Title
Radiocarbon Dating: Applications of Accelerator Mass Spectrometry

Permalink
https://escholarship.org/uc/item/52s156rh

Journal
Berkeley Scientific Journal, 17(2)

ISSN
1097-0967

Author
Purcell, Sean

Publication Date
2013

Undergraduate
At this very moment, cosmic rays are penetrating the Earth’s atmosphere and colliding with atoms in the stratosphere to form secondary cosmic rays of highly energetic neutrons. These energized subatomic particles then collide with the nitrogen-14 that in large part makes up our atmosphere; the subsequent neutron capture produces both hydrogen and radioactive carbon-14 atoms (subsequently referred to as C-14). These radioactive carbon atoms go on to form carbon dioxide molecules that are absorbed by plants, and eventually consumed by humans. This, however, should not be cause for alarm, but rather reason to
Archaeologists recently identified the newly uncovered skull of English king Richard III, using modern carbon dating and genetic techniques.

celebrate. Because C-14 undergoes beta-decay, and C-14 absorption ceases at death, this process serves as a molecular timestamp, effectively putting a date on the death of biological organisms. The exploitation of this chemical phenomenon allows scientists to conduct what has come to be known as radiocarbon dating.

In late 2011, scientists in Europe used a modified radiocarbon dating process to arrive at the startling realization that Neanderthals must have coexisted with anatomically modern humans, a claim that was once widely contested among historians and anthropologists as it defies generally accepted human evolutionary and migratory patterns (Higham, 2011). Similarly, research conducted by Stefano Benazzi at the University of Vienna dated two teeth discovered at Grotto de Cavallo, Italy much earlier than previously thought, to between 43,000 and 45,000 calendar years before present (Benazzi, 2011). These scientists utilized a specialized form of carbon dating known AMS radiocarbon dating, which relies upon atomic mass spectrometry and specialized sample preparation techniques to date particularly old and small samples with remarkable precision.

Carbon dating as a process is relatively new, developed by Nobel Laureate and UC Berkeley professor Willard Libby in 1936 (Libby, 1967). Knowing that organic matter, after death, is unable to absorb significant levels of C-14 and that the atmospheric concentration of C-14 is relatively stable, Libby’s model claimed that because the radioactive isotope C-14 undergoes beta decay with a half-life of approximately 5730 calendar years, organic matter could be dated by determining the concentration of the isotopic carbon in fossils and remains (Libby, 1967). Scientists have since developed a wide array of techniques to measure the radioactive decay of C-14. Two early methods, gas proportional counting and liquid scintillation counting (both radiometric methods which rely on monitoring the decay of specific C-14 atoms over time) while effective, presented scientists with a unique problem. These radiometric-counting methods produced results with significant statistical uncertainty (due to the long half-life of C-14) and required large sample sizes. In April of 1977, Richard Muller, while conducting research at the Lawrence Livermore Radiation Laboratory, found that by using a cyclotron as a high energy mass spectrometer, maximum

Archaeologists recently identified the newly uncovered skull of English king Richard III, using modern carbon dating and genetic techniques.

Oxford’s Radiocarbon Accelerator Unit (ORAU) under scientist Thomas Higham dated a human jawbone discovered at Kent’s Cavern, UK between 44.2 - 41.5 kyr cal BP (between 41,500 and 44,200 years old), filling a “key gap between the earliest dated Aurignacian remains and the earliest human skeletal remains” (Higham, 2011). Similarly, research conducted by Stefano Benazzi at the University

of Vienna dated two teeth discovered at Grotto de Cavallo, Italy much earlier than previously thought, to between 43,000 and 45,000 calendar years before present (Benazzi, 2011). These scientists utilized a specialized form of carbon dating known AMS radiocarbon dating, which relies upon atomic mass spectrometry and specialized sample preparation techniques to date particularly old and small samples with remarkable precision.

Carbon dating as a process is relatively new, developed by Nobel Laureate and UC Berkeley professor Willard Libby in 1936 (Libby, 1967). Knowing that organic matter, after death, is unable to absorb significant levels of C-14 and that the atmospheric concentration of C-14 is relatively stable, Libby’s model claimed that because the radioactive isotope C-14 undergoes beta decay with a half-life of approximately 5730 calendar years, organic matter could be dated by determining the concentration of the isotopic carbon in fossils and remains (Libby, 1967). Scientists have since developed a wide array of techniques to measure the radioactive decay of C-14. Two early methods, gas proportional counting and liquid scintillation counting (both radiometric methods which rely on monitoring the decay of specific C-14 atoms over time) while effective, presented scientists with a unique

Archaeologists recently identified the newly uncovered skull of English king Richard III, using modern carbon dating and genetic techniques.

Oxford’s Radiocarbon Accelerator Unit (ORAU) under scientist Thomas Higham dated a human jawbone discovered at Kent’s Cavern, UK between 44.2 - 41.5 kyr cal BP (between 41,500 and 44,200 years old), filling a “key gap between the earliest dated Aurignacian remains and the earliest human skeletal remains” (Higham, 2011). Similarly, research conducted by Stefano Benazzi at the University

of Vienna dated two teeth discovered at Grotto de Cavallo, Italy much earlier than previously thought, to between 43,000 and 45,000 calendar years before present (Benazzi, 2011). These scientists utilized a specialized form of carbon dating known AMS radiocarbon dating, which relies upon atomic mass spectrometry and specialized sample preparation techniques to date particularly old and small samples with remarkable precision.

Carbon dating as a process is relatively new, developed by Nobel Laureate and UC Berkeley professor Willard Libby in 1936 (Libby, 1967). Knowing that organic matter, after death, is unable to absorb significant levels of C-14 and that the atmospheric concentration of C-14 is relatively stable, Libby’s model claimed that because the radioactive isotope C-14 undergoes beta decay with a half-life of approximately 5730 calendar years, organic matter could be dated by determining the concentration of the isotopic carbon in fossils and remains (Libby, 1967). Scientists have since developed a wide array of techniques to measure the radioactive decay of C-14. Two early methods, gas proportional counting and liquid scintillation counting (both radiometric methods which rely on monitoring the decay of specific C-14 atoms over time) while effective, presented scientists with a unique

Archaeologists recently identified the newly uncovered skull of English king Richard III, using modern carbon dating and genetic techniques.

Oxford’s Radiocarbon Accelerator Unit (ORAU) under scientist Thomas Higham dated a human jawbone discovered at Kent’s Cavern, UK between 44.2 - 41.5 kyr cal BP (between 41,500 and 44,200 years old), filling a “key gap between the earliest dated Aurignacian remains and the earliest human skeletal remains” (Higham, 2011). Similarly, research conducted by Stefano Benazzi at the University

of Vienna dated two teeth discovered at Grotto de Cavallo, Italy much earlier than previously thought, to between 43,000 and 45,000 calendar years before present (Benazzi, 2011). These scientists utilized a specialized form of carbon dating known AMS radiocarbon dating, which relies upon atomic mass spectrometry and specialized sample preparation techniques to date particularly old and small samples with remarkable precision.

Carbon dating as a process is relatively new, developed by Nobel Laureate and UC Berkeley professor Willard Libby in 1936 (Libby, 1967). Knowing that organic matter, after death, is unable to absorb significant levels of C-14 and that the atmospheric concentration of C-14 is relatively stable, Libby’s model claimed that because the radioactive isotope C-14 undergoes beta decay with a half-life of approximately 5730 calendar years, organic matter could be dated by determining the concentration of the isotopic carbon in fossils and remains (Libby, 1967). Scientists have since developed a wide array of techniques to measure the radioactive decay of C-14. Two early methods, gas proportional counting and liquid scintillation counting (both radiometric methods which rely on monitoring the decay of specific C-14 atoms over time) while effective, presented scientists with a unique
AMS techniques can detect quantities as low as one C-14 per trillion C-12 atoms.”

The process of AMS radiocarbon dating, while statistically more accurate, does have a major drawback. Due to the high costs of purchasing and operating a nuclear particle accelerator and its components, access to AMS radiocarbon dating methods is often limited. However, AMS radiocarbon dating offers scientists remarkable capabilities that surpass those of radiometric counting methods.

Current research studies suggest the use of AMS as a biomedical tracer that can be used for labeling when fast analysis (less demanding accuracy than for carbon dating) of a large number of samples is desired, by using low voltage compact AMS facilities (Suter, 2000). AMS is sufficiently sensitive to detect C-14 at levels so low that much of the hazard and most significant interference has been eliminated. Recent studies show that AMS has a sensitivity over radiometric decay counting for long lived radioisotopes and common radionuclides that will allow for smaller samples and lower radioisotope concentrations. New methods are being developed to exploit this selectivity and sensitivity in biochemical laboratories interested in pharmacokinetics and biomolecular interactions. These remarkable characteristics show great promise to researchers studying metabolism, macromolecular binding of candidate drugs and toxins, and even the pathology of bacterial and viral infection.

The combination of accelerator mass spectrometry and radiocarbon dating and counting C-14 through the use of particle physics eliminates both the large sample requirements and timetable of radiometric counting methods while also determining the concentration of stable carbon isotopes.

References


