TREE-RINGS AND RADIOCARBON

St. Gregory High School

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DENDROCHRONOLOGY: The interpretation of the varying width of the annual growth (tree rings) of certain trees as a measurement of time and past climatic patterns

DENDROCLIMATOLOGY: The application of Dendrochronology to the study of past climate patterns

The scope of dendrochronology has ranged from the study of sunspots to dating of archaeological ruins. Tree-ring studies have been applied to fire history, insect infestations, pollution, legal cases, etc. Today, we will focus on the use of the bristlecone pine tree-ring chronology in the calibration of the radiocarbon time scale. The attached one-page summaries should provide an over-view of the related subject matter.

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LABORATORY OF TREE-RING RESEARCH

The unique research program of the Laboratory of Tree-Ring Research, in the College of Arts and Sciences at the University of Arizona, is designed to explore the complex relationships between tree growth and environment, to utilize tree-ring chronologies as a basis for dating ancient structures and events~~, and~~ to derive climatic and hydrologic reconstructions. The science of dendrochronology, developed at the University of Arizona by Andrew Ellicott Douglass, has resulted in the establishment of long term tree-ring chronologies which serve as an index to past climatic conditions and in the dating of wood and charcoal samples from archaeological sites in western North America and the Near East. The present collections are the largest in the world. The numerical extent of our collections is not presently known, but individual specimens probably number between a quarter and a half million. These include dated archaeological tree-ring specimens and cores and sections from living or recently dead trees including millennia-old bristlecone pines. Current emphasis is on modern codification of ring data, better understanding of growth phenomena, extension of ring chronologies into the past, discovery of new datable species, and expansion of tree-ring dating techniques into new areas of the world. Geographical scope has expanded to the extent that the Laboratory's activities can be described as world-wide. Staff and students have collected in Antarctica (with petrified wood), Europe, Africa, South America, New Zealand, Australia, Taiwan, India, and China. Laboratory facilities and study collections are available for research in all aspects of dendrochronology and dendroclimatology.

The staff, presently exceeding 50 people, is divided into informal, but interrelated sections: administration, archaeological dating, data processing, tree physiology, and modern, dendroclimatic, dendrohydrologic, and densitometric studies.

Publications by the staff occur in a wide variety of journals, as papers in proceedings of scientific meetings, as contributed chapters in books, and as edited or authored books. The Tree-Ring Bulletin has been published by the Tree-Ring Society since 1934.

The Laboratory offers graduate-level courses and research in dendrochronology that can be applied to graduate degree programs in other departments of the College of Arts and Sciences, as well as in other colleges of the University.

Suggested Reading:

National Science Foundation, 1977.
Tales the Tree Rings Tell. Mosaic 8(5)2-9.

Trefil, James S., 1985.
Trees are living archives. Smithsonian 16(4)46-52; 54-55.

DENDROCHRONOLOGY

Dendrochronology may be defined as the study of the chronological sequence of annual growth rings in trees. Development of the science of dendrochronology - as opposed to the simple counting of tree rings in a stump - began in 1901 with an observation on aridity in relation to elevation by Andrew Ellicott Douglass, an astronomer interested in sunspots, and continues up to our computer-oriented age. In the southwestern United States most of the tree-ring studies have been conducted on four major species: Douglas-fir, ponderosa pine, pinyon, and Rocky Mountain juniper. Sampling may be done by taking a cross section or, more conveniently, by using a Swedish increment borer, a precision tool designed to remove a small core without causing the living tree any harm. The dating of a sample is guided by two basic concepts: sensitivity and crossdating. Sensitivity is the variation in width from year to year, as, for example, in response to annual changes in precipitation. Crossdating is the systematic comparison of ring patterns, permitting the establishment of absolute dating for each growth ring as the calendar year in which it was formed, between radii of a single tree, between trees, between species, between age classes within a species, and between sites, and major geographical areas in relation to one another and to climatic and historic data. Given the fact that each consecutive annual growth can be dated, it is possible to extend the chronology back into the past by dating and incorporating older and older pieces of wood. With this extended chronology, it is possible to date archaeological tree-ring material, either wood or charcoal, from earlier periods.

Suggested Readings:

Baillie, M.G.L., 1982.
Tree-Ring Dating and Archaeology. The University of Chicago Press, Chicago.

Ferguson, C. W., 1970.
Concepts and Techniques of Dendrochronology. In Scientific Methods in Medieval Archaeology, edited by Rainer Berger, pp. 183-200. UCLA Center for Medieval and Renaissance Studies, Contributions IV. University of California Press, Berkeley.

Fritts, Harold C., 1976.
Tree Rings and Climate. Academic Press, London and New York.

Schulman, Edmund, 1956.
Dendroclimatic Changes in Semiarid America. The University of Arizona Press, Tucson.

Stokes, M. A. and Terah L. Smiley, 1968.
An Introduction to Tree-Ring Dating. The University of Chicago Press, Chicago.

DENDROCHRONOLOGY OF BRISTLECONE PINE

Dendrochronological studies of bristlecone pine, *Pinus longaeva*, in the White Mountains of east-central California have resulted in the establishment of a continuous tree-ring sequence back to 6700 B.C., a total of 8681 years. A second long-term chronology, going back to 3200 B.C., has been established for a site in east-central Nevada. Other sites are being studied. The millennia-old pines have emerged as a unique source of chronological data and the precisely dated wood is essential to certain paleoenvironmental and geophysical investigations. Over 1000 dendrochronologically dated decade samples of bristlecone pine, supplied to four C-14 laboratories, have been used to calibrate the radiocarbon time scale for the past seven millennia, a development of far reaching consequences in the fields of archaeology and geology. In addition, recent advances in other methods of analyzing past climatic variability, such as techniques involving stable isotope ratios have increased the demand for wood of known age and, hence, for chronology development. Current studies relate to the dendrochronology of Europe.

Suggested Reading:

Ferguson, C. W., 1968.
Bristlecone Pine: Science and Esthetics. *Science* 157(3817)839-46.

________, 1970.
Dendrochronology of Bristlecone Pine, *Pinus aristata*: Establishment of a 7484-Year Chronology in the White Mountains of Eastern Central California, U.S.A. In *Radiocarbon Variations and Absolute Chronology*, edited by Ingrid U. Olsson, pp. 237-59. Nobel Symposium 12, Almquist and Wiksell, Stockholm.

________, 1979.
Dendrochronology of Bristlecone Pine, *Pinus longaeva*. *Environment International* 2(4-6)209-214.

________ and D. A. Graybill, 1983.
Dendrochronology of Bristlecone Pine: A Progress Report. *Radiocarbon* 25(2)287-88.

LaMarche, Valmore C. and Katherine K. Hirschboeck, 1984.
Frost rings in trees as records of major volcanic eruptions. *Nature* 307(5947)121-126.

__________________, Donald A. Graybill, Harold C. Fritts and Martin R. Rose, 1984.
Increasing Atmospheric Carbon Dioxide: Tree Ring Evidence for Growth Enhancement in Natural Vegetation. *Science* 225(4666)1019-1021.

Muench, David, 1972.
timberline ancients. Charles H. Belding, Portland, Oregon.

Schulman, Edmund, 1958.
Bristlecone Pine, Oldest Known Living Thing. *National Geographic Magazine* 113(3)354-72.

BRISTLECONE PINE AND RADIOCARBON DATING

Damon, P. E., C. W. Ferguson, A. Long and E. I. Wallick, 1974. Dendrochronologic Calibration of the Radiocarbon Time Scale. American Antiquity 39(2):350-366.

Ferguson, C. W., 1968. Bristlecone pine: science and esthetics. Science 159(3817):839-46.

______________, 1969. A 7104-year annual tree-ring chronology for bristlecone pine, Pinus aristata, from the White Mountains, California. Tree-Ring Bulletin 29(3-4):3-29.

______________, 1970b. Dendrochronology of Bristlecone Pine, Pinus aristata: Establishment of a 7484-Year Chronology in the White Mountains of Eastern Central California, U.S.A. In Radiocarbon Variations and Absolute Chronology, edited by Ingrid U. Olsson, pp. 237-259. Nobel Symposium 12, Almquist and Wiksell, Stockholm.

______________, 1979. Dendrochronology of bristlecone pine, Pinus longaeva. Environment International 2(4-6)209-214.

Klein, J., Lerman, J. C., Damon, P. E., and Linick, T., 1980. Radiocarbon concentrations in the atmosphere: 8000-year record of variations in tree rings: Radiocarbon 22(3)950-961.

Klein, J., J. C. Lerman, P. E. Damon and E. K. Ralph. Calibration of Radiocarbon Dates: Tables based on the consensus data of the Workshop on Calibrating the Radiocarbon Time Scale. (Radiocarbon, June, 1982, in press).

Libby, Willard F., 1971. Radiocarbon Dating - Twenty Years Later. Field Museum of Natural History (Chicago), Bulletin 42(7):2-5.

________________, 1973. The Radiocarbon Dating Method. Pensee 3(2):7-11.

Polach, Dilette, 1979. First 20 Years of Radiocarbon Dating: An Annotated Bibliography, 1948-68; a pilot study presented at: Xth International Radiocarbon Dating Conference, Bern and Heidelberg, August 1979. A special publication of the Australian National University Radiocarbon Dating Research Laboratory.

Ralph, E. K., H. N. Michael, and M. C. Han, 1973. Radiocarbon dates and reality. MASCA Newsletter 9:1-20.

Renfrew, Colin, 1973. Before civilization: the radiocarbon revolution and prehistoric Europe. Alfred A. Knopf, New York.

Schulman, Edmund, 1958. Bristlecone pine, oldest known living thing. The National Geographic Magazine 113(3):355-372.

Wilson, David, 1975. The new archaeology. Alfred A. Knopf, New York.

RADIOCARBON DATING

When neutrons from cosmic radiation are captured by nitrogen nuclei in the earth's atmosphere, the long-lived radioisotope ^{14}C is produced. The ^{14}C nuclei so produced combine with oxygen to form $^{14}CO_2$, and become part of the carbon cycle. All living things achieve an equilibrium concentration of ^{14}C, and when they die, their ^{14}C nuclei decay with a half-life of 5,730 years.

Willard Libby demonstrated in 1946 that the time since the death of an object which had participated in the carbon cycle could be determined by measuring, in a nuclear counter, the radioactivity of ^{14}C remaining in that object and comparing it with the equilibrium radioactivity of ^{14}C characteristic of living objects. This original discovery by Libby has been exploited by researchers in disciplines from anthropology to zoology. Among these researchers are members of the University of Arizona, Department of Geosciences, who for years have studied the ^{14}C content of various anthropological and geophysical specimens.

Among the programs of the local geoscientists is a joint project with scientists from the University of Arizona Laboratory of Tree-Ring Research. The ^{14}C content of tree rings of known age, from the present back to about 6,000 B.C., has been measured and recorded. With this information, scientists are able to check theoretical models of equilibrium ^{14}C concentrations for the last 8,000 years, and to study in some detail the temporal fluctuations of cosmic rays which produced the atmospheric ^{14}C.

Many related papers were presented at the 12th International Radiocarbon Conference, held in Trondheim, Norway June 24-28, 1985, and soon will be published in the journal <u>Radiocarbon</u>.

THE NSF-ARIZONA ACCELERATOR FACILITY FOR RADIOISOTOPE ANALYSIS

A serious limitation of Libby's technique (mentioned in the discussion of ^{14}C dating) is the fact that large quantities of a sample are needed to determine the ^{14}C radioactivity of that sample. Many artifacts which scientists would like to date are too small to allow radioactivity measurements. A new technique has recently been developed for determining the ^{14}C content of a sample. This technique employs a particle accelerator as part of a high energy mass spectrometer.

As a joint project between the Departments of Physics and Geosciences, sponsored by the National Science Foundation, an instrument of this type has been installed and tested in the Van de Graaff Laboratory of the Department of Physics. With this instrument, scientists are able to determine the ^{14}C of samples one one-thousandth the size of those necessary for more conventional measurements. The ability to make measurements on such small samples allows many experiments to be performed which were previously not feasible. The new facility is used by researchers from many departments of the University as well as from laboratories around the world.