Basics of radiocarbon dating

The term “radiocarbon” is commonly used to denote ^{14}C, an isotope of carbon which is radioactive with a half-life of about 5730 years. ^{14}C is produced by cosmic rays in the stratosphere and upper troposphere. It is then distributed throughout the rest of the troposphere, the oceans, and Earth’s other exchangeable carbon reservoirs. In the surface atmosphere, about one part per trillion (ppt) of carbon is ^{14}C.

All organisms absorb carbon from their environment. Those that absorb their carbon directly or indirectly from the surface atmosphere have about 1 ppt of their carbon content as ^{14}C. Such organisms comprise almost all land-dwelling plants and animals. (Other organisms—e.g. fish—have slightly less of their carbon as ^{14}C; this affects how radiocarbon dating works, and there are methods of adjusting for it.)

When an organism dies, carbon stops being absorbed. Hence after 5730 years, about half of its ^{14}C will have radioactively decayed (to nitrogen): only about 0.5 ppt of the carbon of the organism’s remains will be ^{14}C. And if the carbon of the remains is found to be 0.25 ppt ^{14}C, then the organism would be assumed to have died about 11460 years ago. Thus, a simple calculation can find the age, since death, from any ^{14}C concentration. (Remains older than about 50000 years, however, have a ^{14}C concentration that is in practice too small to measure; so they cannot be dated via ^{14}C.)

Ages are conventionally reported together with the standard deviation of the laboratory ^{14}C measurement, e.g. 900±25 ^{14}C BP (^{14}C-dated, years Before Present). This should be doubled to obtain a 95%-confidence interval, e.g. 850–950 ^{14}C BP. (The true range of 95%-confidence, though, will often be larger than this, due to non-laboratory sources of error—e.g. the admixture of impurities with the remains.)

Although a tree may live for hundreds, even thousands, of years, each ring of a tree absorbs carbon only during the year in which it grows. The year in which a ring was grown can be determined exactly (by counting); so radiocarbon dating can be tested by measuring the ^{14}C concentrations in old tree rings. Such testing found errors of up to several centuries. It turns out that the concentration of ^{14}C in the surface atmosphere has not been a constant 1 ppt, but has varied with time. Thus the simple calculation of age from ^{14}C concentration is unreliable.

Tree rings, though, also provide a solution to this problem. The concentration of ^{14}C in an organism’s remains can be compared with the concentrations in tree rings; the tree rings that match, within confidence limits, give the years in which the organism could have plausibly died. Ages determined this way are called “calibrated ^{14}C ages”; others are called “uncalibrated ^{14}C ages”, or simply “^{14}C ages”, and continue to be reported as “^{14}C BP”. (Calibration via tree rings, though, does not extend for 50000 years, only several thousand. Other ways of calibrating are therefore being developed.) Calibrated ^{14}C ages are generally greater than uncalibrated ^{14}C ages, with the differences increasing with age.

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