

From Trace Elements To Prehistoric Diets

By Judith Miles

Archaeologists are constantly adapting to their own uses the advancements made in other fields of research. Currently, we are witnessing the development of a technique to assay chemical content in various substances for purposes of interpreting the diet and the environment of prehistoric people. Generally, this is done by identifying components of the food chain and evaluating the amounts of trace minerals and carbon isotopes that are transmitted through the system. A chemical bone analysis technique is applicable now to many archaeological study areas, and it promises to become more versatile as refinements are made.

The Method

Through the use of highly sophisticated equipment, relative proportions of certain minerals (e.g. strontium, zinc, magnesium, calcium, sodium, copper) and carbon isotopes can be measured to yield information characterizing prehistoric diets. Bone and its components, teeth, and flesh are the principal materials assayed; normal trace element quantities differ relative

to the tissue type being assayed.

Analysis requires a 0.5 gram sample – sometimes less. The measurements cannot be interpreted directly as distinct diets. Instead, interpretation is made from patterns and relative ratios, distinguished in each level of a particular food chain. To do this, analysis must extend to soil, plants (both wild and cultivated), herbivores, and carnivores, as well as human remains. Most importantly, all these must be derived from a single spatial and temporal subsistence base.

Experiments using atomic absorption spectroscopy and electron microprobing reveal which minerals are the most stable (resistant to leaching) under various conditions and thus are most reliable to measure. Carbon isotope analysis, using any of several techniques, can define different carbon isotopes remnant of agricultural, hunting, gathering, and mixed subsistence strategies.

Application of Carbon Isotope Analysis

The application of carbon isotope analysis can be

illustrated in the following manner.

Maize and other plants whose genetic pools have adapted to strong sunlight follow a photosynthetic process called a C_4 pathway; it uses a higher frequency light wavelength than do trees, wheat, and other plant foods that have adapted to a more mesic (moderately moist) climate. The photosynthetic process used by these plants is called a C_3 pathway. C_3 plants are more discriminant against carbon 13 (^{13}C), a fact that results in a more negative ratio of carbon 13 isotopes to carbon 12 isotopes (^{13}C to ^{12}C) in bone collagen of animals that eat C_3 plants as compared to that produced by eating C_4 pathway plants.

(An isotope is one of two or more species of atoms of the same chemical element that have the same atomic number and occupy the same position in the periodic table and that are nearly identical in chemical behavior but differ in atomic mass or mass number and so behave differently in the mass spectrograph . . .

Continued on next page

and may be detected and separated by means of these differences. The "superscripting" (as in ^{13}C) refers to the atomic number of an element; the "subscripting" (in this case, C_3) indicates the number of carbons involved in photosynthesis.

Patterns of the ^{13}C to ^{12}C ratio, derived from skeletal remains, serve to distinguish the relative amounts of C_4 pathway foods (such as maize), C_3 pathway foods (such as wheat), and diets that have consisted of mixed grains. The earliest North American cultures for example did not have maize. The historic movement of maize as it gradually was domesticated and moved northward from Mexico into areas deficient on other C_4 plant foods, can be read in the changing ^{13}C to ^{12}C ratio that occurred in human bones and therefore in the subsistence base.

The earlier C_3 diets show a range difference in the carbon isotope ratio than later maize-based diets. Artificial and botanical evidence of intensified agricultural activities seems to confirm the implications of the carbon isotope analysis.

Applications of Trace Mineral Analysis

Mineral content also provides clues to the food system being exploited. The idea is based on the premise that individuals subsisting on similar diets will show the same relative proportions of different minerals. Trace element analysis of strontium (Sr), for instance, is largely determined by the amount of meat consumption. In accord with the latest scientific information, high levels of Sr suggest a preference for a more *vegetarian* diet, with lower intake of meat. Even when C_4 plants are introduced into the diet, dependency on meat might still be tracked. (Interpretation must take into account the diet of the animals that were consumed.)

An important recent development in trace element analysis is the strontium-to-calcium ratios (Sr:Ca). Generally, Sr:Ca decreases progressively as it moves up the food chain because Sr is discriminated *against* and Ca is discriminated *for*, progressively, in normal mammalian metabolic processes. If Sr:Ca references can be developed for each level in the food chain, then human remains of those who exploited that food chain can be compared for similarities in Sr:Ca ratios. In so doing, we are closer to knowing who ate what and where along the food chain. Prehistoric human burials, the matrix in which they are buried, and samples of the available food base are the raw materials for mineral trace analysis.

Theoretically, the information this kind of analysis yields would give archaeologists evidence to identify people who had "preferential access" to high-protein food sources or to describe a community where food resources were utilized equally but acquired through task specialization. The former suggests an elite element in the social structure; the latter implies an exchange mechanism in the economic system.

Problems to Reckon With

The samples analyzed for trace elements present problems which will come under increasing control as improvements are made in the technique. The amount of environmental contamination in bones must be discerned. Sr:Ca uptake by plants varies according to the available Sr and Ca in the soil, water, and air. Studies show that the highest Sr concentrations in the U.S. currently are in the Southwest. Therefore, care must be taken to obtain samples that were

associated and to ascertain the degree of alteration the samples have encountered since their deposition.

A further complication is that several variables can affect Sr:Ca in bone. Biological development stages affect a person's metabolic rate which, in turn, produces very high variations of Sr:Ca in growing individuals. The most variability seems to occur between 4 and 13 years of age. On the other hand, infants with similar metabolic rates may have entirely different ratios. The controlling factor is whether or not they are weaned, since mammary glands effectively discriminate against Sr in a mother's milk. Other factors include Ca levels in the diet, which affect the amount of Sr absorbed. Thus, the vital statistics and nutritional profile of the individuals comprising the population are important to properly interpret analytic results.

Most of the other technical problems facing researchers in this area have been fairly well defined and therefore can be effectively dealt with. Not the least of these is the use of a destructive analytic process that requires some tough calls – whether the information to be gained is worth the consumption of the material.

Recommendations for Future Research

Carbon isotope analysis found its way into the scientific community several decades ago and thus has fewer problems in application than does the new trace

element analysis of mineral in bone. Given the results of current research, the most important known factors that modify normal Sr:Ca levels are diet, age, health, and sex of an individual, plus any postdepositional effects on the skeleton. Care must be taken to assess the effect of these variables has on the data.

This type of chemical bone analysis can be applied to many different cultural settings and topics of research, such as detection of increased dependence on dairy foods, determination of the estimated age of weaning, explanation of the effects of diet on craniofacial morphology, identification of dietary adaptations to differing environments, pinpointing differential access to protein sources within a geographic area.

A major benefit of trace element analysis is that it can provide insight into the diets of healthy individuals rather than only the nutritionally stressed population as perceived through the more common approaches in paleopathology.

The kind of socio/environmental insights provided by such carefully researched information can add immeasurably to the interpretation of our ancient cultural resources.

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