation [3]. Although such restricted shallow-water environments where methanogens dominate are not widespread today, a unique hypersaline coastal lagoon system, Lagoa Salgada, Brazil provides the ideal conditions to study the modern microbial community and its impact on observed extreme $\delta^{13}C$ enrichment (up to 20‰) in both in situ stromatolites and carbonate sediments. Here we present our findings and correlations of geochemical data with changing environmental conditions during the last 2600 cal yr BP.

Based on ^{234}U isotopic composition of carbonate sediments cored from the centre of Lagoa Salgada, the source of water gradually changed, beginning around 2500 cal yr BP, from partially marine to increasing meteoric water with the lagoon becoming more isolated from the ocean synchronous with the onset of the transition to extremely positive $\delta^{13}C$ values. Moreover, the regional climate began changing from more humid to less humid at the same time. The low S-counts recorded in the sediments is consistent with minor sulphate concentrations in the water. However, this lagoonal system contains highly evaporated water with the highest salinities occurring during the dry season. The positive $\delta^{13}C$ anomaly shows high and stable values (>14‰) from about 2100 to 1400 cal yr BP. Similar high $\delta^{13}C$ values were recorded for the same time period in stromatolite structures growing around the margin of Lagoa Salgada. We propose that the high salinities would inhibit photosynthesis, respiration and nitrogen fixation by osmotic stress and, thus, result in increased methanogenesis. Furthermore, hypersalinity provides higher concentrations of non-competitive substrates, such as methylamines. These conditions favour methanogenesis even if there is sufficient sulphate present for sulphate reduction to occur. In summary, we conclude that the combination of methanogenic metabolisms and extreme evaporative conditions are the key factors promoting the production of the very high $\delta^{13}C$ values observed throughout the lagoonal system as recorded in both the marginal stromatolites and carbonate sediments deposited in the more distal regions of the lagoon. Such unusual environments may have been more widely distributed during the Proterozoic and could account for the intense $\delta^{13}C$ enrichment (>10‰) observed in the sedimentary record.

References:

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