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High-resolution analysis of Quaternary calcretes: a coupled stable isotope and micromorphological approach

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Pedogenic calcretes are abundant in arid and semi-arid regions, and they are widely used as proxy records of palaeoclimatic change. Calcrete oxygen ($\delta^{18}\text{O}$) and carbon ($\delta^{13}\text{C}$) isotopic signatures are indicative of temperature, aridity, or vegetation at the time of calcrete formation. Their microfabrics also reflect carbonate formation mechanisms in response to the prevailing environmental conditions. Many studies have explored calcrete micromorphology or stable isotope composition, but these techniques have not yet been applied simultaneously. This co-analysis is important as it allows us to establish whether calcrete morphology directly reflects environmental change. This study tests the potential of combining these analyses to examine the relationships between calcrete microfabrics, their isotopic signals, and Quaternary climate change.

Calcretes from four river terraces of the Rio Alias in southeast Spain have been analysed in detail. On the basis of morphostratigraphic correlation (Maher et al., 2007) and Uranium-series ages (Candy et al., 2005), these span the period from 304 ± 26 ka (MIS 9) to the Holocene. The oldest profiles have therefore been exposed to multiple glacial-interglacial cycles. A total of 37 micromorphological profiles have been used to extract stable oxygen and carbon isotopic indicators from 77 microfacies.

The morphological and isotopic complexity of the calcrete profiles increases with progressive age. The oldest samples display multiple calcretisation phases, and their microfabrics have a larger isotopic range than the younger samples. Alpha (non-biogenic) fabrics have higher $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values than beta (biogenic) fabrics. Strong positive covariance between $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ within all profiles suggests that both isotopes are responding to the same environmental parameter. We suggest that this is relative aridity. The study demonstrates that the detailed co-analysis of calcrete micromorphology and stable isotope signatures allows calcrete formation patterns to be placed into a wider palaeoclimatic context. Importantly, this technique provides a level of detail that is not possible through bulk isotope sampling alone. It demonstrates the potential of this technique to more reliably constrain the palaeoenvironmental significance of secondary carbonates in dryland settings where other proxy records may be poorly preserved.