

## Dating Methods

Archaeologists use a variety of dating methods to determine the age and time of artifacts. Four methods are discussed below. In biblical archaeology pottery dating is a universal method. Carbon 14 dating is now more accurate as tree-ring dating has allowed for the recalibration of C-14.

### Pottery Dating

Pottery, providing the basis for the most popular method of Levantine archaeological dating, constitutes the most abundant find in Levantine excavation sites. Levantine houses generally contained storage jars for flour and olive oil, cooking pots, vessels for the serving of food, and water jars. In common use were earthenware cooking pots fueled by dried dung, charcoal, and the like. Earthenware oil lamps with their characteristic lip at the side provided a means for the burning of oil for light.

These cultural objects, usually referred to as pottery, had and continue to retain cultural significance. Their manufacture may have been by hand or by wheel. The composition of the clay prepared for the manufacture of ceramics, design, and the firing temperature, varied by period and culture. Some items bear the mark, known as enigmatic marks, of their maker. During the Bronze and Iron Ages, the Levantine pottery industry thrived.

Pottery specialists study the design, composition, and manufacturing of ceramic materials. Through petrography, the microscopic examination of transparent thin sections of pottery, researchers can gain insight into the physical composition of the clay used in the manufacture of the pottery sample. Neutron activation analysis makes possible the determination of the chemical composition of the clay of the pottery sample as a clue to its possible place of origin.

Remains of imported ceramics provide important data concerning cross-dating and ancient commerce and trade. Nearly indestructible pottery shards, fragments of ceramic vessels, constitute primary data from which analysis of chronological, ethnic, and regional change can proceed. Quantitative analysis enables researchers to refine their conclusions and to identify minute chronological and regional developments. Various aspects of pottery making define criteria for defining regional cultures in various periods. Imported ceramic evidence trade relations and permit cross dating. Researchers perform similar typological and laboratory analysis on other classes of finds and materials e.g., metal objects.

### Tree-Ring Dating

The Ancient Bristlecone Pine, *Pinus longaeva*, found in the White Mountains of California, made possible the sequencing of its rings showing that climatic fluctuations provide a recognizable pattern. The Ancient Bristlecone Pine lives to a great age and thrives in the relatively dry southwest. The latter factor permits analysis of annual growth in chronological terms since such growth results from naturally occurring patterned climatic conditions—patterning must remain dependent upon climatic conditions for cross-reference purposes.

Comparison of many bristlecone pine rings from small core samples obtained from over the entire region facilitates cross-referencing. Increasingly older trees provide additional data. Matching of wood samples from various archaeological sites provides a means for the absolute dating of the sample. The present chronology covers over several thousand years in a continuous scale. The Laboratory of Tree-Ring Research at the University of Arizona continues this work.

As a rule, researchers must find trees of the same species with distinguishable rings capable of comparison to rings of known date. A control set of tree ring samples provides an index for comparative purposes. Gaps in ring sequences occur for various reasons.

When trees grow in moist soil a wide ring results but water deficiency produces a narrow ring. Drought conditions or extreme dryness may prevent ring growth altogether. Samples may contain injury rings or false rings. Local climate variations can result in different ring growth for trees in the same general area.



***A bristlecone pine tree from the Ancient Bristlecone Pine Forest in the White Mountains of California. Some of the trees are more than 4,000 years old. A BibArch Photo by John Palmer.***



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Not all tree species lend themselves to tree ring analysis because some tree species do not react to climatic conditions in a way that is helpful to discerning their age. Other environmental factors, e.g., chemical pollutants, insect infestations, volcanic eruptions, and the like, also affect ring growth.

Present day tree-ring research has expanded on a global scale. Of significance for archaeology in the Near East is the possibility of a master chronology for cedar tree-rings based upon the work of Pierre Michel Bikai. He developed a limited scale using the cedars of Lebanon (Bikai 1991).]

A wealth of cedars of Lebanon artifacts in Egypt provides a vast archive for investigation. What remains for the future is the determination of a scale that provides an accurate chronological framework. Even when wood sample dates are clear, archaeologists have to use care

in drawing conclusions for wood samples must be closely associated with the artifacts under analysis and the wood could be in a secondary use.

## Carbon 14 Dating

The basis of this methodology is the production of the radioactive isotope carbon 14 (C-14) through the interaction of nitrogen with neutrons produced by cosmic radiation. The collision of a neutron with a nitrogen-14 nucleus can produce a carbon-14 atom and a hydrogen atom.



Regular carbon atoms, C-12, contain six neutrons in the nucleus. Radiocarbon, an unstable form of carbon, has eight neutrons in the nucleus. Due to the constant production of C-14 and its radioactive decay a small, relatively constant fractional quantity of C-14 exists in the atmosphere. Living organisms maintain equilibrium with C-14 in the atmosphere. They absorb C-14, which remains detectable after their death. Before 1000 BCE the levels of C-14 were a bit higher than they are now. The burning of fossil fuels and the atmospheric testing of nuclear weapons has affected the fraction of C-14 in present-day atmospheric CO<sub>2</sub>.

These organisms replace C-14 atoms that have undergone radioactive decay, at a present day rate of 15.3 disintegrations per minute per gram of total carbon, with fresh C-14 atoms by absorption. The fact that an organism no longer absorbs C-14 from the point of death allows a precise determination of the amount of C-14 remaining in the organism. This requires adequate samples and sufficiently sophisticated sensitive and calibrated equipment. The remaining C-14 disintegrates at a constant rate known as a half-life as follows:



Its half-life refers to the amount of time it takes for the rate of particle emission to decrease by one-half of its existing level through decay. Since C-14 has a half-life ( $t_{1/2}$ ) of 5,730 years the amount of radiocarbon remaining active establishes the elapsed time. Researchers establish the age of a dead organic object by measuring the level of beta emissions arising from the radioactive decay of C-14 in the object and calculating how long it took for C-14 to decay from its point of death to account for the level of beta emissions measured.

## Dating a Sample Using C<sup>14</sup> Analysis

A sample of a living organism emits 15 particles per second. The same size sample of organic material found in an excavation emits 3.75 particles per second. What is the age of the sample BP and what was its age when first analyzed in 1993?

1. The half-life of C<sup>14</sup> is 5,730 years.  $t_{1/2} = 5730$
2. Since 3.75 particles per second are given in 1993 the half-life producing this result took 5,730 years.
3. Thus 5,730 years before 1993 the sample would have emitted 7.50 particles per second (2 X 3.75).
4. An additional full half-life would result in the organism emitting 15 particles per second (2 X 7.50 particles per second). This brings the age of the sample to 11,460 years (5,730 + 5,730).
5. Assuming a constant rate of decay the sample lived 11,460 years before 1993 since at that time it would have emitted 15 particles per second.
6. It should be dated to 11,417 BP (1993 - 1950 = 43 11,460 - 43 = 11,417)
7. Also it can be dated to BCE 9423 [1993 - 11,417 + 1 (since there is no year 0) = 9423]

Calibration issues accompany radiocarbon dating for the rate of production of C-14 has not always been a constant with sampling concerns and the sophistication of instrumentation remaining additional factors. Improved sampling techniques, new and improved instrumentation requiring smaller quantities of organic material for analysis, and the use of dendrochronology for calibration have reduced the standard error of measurement in radiocarbon dating.

One can determine the date of an organic sample using the following equation:

$$\log N_t - \log N_0 = \frac{-kt}{2.303}$$

$N_0$  is the original number of C-14 nuclei in the original sample ( $t = 0$ ). After a period of time  $t$ , the number of nuclei decreases by decay to the number  $N_t$  is the number of C-14 nuclei in the same sample after elapsed time  $t$ . The fraction of nuclei remaining after elapsed time  $t$  is  $N_t/N_0$ . where  $k = 0.693/t_{1/2}$  and  $t_{1/2} = 5730$  years

$$t = (2.303 t_{1/2} \text{ divided by } 0.693)(\log N_0 - \log N_t)$$

Interestingly, in the Levant, calibrated dates in the fourth and third millennia BCE appear too early when compared to dates derived through accepted Egyptian chronology by means of pottery analysis. From 3,000 BCE, the absolute chronology of the Levant relies upon a correlation with Egyptian chronology. This coincides with the import and export of objects. This high dependence on Egyptian chronology requires any change in Egyptian chronology necessitating a parallel change concerning the chronology of the Levant. If the calibrated radiocarbon dates stand then revision in the accepted Egyptian chronology may soon follow.

## Ice Core Dating

Reported in *Archaeology* (Jan./Feb. 1995) and several other periodicals, research using ice core samples from the ice sheet in central Greenland, archived in the National Ice Core Laboratory, shows that chronologies based upon Mycenaean pottery requires some rethinking.



The traditional benchmark of Mycenaean pottery indexes is an eruption of Thera in 1500 BCE. The fact is that the eruption of Thera, which caused the volcanic destruction of the Minoan town of Akrotiri, occurred about 1625 BCE not 1500 BCE as traditionally understood. There is no evidence in the ice core for a major 1500 BCE eruption.

*The National Ice Core Laboratory at Denver is the repository for more than 13,000 ice core samples collected by U.S. researchers in Greenland and Antarctica. NICL photo by Ken Abbott. Courtesy of the University of Colorado.*

This means that the traditional chronology for the first half of the late Bronze Age is off by more than a century. This is consistent with the re-calibration of Carbon 14 based upon improved instrumentation and its adjustment against the results of newly developed tree-ring date indexes.

Studies based on annual growth rings in bristlecone pines in the United States, and oak trees in Europe, confirm a disturbance in global climatic conditions about 1628 BCE. The Carbon 14 dates for Akrotiri suggest the volcanic destruction of the city about 1625 BCE.

Historians have to rethink both their chronologies and their interpretations of the Late Bronze Age in the Mediterranean. This will discredit the scholarship of some and move scholarly thinking closer to the traditional biblical chronology of the period. Consequently, some historians and archaeologists resist the scientific data.