Uses of Radiocarbon Dating

Climate science required the invention and mastery of many difficult techniques. These had pitfalls, which could lead to controversy. An example of the ingenious technical work and hard-fought debates underlying the main story is the use of radioactive carbon-14 to assign dates to the distant past. For other examples, see the essays on Temperatures from Fossil Shells and Arakawa's Computation Device.

The prodigious mobilization of science that produced nuclear weapons was so far-reaching that it revolutionized even the study of ancient climates. Nuclear laboratories, awash with funds and prestige, spun off the discovery of an amazing new technique—radiocarbon dating. The radioactive isotope carbon-14 is created in the upper atmosphere when cosmic-ray particles from outer space strike nitrogen atoms and transform them into radioactive carbon. Some of the carbon-14 might find its way into living creatures. After a creature's death the isotope would slowly decay away over millennia at a fixed rate. Thus the less of it that remained in an object, in proportion to normal carbon, the older the object was. By 1950, Willard Libby and his group at the University of Chicago had worked out ways to measure this proportion precisely. Their exquisitely sensitive instrumentation was originally developed for studies in entirely different fields including nuclear physics, biomedicine, and detecting fallout from bomb tests.[1]

Much of the initial interest in carbon-14 came from archeology, for the isotope could assign dates to Egyptian mummies and the like. As for still earlier periods, carbon-14 dating excited scientists (including some climate scientists) largely because it might shed light on human evolution—the timing of our development as a species, and how climate changes had affected that.[2] It was especially fascinating to discover that our particular species of humans arose something like 100,000 years ago, no doubt deeply influenced by the ice ages.[3] A few scientists noticed that the techniques might also be helpful for the study of climate itself.

From its origins in Chicago, carbon-14 dating spread rapidly to other centers, for example the grandly named Geochronometric Laboratory at Yale University. The best way to transfer the exacting techniques was in the heads of the scientists themselves, as they moved to a new job. Tricks also spread through visits between laboratories and at meetings, and sometimes even through publications. Any contamination of a sample by outside carbon (even from the researcher's fingerprints) had to be fanatically excluded, of course, but that was only the beginning. Delicate operations were needed to extract a microscopic sample and process it. To get a mass large enough to handle, you needed to embed your sample in another substance, a

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[1] Libby (1946); Arnold and Libby (1949); Libby (1967).

[2] E.g., Ericson and Wollin (1964), pp. 6, 12-13; Emiliani (1956).

[3] Bowen (1966), p. 216, drawing on Emiliani.

"carrier." At first acetylene was used, but some workers ruefully noted that the gas was "never entirely free from explosion, as we know from experience."[1] Ways were found to use carbon dioxide instead. Frustrating uncertainties prevailed until workers understood that their results had to be adjusted for the room's temperature and even the barometric pressure.

This was all the usual sort of laboratory problem-solving, a matter of sorting out difficulties by studying one or another detail systematically for months. More unusual was the need to collaborate with all sorts of people around the world, to gather organic materials for dating. For example, Hans Suess relied on a variety of helpers to collect fragments of century-old trees from various corners of North America. He was looking for the carbon that human industry had been emitting by burning fossil fuels, in which all the carbon-14 had long since decayed away. Comparing the old wood with modern samples, he showed that the fossil carbon could be detected in the modern atmosphere.[2]

Through the 1950s and beyond, carbon-14 workers published detailed tables of dates painstakingly derived from samples of a wondrous variety of materials, including charcoal, peat, clamshells, antlers, pine cones, and the stomach contents of an extinct Moa found buried in New Zealand.[3] The measurements were correlated with materials of known dates, such as a well-documented mummy or a log from the roof of an old building (where tree rings gave an accurate count of years). The results were then compared with traditional time sequences derived from glacial deposits, cores of clay from the seabed, and so forth. One application was a timetable of climate changes for tens of thousands of years back. Many of the traditional chronologies turned out to be far less accurate than scientists had believed—a bitter blow for some who had devoted decades of their lives to the work.

Making the job harder still, baffling anomalies turned up. The carbon-14 dates published by different researchers could not be reconciled, leading to confusion and prolonged controversy. It was an anxious time for scientists whose reputation for accurate work was on the line. But what looks like unwelcome noise to one specialist may contain information for another. In 1958, Hessel de Vries in the Netherlands showed there were systematic anomalies in the carbon-14 dates of tree rings. His explanation was that the concentration of carbon-14 in the atmosphere had varied over time (by up to one percent).

De Vries thought the variation might be explained by something connected with climate, such as episodes of turnover of ocean waters.[4] Another possible explanation was that, contrary to what everyone assumed, carbon-14 was not created in the atmosphere at a uniform rate. Some speculated that such irregularities might be caused by variations in the Earth's magnetic field. A stronger field would tend to shield the planet from particles from the Sun, diverting them before

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[1] Technique: Suess (1954); explosion: Barendsen et al. (1957), p. 908.

[2] Suess (1955).

[3] For example: Kulp et al. (1951).

[4] de Vries (1958).

they could reach the atmosphere to create carbon-14.

Another possibility was that the cause lay in the Sun itself. De Vries had considered this hypothesis but thought it *ad hoc* and "not very attractive."[1] However, solar specialists knew that the number of particles shot out by the Sun varies with the eleven-year cycle of sunspots. Also, the Sun's own magnetic field varies with the cycle, and that could change the way cosmic particles bombarded the Earth. In 1961, Minze Stuiver suggested that longer-term solar variations might account for the inconsistent carbon-14 dates. But his data were sketchy. Libby, for one, cast doubt on the idea, so subversive of the many dates his team had supposedly established with high accuracy.[2]

Suess and Stuiver finally pinned down the answer in 1965 by analyzing hundreds of wood samples dated from tree rings. The curve of carbon-14 production showed undeniable variations, "wiggles" of a few percent on a timescale of a century or so.[3] With this re-calibration in hand, boosted by steady improvements in instruments and techniques, carbon-14 became a precise tool for dating ancient organic materials. (By the 1980s, experts could date a speck almost too small to see and several tens of thousands of years old.) Tracking carbon-14 also proved highly useful in historical and contemporary studies of the global carbon budget, including the movement of carbon in the oceans and its complex travels within living ecosystems.

It was particularly interesting that, as Stuiver had suspected, the carbon-14 wiggles correlated with long-term changes in the number of sunspots. Turning it around, Suess remarked that "the variations open up a fascinating opportunity to perceive changes in the solar activity during the past several thousand years."[4] The anomalies were evidence for something that many scientists found difficult to believe—the surface activity of the Sun had varied substantially in past millennia. Carbon-14 might not only provide dates for long-term climate changes, but point to one of their causes.

Related:
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[1] de Vries (1958), p. 99. On de Vries see Paul Damon, interview by Theodore Feldman, 1998, online at http://www.agu.org/history/sv/proxies/damon_interview.html.

[2] Stuiver (1961), said only that the "evidence suggests some correspondence"; Libby (1963).

[3] Suess (1965); Stuiver (1965); Stuiver and Suess (1966); for a review in midstream, see Lingenfelter (1963). Further details in e-mail interview of Paul Damon by Ted Feldman, 1998, http://www.agu.org/history/sv/proxies/damon_interview.html, copy at AIP.

[4] Suess (1965), p. 5949.