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RADIOCARBON DATING OF LATE-PLEISTOCENE EVENTS

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ABSTRACT. Determination of age of fossil organic matter, based on its content of Carbon 14 as measured in the laboratory of W. F. Libby, has been applied to a number of late-Pleistocene samples. Generally speaking, the results are highly encouraging, and lead to the belief that the new method is a valuable tool for the construction of a chronology. Many of the samples assayed, however, were unsatisfactorily fixed as to stratigraphic position, and the figures do not at once provide a complete and incontrovertible time-sequence. Apart from stratigraphic errors and uncertainties, the new method itself is subject to several kinds of error, the seriousness of which cannot be evaluated.

The stratigraphic horizon whose date is most securely established and which provides the soundest clue to the validity of other more questionable dates is the Two Creeks horizon in Wisconsin, representing a forest overwhelmed by the advancing Mankato glacier. Five samples agree within satisfactorily narrow limits in placing the age of this material at 11,400 years, so that in round numbers the Mankato maximum in Wisconsin probably was attained 11,000 years ago. Four samples from the Alleröd horizon in Germany, England, and Ireland give an age averaging about 10,800 years. As this horizon (Zone II of European pollen stratigraphers) underlies solifluction deposits assigned to the Fennoscandian glacial substage, the essential agreement of the dates implies that deglaciation of northern Europe was contemporaneous with that of North America.

Events antedating Two Creeks time have not yet been dated precisely, although the method is believed to be sensitive enough, and the Cary maximum is believed to have been recent enough, to fix the age of the Cary substage when suitable samples can be found. Several samples from older stratigraphic horizons give minimum ages, older than a figure ranging from 16,000 to 20,000 years, which are in agreement with their stratigraphic positions.

The meaning of a number of dates for post-Mankato-maximum events can be assessed only in the light of the pollen chronology. As this chronology is a relative one, based on climatic changes and vegetational responses during deglaciation, its calibration will require samples from many more localities. All of the dates are of the right order of magnitude, with a few exceptions where it seems likely that the stratigraphic position of the sample, and not the radiocarbon age, has been incorrectly given. Most of the available dates, unfortunately, represent isolated determinations that could be either "right" or "wrong" without necessarily affecting confidence in the method itself. The most important and interesting results are these:

The postglacial spread of forests, and of Mesolithic cultures adapted to forests, took place in England about 9,000 years ago. The time of attainment of the Boreal type of climate, *i.e.* the time of the pine zone, differed appreciably according to the latitude of the locality. The pine zone is about 9,000 years old in West Virginia, about 8,000 years old in Connecticut, and about 6,000 years old in Maine; it is about 8,000 years old in southern Minnesota and about 7,000 years old in northern Minnesota. The age of the thermal maximum ("climatic optimum") has not been precisely fixed, but several samples from horizons not far from it give ages ranging from about 6,000 to about 3,000 years ago. In addition to pollen-dated peat and gyttja from Connecticut and the British Isles, samples within this time range date the eruption of Mount Mazama in Oregon and bracket the Boylston Street fishweir in Massachusetts.

INTRODUCTION

THE method of dating specimens of wood, peat, charcoal, and other organic materials by measuring the residual concentration of Carbon 14 they contain has been described by W. F. Libby and his associates (Libby, Anderson, and Arnold, 1949). The method was checked through its use in dating ancient Egyptian objects whose ages were already known within narrow limits. Its accuracy was found satisfactory in these cases (Arnold and Libby, 1949).

The next step was to check the method against stratigraphically dated materials, both archaeologic and geologic, of greater antiquity. For this purpose a committee to procure and screen samples was set up by the American Anthropological Association. The committee consisted of Frederick Johnson (chairman), Donald Collier, Froelich Rainey, and Richard Foster Flint. The last-named member was designated by the Geological Society of America as its official representative. The committee named several collaborators, among them E. S. Deevey, representing special areas of knowledge. The committee kept in close touch with the laboratory at the Institute for Nuclear Studies, where the dating was done, and both directly and through its collaborators maintained a voluminous correspondence with sources of important material. At first fossil bones, teeth, and shells were assayed in addition to wood, peat, and charcoal, but the results were unsatisfactory. It was inferred that chemical exchanges had occurred in such materials, altering the amount of carbon present chiefly through the leaching and deposition of carbonates, and the assay of calcareous material was abandoned.

By September 1, 1950, a large number of dates had been determined, and it was agreed that Libby would present an expanded report on the method while the committee would prepare a summary report (Johnson and others, 1951) on this group of dates. At the same time members of the committee and collaborators were authorized to publish more detailed reports on the stratigraphic significance of various groups of dates. The present paper is one of those reports. It discusses the geologic material dated, mentioning only those archaeologic samples that have a bearing on the geologic record.

The report is in no sense definitive; it is only a report of progress. The data on which it is based are limited in various ways, and some of the limitations can be overcome as the research continues. The foremost limitation is that very few dates more than 12,000 years ago have been determined as yet. A number of minimum dates greater than this have been obtained, but their usefulness is only partial. It is thought probable that refinements of the method will lead to the dating of material as much as 30,000 years old, but such work still lies in the future. Other limitations were imposed by lack of time for collecting and assembling materials for dating. Many samples had been collected many years earlier for other purposes, and stratigraphic descriptions in some cases were inadequate. Some samples, otherwise excellent, came from stratigraphic positions whose correlation was open to doubt through lack of adequate exposure. Conversely, some key deposits whose stratigraphic positions were firmly fixed were searched for wood or peat without success. Bones, teeth and shells, carefully collected and submitted for dating, proved for the time being at least, to be useless. Finally, quantities of material were offered by well-meaning people whose understanding of the rigid limitations involved was imperfect; this alone imposed a heavy burden of correspondence on the committee.

In consequence of these difficulties the results are very spotty and in some respects unsatisfactory. The spottiness is a consequence of the committee's having had to accept what it could get, for it was able to insure the directed field collecting of geologic materials, for dating purposes alone, in only about twenty instances.

Specific attention should be called to five possible sources of error in the date of any sample. These are: (1) Error in fixing the stratigraphic position of the sample. (2) Post-depositional alteration in the proportion of Carbon 14 to total carbon by chemical change and possibly organic activity. (3) Predepositional variation in the steady-state ratio of Carbon 14 to Carbon 12 in organic matter, including the untested possibility that aquatic plants, deriving some of their carbon from freshly dissolved ancient carbonates, may show falsely low values of the ratio. (4) Contamination during or after collecting. (5) Laboratory error, including contamination. Of these five sources of error, the first involves no necessary error in the date obtained; it merely creates a discrepancy between the actual date and the stratigraphic date. The other four involve errors in the actual date itself.

It is believed that these sources have been avoided in the main, but until more dating has been done, the dates here discussed are accepted only provisionally, even though it seems probable that most of them are of the right order of magnitude. It should be pointed out that the laboratory errors assigned by Libby are based on the standard deviation expected in counting random events, and that in a large number of such determinations the limits of error quoted will be too narrow in an appreciable number of cases. Thus we may be sure that some of the dates are erroneous, but only additional work can show which ones they are.

CHIEF GENERAL RESULTS

The dates obtained, as of November 1, 1950, for samples having geologic, as contrasted with archaeologic significance, are listed in the Appendix. From them two general results have emerged. The first is that nearly all the dates fall into the same order as the relative stratigraphic position of the samples from which they were determined. This encouraging result leads to the inference that most of the dates reached are acceptable, although there are at least two exceptions that seem wholly inharmonious with their reported stratigraphic relations.

The second general result is that the dates of events late in the Wisconsin age have proved to be rather consistently less than the dates assumed before the radiocarbon method was employed. Thus the Mankato glacial maximum, earlier assumed to date from 25,000 years ago, has proved to date from about 11,000 years ago. This result seems to have been anticipated by the opinions of some geologists and soil scientists, who had come to believe that the degree of soil development and erosion on the Mankato drift sheet are inconsistent with an age as great as 25,000 years. The shortening of our concept of the time since the Mankato ice began to melt away requires merely that we revise upward our notion as to the rate of melting. The whole process of deglaciation seems to have been more rapid than had been supposed.

Because the age of the pre-Mankato Two Creeks forest bed seems most securely established by five radiocarbon analyses, and because of the key position occupied by the Mankato substage in late-Pleistocene stratigraphy, we discuss this horizon first. We turn then to later events, dated with greater or less certainty. Horizons antedating the Cary-Mankato interval have so far been given minimum ages only, and as they are of less interest for this reason we discuss them last.

CARY-MANKATO INTERVAL AND ITS CORRELATIVES

Two Creeks horizon and Mankato substage. Of all the geologic dates thus far determined by radiocarbon, the most firmly established and probably the most widely significant is that of the Two Creeks horizon in Wisconsin. The stratigraphic position of the horizon is known, and from its date can be derived that of the maximum of the Mankato glaciation.

The salient facts about this deposit are here abstracted from the excellent studies by Wilson (1932; 1936). The deposit is exposed in wave-cut cliffs of Lake Michigan, at several localities in northern Manitowoc County, Wisconsin. These localities lie roughly 25 miles inside the extreme outer limit of the Mankato drift sheet. The horizon consists of peaty material, only a few inches thick, overlying, in one exposure, varved sediments probably deposited during the Glenwood phase of Lake Chicago (Cary substage). The peat underlies lacustrine sediments, in turn overlain without break by Mankato till. The peat is thus post-Cary, and it also antedates the Mankato maximum.

The peat contains much spruce wood, occurring both as stumps rooted in place and as prone logs mostly lying with their tops pointing southwest, the direction of flow of the Mankato glacier. Most of the logs are imbedded in the lacustrine sediments overlying the peat, and the majority of them are splintered at their butt ends, indicating that they were broken off and pushed over while they were parts of living trees. The oldest tree observed had 142 annual growth rings, and a large number of logs revealed through their rings a decrease in rate of growth during the last few years of life.

In the top of the underlying varved sediments occur 3 species of mollusks whose ecologic relations suggest that the peat layer began to form as soon as emergence of the area from beneath the water of Lake Chicago permitted. The base of the peat consists mainly of grasses and arctic mosses, merging immediately into spruce, recording spruce-bog conditions like those common in northern Minnesota today.

The upper part of the peat includes lacustrine silt that filtered down between upright growing mosses, and the accompanying flora and fauna indicate wet ground. Hence the spruce bog was flooded for a time. Thereafter the margin of the Lake Michigan lobe of the ice sheet, in its Mankato readvance, overwhelmed the Two Creeks bog, snapping off the trees, pushing them over, and burying the site beneath till as the ice margin advanced 25 miles beyond the bog to its extreme Mankato position.

The whole sequence appears to be conformable, and to represent an interval of perhaps no more than a few hundred years at most. The varved sediments beneath the peat are not leached of their carbonates; this fact too suggests that the Cary-Mankato interval at this locality was short. Both the implied short interval and the ecology of the bog suggest that deglaciation was probably not extensive; the ice sheet margin may have retreated no farther than the sites of the northern shores of the existing Great Lakes.

The dates obtained are these:

Laboratory No.	Description	Collector	Date (years)
308	spruce wood	L. R. Wilson, 1949	10,877 ± 740
365	root of spruce tree	J H. Bretz	11,437 ± 770
366	peat in which No. 365 was rooted	J H. Bretz and Leland Horberg	11,097 ± 600
536	spruce wood	J H. Bretz and Leland Horberg	12,168 ± 1,500
537	peat	J H. Bretz and Leland Horberg	11,442 ± 640
		Average	11,404 ± 350

From the laboratory point of view the agreement among these samples is considered satisfactory (Arnold and Libby, 1950, p. 12). It adds weight to the reliability of the result. Hence the Two Creeks peat, being closely fixed stratigraphically and well dated chronologically, can properly serve as a key horizon to which other features and events can be related.

It is evident that the Mankato maximum must be younger than the time of death of the Two Creeks spruce trees, by the number of years taken by the glacier margin to advance from the Two Creeks locality through a 25-mile distance to its outermost position. The rate of advance, and the possible fluctuations of the ice margin during the advance are unknown. Hence the time assignment must be arbitrary. Any estimate is limited by the dates of samples nos. 332 and 334, discussed elsewhere in this paper. A figure of 200 to 400 years seems reasonable. If the larger figure is adopted, then, subtracting it from the average date for the overriding of the Two Creeks horizon, we get a round figure of 11,000 years for the Mankato maximum. This is a more useful date than the Two Creeks date, because the latter can be applied only where nonglacial features are exposed between the Cary and Mankato drift sheets, whereas the position of the Mankato drift border is known throughout a wide belt of country extending from southern Ontario to North Dakota. If it can be established by dating additional suitably situated samples that the ice sheet reached this position at about the same time at all longitudes, the drift border could be a very useful time marker.

The well-known estimates made by Kay (1931) as to the dates of the glacial and interglacial ages were based on depths of alteration of tills to gumbotil, assuming a uniform rate of alteration and assuming that the Mankato maximum occurred 25,000 years ago. That the latter assumption is too great by a factor of more than 2 is now known, thanks to radiocarbon dating. However, reduction of the date of the Mankato maximum from 25,000 years to 11,000 years affords no sound basis for recalculating the dates of events earlier in the Pleistocene, because Kay's first assumption is subject to error, as he himself noted. For this reason Kay's results were speculative, and radiocarbon developments make them no less so.

Alleröd horizon. Recognized originally at Alleröd in Sjaelland (Hartz and Milthers, 1901) from intercalation of a band of organic lake mud in late-glacial *Dryas* clays, the Alleröd warm interval as established in pollen diagrams is now known to have a wide distribution. Increasing attention on the part of European workers to the non-tree component of the pollen flora (Firbas, 1934, 1949) has brought forward as the chief criterion for the recognition of this interval a decline from the high values (often several hundred percent of total tree pollen) characteristic of the treeless tundra to values under 100 percent. An increase of locally derived birch pollen is often found to have occurred at the expense of pine pollen blown from a distance, and an abundance of macroscopic fossils establishes the reality of the phase of comparative warmth. A subsequent interruption in the postglacial warming of the climate, recorded by a second maximum of non-tree pollen types and of fossils of such tundra plants as *Dryas*, is a normal feature of the geologic sections, and usually the change to the second cold phase is also marked by a shift from lake mud or peat to clay or sand, implying solifluction. In Denmark and the British Isles (Jessen, 1949) the threefold division of the "Late-Glacial" is designated by pollen zones I to III, II being the Alleröd layer. The late-Pleistocene stratigraphy recognized by the writers is shown in table 1.

As the Alleröd sediments are nowhere overlain by till, their areal distribution is significant for their correlation. They occur in a broad belt of country from Russia to Ireland, including southern Sweden and southern Norway, but, as shown by Schütrumpf (1943), they are unknown north of the central Swedish moraines and their correlatives. A warm interval of similar character is shown by pollen diagrams from the north flank of the Alps (Firbas, 1949). The pattern of occurrence implies that at places near but beyond the limits reached by the latest ice advance Zone III is the equivalent of till. The contemporaneity of the last sub-age of the Würm glacial age in the Alps with the last advance of the Scandinavian Ice Sheet, here assigned to the Fennoscandian sub-age, is not established, but the widespread similarity of pollen stratigraphy in northwestern Europe argues for the contemporaneity of the Alleröd deposits themselves. At several places in northern Germany the Alleröd layers contain a recognizable stratum of volcanic ash derived from the Eifel district. Remains of the early Mesolithic Ahrensburg and Lyngby cultures are stratified

TABLE 1

Summary of late-Pleistocene stratigraphy, with tentative correlations between North America and Europe

Central and Eastern North America: Substages	Central and Eastern North America: Pollen Zones (New England)	Western and Northern Europe: Substages	DeGeer Terminology	Blytt-Sernander Terminology	Pollen Zones (British Isles)	Cultures
	C3 OAK-CHESTNUT			SUB-ATLANTIC	VIII ALDER-BIRCH-OAK	IRON AGE
	C2 OAK-HICKORY			SUB-BOREAL	VIIB ALDER-OAK	BRONZE AGE
	C1 OAK-HEMLOCK		POSTGLACIAL	ATLANTIC	VIIA ALDER-OAK-PINE	NEOLITHIC
	B PINE		0-VARVE 6839 B.C.	BOREAL	VI PINE-HAZEL V PINE	YOUNGER MESOLITHIC (ERTEBÖLLE)
	A SPRUCE-FIR		FINIGLACIAL	PRE-BOREAL	IV BIRCH-PINE	OLDER MESOLITHIC (MAGLEMOSE, ETC.)
MANKATO	L3[2]	FENNOSCANDIAN[3]	8109 B.C.	ARCTIC	III YOUNGER TUNDRA	AHRENSBURG, LYNGBY
TWO CREEKS HORIZON	L2[2]	ALLERÖD HORIZON	GOTIGLACIAL	SUB-ARCTIC	II ALLERÖD BIRCH	
CARY[1]	L1[2]	POMERANIAN[1]	DANIGLACIAL	ARCTIC	I OLDER TUNDRA	MAGDALENIAN

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[1] As it is not certain which European moraines should be correlated with the Cary substage, the table shows one possibility for purposes of orientation only.

[2] "L" stands for late-glacial tundra zones, which antedate Zone A in northern Maine and may therefore antedate the Mankato (Deevey, 1951).

[3] Presumed equivalents: Salpausselkä, central Swedish moraines, valley glaciation in British Isles.

into Zones II and III at several places. Moreover, the areal and stratigraphic relations strongly suggest an equivalence between Zone III and the Mankato substage, so that the Alleröd horizon should be of Two Creeks age.

The support given to these correlations by radiocarbon dating is the most important achievement of the new method. Zone II dates so far available are as follows:

337	Lake mud with *Betula* remains, 0-4 cm. above the volcanic ash layer, collected by Franz Firbas from a bog at Wallensen im Hils, Hannover.	11,044 ± 500
341	Lower peat bed in kaolin pit at Hawks Tor, Cornwall, underlying a gravelly solifluction soil containing a cold flora. Furnished by H. Godwin.	9,861 ± 500
444	Organic mud in an exposed profile at Neasham, near Darlington, Northumberland. Collected by K. M. Blackburn, furnished by H. Godwin.	10,851 ± 630
349	Calcareous silty lake mud, collected by Hiller peat sampler at Hockham Mere, Norfolk. Furnished by H. Godwin.	6,555 ± 280
355	Lake mud at Knocknacran, County Monaghan. Collected by G. F. Mitchell; furnished by H. Godwin.	11,310 ± 720

Excluding no. 349, the only one not collected by excavation from an exposed profile, the figures are consistent in indicating a date of about 10,800 years for the Alleröd horizon. (The unreliability of the method of multiple sampling with a peat sampler is discussed in a later section.) The average figure, 10,767 years, is 637 years younger than the average for the Two Creeks material, but the range of values overlaps to such an extent that the two horizons can be thought of as contemporaneous. Moreover, in the British Isles, where Zone III records the readvance of valley glaciers independent of each other and of the Scandinavian Ice Sheet, the correlation of Zone II with the Alleröd layer has heretofore been open to criticism. The agreement of radiocarbon dates in Germany, England, and Ireland provides the first substantial evidence for the matching of stratigraphic columns across so great a distance.

The dates assigned to the Gotiglacial retreat from the south Swedish to the central Swedish moraines (16,500 to 10,000 years) by De Geer (1940 and earlier papers) imply a discrepancy of about two thousand years in the age of the Alleröd. This part of the varve chronology has been shown by Hansen (1940) to be in error on quite other grounds.

The fact that the "radiation curve" of Milankovitch fails to show a minimum corresponding to the Fennoscandian substage has been employed (Welten, 1944) as an argument against the use of this curve for dating Pleistocene events, a procedure espoused particularly by Zeuner (1945). Zeuner (1948) maintained that the Fennoscandian substage had never been regarded as caused by a radiation minimum, but instead was the result of a temporary increase in precipitation in the Baltic region consequent on reduction of the diameter of the Scandinavian Ice Sheet and of the intensity of its anticyclone. He called attention (1945, p. 157) to the fact that the diameter of the glacier at that time was about 1000 km., agreeing closely with the minimum size deduced by Brooks (1949, p. 65) for active growth of an ice sheet. The transatlantic correlation provided by the radiocarbon dates argues against a special explanation of this sort, inapplicable to the much larger Laurentide Ice Sheet of Mankato time.

It is legitimate to expect that events assigned to the Daniglacial or Brandenburg-Pomeranian interval in Europe will prove contemporaneous with events in the Tazewell-Cary interval in North America, if and when events so ancient become accessible to radiocarbon dating. Deposits corresponding to the older of two levels of Alleröd character, known to occur in several sections in East Prussia (Gross, 1937) and Norway (Faegri, 1940), should be among the first materials selected for investigation.

Mankato correlatives. Several samples, whose stratigraphic relations had led to the belief that they were to be correlated with the Mankato substage, were dated; the resulting dates justified the tentative correlation.

The first of these is no. 385, wood taken from a log buried in sandy outwash near the mouth of the Missouri River. Its location was in a quarry on Taussig Road, Bonfils, Missouri, 2.25 miles east of the town of St. Charles (Robertson quadrangle). The log overlay a lag gravel resting on bedrock, and was overlain by 23 feet of outwash sediments, eolian sand, and loess. The outwash body constitutes a terrace, correlated with the Festus terrace of Robertson (1938, p. 179), with a top, at Bonfils, about 50 feet above the Missouri River.

The wood was collected by L. C. Peltier in 1949. M. M. Leighton and H. B. Willman of the Illinois Geological Survey have correlated the Festus outwash with the Mankato maximum; this correlation was accepted tentatively by Peltier (L. C. Peltier, unpublished communication). The radiocarbon date, 12,148 ± 700 years, tends to confirm this opinion, although the date is perhaps slightly greater than might have been expected. If the full benefit of the margin of error is taken, the figure is reduced very nearly to the average date of the Two Creeks material. As the Bonfils log lies at the base of the Festus outwash, and therefore should date from the beginning of outwash deposition, correlation with the time when the Two Creeks bog was overwhelmed seems reasonable.

The second Mankato correlative consists of two samples of charcoal taken from human occupation horizons occurring in alluvial silt in a stream terrace at two adjacent sites in Frontier County, Nebraska. The occurrences are described in Schultz, Lueninghoener, and Frankforter (1948) and Schultz and Frankforter (1948). The samples were collected by C. B. Schultz, who tentatively correlated the inclosing alluvium as Mankato.

The results of dating are:

No. 470	Charcoal from Medicine Creek site	10,493 ± 1,500
471	Charcoal from Lime Creek site	9,524 ± 450

The dates, when compared with that of the Mankato maximum derived from the Two Creeks figures, bear out the correlation of the alluvium at the Nebraska localities with the Mankato substage.

The presence of man in North and South America as early as the Mankato maximum has long been suspected on inadequate evidence, notably the indubitable association of artifacts with remains of extinct mammals. One of the places where such an association is beyond doubt is Gypsum Cave, near Las Vegas, Nevada (Harrington, 1933), the mammal in this case being the sloth *Nothrotherium shastense*. Bones of the sloth were in turn associated with remains of horse and two species of camel. Two samples of sloth dung from the cave have been dated by radiocarbon analysis. No. 221 gives an age of 10,455 ± 340 years, and no. 222 an age of 8,527 ± 250 years. These dates suggest that the view that man was a comparatively early immigrant into America is well founded, and is not based on misleadingly late survival of mammals now extinct. Similar evidence comes from Chile, where another sample of sloth dung (no. 484) from Mylodon Cave, Ultima Esperanza, is dated as 10,832 ± 400 years old. The sloth was not demonstrably contemporaneous with man in this cave, but a sample (no. 485) of burned bone of sloth, horse and guanaco, associated with human bones and artifacts in Palli Aike Cave 125 miles to the east (Bird, 1938), gives a date of 8,639 ± 450 years. **1***

POST-MANKATO-MAXIMUM EVENTS

Pollen-dated peat samples: general statement. Of the several approaches to the chronology of postglacial time in Europe, the only one available in 1948 in North America was that of pollen analysis. Mud samples (gyttja, not peat) from Upper Linsley Pond, North Branford, Conn., were the first pollen-dated samples collected and the first analyzed. They were obtained through the ice in February, 1948, near the site of the original boring in the center of the lake (Deevey, 1943). Suites of 29 to 32 separate samples at each of three depths were taken with a Davis peat borer slightly larger (1 inch diameter) than standard. Within the limits imposed by the length of the cores (about 15 cm.) and the possible non-horizontality of the bedding within the circle of sampling, the three older samples should and apparently do date three important events at this locality. The oldest (no. 39, 8,323 ± 400 years) came from 11.65 m., at the top of the high-pine Zone B, the next (no. 38, 5,159 ± 350 years) from 9.15 m., in the layer where beech pollen is relatively frequent, at the transition from oak-hemlock Zone C1 to oak-hickory Zone C2, and the third (no. 37, 1,800 ± 500 years) from the level of maximum hickory and minimum beech, the "culmination" of C2. A fourth sample, no. 36, was taken at the "upper surface" of the mud at 5.5 m. with an Ekman dredge, but Zone C3 is only one meter thick at this point, and the age (876 ± 250 years) merely shows that the dredge sank an appreciable distance into the soft bottom.

The pollen chronology (see Deevey, 1949, for a recent review) is based on a sequence of local climatic changes following deglaciation and on phytogeographic responses to such

* Bold face numbers refer to notes added in proof (see end of paper).

changes. It is therefore a relative one, impossible to calibrate at any one locality. The attainment of a given "pollen age" must have occurred later at stations situated farther north, in the general direction of glacier retreat. This statement may not apply to the time around the thermal maximum of post-glacial time, but within the latitudes glaciated in the Wisconsin age, there is reason to expect lags of several thousand years in the incidence of such events as the pine-pollen maximum or the first appearance of forest trees. Samples for radiocarbon assay should be of equivalent pollen age but obtained from widely scattered places, and this phase of the investigation was being planned in the spring of 1949 when Libby requested more material from Upper Linsley Pond.

In the absence of ice, a new site, at the edge of the lake, was chosen for the boring, a new pollen profile was drawn up, and suites of 59 to 70 samples were obtained, this time at four subsurface levels. Three (nos. 122, 120, and 119) were at essentially the same horizons as nos. 39, 38, and 37, and the fourth (no. 121) was in the middle of Zone C1.

Evidence of heterogeneity emerged when the two deeper samples of the new series (nos. 122 and 121) were assayed. Subsequent field work has shown that at this bog-margin locality younger wood has sunk through the sediments to find a false stratigraphic position. Meanwhile an examination of the statistical aspect of multiple sampling (Deevey and Potzger, 1951) has made it clear, not that the method is necessarily unreliable, but that it is very difficult to determine whether or not adjacent peat-borer samples are stratigraphically equivalent. No evidence of non-equivalence could be found in the original series from Upper Linsley Pond, whereas in the new series the two older samples certainly, and the two younger samples possibly, were contaminated. The two latter dates (no. 120, 5,305 $\pm$ 250, and no. 119, 2,141 $\pm$ 250 years) agree so closely with the others as not to affect the subsequent discussion.

Of the American pollen-dated samples collected by Deevey and his collaborators (nos. 37-39, 119-122, 332, 334-336), all but one (no. 335) were taken by multiple sampling. One of the English samples (no. 349) was also taken in this way. Therefore these samples are subject to possible errors in addition to the kinds already enumerated.

The Boreal pine zone.[1] The high-pine pollen Zone B is the best marked and most nearly universal of all features of North American pollen diagrams. Normally overlying a spruce-fir zone, and underlying the maxima of oak and other deciduous types, it records the first postglacial attainment of a warm, probably dry climate, and thus agrees closely in stratigraphic position and in climatic implications with the Boreal zone of the Blytt-Sernander European sequence and with Zones V and VI of later workers (see Jessen, 1949, for a recent discussion). Because of its wide distribution, and because it was expected to differ in age according to the latitude of the locality, the pine zone was selected for intensive study. Older sediments from lakes and bogs normally do not contain enough carbon to meet the existing requirements for dating.

No. 336 was collected by H. C. Darlington from the high-pine level between 12¼ and 12¾ feet at the site of the original boring (Darlington, 1943) in Cranberry Glades, W. Va. This bog lies at an altitude of 3,375 feet. It is one of the very few peat bogs occurring well outside the glaciated region, and its earliest sediments contain pollen of spruce and fir. The pine interval followed, just as in more northern sections, and was succeeded by feebly differentiated deciduous pollen intervals. The age of the pine zone here is 9,434 ± 840 years, and while this is the oldest date yet known for the pine climatic phase, it is significant that it does not antedate the Mankato maximum. It implies, though it does not prove, that conditions favorable for the formation of peat bogs existed as far south as West Virginia, not merely at some part of Wisconsin time, but as late as the Mankato sub-age.

The next date of interest, geographically and chronologically, is that of 8,323 ±400 years for the pine zone of Upper Linsley Pond, Conn., (no. 39), situated on drift which cannot be dated exactly but which is almost certainly pre-Mankato. A lag of about a thousand years is indicated for the attainment of a pollen age equivalent to that of no. 336. Almost as

[1] In accordance with stratigraphic practice, we distinguish carefully between *zone,* which is a layer, and the time represented by a zone, for which we use *climatic phase,* when climatic implications are considered, or the informal terms *time, interval,* or *episode.* Pollen stratigraphers have generally been careless about their usage in this matter, and customarily use the term *period* for the time corresponding to a zone. *Period,* like *stage* and *epoch,* belongs to a very much longer time interval than a pollen-zonated time, and cannot be used without causing confusion.

far again to the north, the highest part of the pine zone at 6.0 m. in Plissey Pond, Aroostook County, Maine, gives a date two thousand years younger still (no. 335, 5,962 ± 320 years). This sample was taken out in one piece by means of a special instrument (Deevey and Potzger, 1951). The exceptionally interesting stratigraphy of the Aroostook County lakes has been described (Deevey, 1951); as there is a typically European sequence of "late-glacial" zones, including a birch zone of Alleröd character, the suggestion was made that the latest regional ice advance (Mankato?) just failed to reach the lakes, but was reflected in a return to tundra climate. Unfortunately the mild-climate layers contain too little organic matter for radiocarbon dating of this zone. The late date for the considerably younger pine zone (probably appreciably later than the "culmination" of the climatic phase) supports the inference, still to be ranked as no more than a guess, that the deglaciation of Connecticut occurred long before the Mankato maximum. Another piece of evidence for this view comes from Urry's (1948) radium dating of the varved clay at Hartford, Conn., at 18,000 years. [2]

Two Minnesota samples from Zone B form a series parallel to nos. 336, 39, and 335. No. 332 was collected by Murray Buell at 8.5 m. in Cedar Creek Bog, Anoka County, Minn., at the site of profile 4 (Buell and Buell, 1941; Lindeman, 1941). Pollen studies of this bog, left unfinished by Lindeman at his death, are now at Yale University; as shown in figure 1, they were complete enough to permit selection of the desired level. Sample 334, of equivalent pollen age, was collected by J. E. Potzger at 8 feet in Johnson Camp Bog, situated in sec. 12, T. 64 N, R. 13 W, 14½ miles northwest of Ely, St. Louis County, Minn. The pollen diagram has been published and the validity of the sample discussed by Deevey and Potzger (1951). Both bogs lie on Mankato drift, and the 900-year gap between the sample dates (7,988 ± 420 and 7,128 ± 300 years, respectively) is in line with their geographic positions, which are about 220 miles apart. As a spruce-fir time of unknown length preceded the dates given at both localities, these figures do not necessarily imply that the retreat of the Mankato glacier margin over the intervening distance lasted 900 years. [3]

If we conclude that the pine time of North American pollen diagrams was attained between 9,000 and 6,000 years ago,

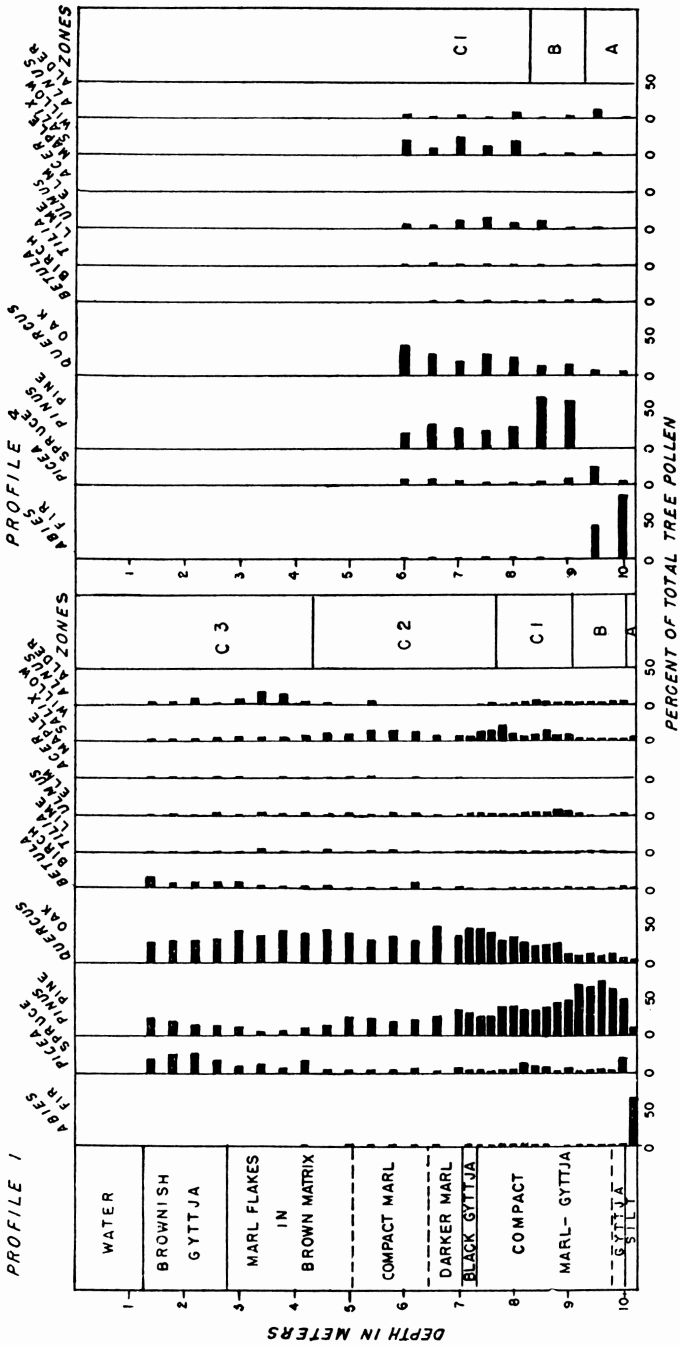

Fig. 1. Pollen diagrams from Cedar Creek Bog, Anoka Co., Minn., profiles 1 and 4, prepared from counts made by the late R. L. Lindeman. Profile 1 is the only one completed; radiocarbon sample no. 332 was taken at the site of profile 4 because of its greater accessibility in summer.

according to the locality, and that it lasted something like a thousand years at any one place, the British samples fall more or less into line, as do the three Danish samples, despite internal inconsistencies among the latter. The best agreement is found in no. 353, a piece of a Mesolithic platform from Star Carr, Yorkshire, pollen-dated as Zone IV, *i.e.* distinctly pre-Boreal. Its age is 9,488 ± 350 years (see Godwin, 1951, for details of this and other British material). The age of another Zone IV sample (no. 340), peat cut from an exposed section at Hawks Tor, Cornwall, given as 8,275 ± 350 years, is too young by comparison, but Godwin admits the possibility of stratigraphic error here; certainly the discrepancy is not serious. No Zone V or Zone VI samples from England have yet been assayed, but no. 358, cut from a bog section in Clonsast, County Offaly, Ireland, supposed by its collector, G. F. Mitchell, to be uppermost Zone VI, gives a sort of *terminus post quem* (5,824 ± 300 years) for the British Boreal, especially as Mitchell has since granted that the sample could have been early Atlantic (Godwin, 1951).

Three Boreal samples from Denmark present a more puzzling problem. All came from an archaeologic site at Aamosen, Sjaelland. Pine cones (no. 432), dated as Zone V, give an age of 7,583 ± 380 years, whereas charcoal (no. 434) and hazel nuts (no. 433) from a Mesolithic summer house at a higher level give the discordant dates of 8,631 ± 540 and 9,929 ± 350 years, respectively, for Zone VI. Of all the post-Mankato-maximum dates, these are the only ones suggesting at first sight that the radiocarbon method may be in error. No. 433 seems most likely to be erroneous, as hazel bushes are supposed not to have spread over northern Europe so long ago as 10,000 years. Details of the stratigraphic relations have not been communicated to the writers, but it seems possible to account for the discrepancy between nos. 432 and 434 on the basis of stratigraphic confusion, particularly when it is remembered that they come from a human occupation site. No. 433, the only one checked by a duplicate determination, may perhaps be laid to a human tendency to collect antiques. **4**

"Postglacial" thermal maximum. A large number of otherwise unrelated phenomena have been interpreted to mean that during the time that was postglacial in middle latitudes there

was a climatic phase of higher temperatures than those of today. For this time we prefer the term *thermal maximum,* because we find the widely used term *climatic optimum* subjective and ambiguous. Events of particular significance for the present discussion are those tied to the pollen chronology.

1. The Littorina Sea invaded the Baltic basin, previously occupied by the Ancylus Lake, bringing maritime climatic conditions deep into northern Europe, and permitting the growth of such trees as elm and lime in places now apparently too cold for them. In the Blytt-Sernander scheme this phase is called the Atlantic. In places situated west of the Baltic, and removed from the influence of moisture-bearing westerly winds from over the Littorina Sea, the climate was moister than the preceding Boreal phase as well as warm; the statement applies not only to the British Isles, but to eastern North America.

2. Subsequently, in Sub-Boreal time, the climate of western Europe and eastern North America became drier while remaining warm. During this time, in western Europe at least, peat bogs became very dry, and the end of the interval is sharply marked by a horizon above which the composition of the peat indicates flooding, so general as to exclude causes other than climatic. This horizon, the *Grenzhorizont,* records the opening of the Sub-Atlantic time of cool, moist climate, with which are associated the end of the Bronze Age and the beginning of the Iron Age. Other boundary horizons or "recurrence surfaces" occur in bogs, each indicating a shift from dry to moist conditions. Five of them have been recognized in Sweden by Granlund (1932), and with varying degrees of success elsewhere. Ordinarily the most conspicuous is the middle one, RS III, and this is considered to be the same as the *Grenzhorizont* of north German bogs.

3. An episode of dry climate has been discerned in pollen diagrams from the Iowa prairie (Lane, 1931) as well as in the more arid Basin and Range Province (Hansen, 1947). The age of some lakes in the Province, as calculated from their salinity, is around 4,000 years. As these lakes are descendants of Pleistocene lakes, their youth has been accounted for by the widely accepted hypothesis that they went dry at the time of the thermal maximum (see Antevs, 1948, for re-

view). Matthes (1939, 1940) marshalled evidence that valley glaciers in many western mountain ranges underwent a parallel history of complete disappearance and rebirth. The stratigraphic evidence does not indicate whether the warm, dry interval west of the Rockies corresponds with all of the time from the beginning of the Boreal to the end of the Sub-Boreal in Europe, or with only part of it.

Absolute dates for the thermal maximum and associated phenomena have been used in Europe widely, in North America less so. These dates have been derived in a variety of ways. The varve chronology of deglaciation in Scandinavia, summarized by De Geer (1940), is a floating chronology, and Lidén's (1938) attempt to connect it with the present day involves an extrapolation. Although the counting of annual layers of gyttja in the Faulensee deposits (Welten, 1944) leads to impressive agreement with the De Geer-Lidén chronology, this sequence also requires extrapolation as well as interpolation, for many layers were missing. The archaeologic stratigraphy of western Europe is closely tied to the pollen chronology, but back of the cultures known to written history the assignment of absolute dates to archaeologic horizons rests on nothing more substantial than Lidén's extrapolation. Radiocarbon dating offers the first escape from a system of dates, which, however reasonable it may be, is supported more by universal opinion than by evidence.

The radiocarbon values so far available are too few in number to assist very much in ordering the various phenomena associated with the thermal maximum. No. 343 is a sample of humified *Sphagnum-Calluna* peat from the raised bog of Shapwick Heath, Somerset. The pollen age of this peat (Godwin, 1948; Clapham and Godwin, 1948) is Zone VIIb, Sub-Boreal; underlying it is a layer of *Cladium-Phragmites* peat belonging to Atlantic time (Zone VIIa), while the overlying transition to Sub-Atlantic conditions is marked, not only by the composition of the peat, but by a causeway, constructed in the late Bronze Age by people who were no longer able to cross the bog dry-shod. The radiocarbon age of 6,044 ± 380 years is later than the commonly accepted date of 7,500 years ago for the opening of the Littorina Sea, but about a thousand years too old if the peat is really Sub-Boreal. However, as the Atlantic-Sub-Boreal boundary is difficult to fix in pollen diagrams from regions so maritime as the British Isles, this result can be accepted provisionally.

Another sample from the same heath, no. 347, falls in Zone VIII, and as this level overlies peat of the major episode of flooding (early Iron Age) and underlies the Romano-British occupation surface of the bog, it should establish the end of the phase of maximum temperatures. Two determinations of the age of this peat (3,099 ± 250 and 3,520 ± 300 years) are sufficiently discordant to suggest that the sample was too bulky to pinpoint the exact horizon desired, and if one subtracts the laboratory error from the younger date, the resulting figure of 2,850 years is probably close enough to the accepted date of 2,500 years for Recurrence Surface III. No. 450 supposedly came from just below the same horizon in a bog at Melbeck, near Lüneburg, Hannover. It was carefully excavated by Fritz Overbeck, and represents a layer two cm. thick immediately below the *Grenzhorizont*. Thus the horizon should have been pinpointed, and the remarkably close agreement between two runs (1,446 ± 250, 1,452 ± 290 years) indicates that it was, but the age is much too young. Possibly the layer actually sampled represents Granlund's Recurrence Surface II, dated at 400 A.D., and not the classic *Grenzhorizont*. The published sections (Overbeck and Schneider, 1938) permit this interpretation, but the confusion, if such it is, is not necessarily of more than local significance. [5]

When we take account of the uncertainties of bog stratigraphy, and of the difficulty of collecting a bulk peat sample from a narrow horizon, the European dates are not out of line with the accepted figures for Atlantic and Sub-Boreal time (7,500 to 2,500 years ago). Sample 462, a piece of charred wood from a lake dwelling of supposed Neolithic "A" date, gives an age of 4,964 ± 300 years, and thus falls about where it should.

Data from the western side of the Atlantic are even more fragmentary, although they are not inconsistent with the stratigraphy so far as it is known. Sample 38, from Upper Linsley Pond, Connecticut, gives the reasonable figure of 5,159 ± 350 years for the transition from warm, moist (Atlantic?) to warm, dry (Sub-Boreal?) conditions, while the age of the sample from the level of the hickory maximum (no. 37, 1,800 ± 500 years) seems a little low for the Sub-Boreal.

Between these two dates we have the figure for the marine silt overlying the Boylston Street fishweir (Johnson and others, 1942, 1949): no. 418, 3,851 ±390 years. The Lower Peat (no. 417) at the fishweir site, which antedates the fishweir itself, gives the rather great age of 5,717 ± 500 years. The pollen stratigraphy at the fishweir site is inconclusive, but suggests that the structure was built shortly after the thermal maximum (Benninghoff, 1942; Knox, 1942; Wilson, 1949). One marine mollusk (Clench, 1942) from the deposits overlying the fishweir is a southern species and thus also implies a date around the thermal maximum. It is interesting to find that the radiocarbon results give ages a little higher than expected; the fishweir is only one of several archaeologic finds antedating a rise of sealevel on the Atlantic coast of North America, but salt-marsh peat from other such sites has not been submitted for dating, in the belief that the circumstances of its burial are exceptionally favorable to post-depositional exchange with younger carbon from sea water. If this exchange proves to be a chimera, a copious supply of such material is available for dating.

West of the Rockies, apart from the Gypsum Cave dates already discussed, and several other cave samples of supreme interest to archaeologists (Johnson and others, 1951), there are two samples connected (somewhat indirectly) with the pollen chronology. No. 247 consists of charcoal from a tree killed by the eruption of Mount Mazama, in the Cascade Range of Oregon (Williams, 1942); its age is 6,453 ± 250 years. No. 428 is a selection of sagebrush-bark sandals from Fort Rock Cave, Oregon, which were overlain by pumice from Newberry Crater (Cressman, 1942); they give the age of 9,053 ± 350 years.

Although the figures imply that the eruption of Newberry Crater antedated that of Mount Mazama by 2,500 years, this it not certain, and the confusion that arises from the dates can be clarified only by further work. The sandals and other artifacts of organic material in Fort Rock Cave were charred, possibly by hot pumice (Cressman, Williams, and Krieger, 1940; Cressman, 1942). Cressman has since stated (L. S. Cressman, unpublished communication) that the sandals assayed came from some distance below the pumice and thus do not date it precisely. Conflicting statements occur in the literature (see Hansen, 1942, p. 105; 1947, p. 100) as to the relative ages of Newberry and Mount Mazama pumice. Evidence that some Newberry pumice is younger was published by Williams (1942, p. 69), and also by Allison (1945). Allison's sections from the basin of Summer Lake showed three layers of pumice interbedded with shallow-water sediments at an altitude some 80 feet above the modern lake. The oldest layer was assigned to Mount Mazama, the youngest to Newberry Crater, on petrologic evidence, while the middle one was not identified. The altitude of the exposures implies that the pumice falls occurred toward the end of the postpluvial shrinkage of Pleistocene Winter Lake. Evidence corroborating that from Summer Lake comes from Fossil Lake in the Fort Rock-Silver Lake basin and from Chewaucan marsh; three layers of Newberry pumice are now believed to postdate the climactic explosion of Mount Mazama (I. S. Allison, unpublished communication). The possibility remains that there were earlier series of pumice falls from Newberry Crater, for in the Summer Lake sections there were older layers of pumice that were poorly exposed and could not be examined.

Layers of pumice and volcanic ash are stratified in many of the pollen profiles published by Hansen (1947), but the distances between localities in most cases are so great and the pollen sequence is so little differentiated that the assignment of ages to the various eruptions on pollen-analytic grounds alone is hazardous. In the region where Mount Mazama pumice is well represented, in some cases underlying the bogs sampled, it appears that a phase of warm, dry climate was well under way when the pumice was deposited. The best evidence of the nature of the climate at this time comes from marked and long-continued maxima of grass and chenopod-composite pollen, for although Hansen relied on an increase of yellow pine pollen as indicating relatively dry conditions, the evidence that different species of pine can be distinguished quantitatively by their pollen grains is insufficient.

Leaving the question of the age of the pumice in Fort Rock Cave as unsettled, we may discuss the date of the explosion of Mount Mazama, apparently more securely fixed by no. 247. If the 215-foot level of Winter Lake corresponds to the Provo stage of Lake Bonneville, if these high levels represent the Mankato maximum, as is believed by Allison, Antevs, and others, and if Mount Mazama pumice was deposited in a lake about 80 feet deeper than Summer Lake today, incorporation of the radiocarbon date of 11,000 years for the Mankato into Allison's argument indicates that the 6,500 year figure for Mount Mazama is entirely reasonable. It is consistent with the evidence that the volcanic explosion occurred after the beginning of the warm, dry interval of postglacial time, a climatic phase which may well have begun at the same time as the pine climatic phase in eastern North America. The writers know of no special reason for agreeing with the belief of Allison (unpublished communication) that sample 247 gives a falsely late date owing to post-depositional exchange of carbon.

The sandals from Fort Rock Cave are the oldest American artifacts yet assayed. Dates are also available for another early culture, the Cochise, in southern Arizona. The Sulphur Spring stage of the culture (Sayles and Antevs, 1941) consists of stone artifacts, and charcoal of hickory and cottonwood, imbedded in river sands and gravels laid down in an episode of alluviation. The same deposits contain bones of mammoth, horse, and dire wolf. As the culture material and the fossils have been carried by water, they are not necessarily contemporaneous with each other or with the alluviation, but the presence of hickory suggests a more humid climate than today, and the charcoal gives a radiocarbon date (no. 216) of 7,756 $\pm$ 370 years. Another charcoal sample (no. 511) from the same stage, but at a different site, gives an age of 6,210 $\pm$ 450 years. The Chiricahua stage of the culture occurs in alluvium apparently deposited in erosion channels cut in the older formation and containing fossils of modern vertebrates. Charcoal from this stage (no. 515) gives an age of 4,006 $\pm$ 270 years. The relation of the San Pedro stage to the Chiricahua is somewhat similar to that between Chiricahua and Sulphur Spring; charcoal from the San Pedro stage (no. 519) is dated at 2,463 $\pm$ 310 years. The sequence of episodes of alluviation during humid phases, separated by arroyo cutting during arid phases, is not without parallel in other parts of the arid western United States (Albritton and Bryan, 1939), and in the Davis Mountains region of Texas the oldest deposits also contained mammoth and horse bones, though no artifacts. It is not to be expected, however, that such cycles were invariably contemporaneous in adjacent valleys, and in the Davis Mountains the youngest of the three bodies of alluvium contains pottery about 500 years old.

The chronology of events around the thermal maximum touches on widely different geographic phenomena, from peat composition and changing sealevel through volcanic eruptions to cycles of alluviation and erosion, and the material assayed for radiocarbon represents a small selection, taken almost at random. It is surprising that the dates obtained fit as well as they do with what was previously known or believed.

Mankato deglaciation. Two samples, not connected directly with the pollen chronology, seem out of line with the results presented so far. If the Mankato ice reached its maximum extent 11,000 years ago, and began its retreat soon afterward, so that the Boreal type of climate was attained within the area of Mankato drift in Minnesota 3,000 or 4,000 years later, it is difficult to account for the apparent presence of active ice in eastern Wisconsin some 6,000 years ago. No. 419 is a section of spruce log (*Picea glauca*) from laminated fine sediments within the limits of the Mankato drift sheet on the bank of Fox River in the SE 1/4 SE 1/4 sec. 3, T. 20 N., R. 17 E., north of Menasha, Winnebago County, Wis. The log was collected in 1925 by F. T. Thwaites, from an exposure made by a grader, and the stratigraphic relations were smeared and obscure. The log was exposed about ten feet below the surface, and was possibly but not certainly overlain by till. It was flattened as though overridden by glacier ice, and microscopic examination by E. S. Barghoorn (unpublished communication) revealed that the cell structure of the wood had been crushed. The growth rings, about 100 in number, are thin, suggesting slow growth and therefore probably a cold climate. No end moraines or other direct evidence of a readvance of the glacier margin have been recognized in the vicinity. Thwaites (1943, p. 136) inferred provisionally that the log is a correlative of the Two Creeks peat horizon, but later (F. T. Thwaites, unpublished communication) stated that it could postdate the Mankato maximum.

The date, 6,401 $\pm$ 230 years, 4,500 years after the Mankato maximum, seems altogether too late to warrant the hypothesis that the wood was overridden by one of the many re-expansions that characterized the shrinkage of the Mankato glacier from its maximum position, as shown by the numerous Mankato end moraines. The locality is barely 25 miles inside the outer limit of the Mankato drift sheet, whereas no. 332, from a bog but little farther inside the area of Mankato drift, indicates that the pine climatic phase had already been reached 1,600 years earlier. If the dates are accepted, the difference would be explicable only on the assumption that the Mankato ice melted very much more slowly in Wisconsin than in Minnesota. That it did so is possible, but two alternative explanations have not been eliminated, namely that there has been contamination or laboratory error in the dating of no. 419, and that the log was crushed by some agency other than glacial overriding.

A discrepancy in the opposite sense is provided by no. 497, wood from a peat-like stratum in sediments ascribed to glacial Lake Agassiz at Moorhead, Minnesota. It was furnished by W. S. Cooper. We owe its description to Rosendahl (1948, p. 289-290), who identified the flora. Rosendahl did not himself see the exposure; his description paraphrases that of a local observer.

The exposure was created during a construction operation in the bank of the Red River. The wood apparently underlay 25 feet of laminated (possibly varved) lacustrine silt. At least 1,800 exposed laminae were reported. The contact of the lacustrine sediments on underlying till was believed to lie not far beneath the wood horizon. The wood was allochthonous, possibly having been carried into the lake by the Buffalo River. Rosendahl expressed the opinion that the wood was deposited "fairly early in the history of the lake." The floral assemblage proved to be similar to that living in the same district today.

After the Mankato maximum, for which we accept a date of 11,000 years, the glacier had to shrink so as to eliminate the massive Des Moines lobe, 300 miles long, before the Moorhead locality could be uncovered. Thus the wood, if actually deposited in Lake Agassiz, should be considerably younger than 11,283 ± 700 years, the date determined. If possible alteration, contamination, and laboratory error are set aside, there are still at least two other possible explanations of the discrepancy. The more likely is that the wood is a correlative of the Two Creeks horizon, and that it was washed out of its first sedimentary matrix by the waves of Lake Agassiz and incorporated in the sediments of that lake. Upham (1895, p. 253) implied that driftwood of very late date is common in deposits along the Red River. The less likely explanation is that the Mankato ice reached its maximum substantially earlier in the Dakotas than in eastern Wisconsin.

History of the Great Lakes. Three more samples, nos. 191, 364, and 504, which also postdate the Mankato maximum, are related to each other because of their relations to the glacial Great Lakes. Their respective dates agree fairly well among themselves, although possibly all are younger than might have been expected.

No. 191 is charcoal, furnished by W. A. Ritchie from the stratigraphically lowest level of a human occupation site on Frontenac Island in Cayuga Lake, New York, 7 miles south of the northern end of the lake. The entire island is less than 20 feet above the lake surface. It can be inferred from Fairchild (1909, p. 59; plate 42), Leverett and Taylor (1915, pp. 409-445; plate 21) and Coleman (1936) that the basin of Cayuga Lake was filled with glacier ice or with lake water, above the level of the present lake, until well after Lake Iroquois had begun to be drained (by stages) by glacial melting north of the Adirondacks. It follows that Frontenac Island could not have emerged until that time, and that the earlier part of the draining of Lake Iroquois therefore occurred at least 4,930 ± 260 years ago, the date of the earliest known human occupation of the island.

From the same sources it appears that Lake Iroquois was drained while Lake Algonquin III[2] occupied the upper Great Lakes region. Hence it appears likely that Lake Algonquin III was in existence more than 4,930 years ago. The date does not imply that it was not in existence very much longer ago than that, and the fact that Lake Algonquin had an ice margin is not in conflict with the fact that 5,000 years ago was around the time of the thermal maximum.

[2] The following equivalents with earlier usage exist:

This paper	*Leverett & Taylor* (1915)
Lake Algonquin I	Early Algonquin (p. 412)
Lake Algonquin II	Kirkfield stage (p. 412)
Lake Algonquin III	Port Huron-Chicago stage (p. 413)
Lake Algonquin IV	Closing transitional stage (p. 438)

No. 504 is a sample of peat, collected by L. R. Wilson (Wilson, 1935) from beneath the surface of Lake Superior at Sand Island near the western end of the lake. The peat represents a flora similar to that now living in the region. According to Taylor (1931; see also Leverett and Taylor, 1915, plate 27) this layer of peat was formed, possibly in a lagoon, at or close to the level of the Nipissing Great Lakes during the very early, one-outlet phase of that water body.

If Taylor's correlation is accepted, the early Nipissing phase was in existence 3,656 ± 640 years ago. Subtracting this date from that obtained for no. 191 we get 1,274 years as the minimum elapsed interval between a time when Algonquin III existed and a time early in the history of the Nipissing lakes—an interval embracing an unknown fraction of Algonquin III time plus the time required for the evanescent Algonquin IV (Leverett and Taylor, 1915, p. 438) which marked the short transition from Algonquin III to Nipissing.[3]

No. 364 is a piece of an oak log occurring as driftwood in beach sand and gravel at Dolton, Illinois, at the southern end of Lake Michigan. J H. Bretz, who collected the sample many years ago, is unable to determine whether the inclosing beach sediments belong to the Toleston strandline of Lake Chicago, to the highest strandline group of Lake Algonquin, or to the highest strandline group of a late phase of the Nipissing Great Lakes. The uncertainty results from the fact that in the vicinity of Dolton all three groups lie within the narrow altitude range of 590 to 600 feet (Bretz, 1939, p. 111; unpublished communication; J. S. Olson, unpublished communication).

The date of the sample (3,469 ±230 years) precludes its assignment to Toleston Lake Chicago, which long antedates Lake Algonquin. The history of Lake Algonquin, inferred from the various references cited above, indicates that its highest strandlines at the southern end of Lake Michigan were made at the end of Algonquin III. But no. 364 is younger than no. 504, believed on good evidence to be early Nipissing. Even if we take the full benefit of the margins of error in the dates of these two samples—that is, add the error to the date for no. 364 (3,469 + 230 = 3,699) and subtract the error

[3] Stanley (1938, p. 966) suggested that additional events might be involved.

from the date for no. 504 (3,656 − 640 = 3,616)—we get a difference of only 88 years between latest Algonquin III and the earliest Nipissing phase. Within the limits of present very imperfect knowledge, this seems improbable. Hence the Algonquin correlation can be rejected at least provisionally.

This leaves the late-Nipissing correlation. Assuming that no. 364 is late Nipissing, and subtracting its date from that of no. 504, we obtain 187 years (neglecting specified errors) as the minimum time elapsed between the early Nipissing and late Nipissing phases. This figure is very small, but it does not seem impossible.

The entire scheme, of course, is predicated not only on the accuracy of the three dates concerned, but on stratigraphic correlations made at different times by several geologists. Many possible errors are involved. The stratigraphy of the three samples has been explored as a test, and whereas the agreement between the dates and the stratigraphy is very far from perfect, it is not wholly inconsistent. The recency of the dates is surprising at first glance, but the time sequence is not inconsistent with nos. 334 and 332, in terms of deglaciation since the Mankato maximum. The fact that these dates fit the relative stratigraphic positions of the corresponding deposits even as well as they do, lends credibility to their absolute as well as relative reliability.

The chief obstacle to accepting them may appear to be the existence of a body of salt water in the Gulf of St. Lawrence region, postdating lakes correlated with Algonquin IV. Some geologists will continue to believe that this series of dates implies impossibly great crowding of post-Mankato-maximum events in the Great Lakes region. This belief may be justified, and the doubt cannot be disposed of until more radiocarbon dating has been accomplished. But the history of the Gulf of St. Lawrence is known with too little certainty to stand in the way of the dates. If there was a sea of arctic character in that region, it was probably not the same sea that postdates Algonquin IV. Fossils from the vicinity of Ottawa include such comparatively warm-climate types as sugar maple, balsam poplar, and yellow birch (Baker, 1920, pp. 178-179), all of which would be expected to live in the same district today. The stratigraphy of the region needs to be thoroughly reexamined.

PRE-MANKATO DATES

A number of samples known or believed to antedate the Mankato maximum, one of them indubitably Illinoian or earlier, were assayed. Thus far all but one have proved to be beyond the reach of precise dating by the laboratory method used, although it is hoped that through the use of a more refined method, currently about to be tried, some of these can be dated. At present the dates can be quoted only as greater than a minimum figure, ranging from 16,000 to 20,000 years. The data on the samples tested are set forth in the following sections, arranged in order of increasing stratigraphic age.

Tazewell-Cary interval. No. 508 is a piece of a log imbedded in unaltered till and collected in 1950 by R. P. Goldthwait, who gave his opinion that the till is Cary. The occurrence is in the E ½ sec. 2, R. 6. T. 1., Montgomery County (6 miles south of Dayton), Ohio.

The log is one of several that probably record a forest overwhelmed by the advancing Cary glacier; therefore its age is presumably late in the Tazewell-Cary interval.

The wood is dated as >17,000 years old. This minimum date agrees with that of no. 481; as far as they go, these two dates agree with the stratigraphic interpretations on record.

No. 465 is a piece of a conifer log from an exposure in sec. 26, T. 4N, R. 1E., Butler County, near Hamilton, Ohio. The log was imbedded in unaltered till, about 50 feet below the surface of the till and of the ground. According to R. P. Goldthwait, who collected the sample in 1949, the till is either Tazewell or Cary. Therefore, the tree concerned was probably killed during the Tazewell or Cary advance.

The minimum date, >15,000 years, agrees fairly well with nos. 508 and 481, and is consistent with either of the two stratigraphic interpretations mentioned above.

No. 438 is a sample of peat furnished by E. R. Eller from a Wisconsin stream terrace on Chartiers Creek, near Bridgeville, Pennsylvania. The occurrence is fully set forth by Schopf and Cross (1947). The peat is related to ponding of the creek by an outwash fill in the Allegheny-Ohio drainage system. In a well-reasoned argument, Schopf and Cross stated the opinion that the peat dates from very late in either the Tazewell-Cary interval or the Cary-Mankato interval, probably the former.

The date, >16,000 years, confirms these authors in that it rules out the Cary-Mankato possibility and admits of the Tazewell-Cary possibility. This sample is expected to be somewhat though not greatly younger than no. 481.

Tazewell sub-age. No. 575 is a piece of wood from a pit in the SW 1/4 sec. 9, T. 34 N., R. 4 E., La Salle County, Illinois. It was imbedded in lacustrine clay correlated with the Lake Kickapoo deposits of Tazewell age, overlain at this locality by Tazewell till. Hence the wood cannot be younger than Tazewell. The section has been described and illustrated by Willman and Payne (1942, p. 307). H. B. Willman, J H. Bretz, and Leland Horberg, all of whom are familiar with the local stratigraphy, concur in the stratigraphic position of the wood.

The date (>17,000) in consistent with those mentioned in the preceding paragraphs as pertaining to the Tazewell-Cary interval.

Iowan or Tazewell sub-age. No. 481 is a fragment of wood from the Mitchellville cut (NE 1/4 sec. 1, T. 80 N., R. 22 W.), Polk County, Iowa. The wood was collected in 1950 by W. H. Scholtes of the Bureau of Plant Industry, U. S. Department of Agriculture. It was imbedded in loess 16 feet below the upper surface of the loess, which is capped by 2 to 3 feet of till. According to an unpublished communication from R. V. Ruhe of the Iowa Geological Survey the till is probably Cary and the loess is Iowan and Tazewell loess. The wood therefore may date from as early as Iowan time.

The date obtained for the wood is >17,000 years.

Farmdale horizon. No. 510 is a piece of wood collected in 1950 by G. D. Smith and C. S. Denny from an exposure one-quarter mile east of the classic Farm Creek exposure near Peoria, Illinois (Leighton, 1926). The wood was imbedded in loess formerly considered to be Sangamon soil but more recently regarded as Farmdale (very early Wisconsin) loess.

Little hope was entertained that this horizon would fall within the scope of the dating method used, and it does not. The date reached is >20,000 years.

Sangamon interglacial age. No. 105 is a piece of cypress stump from the Carolina coastal plain collected by Stephen Taber from a section exposed in the Intracoastal Canal near

Myrtle Beach, Horry County, South Carolina. The sample was taken from a stump rooted in peaty soil overlain by more than 15 feet of the marine Pamlico formation. Taber (unpublished communication) regarded the cypress-stump horizon as probably early Sangamon.

The Pamlico formation represents a sealevel about 25 feet above present sealevel, and a climate at least as warm as the present climate. Although it has been considered to be probably Sangamon, this formation has never been stratigraphically placed with accuracy. The date of no. 105, >20,000 years, throws a little light on the stratigraphic position of the Pamlico. Presumably the only time since the Sangamon age when the sealevel could have been higher than now was the thermal maximum of about 5,000 years ago. Such a figure is ruled out by the great age of no. 105. Hence the Pamlico is apparently at least as old as Sangamon.

No. 480 is a piece of oak wood from Cambridge, England, furnished by H. Godwin. It was imbedded in organic mud indicated by its fauna and flora, as well as by its relation to stream terraces, to be interglacial. It has been stated by Hollingworth, Allison, and Godwin (1950) that the mud probably belongs to the last (= Sangamon?) interglacial stage. The radiocarbon date, >17,000 years, is in accord with that probability.

Illinoian glacial age. No. 466 is a piece of wood from a log exposed in a creek bank in sec. 2, T. 19 N., R. 12 W., Vermilion County (near Danville), Illinois. It was collected in 1950 by H. E. Eveland, G. W. White, and H. B. Willman, from Illinoian till the surface of which had been converted to gumbotil. The position of the wood was 4.5 feet below the base of the gumbotil.

This sample was run as a check on the general accuracy of the dating method. It was expected that it would prove to be beyond the reach of the method used, and the expectation was fulfilled. The date obtained was >17,000 years.

Unknown pre-Mankato horizons. Several samples were assayed from horizons of unknown stratigraphic correlation. The first, no. 363, is a piece collected by Stephen Taber from a large cypress stump rooted in place on the Santee River about 2 miles downstream from the Santee-Cooper Dam, Berkeley County, South Carolina, at an altitude of about 25 feet. The stump, representing a tree larger than any conifer now growing east of the Mississippi River, had been exposed by diversion works. Previously it had been under water, and terraces show that it had earlier been buried beneath about 30 feet of sandy alluvium, dated only (by Taber) as "probably Wisconsin or earlier to Recent." The geology of the district has been discussed by Taber (1939).

Possibly the tree was killed by alluviation in response to rise of sealevel during Sangamon time or some other time of high sealevel. The date obtained, >17,000 years, is consistent with the date of no. 105, definitely related to a rising sealevel higher than the present one.

No. 496, furnished by W. S. Cooper, consists of wood taken from a well at Bronson, Kittson County, Minnesota, in the region of Mankato drift. The collecting was properly supervised, for samples were taken at 2-foot intervals as the boring progressed. The well log (Rosendahl, 1948, p. 291-296) is as follows:

Lake Agassiz sediments	20 feet
Till	46 feet
Gravel, sand, and clay	22 feet
Peat	3 feet
Clay (lacustrine?)	16 feet
Boring ceased at	107 feet

Rosendahl identified the plant assemblage in the peat as representing a spruce-tamarack forest. Progressive decrease in the thickness of growth rings visible in sections of three branches was viewed by him as recording oncoming glaciation.

The obvious stratigraphic assignment of the peat, before radiocarbon dating, was to the Cary-Mankato interval. However, the radiocarbon date, >19,000 years, makes this improbable, at least until the date of the Cary maximum has been determined. It is more likely that the peat dates from at least as long ago as the Tazewell-Cary interval. The 46-foot thickness of till overlying the peat may of course consist of two tills in direct contact with each other. On the other hand, if the peat should prove to be Tazewell-Cary, and if only one overlying till is present, an interesting possibility arises.

Conceivably, the till represents both Cary and Mankato substages at a locality continuously covered by ice throughout the Cary-Mankato interval. With information from more localities, radiocarbon dating can perhaps throw light on the subject, little known hitherto, of the extent of deglaciation between the various substages of the Wisconsin glacial age.

Two samples from Singletary Lake, Bladen County, North Carolina, were collected by David G. Frey by means of multiple sampling with a peat borer. Three organic horizons are known from the sediments of this lake (Frey, 1951), two of them lying below and one lying above the uppermost inorganic horizon that contains a maximum of spruce and pine pollen. If the spruce-pine inorganic zone is of Mankato age, as Frey suggested, the lower organic layers from which the dated samples came should belong to the Cary-Mankato and Tazewell-Cary intervals. Both samples (nos. 475 and 476) prove to be older than 20,000 years, and therefore neither can be as young as the Cary-Mankato interval.

A sample from the upper organic layer, which Frey supposed to be post-Mankato, has not yet been assayed.[6]

Another sample from England, no. 479, furnished by H. Godwin, should be mentioned here, as its stratigraphic position is not precisely fixed. It is from an arctic peat occurring as transported masses in gravel in the Lea Valley north of London. The gravel is identified as the Ponder's End horizon (Warren, 1915), believed to date from some time during the last (=Wisconsin?) glacial age (H. Godwin, unpublished communication). The date obtained, >20,000 years, is a minimum that compares well with the dates of all but one of the pre-Mankato samples from the United States. Hence it confirms expectation.

Summary. Unfortunately the majority of the pre-Mankato dates are not fixed except as to minima. Some of the samples are stratigraphically so ancient that their dates probably cannot be improved. Those believed to be Tazewell-Cary, however, are likely to fall within the range of the more refined radiocarbon dating method soon to be undertaken. The pre-Mankato date now most needed is a date as close to the Cary maximum as possible, so that the time relations of the last two glacial maxima can be determined.

CONCLUSION

The first extensive results of stratigraphic dating by radiocarbon have value and show great promise for the future. The results seem fully as good as the results of the uranium dating of rocks in the early days of the development of that method. The fact that most of the radiocarbon dates fall into the relative stratigraphic positions of the samples encourages belief that the method is reliable and that significant exchange variations in the proportions of Carbon 14 to total carbon within the materials sampled are not likely to have been great.

According to one's point of view, it is refreshing or discouraging to recall the number of instances in which a direct challenge, offered by a radiocarbon date to a previously published stratigraphic assignment, has resulted in significant modification or withdrawal of published statements and cherished views. At the same time, in some of the same instances, acceptance of the radiocarbon dates requires a mental balancing of probabilities that is suspiciously close to special pleading. The new method, like older stratigraphic methods, is subject to possibility of error, recognized and unrecognized, and at present it is impossible to be sure that any opinion about a date, favorable or unfavorable, is free from special pleading. It is therefore necessary, while giving general approval to the new chronology, to keep an open mind about every one of its specific applications.

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APPENDIX

Check list of samples and dates, arranged in order of laboratory number. The errors quoted correspond to the standard deviation ($\sigma = \sqrt{\text{number of counts}}$).

Number	*Description*	*Date (years before A.D. 1950)*
36	Gyttja, Upper Linsley Pond, Conn., 5.5 m., Ekman dredge	876±250
37	Gyttja, Upper Linsley Pond, Conn., 8.05 m., Zone C2	1,800±500
38	Gyttja, Upper Linsley Pond, Conn., 9.15 m., Zones C1-C2	5,159±350
39	Gyttja, Upper Linsley Pond, Conn., 11.65 m., Zones B-C1	8,323±400
105	Wood of cypress from beneath Pamlico formation, Myrtle Beach, S. C.	>20,000
119	Gyttja, Upper Linsley Pond, new series, 4.65 m., Zone C2	2,141±250
120	Gyttja, Upper Linsley Pond, new series, 6.65 m., Zones C1-C2	5,305±250
121	Gyttja, Upper Linsley Pond, new series, 8.65 m., Zone C1	6,911±250
		4,088±250
122	Gyttja, Upper Linsley Pond, new series, 10.15 m., Zone B	6,668±250
191	Charcoal, Frontenac Island site, Cayuga Lake, N. Y.	4,930±260
216	Charcoal, Cochise culture, Sulphur Spring stage	7,756±370
221	Dung of ground sloth, Gypsum Cave, Las Vegas, Nev.	10,902±440
		10,075±550
	Ave.	10,455±340
222	Dung of ground sloth from higher horizon at locality of 221	8,692±500
		8,051±450
		8,838±430
	Ave.	8,527±250

APPENDIX (*Continued*)

Number	*Description*	*Date (years before A.D. 1950)*
247	Charcoal, tree killed by eruption of Mt. Mazama, Ore.	6,389±320
		7,318±350
		5,938±400
		6,327±400
	Ave.	6,453±250
308	Spruce wood, Two Creeks horizon, Manitowoc Co., Wis.	10,877±740
332	Gyttja, Cedar Creek Bog, Minn., 8.5 m., Zone B	7,988±420
334	Peat, Johnson Camp Bog, Minn., 8 ft., Zone B	7,586±490
		6,866±350
	Ave.	7,128±300
335	Gyttja, Plissey Pond, Me., 6.0 m., Zone B	5,962±320
336	Peat, Cranberry Glades, W. Va., 12¼-12¾ ft., Zone B	9,434±840
337	Gyttja, Wallensen im Hils, Hannover, Germany, Zone II	11,044±500
340	Upper peat, Hawks Tor, Cornwall, England, Zone IV	8,011±400
		8,540±780
	Ave.	8,275±350
341	Lower peat, Hawks Tor, Cornwall, England, Zone II	9,861±500
343	Peat, Shapwick Heath, Somerset, England, Zone VIIb	6,044±380
347	Peat, Shapwick Heath, Somerset, England, Zone VIII	3,099±250
		3,520±300
	Ave.	3,310±200
349	Gyttja, Hockham Mere, Norfolk, England, 790-825 cm., Zones II-III	6,619±380
		6,491±420
	Ave.	6,555±280

APPENDIX (*Continued*)

Number	*Description*	*Date (years before A.D.* 1950)
353	Birch wood, Mesolithic platform, Star Carr, Seamer, Yorkshire, England, Zone IV	10,167±560
		8,808±490
	Ave.	9,488±350
355	Gyttja, Knocknacran, Co. Monaghan, Ireland, Zone II	11,310±720
358	Peat, Clonsast, Co. Offaly, Ireland, Zone VI	5,824±300
363	Cypress stump, Santee River, S. C.	>17,000
364	Oak wood from lacustrine beach, Dolton, Ill.	3,469±230
365	Spruce root, Two Creeks horizon, Manitowoc Co., Wis.	11,437±770
366	Peat in which no. 365 was rooted	11,097±600
385	Wood from outwash, Bonfils, Mo.	12,148±700
417	Lower peat, Boylston St. fishweir site, Boston, Mass.	5,717±500
418	Marine silt, Boylston St. fishweir site, Boston, Mass.	3,851±390
419	Wood from Mankato drift, Appleton, Wis.	5,938±300
		6,864±300
	Ave.	6,401±230
428	Sandals, Fort Rock Cave, Ore.	9,188±480
		8,916±540
	Ave.	9,053±350
432	Pine cones, Aamosen, Sjaelland, Zone V ..	7,583±380
433	Hazel nuts, Mesolithic summer house, Aamosen, Sjaelland, Zone VI	9,935±440
		9,927±830
	Ave.	9,929±350
434	Charcoal from same summer house as no. 433	8,631±540
438	Peat from alluvium near Bridgeville, Pa. ...	>16,000
444	Gyttja, Neasham, near Darlington, Northumberland, England, Zone II	10,851±630
450	Peat, 0-2 cm. below *Grenzhorizont,* Melbeck, Hannover, Germany	1,446±250
		1,452±290
	Ave.	1,449±200

APPENDIX (*Continued*)

Number	*Description*	*Date (years before A.D.* 1950)
462	Charred wood, Neolithic "A," Edenside Tarn, Cumberland, England	4,964±300
465	Wood from Tazewell or Cary drift, Oxford, Ohio	>15,000
466	Wood from Illinoian till, Vermilion Co., Ill.	>17,000
470	Charcoal from alluvium, Frontier Co., Neb.	10,493±1,500
471	Charcoal from alluvium, Frontier Co., Neb.	9,880±670
		9,167±600
	Ave.	9,524±450
475	Lacustrine mud from middle organic horizon, Singletary Lake, N. C.	>20,000
476	Lacustrine mud from lower organic horizon, Singletary Lake, N. C.	>20,000
479	Plant debris, Lea Valley arctic horizon, Ponders End, England	>20,000
480	Oak wood, last interglacial stage, Cambridge, England	>17,000
481	Wood from loess underlying Cary till, Polk Co., Ia.	>17,000
484	Dung of ground sloth, Mylodon Cave, Ultima Esperanza, Chile	10,800±570
		10,864±720
	Ave.	10,832±400
485	Burned bone of sloth, horse, and guanaco, Palli Aike Cave, Chile	8,639±450
496	Wood from beneath Mankato drift, Bronson, Minn.	>19,000
497	Wood from Lake Agassiz sediments, Moorhead, Minn.	11,283±700
504	Peat, Sand Island, Bayfield Co., Wis.	3,656±640
508	Wood from Cary till, Montgomery Co., Ohio	>17,000
510	Wood from Farmdale loess, Farm Creek, Ill.	>20,000
511	Charcoal, Cochise culture, Sulphur Spring stage, Ariz.	6,210±450
515	Charcoal, Cochise culture, Chiricahua stage, Ariz.	4,006±270
519	Charcoal, Cochise culture, San Pedro stage, Ariz.	2,463±310

APPENDIX (*Continued*)

Number	Description	Date (years before A.D. 1950)
536	Spruce wood, Two Creeks horizon, Manitowoc Co., Wis.	12,168±1,500
537	Peat, Two Creeks horizon, Manitowoc Co., Wis.	11,442±640
575	Wood from Lake Kickapoo sediments (Tazewell), La Salle, Ill.	>17,000

Notes Added in Proof

1. A sample of burned bone (no. 558) from Lubbock, Texas, associated with Folsom man, gives a date of 9,883±350 years.

2. A sample of gyttja (no. 478) from Upper Linsley Pond, Conn., was taken in March, 1950, at 10.55 m. in the center of the lake by means of the specially constructed large sampler. A new pollen diagram at the site shows the horizon of the sample to be middle C1, and its radiocarbon age is 8,794±550 years, slightly older instead of slightly younger than no. 39. Because of the way it was collected, the new sample indicates that the pine zone in Connecticut is about 9,000 instead of about 8,000 years old.

3. A sample of peat (no. 500) from Lake Cicott Bog, Cass County, Indiana, taken at 22 to 23 feet at the top of the pine zone, gives the age of 5,625±310 years. The validity of this composite sample has been discussed at length by Deevey and Potzger (1951), and its incredibly low radiocarbon age may perhaps be attributed to unconformities in the sediments, of which there is no trace in the pollen diagrams. In view of the elaborate and unsuccessful attempt to circumvent it by statistical analysis, such a difficulty may be regarded as inherent in the method of multiple sampling.

4. A sample of birch wood (no. 435) from another summer house in the same area and at the same horizon as nos. 433 and 434 is dated as 9,425±470 years old, thus confirming the less reasonable of the two discordant dates, and reinforcing the suggestion of stratigraphic confusion by human occupation of the site.

5. Sample no. 449, representing a layer two cm. thick immediately above the *Grenzhorizont* at the same locality, is dated as 1,129±115 years old, and is fully consistent with the result for no. 450.

6. The sample (no. 474) from the lower part of the uppermost organic horizon in Singletary Lake, N. C., gives the date of 10,224±510 years. This is a composite sample and must be regarded with suspicion, but its age agrees precisely with its stratigraphic position as inferred by Frey, in that it is younger than the Mankato maximum and older than the oldest pine-zone sample yet dated (no. 336).

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