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Published in:
South African Journal of Science

Publication date:
1999

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John C. Vogel was responsible for the Groningen Radiocarbon Laboratory from October 1961 to January 1969. The laboratory was established by Hessel de Vries in the early 1950s. At that time, John was working in Heidelberg, where he completed his Ph.D.[1] under the nuclear physicist Professor Haxel. In Groningen, he immediately started to introduce stable-isotope studies, till then his speciality, resulting in the Ph.D. thesis of his successor, Wim Mook.[2]

John's first Groningen publication, *Radiocarbon Datelist IV*,[3] is marked by three noticeable facts: (i) the old De Vries laboratory was demolished, (ii) the Groningen dates were all corrected for the Suess effect and for another value of the counter background, both corrections expressed by a change in the lab number from Gro to GrN, and (iii) the ages were calculated using the half-life of 5570 years and counting back from AD 1950.

Now almost four decades later, we note that the Westersingel laboratory, which was established and equipped by John, has now also been demolished, and in addition to GrN, GrA has also come into effect with the introduction of accelerator mass spectometry (AMS) in Groningen.[4]

Thanks to De Vries[5] and Vogel,[6] we have learnt about the natural ^{14}C variations in the past. Since then a few laboratories have been involved in high-precision analyses of tree rings, which finally resulted in calibration procedures to obtain BC or AD dates from conventional ages. Radiocarbon has come a long way, largely in line with the scientific career of John Vogel. In this contribution we look back in history and discuss ^{14}C variations at several timescales, with emphasis on the work in Groningen and Pretoria.

The 20th century

During the last century, the atmospheric ^{14}C signal has been disturbed mainly by two anthropogenic influences: the Suess and nuclear bomb effects.

The Suess effect is caused by the injection of CO_2 into the atmosphere by burning ^{14}C-free fossil fuel, which dilutes the natural ^{14}C concentration. This contribution, about 2 % in 1950, caused the original confusion in the application of the ^{14}C dating method by De Vries, as he started to use peanut shells subjected to the Suess effect as a modern reference material. After recent wood had been studied more carefully, it became possible to correct for the first results, changing the Groningen ^{14}C date designation from Gro to GrN.[3]

Carbon-14 in atmospheric CO_2 has been monitored directly at several locations around the world, in some cases dating back to the beginning of the nuclear era. Among these laboratories were Heidelberg[7] and Groningen,[8] while Vogel also took care to have air-CO_2 samples collected in Pretoria. The atmospheric measurements, first at the Westersingel laboratory and later at a television transmitter tower in nearby Smilde, were discontinued at the peak of bomb testing (November 1963) but resumed in 1974.[9]

Being one of the few people who has lived a considerable part of his life in both hemispheres, John Vogel was the first systematically to study ^{14}C in tree rings from the northern and southern hemispheres. The first results from Europe, North and South America, South Africa and India, presented at a Nobel symposium,[6] showed that the average ^{14}C concentration in the southern hemisphere is 4.5 ± 1 ‰ lower than that in the northern. More recently, a comparison of wood samples grown during the last century in the Netherlands and South Africa[10] yielded a more precise result of 5.14 ± 0.59 ‰, corresponding to 41 ± 5 years. This north–south gradient in ^{14}C forms a crucial input for studying the global carbon cycle and atmospheric transport.[11]

The Tunguska meteorite

In 1908 a very large meteorite hit Siberia. It was considered possible that this event caused strong and local production of ^{14}C in the atmosphere or even simultaneous production of ^{14}C in tree rings in the vicinity. In order to study this, Vogel undertook an analysis of radiocarbon in the wood of local trees. The outcome was negative.[12]

The ^{14}C content of the rings corresponding to the years 1894 to 1917 did not show a significant increase during that period. By coincidence, tree rings dating from 1907, 1908 and 1909 are presently being measured at the request of Russian colleagues, and were reported at a conference dedicated to the 90th anniversary of the Tunguska event in June 1998.[13]

The last millennium

Atmospheric ^{14}C content has been affected not only by burning of fossil fuel and nuclear weapons testing in the atmosphere. ^{14}C variations can also have natural causes. These natural variations were indirectly observed in tree rings from European and American wood.[5,14] These variations are now — at least for the later part of the Holocene — understood by variation in radiocarbon caused both by a changing geomagnetic field (time scale of millennia) and solar effects (time scale of centuries).

Because of these ^{14}C variations, there is a difference between ^{14}C time (in years BP) and real historical time (BC/AD). These two timescales are related by calibration, that is, ^{14}C measurements for absolutely dated (by dendrochronology) wood. A tree-ring calibration curve has been now constructed well into the Preboreal.[15,16]

De Vries effect and Suess wiggles

The century-scale variations, first observed by De Vries in 1958,[5] manifest themselves in the ^{14}C age-versus-real time curve as 'wiggles' originally drawn by Suess with 'cosmic schwung'.[17] The first real proof of these wiggles was obtained at the Groningen laboratory on tree rings from German oak, dendrochronologically collected and dated by Bernd Becker from the Hohenheim tree-ring laboratory.[18] In this study, single tree rings were analysed with an accuracy of about 10 years, producing a truly high-precision calibration curve, that is, a curve from which ^{14}C ages can be translated into real time.

The largest part of the Holocene calibration curve is now based on bidecadal data, i.e. per 20-year rings. Different types of calibration curves are now widely used in computer programs.[19,20] Most curves merely connect the data points. However, Vogel and Talma[21] have preferred to present smoothed curves. This discussion becomes more and more obsolete when higher resolution curves are produced. Such datasets (tree-ring resolution <3 years) are available for two periods: the last five centuries[22] for American wood and the 2nd/3rd millennia BC by combining the partially overlapping data from Pretoria and Groningen, measured for German oak.[23]

The calibration procedure in itself

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generates interesting mathematical questions. For instance, textbook statistics transforms normally distributed measurements. Calibration programs[19,20] produce different possibilities, and have generated correspondence between Groningen and Pretoria on the validity of the programs. It turned out, after recruiting help from the Groningen mathematics department, that the statistics can be understood from the Bayes theorem, and that the calibration programs are correct after all.[24]

The last 50 000 years

Tree-ring calibration has been pushed back to about 9900 BC.[25] For older ages, only isolated trees are known from Tasmania, for which late glacial ages were obtained.[26] There is, however, still a long way to go before these trees are analysed and dated dendrochronologically, if possible at all.

Thus, to obtain calibration information further back in time, beyond the Holocene, one has to look for other records that can be dated both by ^{14}C and by an other, independent (and one hopes absolute) dating method. One of the first papers dealing with this subject was by John Vogel.[27] A stalagmite from South Africa was dated by both ^{14}C and $^{234}U/^{230}Th$ disequilibrium dating, yielding information on ^{14}C variations during the Upper Pleistocene. The data suggest a peak in the production rate of about a factor of 2 around 34 000 BP. This peak has been observed later in records for another cosmogenic isotope, ^{10}Be, in ice cores[28] as well as in sediments[29] Explanations range from drastic geomagnetic effects[30] to supernova explosions.[31]

Apart from U/Th measurements, much calibration work has been attempted with varves. Until recently, they could extend the tree-ring calibration curve by only a few millennia (reviewed in ref. 32). Recently much progress has been achieved at Groningen. By measuring 250 AMS samples from a varve sediment from Japan, the 'calibration curve' could be pushed back in time to 45 000 BP,[33] resulting in the first high-resolution curve for the Upper Pleistocene.

While the Japanese varve paper was under review, Vogel and Kronfeld[34] published additional U/Th calibration data for the stalagmite. The resolution of this curve is less than that of the varve data. While our varve record confirms the 34 000 BP peak, the general trends of both curves are deviating. Much work remains to be done; all Late Pleistocene records are problematic in the sense that valid questions can be raised about them. For instance, on the one hand the speleothems can potentially suffer from questionable dating for both ^{14}C (uncertain initial and non-constant ^{14}C content) and U/Th (?detrital Th contamination). On the other hand, the varve record is not absolute but floating; although it is fitted to the tree-ring part of the calibration curve, varve counting can be uncertain and missing varves are a notorious problem, especially in the older parts of the sediment.

Concluding remarks

Thanks to Hessel de Vries and John Vogel, the Groningen laboratory has been, since the advent of radiocarbon studies, at the frontier of ^{14}C dating. The conventional proportional CO_2 counter facility has expanded over the years and today produces more than 1000 dates annually. ^{14}C research meanwhile began to benefit from AMS, in operation since the end of 1994. The machine has a throughput of more than 2000 dates annually.

As for the chronology in prehistory, the ^{14}C revolution in the 1950s has been described in a seminal paper by Vogel and Waterbolk.[35] The archaeological chronology of the Netherlands was expanded later by Lanting and Mook[36] in the 1970s, and is presently being revised.[37]

For the geosciences, a similar story can be told by Vogel and Zagwijn[38] as well as by Behre and Van der Plicht.[39] Chronologies were later extended to the Eemian using U/Th series disequilibrium dating.[40,41]

Not only is establishing chronologies crucial, it appeared that ^{14}C variations are important for establishing a proper understanding of geological history in terms of natural isotopes, and establishing the correct timescales. Without these variations, our science would be less exciting indeed.

After Vogel left Groningen for Pretoria in 1967, we collaborated further in research projects involving, for example, combined GrN and PtA tree-ring data, statistical questions and interpretations for calibration procedures, and the Late Pleistocene calibration.

The Groningen Radiocarbon Laboratory has made important contributions to our field of science, and a substantial part of the credit goes to John Vogel. At Heidelberg, Groningen and Pretoria, he has pioneered almost all applications of ^{14}C, U/Th and stable isotopes, which we considered to be beyond the scope of this contribution. Not only did John develop and handle the techniques, he has become an archaeologist and a hydrologist as well.

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