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Geoscientific age determination

Identifying age measurements distorted by fossil fuel emissions

Radiocarbon dating remains a reliable tool if it is supplemented by ^{13}C measurements

[07. December 2016] **Good news for archaeologists and natural scientists! You will be able to continue to use the radiocarbon method as a reliable tool for determining the age of artefacts and sample materials. The reduction of the carbon isotope ^{14}C in the atmosphere accelerated by anthropogenic carbon dioxide emissions and the associated distortion of the radiocarbon age of materials can be precisely identified - by measuring the carbon isotope ^{13}C . This is the result of a study by AWI geoscientist Dr Peter Köhler, which was published today in the journal Environmental Research Letters.**

For how long will we be able to use our best method for determining the age of organic materials? Archaeologists and natural scientists asked themselves this question about a year ago when it became known that mankind (through its consumption of fossil fuels like coal, oil and natural gas) is changing the carbon isotope balance on Earth to such a degree that the radiocarbon method will generate inaccurate ages within a few decades.

"If the global emissions of fossil carbon dioxide continue to rise in the near future, as is proposed by the business-as-usual scenario of the Intergovernmental Panel on Climate Change, the results of our age readings of new organic material in 2050 will be identical to 1000-year-old samples. In 2150 new samples will appear to be the same age as 3000-year-old carbon, and in extreme cases even the same as 4300-year-old material. This means that fresh samples, for example of a tree felled within the next century, when measured using radiocarbon dating will appear to be the same age as wood that is several thousand years old," explains Dr Peter Köhler, geoscientist at the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research.

Over the past year, he asked himself the question of whether and how the distorted age of the material can be identified. He found the solution in another carbon isotope. "If we determine the ^{13}C value of the sample as well as using the radiocarbon method, we can find out whether the age is trustworthy. That's because the ^{13}C value tells us whether the carbon of the sample has been affected by fossil carbon dioxide," says Peter Köhler.

Carbon that living organisms ingest through breathing, photosynthesis or with food, contains three different isotopes: the two stable isotopes ^{12}C and ^{13}C as well as the radioactive ^{14}C . The latter is formed through nuclear reactions in the upper layers of the Earth's atmosphere. When an animal or a plant dies, the ^{14}C in the organism's tissue decays at a constant rate. Its half-life is approximately 6000 years.

Scientists take advantage of this fact when they perform radiocarbon dating. The amount of the remaining ^{14}C isotopes in the sample is determined, a ratio to the number of ^{12}C isotopes is established, which in turn is compared with a standard. "The problem we face is that natural gas, oil and coal are so old that their carbon no longer contains any ^{14}C isotopes. When we burn these fossil

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The Alfred Wegener Institute pursues research in the polar regions and the oceans of mid and high latitudes. As one of the 18 centres of the Helmholtz Association it coordinates polar research in Germany and

fuels, we release large amounts of ^{14}C -free carbon into the atmosphere. As a result, the ^{14}C to ^{12}C ratio – similar to an ageing process – becomes smaller, first in the atmosphere and later in all reservoirs it exchanges with. We know this phenomenon as the Suess effect, named after the physicist Hans E. Suess,” says Peter Köhler.

provides ships like the research icebreaker Polarstern and stations for the international scientific community.

The ^{13}C signal identifies the difference

This Suess effect also applies to the ^{13}C isotope – a fact the AWI scientist took advantage of to solve the dating problem. “The burning of oil, coal and gas not only changes the ^{14}C signal in the atmosphere, but also the stable ^{13}C signal. This means: If my measurement shows a distorted ^{13}C signal, then this also tells me that the ^{14}C -based age has been affected by fossil carbon. If, on the other hand, my ^{13}C signal is within the expected range, then the fossil carbon has not had an effect and the ^{14}C dating method shows the correct age,” Peter Köhler explains.

In his study, the scientist calculated the ^{14}C Suess effect and the ^{13}C Suess effect up to the year 2500 using the BICYCLE computer model, which simulates the global carbon cycle. His calculations were based on the established emission scenarios of the Intergovernmental Panel on Climate Change. Using further analyses he then tested whether his forecasts still held true if mankind managed to reduce the concentration of carbon dioxide in the atmosphere.

In all scenarios the potential distortion of the dating method could be identified with the ^{13}C Suess effect. Only in areas where exchange with the atmosphere is slow (e.g. the deep Pacific Ocean) is it not possible to clearly identify the distortion using the ^{13}C Suess effect. Further methodological difficulties will also arise if mankind starts at a large scale to remove carbon dioxide from the atmosphere by growing biomass for energy production, then captures the released carbon dioxide during its consumption in power plants and stores it in underground geological formations. This so-called BECCS method has already been implemented on a small scale in some scenarios of the Intergovernmental Panel on Climate Change; however, it is only one of many theoretically conceivable methods to reduce carbon dioxide concentration in the atmosphere.

Original publication

Peter Köhler: *Using the Suess effect on the stable carbon isotope to distinguish the future from the past in radiocarbon*, Environ. Res. Lett. 11 124016. DOI: [10.1088/1748-9326/11/12/124016](https://doi.org/10.1088/1748-9326/11/12/124016)

