Radiocarbon Dates for upper Eem and Würm-interstadial samples

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1 text-fig.

Zusammenfassung: Es wird eine Übersicht gegeben von C^{14}-Daten von Eem-interglazialen und Würm-interstadialen Proben von Loopstedt (Schleswig-Holstein), Amersfoort (Niederlande), Lebenstedt, Roggendorf, Karrestobel, Geesthacht, Upton Warren (England), Fladbury (England) und von einer Serie von Holzkohle-Proben aus den Lößgebieten. Sogar die jüngsten Eem-Proben zeigten keine signifikante Aktivität (Alter mehr als 53 000 Jahre). Die Daten stellen das Interstadial Würm II/III (fossiler Boden von Paudorf) auf rund 26 000 Jahre vor heute. Die Daten für das Interstadial I/II sind noch teilweise unzuverlässig, weil Verunreinigung mit rezentem Material (Wurzeln, Humus) für diese alten Proben relativ viel für die totale Aktivität beiträgt. Obwohl die Periode zwischen 33 000 und 42 000 Jahren (vor heute) ziemlich kalt war, ist es nicht unmöglich, daß es sich hier um das Interstadial W I/II handelt. Ein wärmeres Interstadial endete vor ungefähr 48 000 Jahren. Die Daten stimmen mit Emilianis Paläotemperaturkurve (und Milankovitchs Zeitskala) überein.

Summary: Radiocarbon dates have been obtained for Eem-interglacial and Würm-interstadial sections from Loopstedt (Germany) and Amersfoort (Netherlands), for a few isolated peat samples from North-Western Europe and for charcoal samples from Austrian loess regions. Even the upper part of the Eemian proved to be too old to give a significant activity (age more than 53000 years).

According to the present results the interstadial Würm II/III (fossil soil of Paudorf) occurred at about 26000 years ago. Because of various contaminations of the samples (infiltrated humus, rootlets etc.) the results for the interstadial Würm I/II are somewhat controversial, but it is not impossible that it should be identified with the fairly cool period between 33 000 and 42 000 before present. A somewhat warmer interstadial ended about 48 000 years ago. The results fit well with Emilianis paleotemperature curve.

1 The measurements

The measurements described below were made in our large counter. The net count for recent carbon is 36.9 per minute. The present background is 2.4 per minute. It varies 0.05/min for a variation in barometer pressure of 1 cm Hg. For details see (1,2). In the calculations a halflife of C^{14} of 5570 years has been used. The error given is the standard deviation; it includes the error in the background as well as the error in the sample count. Since the background, corrected for barometer effect, was very constant, several background measurements could be averaged. This leads to a relatively small error in the background. The dates given represent the average result of at least two measurements, which, as a rule, are not reported separately.

Our measurements of old samples have demonstrated the importance of an appropriate pretreatment, developed to remove infiltrated organic material. All samples were boiled first with a one per cent solution of hydrochloric acid. After washing with distilled water they were heated at least one night at 90° C with one per cent sodium hydroxyde. The sample was washed then, one per cent hydrochloric acid added, heated again and washed up to a pH of 4 or more. The extracted humus was precipitated with hydrochloric acid, washed and dried.

Before considering the dates obtained, the individual samples will be discussed.

de Voorst, North Eastern Polder (former Zuidersee). This series of samples was collected from a well exposed section of the Eemian at de Voorst (3). Dates from 43000 to "infinite" were obtained from samples between the beginning of the climatic optimum of the Eem Interglacial and the end of the Riss Glacial. The samples have been

measured several times in a period of about one year and a half (4,5). In that period the background of the counter and its variation with barometric pressure has been reduced appreciably (1,2). Though the later measurements were more accurate, all results agreed. So the dates had to be accepted as far as the radiocarbon measurements were concernced, but the much older dates obtained for the samples presented below prove that the samples from de Voorst had been contaminated by young material. The nature of the contamination is unknown. Whatever the origin may be, the present samples are a priori more reliable since they come from layers covered by at least 2.5 meters of sand and other deposits, whereas the profile at de Voorst hardly had any protecting layers at all.

Loopstedt, North-Western Germany, close to the town of Schleswig. The profile at Loopstedt is well known. The present samples came from the southern side of the lake; they were submitted by Professor SCHWABEDISSEN (Köln). New pollendiagrams have been prepared by Dr. KOLUMBE (6). They were put at our disposal already before publication.

The dates obtained were:

sample *d*	depth about 4.5 metres	GRO	1254	age	> 53000
sample *e*	depth 3.65 m	GRO	1242	age	39800 ± 1000
sample *f*	depth 3.00 m	GRO	1234	age	37630 ± 1000
sample *g*	depth 2.40 m	GRO	1270	age	37050 ± 500
sample g^a		GRO	1290	age	35400 ± 400
sample *G*		GRO	1329	age	45300 ± 2000
sample G^a		GRO	1337	age	45300 ± 2000

All samples have been measured at least twice, but only the average value has been given since the results agreed within the limits of error. Sample *d* represents the top of the Eemian, samples *e-g* are assigned to the interstadial Würm I/II. The peat layers *e-g* were embedded in sand; the deposits on top of *g* were also sand. Sample g^a is identical with *g*, but it has not been treated with alkali; consequently it could contain infiltrated (younger) humus. The difference measured, though it is not very large, may be ascribed to this effect. We supposed the result for *g* to be reliable, but on a visit to Loopstedt, together with Dr. ANDERSEN (Kopenhagen), Dr. KOLUMBE (Hamburg) and Prof. WATERBOLK (Groningen), it was observed that the layers *e-g* certainly contained recent roots which were not removed by the chemical treatment. Therefore new samples were collected, from which the roots were removed by a special mechanical method. Part of the roots were collected, and this amount was already large enough to account for at least one half of the activity of sample *g*. After this mechanical treatment the sample was given the normal chemical treatment; the material left was dated (sample *G*). Part of the extracted humus (the less mobile fraction) was also dated (sample G^a). For the present purpose we need only consider sample *G*; the date obtained demonstrates well enough that the actual age of the interstadial is much higher than 40000.

Recently the author has collected charcoal from a sand lens in the upper peat layer (*g*). It was carefully examined under the microscope; none of the pieces contained rootlets. According to Dr. W. VAN ZEIST (private discussion) the vessels of coniferous wood are generally too small even for the finest roothairs. No charcoal from broad-leaved trees was present.

Loopstedt g, charcoal Gro 1365 age 50000 ± 2000

Wierden and Eefde, province of Overijsel and Gelderland, Netherlands. From open pits, well below ground water level, Prof. FLORSCHÜTZ collected well preserved wood. By the species found (for Wierden see 3) the climate could be identified as pleniglacial.

Wierden	Gro	1359	age	38100 ± 500
Eefde	Gro	1367	age	33070 ± 300

Together with these samples the date for another pleniglacial sample (B r e d a , Gro 936, age 32000 ± 900) should be mentioned. For details see (5).

A m e r s f o o r t (Netherlands). As might be well known, the vicinity of Amersfoort (the Eem-valley) has provided the type locality of the Eemian Interglacial Stage (North American S a n g a m o n). Though during the last 50 years many bailer borings had been made here, which did reach the Eemian deposits, no reliable well sampled borings from this locality were available. Guided by the data previously obtained, Dr. ZAGWIJN (Netherlands Geological Survey) executed a number of new borings, which were sampled as detailed as possible by a special coring apparatus. Furthermore samples were obtained from an excavation at Amersfoort, some eight meters deep, dug in purpose for the construction of a tunnel below a railroad crossing. The full discussion of the results obtained at this section and the borings will be published in due course; the various investigations are still carried on at this moment.

The geological and pollenanalytical data obtained by ZAGWIJN can shortly be summarised as follows. Between the Eem Interglacial and what is interpreted as Würm I in fig. 1, there is at least one „interstadial" which may, perhaps, be correlated with the hump at 80000 years in fig. 1 (EMILIANI's time scale). It is of interest to note that BRANDTNER (7) finds two interstadials between Würm I and Eem. Whatever the correlation may be, the age of these interstadials is more than 53000 years (Amersfoort XII and XIV).

Amersfoort XII (wood)	GRO	1248	
	GRO	1252	
	GRO	1257	> 53000
	GRO	1268	
Amersfoort XIV (wood)	GRO	1280	> 53000
	GRO	1285	
Amersfoort XI (peat)	GRO	1259	age 34730 ± 700
	GRO	1276	age 34730 ± 500
Amersfoort XI extracted humus	GRO	1106	age 20470 ± 230

Sample XII came from the first interstadial (?) above the E e m.

Sample XIV was younger than sample XII. Four peat samples from the same period above the Eem also gave ages more than 53000.

The only „recent" sample obtained up to now in Amersfoort was Amersfoort XI, originating from the pit, from a highly kryoturbate loamy peat layer; the pollenspectrum pointed to a very cold climate (Pleniglacial). Though the sample was covered by about four meters of sand, infiltration of young humus was suspected. Therefore humus was carefuly extracted. The date of sample XI refers to the remaining material. The humus is appreciably more active than the rest of the sample. This means that part of the humus has infiltrated, probably from the Alleröd layer which was well developed about 70 cm under the present surface. Since the NaOH-treatment was very rigorous, the result obtained for sample XI ist probably reliable.

F a r m s u m , 40 km North East of Groningen, Netherlands. The peat layer was separated by about one meter of sand from 7000 years old peat, which was covered with clay.

Farmsum II *a* (upper side of peat)	GRO	1278	age 33300 ± 400
Farmsum II	GRO	1279	age 37900 ± 1000
Humus from II	GRO	1133	age 29980 ± 500
Farmsum I *a* (lower side of peat)	GRO	569	age 35860 ± 1000
Farmsum I	GRO	1324	age 43700 ± 700

The samples marked with *a* had been given only an HCl treatment; they are appreciably younger by infiltration of young humus. The extracted material also contains humus of

the sample itself but the low age of the humus fraction indicates that more or less selectively, infiltrated, more mobile, material has been extracted. Because of the large amount of infiltrated material it is not possible to claim that it has been removed completely. So the peat may still be older than 43700 years. The pollendiagram does not exclude that the sample is late Eem, but it may also be correlated with Loopsted *e*-g. Because of these uncertainties this peat layer will not be considered in the discussion (2). The samples were collected by W. ZAGWIJN (Geological Survey, Haarlem) who also made the pollendiagrams.

Geesthacht, near Hamburg (Germany). During excavations in 1955 a good profile was obtained from which several samples were taken by Dr. SCHÜTRUMPF. The samples from what was probably Eem were not studied since they would be too old. At depths of about 5 and 6 meters respectively, huminous layers were found which were preliminary ascribed to Alleröd and Bölling. In our laboratory we found some charcoal in the upper sample which is typical for the end of the Alleröd in the Netherlands; the radio carbon date also confirms this assignment (sample II), though the age is somewhat too low. This may be the correct date but the date may also have been affected by a small infiltration of recent humus since the humus content was very low. Sample III turned out to be much older than Bölling; it is synchronous with the fossil soil of Paudorf (see discussion). Because of the stratigraphy, and because of the fairly young age of the sample, the date of III can hardly be affected by infiltration of recent material.

Geesthacht II, coarse sand, containing about 1 per cent of humus	Gro	1507	10150 ± 80
Geesthacht III, loamy sand with humus	Gro	1515	26600 ± 300

The sand between II and III contained a layer of stones („Windschliff"). In a discussion Dr. DÜCKER (Kiel) pointed out that this is typical for Würm III at the present site; this agrees very well with the dates obtained.

Upton Warren and Fladbury (near Birmingham, England). These samples were submitted by Prof. SHOTTON of Birmingham. They consisted of organic material in a layer of loamy sand in a gravel pit; the organic material was separated from the sand by passing the sample over a sieve which transmitted the sand. Both samples are regarded on geological grounds as of similar age, both being associated with the retreat of the „Irish Sea Glacier", which is itself fixed by the terrace chronology as the first glaciation following the Eem interglacial. The Upton Warren sample dates from a period shortly after the maximum of the ice leading towards the interstadial which is generally correlated with Würm I/II.

Upton Warren *a*	GRO	595	age 41500 ± 1200
Upton Warren	GRO	1245	age 41900 ± 800
Extracted humus	GRO	1063	age > 40000
Fladbury	GRO	1269	age 38000 ± 700

Sample Upton Warren *a* was dated with acid pretreatment only; since the date obtained is essentially the same as after complete pretreatment and since the extracted humus was also old, infiltration of recent humus is improbable.

Chelford (England). Though the correlation was not unambiguous, it was supposed that this sample was correlated to Loopstedt *e*-g; the evidence was obtained from pollenanalysis. The sample was collected by Dr. R. WEST (Cambridge) who also made the pollenanalysis; it was submitted by Prof. WATERBOLK (Groningen). The sample consisted of well preserved wood.

The result was

GRO 1292 age > 53000

Lebenstedt (near Braunschweig, Niedersachsen, Germany), collected by Dr. TODE, submitted by Prof. SCHWABEDISSEN, Köln. The sample consisted of gyttja and humus.

The sample preceded a very cold period which is probably Würm I. For further details see discussion and (8).

Lebenstedt GRO 1219 age 48300 ± 2000

Senftenberg (Austria). Sample of charcoal, submitted by Dr. BRANDTNER (Vienna.) It was found under a fossil soil identified by BRANDTNER as the interstadial Würm I/II (Göttweig fossil soil).

Senftenberg GRO 1217 age 48300 ± 2000

Roggendorf (Austria). Collected and submitted by BRANDTNER (Vienna), from a peat layer which was supposed to represent the interstadial Würm I/II (see 9). On top of the layer considered here (thickness about 1 meter) secondary material was found, even tertiary pollen. Infiltration of recent material, including roots, was nearly impossible.

upper side of peat GRO 1301 age 7760 ± 120
lower side GRO 1198 age 11400 ± 90

Obviously the peat is of holocene and late-glacial age; according to Prof. WATERBOLK, Groningen, (private discussion) the pollendiagram could fit with the present dates. A more detailed discussion will be given by BRANDTNER.

Pollau (Moravia, Tschechoslovakia). Charcoal from Gravettian settlement, just above the „Paudorf" fossil soil. Sample *a* was submitted by Prof. SCHWABEDISSEN (Köln) and collected by Dr. KLIMA. Sample *b* was submitted by Dr. BRANDTNER (Vienna). Since KLIMA (10) had shown that in this region sometimes fossil fuel had been used even at that time, BRANDTNER suggested to use a sample *(b)* consisting of carefully selected charcoal. Since Pollau *a* (which was dated first) is older than both Pollau *b* and Unterwisternitz (see below) it is not improbable that sample *a* has contained some fossil carbon.

Pollau *a* GRO 1272 age 26400 ± 230
Pollau *b* GRO 1325 age 24800 ± 150

Unterwisternitz (Moravia, Tschechoslovakia). Charcoal from Gravettian settlement in upper half of the „Paudorf" fossil soil. Submitted by Prof. SCHWABEDISSEN from older excavations by ABSOLON.

Unterwisternitz GRO 1286 age 25600 ± 170

Aggsbach (Austria). Charcoal from Gravettian settlement ("Eastern Gravettian"), collected by BRANDTNER in 1957.

Aggsbach *a* GRO 1327 age 22450 ± 100
Aggsbach *b* GRO 1354 age 25540 ± 170

The date expected by BRANDTNER was about 30 000 years, i. e. equal to Willendorf (see below). Since sample *a*, which had been given the normal pretreatment, came out much younger than anticipated, another part of the sample was given an extra treatment by which also roots would be removed completely. Sample *b* is still "too young". Moreover it is hard to believe that the difference between *a* and *b* is due to the removal of rootlets, since hardly any rootlets were seen in the sample, nor at the site of the excavation, whereas sample *a* should have contained 2 per cent (by weight) of roots in order to explain the difference. The difference may also be due to an inhomogeneity of the sample.

Willendorf (Austria). Charcoal from Aurignacian settlement. By a mistake in the museum, sample 7 was originally assigned to the same site as the sample from layer 4. Recently it was found that 7 came from another site (Willendorf I instead of Willendorf II). It corresponds to about culture layer 7 in the site II. According to BRANDTNER (private communication) sample 4 should be assigned to a stadial, whereas sample 7 is somewhat younger. Willendorf 4 was submitted by Prof. SCHWABEDISSEN and collected by

Felgenhauer in 1954. Willendorf 7 was submitted by BRANDTNER from an older excavation by OBERMAIER and BAYER; it was carefully checked that it did not contain fossil coal.

Willendorf 4	GRO	1273	age 31840 ± 250
Willendorf 7	GRO	1287	age 30310 ± 250

Istallóskő-cave (Hungaria, Bükk mountains). Charcoal from typical Aurignacian settlement. (Details can be found in 11 u. 12). The charcoal contained some recent wood splinters and seeds. Therefore only good pieces of charred wood were selected; the sample obtained in this way did not contain enough carbon even for the medium size counter. It was only given an acid pretreatment since infiltration of humus was improbable; alkali treatment would have removed an important part of the small sample. The sample was collected by Dr. VÉRTES and submitted by Prof. SCHWABEDISSEN.

Istallóskő-cave	GRO	1501	age 30670 ± 500

So it is hardly older than the Aurignacien from Willendorf. It is assigned to the interstadial Würm I/II.

Karrestobel b. Baindt (Kreis Ravensburg, Württemberg, Germany). The sample came from a peat layer in the Würm moraine (see 13). Further studies are required to come to a more detailed assignment; the date obtained suggests that the present sample comes from the interstadial Würm II/III. At the same locality about six peat layers occur. The sample was submitted by Dr. H. GROSS, Bamberg.

Karrestobel	GRO	1277	age 28840 ± 300

2 Discussion

The series of samples between about 25000 and 31000 years is very consistent, probably since recent contamination has not yet such a large effect as for samples which are more than 40000 years old. The dates for Pollau and Unterwisternitz fix the end of the formation of the fossil soil of "Paudorf" at about 25000. None of the samples marks the beginning of this period (Würm II/III) unless Karrestobel (29000) could be taken for this. Willendorf was already older than the beginning of the Paudorf soil. Considering EMILIANI's paleotemperature curve (14) there is no doubt that this interstadial corresponds to the short and low maximum at 28 000 in fig. 1. Since mixing processes at the bottom of the ocean tend to flatten out short peaks, the actual duration of the formation of the Paudorf soil was probably much shorter. The thickness of the soil also points to a fairly short interstadial.

The older dates offer more problems. The dates for Breda, Eefde, Amersfoort XI and Wierden suggest that it has been cold from the Paudorf interstadial up to at least 38000 years ago, whereas the results for Fladbury and Upton Warren, with their cold fauna, allow to extend the cold period up to at least 42000 years ago. The cold climate is not compatible with the pollendiagram for Farmsum; this supports the conclusion already arrived at that the dates for Farmsum are not reliable. Moreover a new pollendiagram from the same pit gave more conclusive evidence that the original assignment to late Eem was correct. Though the period between 33 000 and 42 000 was cold in North Western Europe, it was probably not as cold as, say, during the period between 24 000 and 12 000; from this period no organic material at all was recovered up to now in North Western Europe. Since Willendorf and Istalloskő-cave (about 30 000) are probably not much younger than the so called Göttweig interstadial, this interstadial could well be correlated with the period between 33 000 and 42 000. According to Dr. BRANDTNER (private discussion) the Göttweig interstadial was fairly cool and so it is not impossible that it is synchronous with the colder period further north.

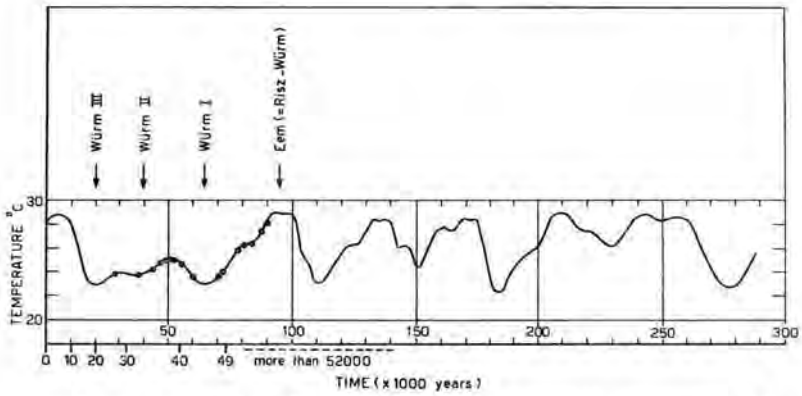

Fig. 1. Paleotemperature curve (from EMILIANI, 14). Upper time scale from EMILIANI. Lower time scale, up to 50 000 years according to C^{14} dates. The group of samples around 40 000 was not reliable, however (see text), and EMILIANIS scale may be correct. Not all samples around 26 000 have been inserted (by points).

The next dates to be considered are Senftenberg, Lebenstedt and Loopstedt *G* (charcoal). Loopsted was correlated by its pollendiagram to the new diagram of Brörup (ANDERSEN, 15). A short report on the Brörup dates is in preparation (16); for the present discussion it is sufficient to state that all dates obtained were "more than 53 000". This does not exclude that Loopsted *G* may be around 50 000 since the upper interstadial in Loopsted is somewhat more complete than in Brörup. New borings by Dr. ANDERSEN gave a more complete sequence. Preliminary measurements of the end of this interstadial gave 48 000 years, in agreement with the Loopstedt date. According to the references given Lebenstedt marks the beginning of a cold period; its date puts it nicely at the end of the Brörup interstadial.

It is obvious that Senftenberg (48 000 years) does not fit at all since it was supposed to date the e n d of a stadial (W I). The charcoal was deposited in the loess before the Göttweig-weathering occurred (comment by Dr. BRANDTNER). Its age (48 000) puts it at the end of an i n t e r stadial; obviously this discrepancy cannot be removed by constructing another set of stadials and interstadials and a new measurement will be performed if new material comes available (see note p. 17).

If the Göttweig is correlated with the Brörup interstadial instead of the colder period between 33 000 and 42 000, some difficulties arise about the „vacuum" created then between the end of this interstadial and the age of the layers just on top of the Göttweig soil (Willendorf, 30 000), even if geological evidence in support of the assignment suggested above is neglected. This assignment, however, also needs reconsideration of various views. It implies that W I occurred between 48 000 and about 42 000. ANDERSEN (l. c.) has put this stadial before the Brörup interstadial. (See also fid. 1). W II would now be around 30 000 (if this nomenclature is still accepted at all).

The climatic history, now arrived at, fits with EMILIANI's paleotemperature curve (fig. 1). It presents the same, qualitative, course of the temperature and, moreover, the timescale agrees with the conclusions drawn in the present discussion.

It is obvious that the first requirement for further work is to collect reliable samples, if possible from continuous, well exposed profiles. The present report demonstrates clearly the importance of infiltration of recent material, and this will become even worse for samples older than Würm I. Recently our apparatus was improved so far that samples up to 70 000 years can be dated; these samples should contain at least 500 gram of carbon, however.

Acknowledgements. I am greatly indebted to all submitters of samples, who also contributed to the comments. They will give more complete discussions in due course. Very stimulating has been the nearly daily contact with Dr. ZAGWIJN (Haarlem) and Prof. WATERBOLK (Groningen).

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Note added in proof. Recently the author saw some of the charcoal from Senftenberg still embedded in the loess (brown earth). The soil contained a large amount of recent rootlets. This means that the discrepancy between Senftenberg and the other samples mentioned above is probably due to recent contamination. A fraction of 0.2 per cent recent material is sufficient to produce the activity found. Then the actual age of the sample would be much higher. This also implies that the Göttweig soil would have to be correlated with the Brörup interstadial, but more conclusive samples will be dated in the near future.