

Tips About Some Chronometric Dating Techniques

By Judy Miles

High tech analysis has opened up some new and different approaches to archeological research – avenues that do not require a degree in biochemistry or chemical engineering. One does, however, need a general knowledge of the techniques and some idea about which questions to ask. What follows is information that can help illuminate the results obtained from four of these sometimes high-priced dating techniques.

Archeomagnetism

Archeomagnetic dating is the process of determining the magnetic alignment of particles in intensely burned clay, and comparing it with the history of the earth's magnetic field in order to derive an approximate date the sample was burned. This is possible because the magnetic alignment in a sample heated to several hundred degrees centigrade tends to parallel that of the earth's magnetic field as the sample cools. Before planning archeomagnetic dating analysis into your project, make sure your sample is from the past few thousand years – that is, within the known history of the earth's magnetic pole movement.

The accuracy of the obtained date will relate directly to the extent of documentation used to establish the magnetic pathway in the 500 to 1000 square mile area where the archeomagnetic sample was collected. The regional pathway calibration is necessary because the earth's magnetic field is not uniform. If the region's magnetic history has not been documented, it can be done by sampling naturally magnetic sources. A specialist can help develop a sampling scheme. Archeomagnetic dating in the Southwest is not useful for dating artifacts from the past 200 years because the natural pole has changed very little during this period. Otherwise, the Southwest has a well documented polar curve.

A stronger, more accurate reading can be obtained from clay samples containing magnetite rather than those with hematite minerals, however the latter is acceptable. Limestone derived soils are magnetically weak and not so good for analysis. Volcanic soils/rocks in clay are contaminants and can interfere with the magnetic readings of the clay. In areas where this contaminant prevails, such as at Bandelier National Monument, the best procedure is to collect pure samples of possible contaminants (e.g., tuff rock and soils in the case of Bandelier) and analyze it relative to a sample of the feature being dated. This step corrects for the degree of contamination.

Precision in archeomagnetic analysis is probably more important than accuracy in interpreting dates, because the real utility of the technique is relative dating (or within 50 to 100 years). Two samples from one feature are too few for precision. When a third sample is taken, the confidence in precision doubles over that of two samples. Statistically, five samples from one feature are needed. To these five, other samples can be added to determine the degree of contamination.

Rock Varnish Dating

The stain on rocks called desert varnish is actually oxidized manganese (black outer surface) and oxidized iron (red stain on underside). The oxidation is a biogeochemical function of fungi and bacteria feeding on organics in the dust adhering to the rock's surface. Dating the varnish is tricky since several conditions must be met to obtain a reasonably accurate date. The technique is most successful in dating varnish on lava flows. Dating desert varnish from sandstone formations like those at Canyon de Chelly National Monument is still in the experimental stage.

The process involves chemical analysis of a sample

of the varnish to determine the cation ratio of calcium and potassium to titanium. A potassium/argon date from a sample of the associated lava flow is then determined. The resultant is used to calibrate the calcium-potassium/titanium ratio, which is a linear function over time. The derived regression line representing the ratio can then be used to obtain a numerical age from other varnish samples. However, each potassium/argon calibration is specific to an individual lava flow and should not be used to date samples from other areas.

Problems recognized by experts in dating varnish have to do with factors that influence the rate of calcic formation. These factors are variations in solubility, rate of dissolution, carbonate influx rate, and ground water balance. If the technique is further refined, these conditions will need to be known.

Thermoluminescence Dating

Thermoluminescence (TL) dating measures cumulative radiation exposure as seen through heat induced luminescence from a compound's mineral crystal defect structure. About a .5 gram sample is needed for TL analysis. It is standard procedure also to collect a sample of the surrounding matrix.

TL is not an appropriate technique for determining accurate absolute dates or dating samples containing metal. It is valid for relative dating or differentiating items separated by a hundred years or more. Its upper limit for dating ceramic artifacts is 50,000 years; for rock samples, 500,000 years.

A few safeguards against accidentally changing the structure of the crystals analyzed include (1) not washing porous samples such as ceramics, sandstone, and limestone; and (2) limiting exposure to sunlight and artificial white light to an absolute minimum, since light can alter the crystal defect structure.

The technique has an inherent margin of error of about 10 percent, conventionally accepted as allowable. Unfortunately, commercial TL dating laboratories no longer operate in North America but several university campuses carry out TL analysis for their own programs.

Radiocarbon Dating

Other than tree-ring dating, radiocarbon dating is probably the next most frequently used chronometric technique in archeological analysis. If a well preserved sample is obtained, treated carefully, and analyzed properly, the resulting date can be quite accurate. Such accuracy has been useful in trying to answer broad questions such as – What are some of the evolutionary stages in humans? When did humans first populate the New World? When did animal domestication occur?

Radiocarbon dating is a technique that analyzes the carbon content of organic materials, usually bone and charcoal. Recent developments have made possible the radiocarbon dating of individual amino acids extracted from bone collagen. For accurate analysis, a certain amount of organic carbon must be present. Its presence is determined through microanalysis that determines the percent of nitrogen content; less than .2 percent nitrogen means the bone collagen has deteriorated past the limits of radiocarbon dating.

Preservation of original organic carbon in bone is

lessened by hot and humid climates, alkaline soil, high degree of plant activity, handling with oily hands, and packing in organic containers. However, if the radiocarbon lab processes the samples correctly, low level contamination of the original carbon is removed.

A radiocarbon calibration curve is used in determining the calendrical date of a sample. The calibration curve is independently based on tree-ring dated samples. The comparison reveals short term/high frequency natural perturbations in the radiocarbon calibration curve known as the de Vries effect. These variations are thought to be caused by magnetic modulations of radiocarbon production rates and the effects of nondipole components on the geomagnetic field.

The de Vries effect can greatly extend the range in which the calendrical year has a statistical probability of occurring. Considering this has led to the realization that precision is ultimately reduced for radiocarbon samples from the past 400 years. On the other hand, if the de Vries effect is ignored for samples from this time span, the dates will invariably be too young by several hundred years.

Another problem in the radiocarbon calibration curve is caused by the Suess effect. These are huge changes in the concentration of carbon in the world's carbon reservoirs. Much of the flux is due to excessive burning of fossil fuels. As they burn, their carbon dilutes the modern carbon in the various reservoirs containing carbon-based materials, thus giving an erroneous older age to a sample.

A deduced equilibrium value of carbon isotopes in the earth's different carbon reservoirs is used to calibrate the age of a radiocarbon sample. There is a type of secular variation that upsets the radiocarbon equilibrium. These effects include changes in the atmospheric rate of radiocarbon production, variations in the size of carbon reservoirs, and rates of radiocarbon transfers between reservoirs. A deduced equilibrium value of carbon isotopes is used to calibrate the age of a radiocarbon sample. If production or transfer rates of radiocarbon are drastically altered within the lifetime of the organic sample, the formerly deduced equilibrium value would not represent the conditions during which the sample "lived." In these cases, if a new equilibrium value is not calculated (again through tree-ring dates), the resultant date will be erroneous.

When radiocarbon dating samples from an ocean environment, one must be aware of the marine reservoir effect that adds dead carbon in samples. Dead carbon has no radiocarbon atoms present. Sources for dead carbon include coal, limestone, oil, and volcanic carbon dioxide. It works into the marine food chain by being brought to the ocean surface via upwelling, thereby making it available to plankton. Dead carbon makes its way through the food chain to animals such as mollusks, fish, and sea mammals. Samples from these organisms will date too old, due to the dilution of their modern carbon with dead carbon.

There are major time spans where all of these problems affect dating in a specific manner. Generally unmodified radiocarbon dates are too young compared to calendrical dates (derived from tree-ring dating) for the period of about A.D. 1400 to 300 B.C. Likewise, they are too old for the periods of 300 B.C. to 6000 B.C. and A.D. 1400 to the present. Below is a litany of suggestions that will assist one in knowing when to request radiocarbon dating and how to analyze its value.

1. Know which half-life was used to obtain a radi-

ocarbon date. If it was any other than the Libby half-life of A.D. 5568 plus or minus 30 years, an adjustment must be made.

2. Have the lab assess the carbon reservoir exchange rates and adjust for this in its computations.

3. Run a test to determine the nitrogen content of a sample since it is proportional to the carbon needed for dating. This is especially important for samples that appear to be in a poor state of preservation or very old.

4. Ask if the organic samples combusted during the analytical process were allowed to set after burning in order to let their radon gas dissipate. Radon will interfere with the radiocarbon counts.

5. Do not try to radiocarbon date bone that has probably received a high degree of contamination. Samples to avoid will be those from an extremely hot and humid climate, alkaline soil, a matrix of high plant activity, and those showing or known to have been in contact with oily residues.

6. Do not try to radiocarbon date tooth enamel. Its chemical makeup is not appropriate for such analysis.

7. Do not average resultant dates; they are logarithmic numbers. Averaging should be done with count rates obtained during the analysis.

8. Remember that the notation "B.P." on a radiocarbon date refers to "before A.D. 1950."

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