Y-144-4), we have evidence that the date of the peat is correct; the aquatic plants of the peat might have incorporated some fossil carbon from the water, but the wood must have obtained its carbon from the air. The confirmation of the age of the peat, suggested to be Sub-Boreal on the basis of the pollen sequence, is the most important result of the study from the stratigraphic point of view. However, lack of knowledge of isotope equilibria in lakes and in the sea presents a more challenging problem to C^{14} dating at present than does late-Pleistocene stratigraphy, and since the modern value to which ancient carbonate carbon should be referred is no longer obvious, we intend to continue the methodologic attack.

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Copenhagen Natural Radiocarbon Measurements, I.[1]

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CONSTRUCTION of a C^{14} dating apparatus in Copenhagen began in the fall of 1951, and the first unknown samples were dated in the summer of 1952. The technique used is largely that developed by Anderson, Arnold, and Libby (*1*) and later modified by Kulp (*2*). The only significant deviation from the classical set up is the use of a double screen wall counter as described by Anderson and Levi (*3*). This instrument (Fig. 1) consists of two independent detector units in a common envelope and a triple sample cylinder. The sample is mounted on the middle section of the cylinder, while the two outer sections provide the areas for the background countings. As in the conventional screen wall, the positions of the sample cylinder can

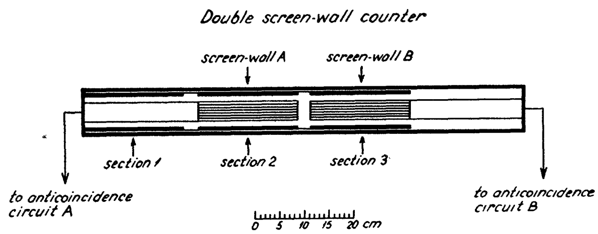

Fig. 1.

be alternated between two extremes. In one position, the sample on the middle section is exposed to detector A and a background area to detector B (cf. Fig. 1); in the other position, the sample is exposed to B and the other background to A. This arrangement has two advantages. First, the counting time necessary to arrive at a given statistical accuracy is reduced by ½, and second, background and sample counts are registered simultaneously, whereby the effect on the net count of possible temporal fluctuations in the background is eliminated. The overall length of the screen

[1] The authors wish to express their gratitude to the Carlsberg Foundation for sponsoring the construction of the dating apparatus and the pertaining equipment. The series of investigations presented here were likewise carried out with financial support from the Carlsberg Foundation. Moreover, our sincere thanks are due Professor P. Brandt Rehberg, head of the Zoophysiological Laboratory where the apparatus is installed, for the hospitality granted and for his kind interest in the work. Several firms have aided the project by placing equipment or chemicals at our disposal at a reduced price or free of charge. We wish to express our appreciation to Brüel and Kjær, Copenhagen, for electronics equipment; Norsk Hydro, Oslo, for supplying argon gas; British Petrol Co., Copenhagen, for supplying butane gas; Det Danske Stålvalseværk, Frederiksværk, for the steel plates forming the shield; and Radiation Counter Laboratories, Skokie, Ill., for a set of 24 a-c counters.

[2] On leave of absence from the Los Alamos Scientific Laboratories. A fellowship and travel grant from the Danish Rask Ørsted Fond and a grant in aid from the Wenner Gren Foundation for Anthropological Research are gratefully acknowledged.

TABLE 1

Sample No.	Material	Date	Net cpm	Mean
K— 5	Coke	2/28/52	-0.15 ± 0.14	
K— 7	"	3/6/52	-0.14 ± 0.06	
K—13	"	6/10/52	-0.20 ± 0.08	
K—14	Coal	9/14/52	-0.09 ± 0.08	
K—20	"	1/30/53	-0.11 ± 0.06	-0.13 ± 0.04
K— 3	Contemporary pine	3/1/52	5.76 ± 0.09	
K—10	" birch	4/20/52	6.06 ± 0.12	
K—11	" birch	5/1/52	5.79 ± 0.20	
K—12	" beech	5/24/52	5.94 ± 0.14	5.88 ± 0.06
K—15	Contemporary beech	9/23/52	5.55 ± 0.08	
K—16	" pine	9/30/52	5.74 ± 0.06	
K—19	" pine	1/13/53	5.65 ± 0.07	5.66 ± 0.04

wall counter is 35 in., the diameter 3 in. The counter is shielded by 8 in. of iron on all sides.

The samples measured for calibration are listed in Table 1. "Dead" (inactive) samples consistently turned out slightly negative. This may be due either to a minor radioactive contamination of the sample cylinder, which is suppressed by the carbon sample, or to the reduction in diameter of the sensitive volume of the counter. With a background of 5.8 cpm, the mean decrease in the count found with a "dead" sample in position corresponds fairly well to the reduction in diameter of 1.5%. A correction for this effect has been made in all cases listed below.

Samples of contemporary wood measured during the summer of 1952 gave 5.88 ± 0.06 cpm above background. A series of contemporary samples measured during the following period seems to indicate a minor decrease in this value to 5.66 ± 0.04 cpm, which may be caused by lower efficiency of the counter. The difference between the two mean values for modern wood is just at the limit of the statistical uncertainty. It was considered safest to reckon with two values for modern wood and to calculate the unknown samples according to the modern wood value measured during the respective period. Therefore, the Ruds Vedby series (Table 2) is calculated on the basis of 5.88 cpm for modern wood, while the value of 5.66 cpm has been used to calculate the Bølling series. The value of 5.88 cpm obtained for modern wood is somewhat lower than the values reported by Kulp (*4*) and Libby (*5*) for the same chemical treatment (HNO_3 extraction).

After demounting, all carbon samples were analyzed for their carbon content and the dates were corrected accordingly. Libby (5) has pointed out that the carbon content of the samples can vary even though their ash content is below 1% in all cases. The first samples measured in this laboratory showed variations from 83% to 93% C. After the introduction of a more uniform extraction procedure, the variations so far observed were within 88–91% C. Adsorption to the carbon powder of varying amounts of volatile material (mainly water vapor) may account for the differences.

Table 2 gives the age determinations obtained for a series of geological samples. The calculation is based on a half-life for C^{14} of 5568 ± 30 years (*6*). The errors reported are standard deviations of the counting data; all figures given represent separate runs. All samples are from the late glacial period known as the Allerød oscillation. These measurements are the first in a series of investigations aiming at the establishment of a direct connection between results obtained by means of the radiocarbon method and that of pollen analysis.[3] In the course of these investigations, it is intended to date some of the most characteristic horizons in the European pollen diagrams in the absolute time scale. The measurements presented here give the age of the sharp transition (Birch fall) in the pollen diagrams between Allerød (pollen zone II) and Younger Dryas (pollen zone III).[4] All samples are taken from lake and bog deposits. The Ruds Vedby series is from a calcareous site on Zealand, the Bølling series from a noncalcareous site in Jutland. Sample K—107, dated to 11.160 ± 320, is interesting from the viewpoint of interlaboratory check, as it is identical (half of the original sample) with Libby's sample 337 which was dated to 11.044 ± 500 (*7*).

The results obtained on samples taken in or a trifle underneath the transition period between Allerød and Younger Dryas and which, from a radiocarbon point of view, are simultaneous, are plotted in Fig. 2. The scattering of the dates around the mean value is in

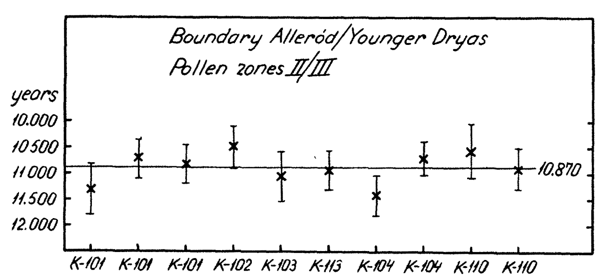

FIG. 2.

[3] Cf. Knut Faegri and Johs. Iversen. *Textbook of Modern Pollen Aualysis,* Copenhagen (1950).

[4] The samples suited for C^{14} dating are chosen by a committee consisting of Th. Mathiassen (chairman), H. Larsen, and J. Troels-Smith from the National Museum, and S. Hansen and J. Iversen, from the Danish Geological Survey (D.G.U.).

TABLE 2

GEOLOGICAL SAMPLES

Sample No.	Description*	Age (years)
	Ruds Vedby series	
K—101	Boundary Allerød period (II)/Younger Dryas period (III). Wood taken from a thin, dark, synchroneous stripe No. 4 in an open profile at Ruds Vedby, Zealand, Denmark. This stripe represents the exact zone boundary II–III D.G.U. 5b. The wood was isolated from the peaty lake mud of the following sample K—102. Submitted by Johs. Iversen.	11.310 ± 500 10.720 ± 380 10.820 ± 370 Av. 10.890 ± 240
K—102	Boundary Allerød/Younger Dryas. Peaty lake mud from stripe No. 4 mentioned above. D.G.U. 5d. Submitted by Johs. Iversen.	10.500 ± 400
K—103	Boundary Allerød/Younger Dryas. Calcareous lake mud taken from a 1-cm-thick layer underneath the dark peaty stripe No. 4. Pollen zone boundary II–III. Submitted by Johs. Iversen.	11.060 ± 480
K—113	Allerød. Lake marl underneath samples K—101, 102, 103, above dark stripe No. 6. Position: The very end of the Allerød maximum (zone IIb), a trifle underneath the Allerød boundary (II–III). D.G.U. 8. Submitted by Johs. Iversen.	10.930 ± 380
K—104	Allerød. Calcareous lake mud from dark stripe No. 6. Position a little underneath the Allerød boundary (II–III). D.G.U. 10. Submitted by Johs. Iversen.	11.410 ± 390 10.700 ± 310 Av. 10.990 ± 240
K—105	Allerød. Calcareous lake mud from dark stripe No. 7, slightly above the middle of Allerød. D.G.U. 13. Submitted by Johs. Iversen.	11.800 ± 410
K—106	Allerød. Lake marl slightly below the middle of Allerød. D.G.U. 14. Submitted by Johs. Iversen.	11.710 ± 410 12.180 ± 620 Av. 11.880 ± 340
K—114	Lime isolated from sample No. K—113 D.G.U. 8. This sample was measured in order to trace a possible difference between the age of the carbon in the organic and the carbonate fraction of the samples, respectively. The difference seems sufficiently small to indicate that a possible intrusion of the carbonate carbon into the organic carbon of the samples is of little significance for the dating results.	12.280 ± 480
	Bølling series	
K—111	Younger Dryas. Noncalcareous lake mud from the boundary between pollen zones III and IV. The sample is from a noncalcareous site at lake Bølling, Silkeborg, Jutland. D.G.U. 37. Submitted by Johs. Iversen.	10.300 ± 350
K—110	Boundary Allerød/Younger Dryas. Lake mud (noncalcareous) from a 1–1.5 cm thick layer 50 cm underneath sample K—111. D.G.U. 38a. Submitted by Johs. Iversen.	10.890 ± 380 10.550 ± 520 Av. 10.770 ± 300
K—112	Allerød. Noncalcareous lake mud from other section. Stratigraphical position not yet exactly determined. D.G.U. 42a and 42b. Submitted by Johs. Iversen.	11.790 ± 480 11.600 ± 530 Av. 11.700 ± 360
	Hannover sample	
K—107	Allerød. Peaty lake mud from pollen zone II, at Wallensen im Hils, Hannover, Germany. The sample is identical with Libby's No. 337, which was dated to 11.044 ± 500 years. Submitted by F. Firbas.	11.160 ± 320

* The datings were carried out on the organic fraction of the sample.

agreement with statistics. As the original samples are of different chemical composition (wood, peaty mud, lake-marl), collected in sites more than 200 miles apart, the internal consistency of the results presented here seems to make the occurrence of noticeable exchange with carbon of different specific activity, or intrusion of other radioactive species improbable.

Most determinations are made on samples of gyttja (lake-mud) which consists of a variety of remains of water plants, plankton, bacteria, limnic invertebrates, together with land plants, leaves, etc. deposited in the lake. The contemporary specific activity of this material is not exactly known and may vary from place to place. Craig (*8*) has shown that the C^{13} content of organic carbon in marine plants and marine invertebrates is about 1% higher than that of wood and land plants. The C^{14} content thus might be 2–3% higher and a similar effect may be found for fresh water plants. It should, however, be taken into account that not all organic material deposited as lake mud is of limnic origin and that the specific activity of water plants may depend on whether they photosynthesize CO_2 from the air and CO_2 dissolved in the water, or they photosynthesize bicarbonate. In view of these considerations, the mean specific activity for this group of material was tentatively taken to be 1% higher than the corresponding value for wood.

On the basis of these assumptions the mean age determination of the samples from the transition period between Allerød and Younger Dryas, as shown in Fig. 2, is calculated to be 10.870 ± 130 years. With an error in the mean value of this magnitude, however, the uncertainties in the determination of the half-life of C^{14} and of the value for modern wood are no longer negligible. If this is taken into account, the date becomes 10.870 ± 160 years.

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Radiocarbon Dating of the Alleröd Period

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THE AIM of the first radiocarbon assays in Copenhagen[1] is the dating of the late glacial Alleröd period, and, at the same time, a check of the applicability of certain material taken from sediments of various types.

The Alleröd period covers a great, late glacial, climatic fluctuation first demonstrated at Alleröd in North Zealand by Hartz and Milthers in 1901 (*1*). In the clay walls of the brickwork at Alleröd, we find a continuous band of pure organogenic lake mud, containing remains of a temperate flora and dividing the clay into an upper and a lower bed. Both beds are characterized by Arctic plant fossils, e.g., Dryas octopetala. Obviously, the mud layer represents a mild phase, the Alleröd period (Zone II), interposed between two cold periods, the Older Dryas Period (Zone I), and the Younger Dryas Period (Zone III). This classical Alleröd section has since been found in numerous other places in Denmark (e.g., Ruds-Vedby, Fig. 1). The same climatic development can be demonstrated by pollen analysis everywhere in Danish late glacial series, even where the stratigraphy is different.

In later years, the Alleröd oscillation has been alleged in many other countries in northwestern Europe and also in the Alps. In North America, a late glacial bed containing tree trunks that have succumbed to a new advance of the ice (Two Creeks Forest bed [*2*]) has been compared with the Alleröd section. A proof that a local climatic oscillation in late glacial times is part of a universal development, identical with the Alleröd period, can be furnished only by an unambiguous demonstration of the synchronism of these events. For the time being, the only means of absolute dating is the radiocarbon method. It there-

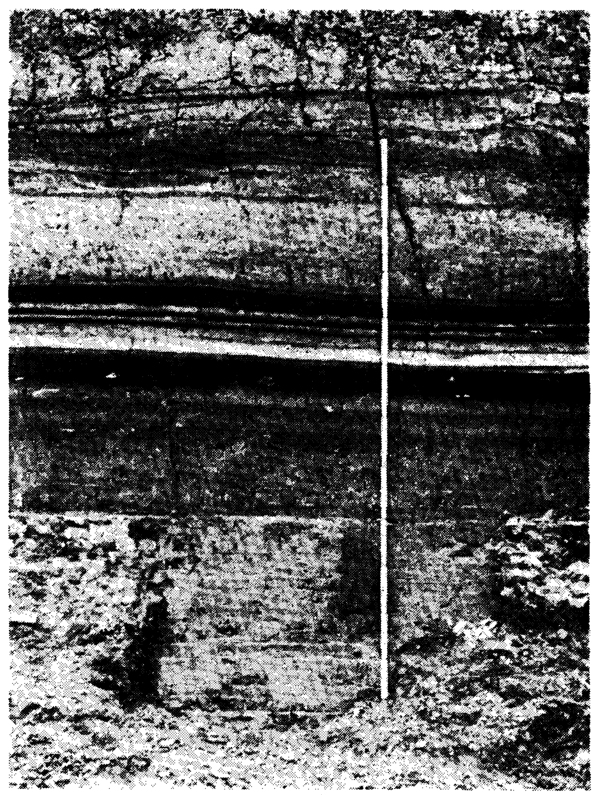

Fig. 1. Part of Alleröd section at Ruds-Vedby. Clay above and beneath: layers of organogenic lake mud (dark) and lake marl (white) in the middle cover the Alleröd period.

[1] Cf. the paper by Anderson, Levi, and Taüber, "Copenhagen Natural Radiocarbon Measurements," also in this issue.