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The Record of El Niño Events in Terrestrial Carbonates: Preliminary Results of a High-Resolution Isotope and Trace Element Study

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Generations of Australian school-children have learnt Dorothea McKellar's phrase describing their country as 'a land of droughts and flooding rains'. Today's scientists describe it as a land influenced by the El Niño-Southern Oscillation (ENSO) climate phenomenon. While this oscillation has its largest signature in and over the tropical Pacific and Indian Oceans, it affects oceanic and atmospheric conditions globally.

The dramatic effects of the most recent El Niño events have highlighted several shortcomings in our understanding of ENSO. These include the age of onset of modern ENSO variability, long-term (>10^3 years) changes in the frequency of past extreme El Niños and their relationship with varying global climate conditions, and the frequency and magnitude of ENSO in Earth's greenhouse future. Considering the profound human and economic implications resulting from this short-term fluctuation in climate, it is apparent that a better understanding of the long-term changes in ENSO frequency and magnitude is an important scientific as well as sociological goal.

While most older studies seem to show that throughout the Quaternary ENSO operated much the same as today, two recently published records point to an El Niño which waxes and wanes over the millennia. The latter suggest, for example, that ENSO was much weaker or even inactive from 12,000 to 5,000 years ago. If El Niño sometimes takes a break, no one is sure why - so no one is sure of El Niño's future. From 8,000 to 5,000 years ago, during the so-called Altithermal regime, the world was warmer than today. If El Niño could be suppressed or eliminated by warmer climate alone, then it might again fade with expected greenhouse warming over the next centuries. But if something else was the trigger, such as the changing strength of the seasonal cycle, the proposed analogy between the Altithermal regime and greenhouse conditions might not hold. High-resolution records of prehistoric El Niños are therefore needed to address these questions.

In an attempt to contribute to this issue, we are currently carrying out combined high-resolution (laser-ablation and micro-sampling) isotope (O, C, Sr, U) and trace element (e.g. Mg, Sr, Ba) studies on fluvial barrage tufas from north-western Queensland (Australia). The study area and sample material are especially appropriate to address the questions outlined above for several reasons: (1) the area is characterised by a monsoon type climate; (2) a clear correlation between ENSO and the northern Australian monsoon variability exists; (3) the hydrology of the catchment is known and is assumed to have been broadly constant during the last >300,000 years; (4) tufa deposition has occurred during several episodes over the last >300,000 years; (5) tufa carbonate is precipitated at or close to chemical and isotopic equilibrium with the surrounding waters; (6) different interrelated and unrelated proxy records (e.g. various isotopes and trace elements) can be obtained on a single sample; (7) tufas can be precisely dated by several methods (^{14}C, U-series, U-Pb) and therefore be correlated with other climate archives independent of their absolute age; (8) the tufas have simple growth structures with clearly visible seasonal layering and an annual extension rate of up to 1.5 cm, making them particularly well suited for high-resolution work.

The relatively high growth rate of the tufas will allow resolution of seasonal/sub-seasonal changes in environmental parameters and the magnitude and duration of single El Niño events at a particular time. Using this approach for samples of different age makes it possible to examine the influence of variations in global climate and seasonality on ENSO frequency and magnitude.

A modern tufa sample representing the period from 1986 to 1999 is used to calibrate the proxy records by correlating the chemical/isotopic data with meteorological and hydrological observations. First investigations on this modern sample revealed a distinct seasonal pattern of the δ^{18}O signal, with high values during the dry season and low values during the wet season. While the dry season values are fairly uniform over the years, the wet season values exhibit a pronounced inter-annual variation which anticorrelates with the December-March averages of the Southern Oscillation Index.

Considering these encouraging findings, the ongoing study promises to provide new insights into the history of ENSO.