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Carbon dating: Developing a measurement tool for a 23-year-old cold case

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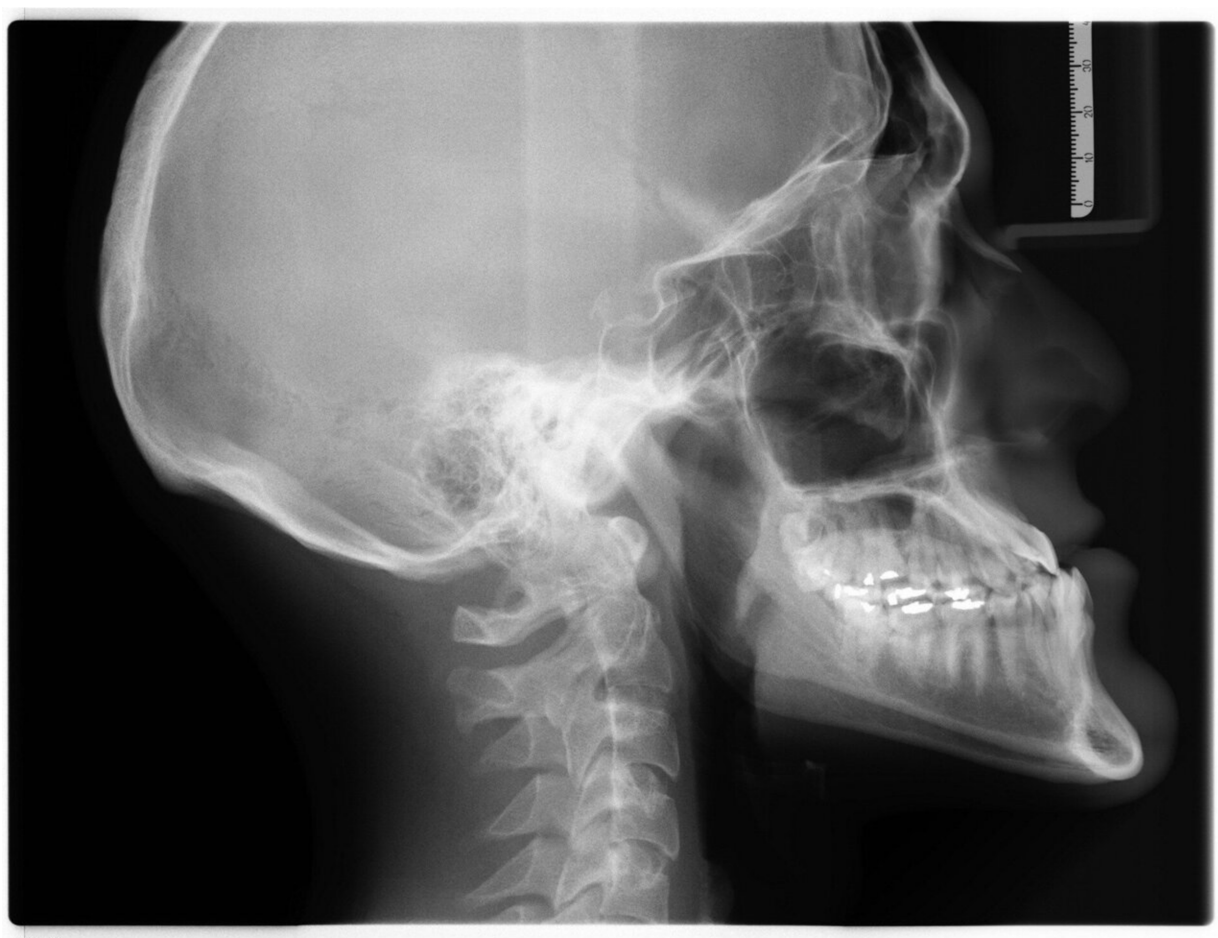

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When local law enforcement are unable to identify skeletal remains, they may seek out external resources and capabilities like those at Lawrence Livermore National Laboratory's (LLNL) Center for Accelerator Mass Spectrometry (CAMS). That's exactly what happened in 2007 when police from Newfoundland, Canada, were six years into an investigation with nothing but dead ends.

In the hopes of gaining new insights about their John Doe, Newfoundland investigators reached out to LLNL scientist Bruce Buchholz and collaborators at the Karolinska Institute in Sweden after coming across some of their research papers on the use of carbon dating to estimate a deceased person's year of birth and death.

Using accelerator-based technologies at CAMS, Buchholz measured the amount of carbon found in the individual's teeth and hair. Results from these analyses indicated the deceased was in his 30s when he died, likely born in 1958 (+/- 2.5 years) and dying between 1994–1997.

Ideally, this information would have brought investigators one step closer to identifying the unknown man, but in this instance, his identity remained a mystery—until recently. With modern advancements in genetic genealogy, investigators found a DNA match with that of the John Doe's first cousin, determining that the remains belonged to that of Temistocle Fernandez Casas of Cuba.

"I was very pleased to hear that after all these years they made progress on this case," Buchholz said. Over the course of his 26-year LLNL career, Buchholz has helped date the human remains of several dozen cold cases.

An ideal measurement tool

In the early 2000s, Buchholz and his collaborators were in search of a good control tissue that could be used to date DNA in their cell turnover studies. So, they thought: "Let's try teeth." Once a tooth is formed, the amount of carbon-14 (^{14}C) in the enamel will never change, making it the ideal dating tool for humans. Since certain teeth are formed across specific age ranges, measuring the ^{14}C content in various teeth can help researchers estimate a range of birth years.

Hair, on the other hand, continuously grows at a rate of about one centimeter per month. "The ^{14}C content in your food becomes the ^{14}C in you," Buchholz said. "Measuring the ^{14}C closest to the hair's root can tell us how much ^{14}C was in a person's food over the last couple months, helping us to calculate a range of years for when they died."

The above-ground nuclear tests that took place before the 1963 Nuclear Test Ban Treaty are what make these types of measurements possible, which is why this method is often referred to as "bomb pulse dating." Up until 1955, the amount of ^{14}C in the atmosphere was relatively stable, but above-ground nuclear testing caused the amount of ^{14}C in the atmosphere to double over its natural levels. Much of this excess ^{14}C then oxidized to form carbon dioxide (CO_2) and dispersed and equalized around the globe.

In the late 1950s, researchers in Europe started taking CO_2 samples from the atmosphere every couple of weeks—measurements which are still taken today. Researchers can use this data to estimate an individual's date of birth and death, comparing the amount of ^{14}C found in their enamel or hair against a record with the known atmospheric levels of ^{14}C over time, pinpointing where the levels match up.

"Using a high-precision accelerator mass spectrometry instrument like the one at CAMS maximizes the forensic value by placing tight constraints on the year of birth and death," said CAMS director Scott Tumey. "Performing these measurements at a national laboratory provides law enforcement with a high degree of confidence in the reliability of the results."

Comparing carbon ratios

Dating the carbon in teeth only requires about one-third of a whole tooth, or 100 milligrams. To prepare the sample, it is crushed and dissolved in acid, which releases CO_2. When this process is performed on hair, instead of dissolving the hair in acid, it is burned. Because hair has a high carbon content, only 3–4 milligrams of hair is needed.

The CO_2 from either the tooth or hair sample is then reduced to graphite—the crystalline form of carbon—and is put into an ion source at CAMS, where the graphite's neutral atoms are converted to ions by putting a negative charge on them. An accelerator can then use that negative charge to accelerate the sample, making it possible to detect, count and compare the ^{14}C to carbon-13 (^{13}C) atom ratios.

"We can compare the ^{14}C to ^{13}C concentrations in an unknown sample to the ^{14}C to ^{13}C ratio of certified isotopic standards, supplied by the International Atomic Energy Agency and the National Institute of Standards and Technology, and from that ratio of ratios we can calculate a person's age using the extensive atmospheric records that are available," Buchholz said.

"Through our calculations, we're eliminating possibilities, not identifying absolutes." The teeth, hair, carbon dating and CAMS capabilities only tell one piece of the story, and in Casas's case, the story isn't over yet.

Today, the amount of ^{14}C in the atmosphere is nearly back down to pre-industrial levels. This is mostly due to its natural diffusion into the oceans and incorporation into plants by photosynthesis, but also due to the combustion of fossil fuels. Unlike the natural atmospheric and bomb pulse CO_2 that contains ^{14}C, the CO_2 that comes from fossil fuels does not contain ^{14}C. As a result, the bomb pulse has been diluted over time. Buchholz estimates that after 2025, atmospheric levels of ^{14}C will be back down to pre-industrial levels, limiting the use of bomb pulse dating to those born or deceased between this time frame.

However, the power of carbon dating goes beyond forensic applications. As the bomb pulse decreases, CAMS capabilities remain vital to measuring ^{14}C using traditional radiocarbon dating for a wide variety of carbon cycle and sequestration studies.

Provided by Lawrence Livermore National Laboratory

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