Uranium/thorium dating of late Pleistocene peat deposits in N.W. Europe.

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Publication date:
1992

CHAPTER 1
INTRODUCTION

Dating of peat by means of uranium series disequilibrium, ($^{230}Th/^{234}U$, also known as UTD) with special emphasis on dating the early Weichselian interstadial and last interglacial peats in north western Europe, is the subject of this study.
In principle it is possible to date peat up to 350 ka by UTD, which provides us with an important extension of the ^{14}C timescale (with a range up to ± 50.000 BP).

The first applications of uranium series dating were to deep sea sediments. Joly (1908) observed higher Ra contents in deep sea sediments than in sediments of the continental shelf. He concluded that Ra was scavenged out from sea water by deposition of suspended matter. Later Piggot and Urry (1942) showed that the Ra excess was supported by an excess of ^{230}Th. In the 1960's the cyclicity of interglacials and glacials, as predicted in the Milankovitch theory on the cyclicity of the ice ages, was recognised in the ^{18}O isotope record of deep sea cores. The chronology for this new record was provided by uranium series dating of fossil coral reefs in Barbados (Mesollela, 1969), New Guinea (Veeh, 1970) and direct dating of deep sea sediment.

Cherdyntsev was the first who studied the possibilities of uranium series dating of terrestrial materials such as peat, speleothems and travertines. It was not until the publication of his translated work in 1971 that his work received the attention of a large group of researchers throughout the world. The first results of peat dating were published in 1980 (Vogel & Kronfeld, 1980). Vogel's publication and more recently Kafri et al. (1983) and De Vernal et al. (1986) showed very straightforward dating of organics with simple corrections for the presence of thorium at $t=0$ and an assumed closed-system behaviour of the material to be dated. Van der Wijk (1986,1987 and 1988) studied the corrections for detrital thorium in fossil peat samples in more detail, his work shows in general a good agreement between radiocarbon ages and U/Th ages obtained for peat samples from several sites in N.W.Europe. This is especially true if no corrections are applied for the presence of detrital thorium.

After van der Wijk had completed his studies a new project was funded by the letherlands Organisation for Scientific Research (NWO) section Earth Sciences AWON), grant number: 751.357.011, entitled: U/Th dating of the Eemian interglacial ı N.W.Europe and the correlation with the palaeotemperature curves deduced from eep-sea cores. This study results in the present thesis. The number of potential sites is umerous. However, only a small fraction of the sites in N.W.Europe turned out to be ateable by UTD. The main subject became the investigation of open-system behaviour[1] f peat layers and the corrections for detrital thorium. This more thematic approach was ecessary since the first results were in obvious contradiction with geological and/or alaeoecological evidence. For some unknown reason all obtained (for detrital Th orrected) ages turned out to be too young. This problem was already noted by Vogel n 1980, but not recognised as such. He stated that:

> "the dates for the samples from Bavaria suggest that the Riss/Würm[2] Interglacial of the northern Alps should be correlated with the whole of Stage 5 of the oxygen isotope record preserved in the deep sea cores, and not with stage 5e as various authors have propounded. It would seem to be a matter of urgency that this problem be investigated further by means of the new dating method proposed here."

The end of this interglacial was dated at 86 - 89 ka, which to our present knowledge is ıbout 25.000 years too young. Van der Wijk also recognized this problem, but solved it y proving that the uncorrected ages can yield reliable UTD dates. However, his omparison between ^{14}C and U/Th ages (van der Wijk et al, 1988) for example for the Tervola site in Finland is now believed incorrect. The ^{14}C ages for Tervola (Su-688: 8.000 +4100 -2400 and Su-689: 48.000 +3500 -2400 BP) are very close to the detection imit and are in disagreement with the existing Thermoluminescence dates (Hütt et al,

[1]Open system behaviour is the free exchange of uranium between peat and ground water after leposition.

[2] The Riss/Würm interglacial is the Bavarian equivalent of the Eemian interglacial in N.W.Europe. See able 1.1.

1982) for both the overlying and underlying deposits. Therefore, the U/Th ages have to be older. The present study shows that the discrepancy between the obtained young ages and the expected older ages (van der Wijk et al., 1988) was due to the short leaching time and isotope fractionation during the leaching procedure. As the spiking of samples took place after the separation of the leachate and residue the fractionation i.e. the depletion of ^{230}Th could not be observed. A brief explanation and comparisons are presented in chapter 4 of this thesis.

The assumption that a peat layer behaves as a geochemical closed system was studied in detail. After the first results new sampling techniques were tested both in the field and the laboratory. After the analyses of several sites in detail we were able to construct a suitability diagram for the U/Th dating of peat. This makes a decision on how to sample, treat the material and evaluate the results much easier.

By careful sampling and evaluation of the obtained ages for early Weichselian and last interglacial peat samples, it was possible to construct a new chronology for the Late Pleistocene in North Western Europe. Correlations were made with other chronologies and records.

ON GLACIALS AND INTERGLACIALS; A SHORT INTRODUCTION.

In his orbital theory on the causes of the alternating glacial (cold) periods and interglacial (temperate, warm) periods, the Yugoslavian astronomer Milankovitch predicted a cyclicity (Milankovitch,1941). His theory consists of three components that change the intensity of the seasons. The first, the tilt of the earths axis (between 21.5 and 24.5°), has a periodicity of 42.000 years and intensifies the seasons in both hemispheres. The second is the eccentricity of the earth orbit (from a near circle to an eccentric ellipse) with a periodicity of 100.000 years. The growing distance to the sun will intensify the season in one hemisphere and modify the seasons in the other. The precession or wobble is the third component. The precession of the earths axis is caused by interaction by the first two and determines whether a summer falls near or at a far point in the orbit and has a cyclicity of 23.000 years. For a long time there was a lack of an independent record of ice-age timing to test the cyclicity as predicted by Milankovitch.

Emiliani (1955) produced the first more or less complete record of the

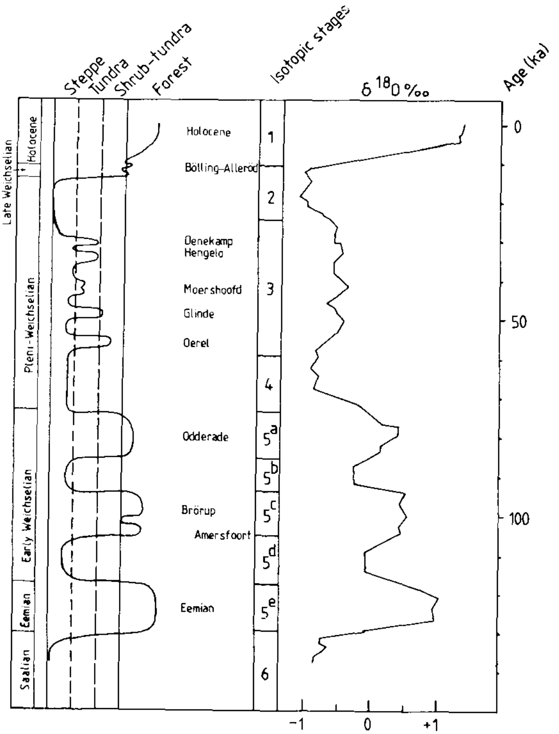

Fig. 1.1. *Schematic diagram showing the correlation of the Last Interglacial/Glacial cycle in N.W.Europe (and its vegetational characteristics) (after Behre, 1989) and the generalized ^{18}O deep sea record (after Martinson et al, 1987).*

alternations of interglacials and glacials. He studied the isotope composition of single cell marine organisms called foraminifera. It is now understood that the abundance ratio between the natural oxygen isotopes $^{18}O/^{16}O$ in the carbonate shells of foraminifera is closely related to the amount of water locked in glaciers and ice-sheets. As water evaporates from the relatively warm low-latitude ocean and moves away from the source, its ^{18}O returns preferentially to the oceans as precipitation. The snow that falls on the distant high altitude glaciers and high latitude ice-sheets is therefore relatively depleted in ^{18}O and as these glaciers and ice-sheets grow the oceans become more and more enriched in ^{18}O. This higher $^{18}O/^{16}O$ abundance in sea water propagates into carbonate shells of dead foraminifera later recovered from marine sediments. By analyzing drilled

TABLE 1.1. The Sub-Division of the Late Quaternary Biostratigraphy in N.W.Europe.

Netherlands	Great Britain	Ireland	Sweden	Finland	France	N. Germany	Greece
Holocene[1]	Flandrian	Littletonian	Holocene	Holocene	Holocene	Holocene	Holocene
Weichselian[2]	Devensian	Midlandian	Weichselian	Weichselian	Weichselian	Weichselian	
Odderade[3]	Upton Warren		Jämtland		St. Germain II	Odderade	Elevtheroupolis
Brörup/ Amersfoort[3]	Chelford	Aghnadarragh	Interstadial complex	Peräpohjola	St. Germain I	Brörup	Drama Doxaton
Eemian[1]	Ipswichian	Gortian?	Leveäniemi	Tepsankumpu	Eemian	Eemian	Pangaion
Saalian	[2]Wolstonian	Munsterian	Saalian	Saalian	Saalian	Saalian	Neakaterini

1) Interglacials, 2) Glacials, 3) Interstadials.

cores from the sea-floor, Emiliani found that the isotope ratio rose and fell according to the cycles predicted by the Milankovitch theory. This new deep-sea chronology is divided in odd and even "isotope stages". The warm interglacial stages have odd numbers and relatively low $^{18}O/^{16}O$ ratios (see figure 1.1.). The cold glacial stages have even numbers and relatively high $^{18}O/^{16}O$ ratios.(see figure 1.1.).

In N.W.Europe the subdivision of the Last Interglacial/Glacial cycle has been based for a considerable period of time on the lithostratigraphical evidence of the positions of end moraines (so-called morphostratigraphy). As all the ice-advances were described locally, every region or country gave different names to the same interglacials and glacials. In table 1.1 the most important used names of the Last Interglacial/Glacial cycle are given.

During the last Glacial period N.W.Europe was partly covered by ice-sheets (see figure 5.1.). Outside the area of glaciation a lot of organic deposits were preserved. Inside the area of the maximum Weichselian glaciation less organic deposits were preserved due to glacial erosion. As deduced from its pollen and macrofossils these organic deposits indicate slightly cooler conditions than today for certain intervals within the last Glacial. These organic deposits are often sandwiched between full glacial or periglacial sediments and indicate climatic amelioration within the last Glacial period. These temperate stages are called interstadials. A glacial period can thus be subdivided into stadials (full glacial conditions) and interstadials (temperate conditions). The most important interstadials of the N.W.European mainland are mentioned in figure 1.1.; the N. European and British equivalents are to be found in table 1.1.

At some places complete records embracing several interglacial/glacial cycles are documented. The records are called Long Terrestrial Records and are the terrestrial equivalents of the deep-sea cores. Important Long Terrestrial Records in Europe are the Tenagi Philippon (Wijmstra,1969), Padul (Florschütz et al.,1971), La Grand Pile (Woillard,1975) and Les Echets (de Beaulieu and Reille,1984). As site-to-site correlations are often problematic, much of the correlations are based on the ^{14}C chronology (of the last 50.000 years only) (Woillard and Mook,1982) and on the recently published papers on the biostratigraphy of the Last Glacial by Behre (1989) and the special issue on the Last Interglacial/Glacial cycle of Quaternary International (Schlüchter and Rutter,1989).