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## THE LATE-GLACIAL CHRONOLOGY OF EUROPE—

### A DISCUSSION

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**ABSTRACT.** Recent refinements in pollen analysis plus the introduction of radiocarbon dating have increased understanding of the chronology of climatic fluctuations, morainic development, and vegetational succession in Europe during the Late-Glacial phase of the Weichsel or Würm glaciation. The Alleröd warm fluctuation in the pollen diagrams provides the key horizon for correlation over a broad area; it is firmly related to ice retreat prior to the formation of the Central Swedish-Salpausselkä moraines on the basis of varve chronology, radiocarbon dating, and the location of Alleröd-bearing bogs with respect to the Scandinavian moraines. The Alleröd interval is identifiable over a broad area from the glacial region southward to the Alps, and its correlation is supported by radiocarbon dating and by the occurrence of volcanic ash within it.

An earlier warm fluctuation (Bölling) is becoming widely recognized in pollen diagrams from Denmark and adjacent regions, and its correlation with a retreatal phase of the Scandinavian ice sheet is being studied. Correlation of the Bölling interstadial with the moramic sequence in the Alps is not yet firm, but radiocarbon dating has not yet been widely applied in the Alpine region.

The pollen diagrams of the periglacial zone are generally bottomed on a treeless tundra phase that fades downward into unfossiliferous sediments of the High-Glacial phases, when, according to Gross, frost action inhibited orderly accumulation of pollen-bearing sediments. Correlation of earlier stages between the Alps and the Scandinavian ice margin is thus not aided by pollen analysis nor as yet by radiocarbon dating. The latter technique can be applied to much of this time range, however, so firming of the correlations can soon be expected.

#### INTRODUCTION

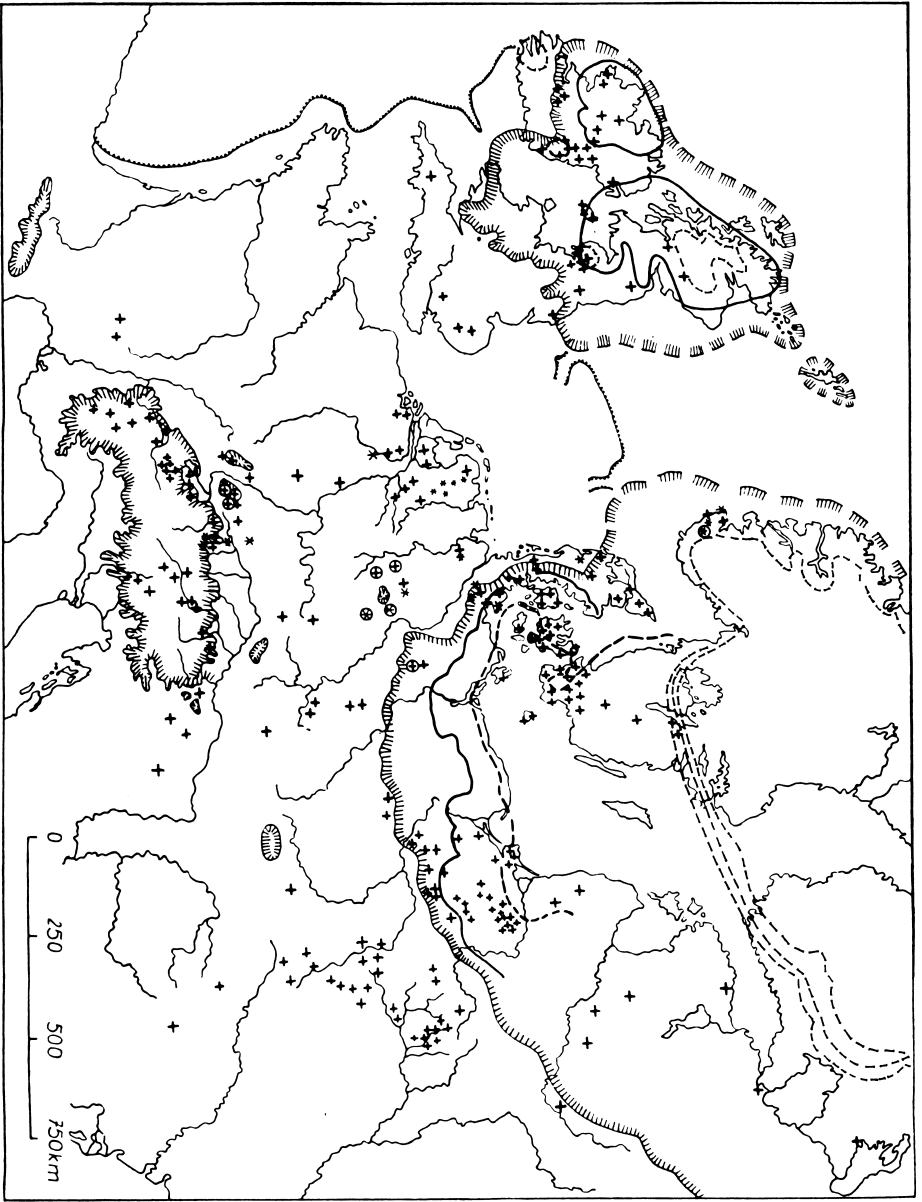
The absolute chronology of the Late-Glacial phase of northern Europe, as worked out during the past 50 years on the basis of moraines, varved clays, drainage of the Baltic Sea, and pollen profiles, has not required the degree of modification necessitated in the correlative American chronology upon the introduction of the radiocarbon-dating method. The DeGeer (1940) chronology for the last 11,000 years has been confirmed by radiocarbon dates for the Alleröd interstadial (centering around 11,500 years ago), a subdivision of the Late-Glacial based on a zone in the pollen profiles. The new techniques of counting non-arboreal pollen and of determining tree-pollen frequency have permitted the subdivision of the very basal portions of the pollen profiles so that the inferred climatic fluctuations during the earlier stages of ice retreat may be correlated with ice borders, periglacial features, and the movements of Early Man and his mammalian associates.









The following discussion is precipitated by a comprehensive summary by Hugo Gross (1954, 1955)<sup>1</sup> of Bamberg, Germany, of the status of Late-Glacial chronology of Europe, with especial reference to the Alleröd interstadial and

\* The writer is pleased to acknowledge the criticisms of a draft of this discussion proffered by C. S. Stearns, Sheldon Judson, and Meyer Rubin.

<sup>1</sup> The writer has prepared mimeographed translations of the two Gross papers for distribution to interested persons.

Fig. 1. Distribution of Late Glacial Interstadial occurrences in Europe (Gross, 1954).



- 
 Maximum der Weichsel-(Würm)-Verstüung
- 
 Pommersches Stadium
- 
 Gotiglaziale Anfangsmoräne
- 
 Mittelschwed. (Salpausselkä-) Stadium
- 
 Letztzeitliche Kfiste
- 
 Profile mit Alleröd-Schicht
- 
 Profile mit vulkan. Tuff in der Alleröd-Schicht
- 
 Profile mit Alleröd- u. Bölling-Interstadial

to the new radiocarbon dates. Gross has been occupied for many years with the study of the geology, palynology, paleontology, and archeology of the Alleröd interstadial and other Late-Glacial phases, especially in East Prussia (Gross, 1937, 1951) and more recently was among the first Europeans to offer a comprehensive discussion of the effects of radiocarbon dating on problems in Pleistocene chronology (Gross, 1952). The discussion here is concerned with some of the central problems considered by Gross, and is amplified by reference to some of the many other recent papers that deal with this matter. American readers interested in the Pleistocene of Europe probably rely for most of their information on the summaries by Deevey (1949, 1953), and Zeuner (1952) and the occasional reviews and comments by Antevs (1953). The flood of research papers, monographs, and books which have appeared since the war from Europe, particularly Germany, is so impressive that any systematic survey is difficult on the part of one not familiar with the area and the problems. Three journals (*Eiszeitalter und Gegenwart*, *Zeitschrift für Gletscherkunde und Glazialgeologie*, and *Quaternaria*) are devoted almost solely to studies of glacial geology and Pleistocene history, and in addition pertinent papers appear frequently in the host of general and regional journals. A few authors, particularly Scandinavian, have published in English, and an increasing number of papers bear English abstracts. American Pleistocene geologists, however, cannot afford to ignore the rapid European progress on problems of mutual interest that are concerned ultimately with Pleistocene climate and have implications concerning world-wide climatic changes.

#### ALLERÖD INTERSTADIAL

The Alleröd zone in the pollen profile is the key horizon for relating the pollen record to the glacial stratigraphy and morphology (table 1). In northern Europe the Alleröd is identified generally by a temporary decrease in the count of non-arboreal pollen (NAP), an increase in the absolute frequency of tree pollen, and among the tree pollen an increase in birch, pine, and other indicators of a cool-temperate climate. The zones above and below are commonly characterized by pollen of the tundra plant *Dryas octapetala*, and are called respectively the Older and Younger Tundra phases (or Older and Younger Dryas). Following the Younger Tundra zone comes the succession of Preboreal, Boreal, etc. phases of the Post-Glacial long established in the pollen stratigraphy of northern Europe.

Where the Alleröd layer occurs in lake sediments, it is commonly coincident with mud rich in organic matter compared to the mineral clays or sands of the Tundra zones below and above. The Alleröd layer has been identified in a wide variety of other environments, such as sands, alluvial soils, and even marine sediments.

Radiocarbon dating of the Alleröd pollen zone has been extremely successful (table 2). An early group of four dates from the Chicago laboratory for samples from the British Isles and from Wallensen, Germany, was followed by analyses at Copenhagen of 10 samples carefully collected from various laminae in the upper half of the Alleröd beds at an exposure at the Ruds Vedby brickwork, Denmark (Iversen, 1953; Krog, 1954). The Ruds Vedby

TABLE 1  
Phases of the Last Glaciation in Europe (Gross, 1954)  
Modified in last column by addition of new radiocarbon dates

Epoch	Positions of Ice Border		Vegetational History		Climate	Zone (Firbas)	C-14 Dates (BP)
	According to DeGeer	Weichsel	Würm	Phase			
Postglacial (beginning)	Finglacial (beginning)		Würm	Pre-boreal	Plant Cover Pine-birch forest	IV	10,300
		Salpausselkä II Central Swedish ice-border belt Salpausselkä I	Final Glaciation of the Alps (Daun, Gschmitz, Schlern)	Younger Dryas	Park tundra	III	10,750
				Alleröd inter-stadial	Pine phase Sparse forest cover	IIb	11,800
Late-Glacial	Gotiglacial	Central southern Sweden, Leningrad		Older Dryas	Birch phase Park tundra Tundra	IIa Ic	12,300
		Langeland N. Pomeranian		Bölling interst.	Park tundra	Ib	13,000
	Daniglacial	Samlund	Ammersee stadial (Bühl in broad sense)	Oldest Dryas	Treeless tundra	Ia Ia?	15,150
High-Glacial (end)	Pomeranian	S. Pomeranian end moraines	Inner young moraines (Zürich, Singen, Olkofen)		Frost rubble Tundra		15,750

series has fine internal consistency and shows that the Alleröd started before 12,000 years ago and extended until about 10,800. The early Chicago date of 11,044 for the Alleröd at Wallensen northwest of the Harz Mountains in central Germany (Firbas, 1954a) has been confirmed by new determinations at Copenhagen (11,160) and Heidelberg (11,800). An additional Alleröd date comes from Bölling Lake in Denmark (11,700); the mean of unpublished analyses of Dutch Alleröd samples at the Groningen Laboratory is 10,980.

TABLE 2  
Radiocarbon Dates from the Late-Glacial of Europe

Sample No.	Description	Age (years BP)
<b>POLLEN-DATED SAMPLES</b>		
<b>Younger Tundra Phase</b>		
K-111 <sup>(1)</sup>	Bölling Lake, Denmark. Lake mud, Top of Younger Tundra.	10,300 ± 350
GRO-961 <sup>(4)</sup>	Schalkenmehren crater, Eifel Mountains, central Germany. Lake mud over latest tuff.	10,550 ± 100
GRO-458 <sup>(4)</sup>	Schalkenmehren crater. Material similar to GRO-961.	10,770 ± 250
K-110 <sup>(1)</sup>	Bölling Lake, Denmark. Lake mud, Base of Younger Tundra. Mean of two measurements.	10,770 ± 300
<b>Alleröd Phase</b>		
Ruds Vedby, Denmark <sup>(4,5,9)</sup> . Arranged in order from top of Alleröd down to middle. Lower part of exposure not sampled.		
K-101, 102, 103.	Wood, peaty lake mud, and calcareous lake mud respectively. Boundary Alleröd/Younger Tundra. Mean of 5 measurements.	10,750 ± 200
K-113	Lake marl, End of Alleröd maximum.	10,930 ± 380
K-104	Calcareous lake mud, just below K-113. Mean of two measurements.	10,990 ± 240
K-105	Calcareous lake mud, Middle of Alleröd.	11,800 ± 410
K-106	Lake marl, just below K-105	11,880 ± 340
Wallensen im Hils, NW Germany <sup>(7)</sup> . Mud directly above Laacher volcanic tuff, Upper part of Alleröd.		
C-337 <sup>(9)</sup>	Peaty mud.	11,044 ± 500
K-107 <sup>(1)</sup>	Same as C-337.	11,160 ± 320
H- ?	Coarse detrital gyttja.	11,800 ± 300
<b>Bölling Lake, Denmark.<sup>(1)</sup></b>		
K-102	Lake mud. Mean of 2 measurements.	11,700 ± 360
<b>British Isles<sup>(6,8)</sup></b>		
C-341	Hawkes Tor, Cornwall, England. Peat. Alleröd <sup>(8)</sup> or Younger Tundra <sup>(2)</sup> .	9861 ± 500
C-444	Neasham, northern England. Lake mud.	10,851 ± 630
C-355	Knocknacran, Ireland. Lake mud.	11,310 ± 720
<b>Holland<sup>(9)</sup></b>		
GRO-?	Mean of several samples.	10,980
<b>Older Tundra Phase<sup>(9)</sup></b>		
H 77/54	Gaterslebener Lake, near Aschersleben, central Germany. Wood from clay-mud, Beginning of Older Tundra.	12,300 ± 260
<b>Bölling Phase<sup>(9)</sup></b>		
H 106/89	Gaterslebener Lake, near Aschersleben, central Germany. Sedge peat. Before or at beginning of Bölling.	12,700 ± 320
H 88/74	Material similar to H 106/89.	13,250 ± 280

TABLE 2 (continued)

Sample No.	Description	Age (years BP)
Oldest Tundra Phase <sup>(13)</sup>		
W-93 <sup>(10)</sup>	Poggenwisch, Holstein, northern Germany. Calcareous gyttja. Hamburgian II culture. Slightly later in Oldest Tundra than W-172.	15,150 ± 350
W-172 <sup>(11)</sup>	Meiendorf, Holstein. Gyttja. Hamburgian I.	15,750 ± 800
ARCHAEOLOGICAL SITES		
Germany—Antler Series <sup>(12)</sup>		
W-264	Meiendorf, Holstein (see W-93). Hamburgian (Magdalenian).	11,870 ± 200 11,790 ± 200
W-271	Poggenwisch, Holstein (see W-172). Hamburgian (Magdalenian)	11,750 ± 200
W-261	Stellmoor, Holstein. Hamburgian (Magdalenian).	12,450 ± 200
W-266	Munzingen, near Freiburg. Magdalenian.	10,100 ± 250
W-269	Kneigrotte, Thuringen. Magdalenian.	8,800 ± 200
W-267	Petersfels, Baden-Württemberg. Magdalenian.	8,200 ± 200
Southern France		
C-577 <sup>(14)</sup>	LaGarenne. Burned bone. Magdalenian.	11,109 ± 480
C-578 <sup>(14)</sup>	LaGarenne. Charcoal and burned bone. Same horizon as C-577.	15,847 ± 1200
C-579 <sup>(14)</sup>	LaGarenne. Burned bone, same horizon as C-577.	12,986 ± 560
C-406 <sup>(10)</sup>	Lascaux Cave. Charcoal. Upper Perigordian or very early Magdalenian. <sup>(15)</sup>	15,516 ± 900
W-151 <sup>(11)</sup>	Abri Pataud. Charcoal. Perigordian IV.	23,600 ± 800
W-191 <sup>(11)</sup>	Abri Pataud. Same horizon as W-151.	24,000 ± 1000

(1) Anderson, Levi, and Tauber, 1953.

(2) Iversen, 1953

(3) Krog, 1954

(4) Straka, 1956

(5) Straka and DeVries, 1956

(6) Arnold and Libby, 1951

(7) Firbas, 1954a

(8) Godwin, 1951

(9) Firbas, Müller, and Münnich, 1955

(10) Suess, 1954

(11) Rubin and Suess, 1955

(12) Rubin and Suess, 1956

(13) Schüttrumpf, 1955

(14) Libby, 1951

(15) Movijs, 1951

Radiocarbon Laboratories

C — Chicago

GRO — Groningen

H — Heidelberg

K — Copenhagen

W — Washington

A distribution map (fig. 1) compiled by Gross shows Alleröd localities in Europe ranging from Russia, southern Norway, and Scotland in the north to Romania and southern France in the south. Its identification is apparently not difficult in the north close to the glacial border, where the climatic fluctuations were pronounced and where many of the pollen profiles have a base of known glacial correlation. In this region it has been widely identified in scores of profiles examined in the half-century since it was first demonstrated in Denmark by Hartz and Milthers. South from the glaciated and immediate periglacial regions, however, both of the above conditions useful for its identification are less favorable. The fluctuations of the Alpine ice cap had a limited effect on the climate and vegetation of southern Europe, and the correlations

of these fluctuations with those of the North European ice sheet have been subjects of disagreement. Although Gross does not discuss the problem, it is possible that some of the reported Alleröd occurrences beyond the regions of the Last Glaciation and its immediate periglacial area may actually represent an earlier (or later?) warm fluctuation (see below).

Important confirmation of pollen correlation of Alleröd beds in the periglacial region has come from the discovery of volcanic ash in the Alleröd horizon at 8 lacustrine bogs in central and southern Germany. The source of the ash is the Laacher volcanic region in the Eifel Mountains in the middle Rhine valley south of Bonn, 100-200 miles from the Alleröd sites in question. The bogs in the volcanic area itself show that the datable eruptions continued throughout the Younger Tundra phase and into the beginning of the Preboreal (Straka, 1956; Frechen and Straka, 1950). These bogs bottom in thick ash, however, that may date back to the Alleröd. It is possible that only the Alleröd eruptions broadcast their products to a great distance, so that over most of the periglacial area the ash may remain a useful key indicator for Alleröd time.

In northern Europe the Alleröd interstadial has long been correlated with the ice retreat prior to the construction of the late Gotiglacial Salpausselkä-Central Swedish moraines, for Alleröd development is found nowhere north of these moraines. The extent of ice recession during the Alleröd interval is not known. The succession of dates (12,000 to 10,800 years BP) determined at Copenhagen for the upper half of the series of Alleröd laminae at Ruds Vedby (Denmark) suggests that the interstadial endured for at least 1000 years (Iversen, 1953).

#### YOUNGER TUNDRA PHASE

The beginning of ice recession from the Central Swedish moraines marked the end of the Gotiglacial ice-retreat phase of the Late-Glacial and the beginning of the Finiglacial phase of the Post-Glacial (table 1). This event was dated as 7912 BC in the DeGeer (1940) varve chronology, or 9862 before 1950. This figure was later adjusted by Caldenius to 10,152 BP on the basis of relations of varves to the correlative Salpausselkä moraines studied by Sauramo in Finland.

In Denmark the beginning and end of the Younger Tundra phase are dated by radiocarbon samples from Bölling Lake as 10,770 and 10,300 BP respectively (Iversen, 1953). These dates bracket two determinations of the Younger Tundra zone at Schalkenmehren in the middle Rhine valley (10,770 and 10,550) (Straka, 1956), and are so close to the dates in the varve chronology that the work on the Swedish and Finnish varves by DeGeer, Liden, Sauramo, and others must be considered correct for the last 11,000 years.

#### THE BOLLING INTERSTADIAL AND OLDER TUNDRA PHASE

In pollen profiles in the former Bölling Lake in western Denmark, well outside the correlative of the Pomeranian moraine, Iversen discovered a brief increase of birch within the Older Tundra zone. This was interpreted as registering a warm fluctuation prior to the Alleröd, and the succession of pollen

zones have since been called Oldest Tundra, Bölling, Older Tundra, Alleröd, and Younger Tundra.

The Bölling phase has been identified at three localities in the Hamburg-Bremen-Lübeck area in adjacent Germany and at six localities in Holland (Gross, 1954, p. 194; 1955, p. 110). It has also been found beneath the ash-bearing Alleröd layer at Gaterslebener Lake near Aschersleben in central Germany. Still farther south in southwest Germany the Bölling is suggested by a pre-Alleröd birch expansion in pollen profiles, but in this area the climatic effects of minor fluctuations of the Scandinavian and Alpine ice sheets were only weakly recorded in the vegetation (Gross, 1954, p. 202).

The correlation of the Bölling interstadial with a retreat phase of the Scandinavian ice sheet has been discussed at some length by Gross (1954, 1955). At Heiligenhafen near Lübeck the Bölling occurs in a bog developed on the main Pomeranian moraine, and at the edge of Gaterslebener Lake the pollen-bearing sediments rest on the Youngest Loess, which Gross correlates with the Pomeranian. According to this view the Bölling must postdate the Pomeranian stadial (the last phase of the High-Glacial). The retreat from the Pomeranian moraine to the Langeland moraine along the Baltic coast defines the Daniglacial phase of the Late-Glacial;<sup>2</sup> it was marked by the formation of a broad zone of stagnant ice in northern Germany between the two morainic belts. In the ice-block lakes which soon formed in this zone were deposited sediments bearing subarctic fauna previously assigned to the "Masurian interstadial". Sediments of this type were locally overridden on the north by the Langeland ice advance. The climate during this time, however, was still sufficiently severe so that active solifluction and thawing of permafrost prevented orderly accumulation of pollen-bearing sediments, according to Gross. Gross believes that as far as the vegetation was concerned the important break in climate came rather in the retreat from the Langeland moraines (starting the Gotiglacial interval); pollen of the Oldest Tundra zone was then deposited undisturbed on top of the fossil-bearing fresh-water sediments, and the Bölling phase soon followed.

Many of these relations are still under study by various workers, however, and the glacial and periglacial sequence is not everywhere firmly related to the pollen stratigraphy in northern Germany and eastern Denmark. Gaps in the continuity of the various Pomeranian moraines, lack of stratigraphic sections, and disturbances by periglacial frost action seem to cause differences in interpretation.

<sup>2</sup> The term Daniglacial was first used by DeGeer for the interval of ice retreat across Denmark from moraines correlative with the Brandenburg moraine up to the Scanian moraines of southern Sweden, which he correlated in turn with the Pomeranian moraines; the term Gotiglacial was used for the interval from the Scanian to the Central Swedish moraines. The correlation of Scanian with Pomeranian has since been questioned, and Zeuner (1952, p. 31), in adopting the view that the Pomeranian is older than the Scanian, has confined the Daniglacial to the interval from Pomeranian to Scanian. Gross (1954) further confines the Daniglacial to the interval from the main Pomeranian to the North Pomeranian moraine (see table 1) and assigns to Gotiglacial the balance of the retreat to the Central Swedish moraines. Flint (1947, p. 333) and Deevey (1949, table 2), on the other hand, use the term Daniglacial for the first part of DeGeer's interval, i.e. the retreat from the Brandenburg to the Pomeranian moraine.

The Bölling fluctuation has been dated by radiocarbon analysis of samples collected from the deposits at the Gaterslebener Lake locality near Aschersleben east of the Harz Mountains in central Germany. This is well beyond the border of the last ice sheet and an ideal site because the later Alleröd fluctuation here is defined by volcanic ash (Müller, 1953). Two samples from the base of the Bölling zone were determined as 12,700 and 13,250 years old, and one from the lower part of the overlying Older Tundra zone as 12,300. On the lake border the basal peat of the Oldest Tundra phase is strongly disintegrated (by frost action?) and rests on the Youngest Loess, which is correlated with the Pomeranian stadial (Gross, 1954, 1955). The relatively young radiocarbon dates support Gross's correlation of the Bölling with the later Gotiglacial (post-Langeland) retreat rather than with the Daniglacial (post-Pomeranian pre-Langeland) retreat.

#### OLDEST TUNDRA PHASE

Prior to the Bölling zone the pollen profile shows higher percentages of non-arboreal pollen, decreased tree-pollen frequency, high content of willow and relatively low content of birch (Schütrumpf, 1955). The pollen-bearing sediments generally bottom in sand or clay that contain only scattered pollens secondarily transported or blown in from distant sources.

According to Gross, the Oldest Tundra phase terminated with the retreat of the ice from the Langeland moraine during the Bölling phase, as explained above. According to this concept, much of the early record of the Oldest Tundra phase during ice retreat from the Pomeranian to the Langeland moraine would have been destroyed by periglacial solifluction. Pertinent to the chronology of this interval is the pollen analysis and radiocarbon dating of Upper Paleolithic archeological sites in the Hamburg region. The Hamburgian I cultural stage at the site of Meiendorf is dated as 15,750 BP, and the Hamburgian II stage at nearby Poggenwisch as 15,150 BP. The pollen profiles at both sites have been studied by Schütrumpf (1955), who assigned the cultures to the Oldest Tundra phase, with the Hamburgian II site appropriately showing already the pollen changes pointing to the distant approach of the Bölling interstadial. Inasmuch as the Oldest Tundra and Bölling phases are identified in profiles at nearby Heiligenhafen on top of the main Pomeranian moraine (Gross, 1955, p. 111), we can extend the main Pomeranian back at least to 15,750 BP. At Grömitz near Lübeck on the Baltic coast (Gross, 1955, p. 111) Hamburgian II artifacts are deeply imbedded in till whose correlation with a somewhat later Pomeranian moraine is implied. This relation suggests that the Pomeranian (or at least the Daniglacial in Gross's sense) survived 15,150 BP, although Gross proposes that the burial of the artifacts may have resulted from solifluction rather than overriding by glacier ice.

Other radiocarbon dates of archeological sites in Europe have not as yet contributed much to the correlation problem. The Hamburgian culture is correlated with the Upper Paleolithic Magdalenian VIa, which has been found farther south at Schussenquelle also in the Oldest Tundra zone. At Andernach am Rhine, however, it appears in Alleröd beds with confirmatory Laacher

volcanic ash (thus about 11,500 BP). On the other hand, three different samples from a single Magdalenian layer at La Garenne in southern France were dated as 15,847, 12,986, and 11,109 BP, and charcoal from Upper Perigordian (or very old Magdalenian) at Lascaux Cave in the Dordogne of the same region as 15,516 BP. Perigordian IV, on the other hand, was dated as 24,000 and 23,600 at Abri Pataud in the Dordogne.

The anomalies among these dates for the Magdalenian of central Germany and southern France may be explained by appealing either (1) to local persistence of older cultures, (2) inherent errors in using Paleolithic cultures as index fossils even in nearby areas, or (3) inaccuracies in the sampling or in the C-14 dating. More analyses are needed for this time range, particularly at those archeological sites which can be related to the pollen stratigraphy or to the glacial sequence.

A test series of new radiocarbon analyses on unburned antlers from several Magdalenian sites in Germany has been released subsequent to Gross's discussions, but proved somewhat disappointing: the dates are consistently younger than expected on the basis of the pollen chronology and the other C-14 dates. Pertinent Hamburgian dates are 11,790 and 11,870 for Meiendorf (dated as 15,150 from gytja), 11,750 for Poggenwisch (dated as 15,750 from gytja), and 12,450 for Stellmoor. Magdalenian sites in southern Germany yielded antler dates ranging from 10,100 down to 8,200 (table 2).

#### CORRELATION WITH THE ALPINE SEQUENCE

Correlation of the maximum and retreatal phases of the Weichsel glaciation of the Scandinavian ice sheet with those of the Würm glaciation in the Alps has never been completely satisfactory. Attempts at connection via the periglacial loesses and terraces of central Germany by Zeuner (1952) have been clouded by undue application of the radiation curve of inferred climatic fluctuations. The point has been reached, in fact, where Narr (1953), in view of the misuse of the terms Würm I, II, and III outside the Alps, recommends that a separate terminology be employed for the periglacial loesses and terraces, at least as far as archeologic dating is concerned.

Identification of the Alleröd layer in pollen profiles at many localities in southern Germany and in the Alpine piedmont again provides a key horizon for Late-Glacial correlation, and on the basis of many profiles Firbas (1949, 1950) has constructed forest maps of Europe for the Alleröd as well as for succeeding phases of the Late- and Post-Glacial. As mentioned above, the correlation of the Alleröd horizon in areas far removed from the margin of the Scandinavian ice sheet might seem to rest on a weak foundation because the age of the base of an analyzed bog may not be known and because vegetation is dynamic in its composition and migrations. Americans unaccustomed to the bulk and precision of European pollen analyses might sympathize with Deevey's earlier skepticism (1949, p. 1326): "It may be churlish to remark that there is no proof that the pollen spectra from which (Firbas' maps) are drawn are of exactly the same age." Firbas (1954b), however, has since specifically discussed the problem of synchronization of European pollen diagrams in some detail, and the increasing network of pollen profiles from

central and southern Europe presents an impressive picture, especially when they include analysis of the non-arboreal pollen and the tree-pollen frequency. The Alleröd correlations are confirmed at least for southern Germany by the fortunate occurrence of Laacher volcanic ash within the Alleröd layer at several localities. Radiocarbon dating of other Alleröd occurrences can be expected to support the general chronology.

Within the Alps, great hope was held for an independent absolute chronology of the Post-Glacial by Welten's careful pollen study of the varved gyttja of Faulensee Bog near Interlachen, Switzerland (Deevey, 1946). The bog is located on a moraine which Welton correlates with the Central-Swedish-Salpausselkä moraines, and the pollen-varve chronology places the beginning of the Post-Glacial (change from willow to birch) at about 8600 BP, compared to 10,800 for northern Europe. Zeuner (1952, p. 90; but *cf.* p. 155), however, has objected that the moraine on which the bog is located represents the Bühl stadial, correlated by him with the Pomeranian of the north, or at best (Gross, 1954) with the Langeland, rather than with the Salpausselkä. Such distant correlations of moraines must be considered largely as opinions. Gross further rejects Welten's chronology, however, on the basis of the fact that the Alleröd (ca. 11,500 BP) has been identified in Alpine valleys as high as 2100 m above sea level, indicating that the ice must have receded from the Faulensee site (590 m) long before 9600 BP, the date required by Welten. It might be pointed out, however, that if the chronology does in fact start at an earlier date, as Gross insists, the pollen profiles should reveal an Alleröd oscillation, and apparently they do not.

The identification of the Alleröd in the Alps confirms for Gross (1954, p. 201) the correlation of the "Final Glaciation" (Schlern, Gschnitz, and Daun stadials) with the Central Swedish moraines and the Younger Tundra phase, as had long ago been suggested by Penck. Gross correlates the next older stadial ("Bühl") of the Alps with the Langeland Moraine near the Baltic coast, and the moraines next downstream (Zürich-Singen-Olkofen) with the Pomeranian (see also Zeuner, 1952, p. 155). Despite glacial retreat from the last-named Alpine moraines far up the valleys to the Ammersee moraines, the climate apparently remained sufficiently severe in the Alpine piedmont for frost cracks to form in the Youngest Loess, and presumably the accompanying soilfluction caused destruction of incipient pollen-bearing deposits (Gross, 1954, p. 202). At least Gross selects this type of evidence to strengthen his correlations with northern Europe, where he had employed the same line of reasoning for the ice retreat from the Pomeranian to the Langeland moraines. Although such correlations based on loess may be questionable in detail, it may be noted that the pollen record shows a very slow advance of the forest up the deglaciated valleys, considering the high elevations to which the snow-line had retreated by this time (Firbas, 1950). The absence of protective forest cover during this interval would favor disturbance of the ground by frost action, and Gross's line of reasoning is thereby supported. Firbas suggests that forest migration may have been controlled by the length of growing

season: this would seem to imply that Alpine glaciers receded because of decreased winter nourishment rather than increased summer warmth.

Although pollen chronology has aided in the correlation of the Late-Glacial events of Northern Europe and the Alps, there remain internal problems for the earlier stages for both regions. For example, in contrast to the correlation presented by Gross (table 2), some of the Alpine geologists consider that the Zürich (Olkofen) moraines represent Würm I moraines that were later overridden by Würm II ice that terminated at the Killwangen-Schaffhausen moraines (Klebelsberg, 1949, p. 693-704). Upstream from these moraines of the Würm maximum (W-II) are in turn the moraines of the Schlieren stadial (Würm III), then the overridden Würm I (Zürich-Olkofen moraines), then the Ammersee ("Bühl") moraines mentioned above, and finally the triple succession of the "Final Glaciation" (Schlern, Gschnitz, and Daun). Klebelsberg does not offer to correlate the Würm stages beyond the Alps, and the question may be left open at least for the pre-Ammersee stadials. The stratigraphic position of various interstadial deposits reported in the Alps leaves the outsider confused (Ebers, 1955; Klebelsberg, 1949, p. 692-709), especially with the variable use of the terms Würm I, II, and III. Now even the relation of Riss to Würm is being challenged (Zeuner, 1954; Narr, 1953). Judson (Movius and Judson, 1956) has recently analysed a part of the problem with circumspection, but the correlations must still be considered fluid.

Here beyond the time range of effective pollen studies, and without as yet the aid of radiocarbon dates, correlations must depend largely on detailed studies of the glacial and periglacial stratigraphy, morphology, pedology, and paleontology, which in the long run are the more fundamental approaches. American workers must not discount the difficulties in intra-continental correlation, however, for it has been only recently that comprehensive studies of the younger glacial substages of the Rocky Mountains have permitted direct correlations with the late Wisconsin substages of the continental ice sheet (Horberg, 1954): earlier correlations by means of the loesses, buried soils, and terraces of the Great Plains have not been fully satisfactory. For the same time range in Europe, however, correlations are aided by pollen stratigraphy as well as radiocarbon dating, so the problem should soon be resolved.

The Riss-Würm complications in the Alps are matched in a sense in northern Europe by the position of the Warthe, which is now generally allied to the Saale (Woldstedt, 1950a, p. 359-363; 1950b; 1954; Von der Brelie, 1955) or at best considered as a separate stage (Klebelsberg, 1949, p. 630) rather than as the first sub-stage of the Last Glaciation, the view more familiar to American readers (Zeuner, 1952, p. 114; Deevey, 1949, p. 1323; Flint, 1947, p. 329). These problems are reminiscent of the Iowan-Illinoian controversy in America 25 years ago, and in fact resemble new difficulties that have arisen in the early Wisconsin in connection with the Tazewell, Iowan, Farmdale, and an unnamed drift in southern Ohio (Flint and Rubin, 1955). Just as radiocarbon dates have necessitated important revisions of the late Wisconsin chronology and are involved as well in early Wisconsin problems, so also in both northern Europe and the Alps the application of this technique may

settle some problems and create others, and eventually permit detailed trans-Atlantic correlations for the last glacial age. Reliable pollen chronology unfortunately would seem to start not before the Late-Glacial all over Europe. Its application to earlier interstadial or interglacial deposits has not been fully developed as yet (Von der Brelie, 1955).

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