Paleoenvironmental Reconstruction

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Soils

Soils are intimately related to the environment because soil development is directly linked to local environmental conditions. The nature of past environments has long been a fundamental question in archaeology, and therefore many attempts have been made to use soils from archaeological contexts to provide paleoenvironmental reconstructions. Such attempts have met with mixed success, however, because the relationship between soil genesis and environmental conditions is very complex. Moreover, using a specific soil or soil characteristic to reconstruct paleoenvironmental specifics, such as past climate conditions, can be difficult.

As previously noted, it is important to distinguish between "environment" and "climate" for the purposes of paleoenvironmental reconstruction. Soils are better suited for environmental reconstructions, though the discussion below will explain that, under some circumstances, a degree of climatic or even vegetation specificity can be involved.

Climate influences pedogenesis most directly through precipitation and temperature, and indirectly through flora and fauna. The most direct impacts produced by biota probably come from (1) the addition of a wide range of chemical compounds, (2) bioturbation, and (3) rooting. Using soils to reconstruct past climatic and biotic conditions, however, has proven to be very difficult for a number of reasons. Plant and animal communities are closely linked to one another and to climate, and consequently, it is difficult to sort out the varied influences in the factorial approach (…). Further, soils are not sufficiently sensitive in responding to discrete climate changes that may be culturally significant. Such changes can be more readily detected using plant or animal remains, particularly in a high-resolution, microstratigraphic context. However, as is the case with many environmental proxies, the microclimate and local vegetation can influence local soil forming processes in a dominant way, thus obscuring the regional climatic and vegetation conditions that may be of interest. In addition, climate changes in the Holocene, the time period with which most North American archaeologists work, were often of insufficient magnitude to be detectable in the pedological record.

The properties of soils that seem to be the best indicators of the climatic conditions during which soil formation occurred include organic matter content, the depth of leaching (which determines the presence or absence of $CaCO_3$ and more soluble salts), depth to the top of the zone of accumulation of the carbonate or salts, and overall profile morphology (Table 1).

There is only a limited amount of information that helps to identify the pedological features most closely related to past plant and animal communities. Further, as noted above, the distribution of plants and animals is so intimately linked to climate that sorting out the effects of each is often difficult. The soil characteristics that seem to be most directly indicative of vegetation and that also persist in buried soils over long intervals are the E horizon and related podzolic characteristics, and some overall profile morphologies.

A significant environmental characteristic of soils is that they are largely the products of immediate, localized conditions. The physical, chemical, and biological characteristics of a soil profile were determined by the parent material at that site, by the flora and fauna living at that site, and by the meteorological conditions (such as precipitation and temperature) that operated on the site over time. This is in contrast to other proxy environmental indicators (e.g., sediment characteristics, pollen) that are affected by both regional and local conditions.

In using soils to reconstruct environmental conditions, therefore, the key is selecting those pedogenic characteristics that are indicative of relatively specific conditions such as drainage, topographic setting, rainfall, or plant communities. The best results in using soils as paleoenvironmental indicators seem to be obtained for local environmental reconstructions. Soils are particularly useful in assessing local drainage conditions and paleotopographic settings because pedogenesis is sensitive to both surface and subsurface water movement and because the topographic setting affects water movement.

The localized nature of pedogenesis also raises a cautionary issue. The reconstruction of regional environments using soils should not be based on one or a few soils from an archaeological site because local pedogenic conditions may not necessarily reflect regional environmental conditions. The reasons why an archaeological site is located where it is may be due to unusual characteristics, such as access to water or other resources – characteristics that may have a profound impact on local pedogenesis but may not be expressed in the regional soils of the same age and stratigraphic position. Springs, for example, are key locations of hominin and animal activity and as such have been the focus of archaeological research. However, spring localities are microenvironments and, therefore, are not necessarily representative of regional environmental conditions. On the contrary, the very conditions that make springs attractive to people (water along with availability of floral and faunal resources) may be because of the absence of such conditions elsewhere in the region (…).

Equifinality is also an issue in the paleoenvironmental interpretation of soils. In particular, long periods of soil formation apparently can produce some pedological characteristics similar to those produced under particular climatic conditions. As a corollary to equifinality, relatively few specific soil features or types of surface or buried soils are related to unique or easily circumscribed environments of formation. For example, argillic horizons occur in modern surface soils in a wide variety of environments throughout North America.

The polygenetic nature of soils can also confound their paleoenvironmental signal: the very characteristics that make soils useful as indicators of the passage of time compromise their utility as paleoenvironmental proxies. As soils form through time they may be subjected to a succession of environments. The longer the duration of pedogenesis, the more changes a soil will likely experience, i.e., the more polygenetic it will be. At best, therefore, soils represent some sort of "averaging" or mixing of whatever morphological and chemical characteristics may be linked to the environment. Broadly speaking, soils that formed over relatively short periods and did not experience many environmental changes are more useful for reconstructing the environmental conditions at the time of pedogenesis than are soils that formed over a longer interval and were subjected to a variety of environments (or at least much more effort is required to reconstruct the environmental history of polygenetic soils). The problem with pedological features that develop relatively quickly, however, is that they tend not to persist in buried soils (…).

Finally, a stratigraphic sequence with a buried soil, though suggestive of changes in landscape stability, is not necessarily indicative of environmental changes. Certainly this is the case with multiple weakly expressed A-C soils buried in floodplain deposits. The cycles of sedimentation and stability are simply part of the natural evolution of a floodplain, relating to variability in precipitation and runoff from year to year (…). Soils can also be buried due to human activities such as construction (…).

ISOTOPES IN ARCHAEOLOGY

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Isotopic proxies have been employed within archaeological research since decades; however, their use has surged in recent years. Together with the increase in the number of published case studies, there have also been significant technical developments that improved greatly on available analytical techniques. Throughout the years, the introduction of novel isotopic proxies refined and expanded the existing knowledge on past environments and human activities. Such developments allowed for and were motivated by a growth of archaeological research topics. These have included, among others, climatic and environmental reconstruction, studies of past human diet, nutrition, and mobility, building accurate chronologies, past animal and crop management practices, pottery use, etc. Thus, an attempt at offering a complete overview of the applications and methodologies involved in isotopic analyses applied to archaeological research would represent an undertaking well beyond the limited scope of this special issue. Instead, this issue is aimed at highlighting a selection of special themes that represent a mix of well-established and recent topics with-in isotopic studies applied to archaeological research.

There is an increasing recognition among the archaeo-isotope community of the need to build isotopic baselines which establish the environmental isotopic signals for the pastime periods and regions under study. An example of this is given by Knipper et al. that investigated the diets of humans from the late Iron Age burial site of Basel-Gasfabrik (Switzerland). Human diet reconstruction was done using a Bayesian mixing model and relied on stable isotope measurements on humans and a large amount of locally available archaeological faunal and botanical remains. The outcome of the study observed interindividual differences in dietary intakes (e.g. millet consumption) although there were no significant gender differences. The emphasis on the need to employ archaeological baseline material contemporaneous with the period under study is suggested by the results from the study by Roffet-Salque et al. This study concerned pottery use which is often investigated through carbon stable isotope analysis of fatty acids recovered from the clay matrix of archaeological ceramic vessels. However, Roffet-Salque et al. showed that special care must be taken when employing modern fat references for archaeological studies, namely when modern animals are not fed only on purely natural pastures. Essential to isotopic studies of diet and mobility is the understanding of how isotopic signals are transferred from the environment (e.g. water, foods) towards consumer tissues. This is often determined through animal and human feeding experiments. Also, studies that identify the importance of other effects (e.g. cooking) on isotopic signal transfer are relevant. Tuross et al. discuss the impact, for different parameters, that has to be considered when interpreting oxygen stable isotope ratios measured in human teeth and bones. Each human tissue has specific formation times and isotopic offsets towards oxygen pools. Furthermore, heating, through cooking, modifies the isotopic ratio of consumed water and foods.

(…)

The interpretation of dietary or mobility reconstructions based on a limited number of isotopic proxies may remain ambiguous. This ambiguity may be reduced by the inclusión of additional isotopic proxies, that is, by including less commonly employed isotopic systems (e.g. sulphur isotopes) and/or performing isotopic measurements on a larger variety of consumer tissues and/or molecular compounds (e.g. bone mineral, amino acids, fatty acids). In this respect, Jaouen and Pons discussed the potential of progressively employing non-traditional isotopic proxies (e.g. Ca, Cu, Fe, Mg, Sr, Zn), measured in mineral samples of bone and teeth, in diet reconstruction studies. Both the contributions from Pestle et al. and Díaz-del-Río et al. employed a multi-isotopic approach in the study of human diet or mobility. Díaz-del-Río et al. investigated the mobility of individuals from burial sites near Madrid (Spain) dating to the Late Neolithic, Chalcolithic, and Bronze Age using strontium and oxygen isotope ratios measured in teeth and bone. A minimum number of migrants could be identified. In addition, carbon isotope ratios suggest a dietary shift at c. 2500 cal BC towards the higher incorporation of C4 plant foods.

The study of the archaeology of the individual is linked to multi-proxy approaches. Previous case studies have re-constructed the isotopic life histories, often of high-status individuals, by taking isotopic measurements from multi-ple tissues corresponding to specific life periods of an individual. Jørkov and Gröcke performed a large diachronic study to investigate the diets of individuals buried at the Assistens cemetery in Copenhagen. Comparison of bone and hair stable isotope analysis allowed for interesting observations on nutritional status and dietary intakes across social groups and time. Kinaston and Buckley investigated intrapopulation variations in diet through carbon and nitrogen stable isotope analysis of bone and teeth of individuals from a >300-year-old burial ground Atta mako Island (Solomon Islands). The authors of the study found that dietary differences among adult males and females were not observed in children and that survival to adulthood was related to the consumption of higher trophic level foods.

The application of stable isotope research to archaeology is not limited to the study of human diet and mobility, and the study of crop or animal management practices is of great archaeological interest. Pickard et al. investigated animal foraging through carbon and stable isotope analysis of domesticates from the Late Chalcolithic site of Çamlıbel Tarlası (Turkey). Differences in isotopic values between cattle and other domesticates (pigs and caprines) were interpreted as a difference infeed or in feeding areas. Marciniak et al. compared carbon and nitrogen isotope ratios measured in bone collagen and oxygen and strontium isotope ratios measured in tooth enamel on LBK and TRB domesticates from Kopydłowo (Poland). Higher isotopic diversity observed for TRB cattle was interpreted as a greater variety of herding practices and landscape exploitation.

The overview given above of the contents of this special issue illustrates the importance and dynamics of isotopic studies in archaeological research. It is expected that this will continue to grow under novel methodological development sand the widening of research questions.