Investigating climates, environments and biology using stable isotopes

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The Earth is an extremely dynamic system, with intimate links and feedbacks between the hydrosphere, atmosphere, biosphere, lithosphere and convecting mantle. The importance of the atmosphere as a geological agent was recognized as early back as Chamberlain (1897), but it has typically been neglected in research on past climates. Continental sediments and fossils are also somewhat neglected in the deep geologic record when it comes to linking that system with the oceanic carbon cycle and climate change. One proxy that may inherently link all these systems, which can be easily investigated, is through the analysis of stable-isotope ratios (traditional and non-traditional isotopes). This Special Issue does not include non-traditional stable isotopes, but the editors refer the reader to Johnson et al. (2004). Traditional stable isotopes are widely used in the biological, archaeological, ecological and geological communities, however, these research communities are only just becoming integrated in their scientific purpose.

In this Special Issue we have tried to put together studies that are normally only received by audiences interested in that topic. This has been purposefully done in order to highlight the need for integration in studies of past climates and environments. Integrative science is the future of palaeoclimatic reconstructions, and through such integration a better understanding of the dynamics of the Earth System will emerge.

This Special Issue is divided into three main sections, Atmospheric, Continental and Oceanic. Most of the papers deal with the atmosphere and continental realm as these are research areas that we feel need a great deal more scientific endeavour, especially beyond the Holocene Epoch.

Cosford et al. begin by discussing oxygen-isotope records from southeastern China and its record of the Asian Monsoon. This record clearly shows that the patterns recorded reflect major changes in oceanic circulation and that millennial scale changes in the North Atlantic Oscillation may have been inherently linked with Pacific circulation patterns. This ultimately affects the climate of the Asian continent and the distribution of the monsoon through time. However care must be taken as spatially variable signals can affect the climatic interpretation, and thus a spatial pattern of oxygen isotopes in stalagmites from a region is required in future research of this kind.

Next we jump back in time to the Late Cretaceous and an investigation on carbon and oxygen isotopes in dinosaur tooth enamel and freshwater fish scales by **Fricke et al.**. Avery careful investigation of stable isotopes among taxa show that the data are recording and preserving primary information that can be used to investigate the continental climate and environment. Unique to this study is the incorporation of analyzing terrestrial organic matter, which when compared to the dietary offset is considerably greater than modern mammals. Geographic comparisons between the Judith River, and Two Medicine and Dinosaur Park indicate a spatial distribution of rainfall with the latter regions receiving more precipitation. Such information now needs confirmation from other proxies, but the ability to use dinosaurian remains to reconstruct continental climates and environments is an exciting new avenue for deep time continental research.

Ufnar et al. apply such a model to understanding the mid-Cretaceous meteoric cycle using stables isotopes preserved in sphaerosiderites from a latitudinal transect in North America. The Cenomanian latitudinal trend they observe is much steeper than a modern transect and it is also steeper than the Albian trend. This is interpreted as resulting from a more rigorous hydrologic cycle, which also would have transported significant heat towards the poles and thus a possible explanation for high-latitude floral and faunal communities. A mass-balance model of the stable-isotope data is also produced, which supports the intensified hydrological cycle. The Cenomanian hydrological cycle would have also had a major influence on weathering, oceanic nutrient inputs and oceanic currents, especially upwelling regions.

The next contribution starting the continental theme is from **Grimes et al.** who conduct a review on direct laser fluorination analysis of phosphate for oxygen isotope analysis. Such a technique can be successfully used on small mammal teeth, but also could be used on other continental phosphatic materials such as fish debris and otoliths. This paper discusses the advantages and disadvantages of the laser technique and how it may be used with small mammal teeth to reconstruct continental climates (mean annual temperatures) in the geologic record.

Fiorentino et al. use carbon isotope data generated from radiocarbon dated plant remains to investigate the climate of Syria during the III millennium B.C. and although this is not a conventional method the results are exciting. Data generated in this matter does require screening, for example fruits may contain unusual levels of humic acids, which produce a greater analytical error. By dating the individual elements a precise chronological reconstruction can be gathered from archaeological plant remains. This is especially important since some material may be reworked and/or not deposited at the time the plant was harvested. The carbon-isotope data in this study support other evidence for an aridity crisis, thus showing the potential of this technique for archaeological and climate investigations.

The above two contributions deal with analyzing samples in new, exciting ways to investigate the continental climate, but now we look at traditional techniques to reconstruct floral communities using stable isotopes and how the fauna respond and adapt to these changes. **DeSantis and Wallace** present carbon-isotope data from Late Miocene to Early Pliocene mammals from Tennessee in order to reconstruct the palaeofloral community and climate. The data show a clear lack of any C_4 plants into the dietary and that C_3 plants dominate the flora. Of particular interest is that the Tennessee region was sufficiently covered by forests during this time interval. A lack of variability within teeth, in both carbon and oxygen isotopes, suggests that seasonal variation was minimal and that this community may have been part of a refugium.

Following on from this theme **Drucker et al.** provide a detailed review of carbon isotopes from large herbivores in Europe and show that the magnitude of the forested region will affect the carbon-isotope ratio of collagen. Such a finding can be used to investigate the response of various species within different regions to climatic changes that ultimately affect the distribution and density of forests. These authors also argue that the carbon-isotope shift in Late Glacial to Early Holocene large herbivores is not associated with changes in the isotopic composition of atmospheric CO_2 but instead with forest cover.

MacFadden continues the discussion of Pliocene horse diets from Florida, Texas and Mexico. In combination with tooth morphology, he shows that tooth morphology does not show any geographical difference and therefore the diet evolved independently of this aspect. The dominant diet of these horses consisted of C_4 plants, although some individual within each population show a significant contribution of C_3 plants. Local variation in climate and environment may have led to these differences, and that migration patterns possibly also had an effect on the carbon-isotope ratios.

In concert with the previous manuscript, **Palmqvist et al.** also using palaeophysiological characteristics to discern diet and trophic structure within an Early Pleistocene vertebrate assemblage from Spain. Morphometric ratios allowed groups of animals to be discriminated into dietary groups, such as grazers, browsers and mixed-feeders. However, variations in carbon-isotope ratios suggest that other physiological differences are also present which are not reflected in preserved fossil material (e.g., hindgut *versus* foregut fermenters). Oxygen isotopes and nitrogen isotopes also help to constrain the structure of the community and suggest a complex interplay between predators and grazers within forested regions and open habitats.

On closing this Special Issue we have included two very disparate oceanic studies that both look at Pleistocene environments. A lack of oceanic manuscripts was purposely chosen as we believe there is ample support for such a community, but by including these we hope to draw that community to this Special Issue and thus the other datasets out there discussing atmospheric and continental reconstructions. **Meyers and Arnaboldi** reports on the nitrogen- and carbon-isotope evolution of sapropels from the Tyrrhenian and Levantine Basins. These records show not only similarities between the western and eastern Mediterranean Sea but also differences. During the formation of the sapropel high oceanic productivity and nitrogen fixation was evident, which is consistent with a salinity-stratification model. However, carbon-isotope differences between these two regions suggest that subtle changes in the dissolved organic carbon pool from the input of fluvial derived carbon and recycling of organic matter is a factor that must be considered from other sedimentary cores within the region. It also suggests that wetter conditions during sapropel formation were stronger in the eastern Mediterranean.

A multi-component study on otoliths, shells, benthic foraminifera and shark teeth by **Pellegrini and Longinelli** show that isotopic data generated from a group of organisms that inhabit different environments can produce a clearer insight into animal movements and oceanic pathways. The sedimentary sequence dated as Late Pliocene to Early/Middle Pleistocene from Central Ecuador was investigated. Mollusc and otolith oxygen-isotope data suggest that the climate shifted from a cold-temperate environment in the lower part of the sequence to one reflective of warmer oceanic conditions in the upper part of the section: similar to modern conditions. Overall the data indicate that the influence of the Equatorial Counter-current and Humboldt Current had a major influence on the environment and community structure of the region in Central Ecuador.

As editors we thanks the many reviewers who assisted in the formation of this Special Issue. However, we are indebted to the authors who worked hard on producing their manuscripts and being patient through the publication process. All of this made this Special Issue a reality.

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