ARTIFACTS AND FEATURES
RADIOCARBON DATING

This article is one of an occasional series discussing matters archaeological, especially with reference to the Maturango Museum. In previous articles we have talked about why chronologies are important in archaeology, and about a few qualitative techniques for establishing dates or sequences. Last time we started discussing quantitative chronological techniques, with the example of dendrochronology or tree-ring dating. Today we will briefly cover radiocarbon dating, which was the second major breakthrough in archaeological dating, after dendrochronology. The radiocarbon technique was developed in 1948 by Dr. Willard Libby, as an outgrowth of the Manhattan Project, and is based on measuring the radioactive decay of ^{14}C (carbon-14) in the remains of once-living organisms.

Naturally-occurring carbon is a mixture of three isotopes: carbon-12 (97%), carbon-13 (3%), and carbon-14 ($<<$1%). Of the three, carbon-14 is radioactive with a half-life of 5733 years, and is created in the upper atmosphere by charged particle showers from the sun. Atmospheric circulation mixes it with the atmosphere, and it is absorbed into the oceans. Plants and animals take in natural carbon as part of respiration and feeding, and this carbon contains a small percentage of carbon-14; as long as the organism is alive, its carbon-14 content remains in equilibrium with the atmosphere. When the organism dies, its carbon intake ceases; because of radioactive decay, the concentration of carbon-14 in the organism then decreases in a predictable way. By measuring the radioactivity of a sample of carbon from a dead organism, the time since death can be calculated.

The classic method of measurement uses a Geiger counter to detect radioactive decay in the sample, and typically requires samples with a mass of several grams. A recently developed technique called Accelerator Mass Spectrometry (AMS) measures the carbon-14 content directly, and can work successfully with milligram-size samples; however, it is more expensive to perform. (AMS was used in the recent dating of the Shroud of Turin, in which minimizing damage to the artifact was of great importance).

As always, things are never as simple as they seem. Libby assumed the carbon-14 content of the atmosphere has been constant throughout history; detailed study, however, correlating tree rings with radiocarbon, has shown that the carbon-14 content has varied with solar activity, so "radiocarbon years" are not the same as calendar years. Raw dates are always reported as RCYBP, or "radiocarbon years before the present", and calibration curves have been developed to convert them to calendar years. Furthermore, the oceans contain huge quantities of carbon dioxide, which has been dissolved over millions of years, and since mixing in the deep ocean basins is slow, the deep waters contain a disproportionate amount of carbon dioxide from which the carbon-14 is depleted (the "reservoir effect"). In coastal regions where deep water wells up the carbon dioxide is released and mixes with the atmosphere, and causes dates to appear too old. Other complications can arise as well. Wood can lie in the desert a long time without decaying; if someone subsequently burns the wood as fuel, and you date the charcoal from his fire, you are measuring the age of the fuel, not of the fire (the "old wood" problem). Streams and oceans dissolve calcium carbonate from rocks, and this gets incorporated into the bones of fish and the shells of shellfish. This carbon contains no carbon-14, and it makes the age of the bone or shell appear too large (the "dead carbon" problem). Contamination by coal or petroleum causes the same result.

These problems are manageable, however, and radiocarbon dating is a widely-used technique today, with its own journal (*Radiocarbon*). A number of universities, commercial labs, and national labs provide radiocarbon dating for a fee (typically around $300 for conventional and twice that for AMS). It therefore continues to be a very valuable tool for archaeology.

Of course, corroborative techniques are needed, especially for work in areas where there is little material suitable for radiocarbon dating (such as the Mojave Desert and the Great Basin). In our next column we will continue with discussion of such a technique: obsidian hydration.