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POLLEN ANALYSIS AND ITS BEARING UPON AMERICAN PREHISTORY: A CRITIQUE

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EXTENDING over a wide area in northern and central Europe great beds of peat cover stretches of moor and occupy valleys and depressions where sluggish drainage has favored the growth of marsh vegetation.[183] More than any other soil type they are entirely dependent in substance on the vegetation which they support. Thus they are peculiarly reflective of changes of a climatic nature, and this, combined with the preservative effects of bog acid, both upon pollens and artifacts, has made them a peculiarly effective medium for investigation.[184] While most thoroughly studied in Europe, peats occur in both the northern and southern hemisphere wherever conditions permit. Typically and most extensively however, they are a circumpolar phenomenon closely attendant upon glaciation.[185]

The close of the glacial period brought about the conditions which resulted in most of the peat deposits in which we are interested today, both in America and Europe. The melting ice, high humidity and blocked drainage resulted in rapid accumulation of the deposits.[186] As the ice retreated northward and new drainage channels were carved out, the rate of peat accumulation adjusted itself. Peat cannot accumulate, however, unless swamps or ponds of some nature are present. Hence peat bogs are typically confined to the woodland areas of North America, in the United States east of the Dakotas and north of the 40th degree of latitude.[187]

Deposits of interglacial peat, though known, and of some importance to the paleobotanist where their age can be established, do not concern the American archaeologist, at least at present. The importance of peat bogs throughout the postglacial period lies in their preservation of pollens with which it becomes possible, through comparable profiles, to establish an arbitrary time scale over a period too short to allow the evolution of suitable index fossils[188] yet long enough to have witnessed vast archaeological changes. *The pollen analytical method, in short, aims at the establishment of a postglacial chronology based upon climatic fluctuation which may or may not be synchronous throughout the world.*

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[183] Seward, 1931, p. 501; Rigg, 1916, p. 316. [184] Newbigin, 1936, p. 68.

[185] *Ibid.*, p. 63. Also see Fig. 7. [186] Soper, 1919, pp. 7, 9, 13, 35, 37.

[187] *Ibid.*, p. 6. See also Giles, 1930. [188] Godwin, 1934, p. 326.

At first, knowledge of the postglacial fluctuation of forest types was derived from studies of vertical succession in buried forest beds, and from observation of the grosser remains in peat bogs such as twigs, leaves and stumps. During this period of reconstruction of climate through studies of gross structure, it became apparent that postglacial times in Europe had witnessed cyclic variations of precipitation and temperature which seemed to hold true over wide areas. These observations gave rise to a terminology which is still current, and worthy of repetition at this point. Blytt, in 1882, indicated it as his opinion that, after a transitional, immediately post-glacial, sub-arctic period, the climate of northwestern Europe went through a cycle, repeated twice, of warm dry "continental" climate and warm damp "oceanic" periods.[189] These were called, respectively, Boreal, Atlantic, Sub-boreal, and Sub-Atlantic. Sernander reaffirmed this evidence[190] and the theory, now supported by many workers and a considerable body of evidence, is popularly known as the Blytt-Sernander hypothesis.

As time passed and the limitations of the older types of investigation became apparent, attention was directed to the possibilities offered by the newly devised method of pollen analysis. The idea was a Swedish innovation originating with Professor Lagerheim of the University of Stockholm.[191] The development of methods and technique, however, came about through the efforts of Lennart von Post of the Swedish Geological Survey. Since 1916 he has been a constant contributor to the subject and his cautious and scientific approach have led to a more elastic revision of the Blytt-Sernander hypothesis—a revision now widely accepted.[192] This modification von Post regards as necessary because, as he says, "For other regions . . . where the climatographical situation is too different from that of Scandinavia, the Swedish scheme . . . affected these investigations like a strait-jacket."[193] Accordingly he divides postglacial time on a climatic basis into (1) a period of increasing warmth, (2) the period of maximum warmth, and (3) the period of decreasing warmth. These periods somewhat correspond to Auer's arrangement of Fuegian climatic fluctuation—that is, to his *Subarcticum* of late glacial time, the *Melioratum Periode* of postglacial time and the third *Peioratum Periode* of climatic regression which probably saw the first appearance of man in Fuegia.[194]

The amount of work which has been accomplished in Europe is

[189] Blytt, 1882. [190] Sernander, 1908. [191] Lagerheim, 1905.
[192] Godwin, 1934, p. 279; Fuller, 1935; Sears, 1935.
[193] von Post, 1931, p. 52. [194] Auer, 1933, p. 287, 297.

enormous as contrasted with that carried out in the New World and it is unlikely that the same amount of information will be available here for a generation or more.[195] In addition, European workers have had the added advantage of opportunities to check their observations against a number of other indices of postglacial change such as archaeological remains,[196] the Litorine Transgression, and the movement of marine mollusks.[197] It remains to be seen whether, lacking certain of these cross checks, the method can be made as applicable to archaeological problems here in America.

So far as the writer has been able to ascertain, it was a paper by Dr. Paul B. Sears, then associated with the University of Oklahoma, which first succeeded in arousing the interest of American archaeologists generally in the possible application of the pollen technique to American problems. This paper appeared in the *American Anthropologist* during 1932[198] and was entitled the "Archaeology of Environment in Eastern North America."

Dr. Sears' paper, while concerned wholly with the possibilities of determining the influence of climatic fluctuation upon the peoples of the eastern woodland, chanced to come at a time when attention was shifting westward to the area of the high plains. Strong was making his first studies of Nebraska archaeology. The magic word "Folsom" was on every archaeologist's tongue. It was, perhaps, but natural that the chart of suggested postglacial climatic fluctuations extending back for ten thousand years and accompanied by a series of estimated dates, should have immediately intrigued students of the subject. Archaeologists, impressed by the apparent successes of the method in Europe showed an immediate tendency to utilize the new method in the solution of pressing problems on the high plains. Though the results have been disappointing and though Dr. Sears has lately expressed an opinion[199] in the direction of von Post's more cautious modifications of the Blytt-

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[195] G. Erdtmann has also been an extremely valuable worker in this field and is chiefly responsible for making the method internationally known. His bibliographies of the huge mass of data assembled by European workers are indispensable to any serious approach to the subject and he has contributed to the improvement of the technique as well. See, for example, Erdtmann, G., 1931*b*. Erdtmann, and Erdtmann, 1933.

[196] Godwin, 1934, p. 346. [197] Clark, 1936, Chapter I.

[198] Sears, 1932*a*. It was, however, preceded by a briefer statement in Science, N.S., 73: 640–641, 1931.

[199] Sears, 1935. His latest comment (1938) is extremely measured and reveals full consciousness of many non-climatic factors influencing vegetational change.

Sernander hypothesis,[200] the archaeologist is still unwearied. At each site he dutifully saves samples of soil and hopes for the best. It is not my intention to discourage these painstaking analyses but to indicate briefly the history of the new method in North America and the difficulties which beset it.

It is a long deplored fact that American paleobotany has lagged considerably behind the development of this subject in Europe. In 1912, for example, we find the distinguished botanist Edward W. Berry complaining: "One phase of the study of fossil plants, alike disgraceful to American geology and to American botany, is our lack of knowledge of the flora which immediately preceded the present one. As compared with the monumental work on the glacial, interglacial, and postglacial floras in Great Britain and Scandinavia, Denmark, and Germany, almost nothing has been done in the United States."[201] Even at this early date Berry specifically recognized the need for peat bog study and urged its intensive development.[202] It was not, however, until the pioneer work of Dachnowski-Stokes in 1921[203] that peat as a possible indicator of past climates began to be seriously studied in America. The pollen-analytical method was still unknown here so that time estimates were based on the rate of growth of the deposits, and determination of climatic oscillation upon the gross examination of the contained remains of plants.

Dachnowski-Stokes recognized the limitations of this method, and after considerable discussion, in which he brings forward evidence for a long postglacial warm period,[204] he frankly admits: "As to the end of the late glacial time, the climatic characteristics from the last glacial recessions to postglacial and present conditions stand as yet considerably ill-defined."[205] As a correlative of this he confesses the inadequacy of the data to supply evidence of parallels in climate over wide areas.[206]

Shortly after this he attempted a bolder statement of his theories, including a rather detailed chart of climatic fluctuations dating from the period of the ice withdrawal.[207] Apparently acting upon the assumption of an exact contemporaneity of the Würm and Wisconsin ice movements[208] he postulates "that there have been several climatic

[200] von Post, 1931, pp. 48–54. [201] Berry, 1912, p. 174. [202] *Ibid.*, p. 175.
[203] Dachnowski-Stokes, 1921. [204] *Ibid.*, p. 81. [205] *Ibid.*, p. 86.
[206] *Ibid.* [207] Dachnowski-Stokes, 1922.
[208] While the major correlation is probably justified, the fact of a more southward stand of ice in America as well as the question, still debatable, of the influence of the period of marine transgression in bringing on the first "oceanic" Atlantic climate in

waves since the last glacial period, each of relatively long duration. The climatic pulsation, resembling a climatic belt, consisted of a cold and humid period bordering the glacial readvance, followed by a warmer dryer period in the accompanying interstadial time, with a tendency toward optimum conditions which favored the growth of forests. It is quite probable that the last climatic wave or belt, possibly in diminishing intensity, continues to shift northward at the present time."[209]

The scheme and the estimated dates do not seem to have taken hold. Diverse estimates upon the rate of peat accumulation are partly responsible for this, along with the difficulties involved in calculating the relative age of the deposits.[210] (See footnote 208 above.) The chart reproduced by Dachnowski-Stokes is considerably at variance with the later one of Sears in the *Anthropologist* and it is interesting to contemplate in connection with these various schemes the variety of places into which it might be possible to insert the molluscan fauna which the writer has discussed elsewhere.[211] Dachnowski-Stokes, for example, goes further back in time than Sears, and inserts a warm humid phase as long ago as 18,000 B.C. We need not labor the point, however. Suffice it to say that the greater sensitivity of the pollen technique has tended to shift attention away from schemes based on less refined methods.

Before turning to pollen analysis proper, it may not be amiss to indicate that the year 1922 also saw the appearance of Gleason's "The Vegetational History of the Middle West"[212] to which we shall devote more space in a later section. Based on a study of relict vegetation, including the appearance of prairie relicts in the present deciduous forest region of the north central states, it argues for the existence of a postglacial dry warm period during which prairie conditions obtained farther eastward than at present.[213] Recently some of the inferences derived by Gleason, including his theory of an early postglacial xeric period, have been strongly challenged by Transeau.[214] This does not, however, greatly alter Gleason's point, used elsewhere in this paper, of a restric-

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Europe, makes us pause. Again, particularly at the time of Dachnowski-Stokes' work, there is a lack of geological data bearing on the relationship of certain of the bogs investigated to the various substages of the Wisconsin ice.

[209] Dachnowski-Stokes, 1922, 229–230.

[210] Sears, P. B., and Elsie Janson, 1933, pp. 349, 350.

[211] Eiseley, 1937.

[212] Annals of the Association of American Geographers, 12: 39–85, 1922.

[213] See also Cowles, 1928, pp. 380–382.

[214] Transeau, 1935; also Fernald, 1935.

tion of bog areas westward,[215] nor need we labor the problems of floristics farther at this point. It is to pollen methods that most botanists now look for confirmation of their theories of past climates.

Vaino Auer, the Finnish scientist, also noted for his study of pollen profiles in Tierra del Fuego, is, to my knowledge, the first man to carry on an investigation of American peat bogs by means of the pollen technique.[216] His investigation covered some thirty peat bogs in the neighborhood of the St. Lawrence River. In general, Auer finds that the Blytt-Sernander classification of postglacial climates can be adapted to the Canadian situation.[217] He says: "Thus the earlier dry and warm period corresponds to the boreal period, the then following one, the Atlantic period, and the thereupon following dry and warm period corresponds to the sub-borealic one." Auer indicates certain differences between the profiles and those of Europe, however,[218] and further remarks, "that the character of the various periods may have been different from that of the corresponding periods in Europe, and that the beginning and end of each period may, perhaps, have been of slightly different age on each continent." In a later work Auer expresses far more doubt than this over the possibility of world-wide pollen profile correlations[219] and remarks that the only certainty seems the fact of climatic improvement in postglacial time.

Following Auer, several other investigations were carried out. Lewis and Cocke[220] studying pollen samples from the Great Dismal Swamp of Virginia reported some evidence of climatic variation not inimical to the results of Auer's previous analyses, but climatic theories are held in abeyance by the authors.

Sears has reviewed a great deal of following material[221] and has attempted to fit it into the scheme of his own researches, the results suggesting "a strong parallel with European postglacial fluctuations" with "two major periods of desiccation, or continental climate, the second warmer than the first."[222] Lately, however, since the work of Voss and Fuller[223] in the Lake Michigan region has revealed no clear

[215] Sears, 1932*b*, indicates some confirmation of Gleason's views on the origin of the "prairie peninsula" except that he does not regard the period of prairie expansion as having been excessively warm since bogs survived the postglacial dry in this area. Sears hesitates however and adds that his view may have been based upon "a too static conception of the character of relicts." [216] Auer, 1927.

[217] *Ibid.*, p. 28. [218] *Ibid.* [219] Auer, 1933, p. 306.

[220] Lewis, I. F., and E. C. Cocke, 1929. [221] Sears, 1932*b*.

[222] *Ibid.*, p. 5. Bryan, 1932, provides a good summary of the earlier American pollen studies. [223] Fuller, 1935; Voss, 1934.

evidence of the alternation of moist with dry phases during postglacial time, Sears has expressed himself on the advisability of examining more evidence before definitely accepting the Blytt-Sernander hypothesis. In the meantime, he says: "The simple schedule of von Post[224]—a period of increasing warmth, period of maximum temperature, period of decreasing warmth—is broad enough to allow of future refinement, and does no violence to facts."[225] With this statement by the most ardent advocate of the Blytt-Sernander hypothesis among American pollen specialists, the subject is brought down to date. It will be seen that the conclusions just voiced are somewhat more temperate than the suggested chronology which appeared in Sears' *Anthropologist* article and reflect as well the caution of such men as von Post and Auer. In the following sections it will be our purpose, at the risk of some repetition, to survey certain of the difficulties involved in the proper use of the pollen analytical method in order that these may be fully visualized by the anthropologist and some notion gained of its present limitations in the field of archaeology.

THE TECHNICALITIES OF METHOD

The technicalities of method involved in pollen analysis, while well known to all workers in this field, are complicated and insufficiently known to the layman. Some comment, though brief, should indicate the care and discrimination which must be exercised in the calculation of results. Since the method is more or less in its infancy in North America and there is a serious scarcity of trained workers it is especially desirable that some of the difficulties involved should be realized.[226]

The pollen flora of recent geological deposits is always derived from the surrounding vegetation. The pollen of the forest trees, however, always represents a large proportion of the total pollen in all peat bogs and is the major concern of the observer. This is because the trees represent the natural climatic dominants and, in a general way, are less likely to reveal purely local successions which are due to edaphic changes in the bog as it continues to age.[227] Often the non-tree pollens yield valuable information relative to these local conditions but are not regarded with such favor as chronological indices, at least in Europe.

[224] von Post, 1931. [225] Sears, 1935.

[226] Even a slight clumsiness in the handling of the cover-slip at the final mounting, for example, will cause an over representation of large pollen grains, by the squeezing out of smaller grains around the edges of the cover glass. This apparently trifling point is indicative of the care which must be used at all times even in such routine matters as the handling of material. [227] Godwin, 1934, pp. 278, 287.

In America, Sears has emphasized the uses of grass pollen.[228] It remains to be seen, however, whether the latter will prove as acceptable to other workers in the area of the "prairie peninsula."[229] Certainly care must be exercised in cases of attempted correlation of the central continental group of peat lands characterized by fluctuating and unstable supplies of moisture with the northern peat region whose supplies of moisture are more abundant and sustained.[230] This problem is apt to grow more difficult south and west where moisture becomes scant and insufficient. Bogs or alluvial muds in such areas must inevitably dry up at many periods and hence their pollens, even when preserved, do not represent the sustained sections of the northern bogs, but only unstable and largely unpredictable "catches" of pollen. Such "catches" are not without their uses as when, for example, a trace of corn pollen, even a single grain, might throw light on the early practise of agriculture in the neighborhood. The validity of such climatic rhythms as might be observed, however, is something that only the future can determine. Certainly our technique would have to be immensely refined beyond that of the present to deal satisfactorily with deposits representing such a complex of influences—climatic and otherwise.

Bacteria and complete oxidation are involved in the processes of pollen decay. Hence pollen is always best preserved in unaerated, waterlogged deposits whether of organic or inorganic origin. In the latter case, clays and silts often preserve pollen but identification of the grains, owing to the coarseness of the containing medium, is more difficult than in the case of peat. Acid bogs are always better preservers of pollen than the alkaline ones.

Tree pollens vary greatly in their ability to resist disintegration, but as Godwin says, "it is difficult to see how such differences can be evaluated."[231] Probably such variation is not of importance so long as

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[228] Sears, 1932*b*, p. 4.

[229] Voss, for example, says of the non-tree pollens: "I regard them as having less value as climatic indicators than the tree pollens. It is extremely difficult to separate into species many of the pollens of the large families such as Cyperaceae and Graminaceae. Furthermore, many members of these families have wide ranges of distribution which, in general, is not true of members of tree families. Non-tree pollens are only of value in the interpretation of local conditions . . . ." Voss, 1937*b*.

[230] Dachnowski-Stokes, 1935, pp. 173–77.

[231] Godwin, 1934, p. 289. Also Voss, 1937*a*. Voss also indicates (p. 120) the interesting fact that in the study of one bog the presence of a large number of snails which devoured considerable organic vegetable material strongly influenced the pollen count—another indication of the complex play of influences which must be taken into account.

we are dealing with similar deposits and similar plants. It is not beyond the range of imagination, however, to conceive of it as being a factor of some weight when attempting to correlate muds or other alluvial deposits with bog successions far northward and, in the south, where there is less reliance upon the pollens of the climax forests.

A minimum of 150 counted grains of tree pollen is regarded by most authorities as a necessity, in the case of most samples,[232] and this exclusive of certain types, in order to eliminate, or at least reduce, the margin of error. Great care needs to be taken to identify the pollen grains and Erdtmann has emphasized the fact that everyone working in this field "should have access to reference preparations of pollen-grains from recent trees."[233] This, of course, forms more of a problem in America than Europe where pollens have been longer studied. It is noticeable that in one of the first American studies, that of Lewis and Cocke,[234] difficulty was indicated in this regard. Erdtmann has expressed himself most emphatically upon the subject, declaring "a thorough study of the recent and sub-recent pollen flora of American bogs would be more valuable as a start for pollen statistics in America than the presumably hazardous task of identifying a multitude of pollen types from old deposits with material often much decayed and altered."[235] Fortunately, these efforts seem well under way, though the publishing of more American material bearing on identification and technology should be urged. Many prospective workers are handicapped by insufficient information of a practical nature because of the dearth, until very recently, of botanical interest in this field.

THE PROBLEM OF CORRELATION BETWEEN EUROPEAN AND AMERICAN POSTGLACIAL CLIMATIC FLUCTUATION

In Europe, if, for the moment, we accept the elaborated Blytt-Sernander classification[236] rather than von Post's more generalized scheme, we find that these cyclic climatic changes are capable of a certain amount of check through other sources such as faunal sequences,[237] land movement, and archaeological remains. Most of these cross checks are yet inapplicable in the New World.

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[232] Barkeley, 1934; Erdtmann, 1931*b*. [233] Erdtmann, 1931*b*, p. 400.

[234] Lewis and Cocke, 1929, p. 40. [235] *Op. cit.*, p. 401.

[236] For a full chart of this climatic scheme as related to the archaeology of northern Europe see Clark, 1936.

[237] Not so developed for postglacial America, though the postglacial disappearance of *Bison antiquus* Taylori, Elephas, Equus, and Camelops as well as the giant sloth may be of assistance if we can determine more exactly the time of their disappearance. The

If we now examine Sears' most detailed chronology we observe that he maintains a somewhat similar sequence for eastern North America.[238] This sequence, however, is based entirely on pollen and rates of peat accumulation and not at all on faunal or other evidence. This is not said as criticism. The necessary material has simply not been available. It is to be hoped, however, that the remains of fossil "Pleistocene" forms which have occasionally been reported from bogs in the eastern United States will, in the future, be checked for possible pollen correlations with the deposits from which they have been secured. Such studies will inevitably help to establish the exact period of postglacial extinction of these animals.

The sequence maintained by Sears has, of late, been vigorously questioned. Fuller has recently summarized considerable data[239] bearing upon the peat deposits of the Lake Michigan region and at the risk of some repetition his main points should be summarized along with the similar observations of Voss. The work of these writers substantiates the period of conifer dominance[240] recognized in the cool humid of Sears and dated provisionally by him in the neighborhood of ten thousand years ago. The evergreen forest, Fuller observes, "seems soon to have been invaded by a deciduous element and probably before a fourth of postglacial time had elapsed the forests around the southern tip of Lake Michigan had assumed an aspect and composition very similar to those existing at the coming of the ox and of the white man. The record seems to show that for some three-fourths of the post-glacial period (perhaps for 15,000 years) oak-hickory forests with an admixture of elm, basswood, and a small amount of maple have occupied the morainic uplands of northern Illinois and southern Wisconsin . . . . No variation in the pollen diagram is great enough to indicate a decided climatic or vegetational change."[241]

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lemmings, circumboreal in distribution, and indicative of glacial conditions when found southward in Europe, have not been found fossil in the New World although doubtless they moved southward in this region as well. (Allen, 1919.)

[238] Sears, 1932*a*, pp. 617–21. [239] Fuller, 1935.

[240] It is worth noting that in the case of all these waves of vegetation passing northward the climate is not the only factor to be considered. "Succession," as Blake has said, "waits on the formation of soil." (Blake, 1926.) After the glacial scouring, the tundra plant remains collect and form soil for the succeeding biota along the retreating edges of the ice. (Voss, 1934.) Also see Lee, 1924. Hutchinson has pointed out that deciduous hardwood forest encroaches on the conifers but lags behind temperature changes, being partially dependent on rate of soil development. He regards these as climax forests, one of whose prime requirements is most highly developed soil. (Hutchinson, 1918.)

[241] Fuller, 1935, p. 485. In confirmation, Hansen, 1937, p. 147, says: "the deciduous

Voss, in a study of fourteen bogs distributed in Illinois, Wisconsin and Minnesota has also failed to correlate his results with the Blytt-Sernander hypothesis and maintains with Fuller that beyond the period of conifer dominance his pollen charts show no evidence of climatic fluctuations similar to those in Europe.[242]

Sears has countered that perhaps periods of xeric vegetation are not so distinct in the Lake Michigan area owing "to the buffering of this region by the proximity of Lake Michigan, or to certain technical difficulties in connection with the analysis, as for example the problem of distinguishing various species of oak."[243] More recently, in a paper read before the Symposium on Early Man held at the Academy of Natural Sciences in Philadelphia,[244] he has maintained that the more detailed use of grass pollens might reveal changes not evident in the tree profiles.[245] It would seem dubious, however, whether for the purposes of archaeological dating, much reliance can be placed on climatic changes seemingly so minute as to have affected grass and not trees,[246] or to involve detailed distinctions in oak forest. Certainly such technicalities seem to imply a long and wearisome period of detailed development. Again, if climatic "buffering" has affected the record, the close association of so many of the peat bogs with the area of the Great Lakes leaves many of them suspect. The data derived from Voss and Fuller are powerful, and unless met or disproved by later studies, all attempts to perceive in American bogs postglacial climatic rhythms similar to those occurring in Europe stand in danger of collapse—this Sears himself has freely granted.[247]

Cooper has also added geological data which, in relation to certain areas, may have a bearing upon cases of observed aridity in relation to climate. He points out that in many areas drained by the Mississippi and its tributaries, desiccation of the surface soil may have resulted from a lowering of the water-table owing to downcutting by this major

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forests have apparently remained much the same during the last two periods of postglacial forest development."

[242] Voss, 1934, p. 40. In a recent letter Voss indicates his conclusions to be unchanged (Dec. 12, 1937). [243] Sears, 1935, p. 497. [244] Sears, 1937.

[245] Lane's study of the McCulloch bog in Iowa is one of the best known profiles in which reliance is placed on grass pollens. His study purports to show coniferous forest replaced by deciduous, and then prairie which was twice interrupted by waves of amaranthchenapod (semi-arid) vegetation. (Lane, 1931.)

[246] See quotation from Voss, footnote 229, above.

[247] Remarks from the platform at the Symposium on Early Man. Philadelphia, March 17, 1937.

stream. "This hypothesis," he says, "does not exclude the possibility that a period of comparatively dry climate may have been a contributory cause."[248] He insists, however, that in the upper Mississippi area downcutting had a decisive effect on soil aridity whereas there is no direct evidence as to climate. While it is obvious that this geological factor is not applicable everywhere, it is added argument for the necessity of careful geological observation as a necessary complement of all pollen analytical studies and attempted observations on climate derived from locally observed erosion cycles.

If we now turn to a survey of recent European literature we find that attempts to correlate American fluctuations of climate with those of Europe are further complicated by the fact that there is considerable disagreement as to whether the change from the Boreal to the Atlantic period, that is, from dry to wet in northwestern Europe, was a local phenomenon due to geographical conditions in the Baltic or whether it represents a more far-reaching climatic oscillation such as might have extended into North America.

Dr. Brooks, the well-known climatologist, has expressed himself in favor of the view that the so-called Atlantic period is a purely regional oscillation.[249] Antevs has also pointed out that the course of the ice-retreat in eastern North America is not directly comparable at all points with that of Europe. He says, in part, "It seems possible that the early part of the first oscillation in Canada coincided in time with the Fenno-Scandian halts and that the subsequent temperature rise in northern Europe did not affect North America. It is accordingly held that the rapid decay of the European ice after its border had left the Fenno-Scandian moraines was due to the breaking in of the Gulf Stream into the Norwegian Sea. If this be so the border of the Labrador ice may have stood somewhat north of Cochrane when the European ice had shrunk to mere remnants."[250] It is hardly necessary to point out the effect that this dissimilar stand of ice may have had upon the pollen content of peat bogs so far as time of deposition is concerned, even though climatic improvement was essentially the same on both sides of the Atlantic. Thus we arrive inevitably again at the mature

[248] Cooper, 1935, pp. 102–3.

[249] Brooks, 1931*b*. Dr. Erdtmann shares this view saying, "The increase of humidity during the Atlantic period was a consequence of the inundation of wide areas in the southern part of the North Sea and the establishment of a connection with the Baltic." (Erdtmann, 1931*a*.) Clark, 1936, on the other hand, favors Simpson's theory of fluctuations of solar radiation. This, of course, implies world wide changes of a similar nature.

[250] Antevs, 1928, pp. 167–68.

thesis of Auer: that, lacking a fixed point in time, we cannot assume that the same order in Europe and Canada, or in Fuegia, are of exactly the same degree of antiquity.[251] At best, we can postulate a maximum period of postglacial warmth now decreasing and so formulate a generalized scheme along the lines which von Post has suggested. Later it will be possible to discern many regional variations and utilize them archaeologically. That time, however, has not arrived. The necessary data still lie in the ground.

GLACIAL DRIFT AND THE ANTIQUITY OF PEAT BOGS

When we come to consider the Wisconsin ice itself we are forced to take into account the fact that it is very lobate. These lobes, in the opinion of Kay,[252] have resulted from the extension of the ice at somewhat different times from the Labrador, Keewatin and intermediate ice centers, the youngest substage probably reaching its height in Iowa and the Dakotas. Knapp, for example, comments as follows upon the movements of the Wisconsin ice in Minnesota: "In the latest stage (known as the Wisconsin stage) there was one movement into Minnesota, from the northwest, another from the north, and a third from the northeast . . . . These movements were not synchronous in their advance, culmination, and waning, but each had its time of waxing and waning."[253] Schwartz,[254] Cooper[255] and others all substantiate this observation. It is a commonplace of geology. Leverett, in fact, has differentiated as many as five substages, not all covering the same areas. Under such circumstances there can be no certainty that maximum ice conditions along the southern border of the Wisconsin glaciation were everywhere attained at the same time.[256]

The immediate bearing of this fact upon the problems of pollen analysis lies in its significance for the relative datings of postglacial bogs. A bog in the neighborhood of the Wisconsin ice border may lie within the area of one of the late tongues or sub-lobes of the ice, and yet be several thousand years older than the bogs lying upon a later drift in the same general region. Voss has been one of the few pollen specialists to recognize and attempt to deal with this problem.[257] He classified the bogs studied by him according to Leverett's scheme of substages and could find no trace of climatic fluctuation throughout the

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[251] Auer, 1933, pp. 302, 303, 306. [252] Kay, 1931, p. 444.
[253] Knapp, 1923, p. 16. [254] Schwartz, 1936, p. 86. [255] Cooper, 1935, p. 6.
[256] Cooper, *op. cit.*, p. 16. [257] Voss, 1934, 1937*a*; also Hansen, 1937.

entire profiles of the Substage IV bogs.[258] The problem presented by this lack of fluctuation we have discussed in another connection. At this point it is worth noting that unless the relative antiquity of the peat bogs lying upon the various drifts of the Wisconsin ice can be determined, we cannot assume exact contemporaneity of origin.

Too often this geological feature is entirely ignored by the botanist, who fails to give the geological background of the peat area he may be investigating.[259] Thus, in a recent review, we find Richardson protesting,[260] in the case of a peculiarly important site well within the Arctic Circle where clear data might throw a great deal of light on postglacial climate, that there is no attempt to consider the geological problem as to whether the peat is interglacial or postglacial. Such lack of treatment of the features of the geological surroundings and background of the bogs discussed tends to vitiate all conclusions as to their position in the pollen profiles.[261]

It must also be remembered that the Wisconsin ice advanced some ten degrees farther south in America than the Würm in Europe.[264] What this represents in time is somewhat problematical as is also the question of whether forest followed directly on the margin of the retreating ice or whether a period of tundra vegetation represents the first stages of retreat.[265] A subarctic period of tundra is by no means so

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[258] Voss, 1934, pp. 39–40.

[259] Thus Oswald, 1935, supplies no information whatsoever of a geological nature. He contents himself with one passing reference to the withdrawal of the ice—a statement which, as we have seen, is much too general a term to be used where the dating of bogs is concerned. Wherever possible, attempts should be made to correlate the peat deposit with a definite substage of the Wisconsin and where this cannot be done the fact should be so indicated. [260] Richardson, 1937.

[261] Thus Voss, at present (1938) working on material from fifty or more bogs from the eastern and northeastern part of the United States writes, "My greatest problem now is that of obtaining the glacial history of the areas involved. In some of our up-to-date states I find that little has been done relative to glacial history while in other states the glacial geologist is sometimes too conservative in voicing his opinions." (Voss, 1937*b*.) A vast battery of geological statements confirms the difficulties of dealing in an exact manner with the more involved fluctuations of the Wisconsin ice. As a single example, de Geer, 1933. [264] Leverett, 1930.

[265] Fuller, *op. cit.*, p. 484. In addition American phytogeographers have encountered some difficulties in mapping and interpreting the transition between eastern deciduous forest and northeastern coniferous forest even at the present time. This feature is worth some consideration in any survey of paleobotanical studies of peat bogs and the fluctuations of climate represented in their pollen remains. See Tansley, 1920. McLaughlin observes that during one of the minor late ice fluctuations in northwestern Wisconsin "the climate was sufficiently mild for the growth of plants within Fox River valley and at

easy to substantiate here as clearly as in Europe. Sears himself comments that "the more northerly bogs are too youthful, and in most of those in the central states the record of early postglacial time is too condensed, if it is present at all."[266]

In connection with the withdrawal of the Wisconsin ice a point made by Godwin must not be forgotten.[267] He dwells on the fact of diffusion which makes the dating of archaeological remains not necessarily the same for all cultures and then adds: "It is possible to demonstrate that in all the sciences to which we have referred in discussing the correlation of the temporal sequences of postglacial time, in geology, climatology, archaeology and pollen analysis alike the same problem of sloping horizon recurs, though nowhere possibly so strongly as in archaeology. There is no simple key to such a problem, but coordinated investigation should finally yield a simple system the internal coherence of which will be a major guarantee of its validity." When the more southward extension of the Wisconsin ice is considered, it is not impossible that when the first southern island glaciers in the Rockies were commencing to retreat and their waters were forming lakes in the lowlands, northern Europe may still have only been experiencing the first faint tinge of climate amelioration. Because of breaks in the deposition of varves in American late glacial lakes, such a chronology as that elaborated by de Geer and his associates for Sweden may never be attained in America.[268] Thus, while it is assumed that the major fluctuations of the ice were synchronous in both the Old and New Worlds, the details present a blurred outline hard to correlate and of almost no value to the archaeologist. Until it becomes possible to establish a time scale of the exactness of de Geer's for the Upper Mississippi region and points east, the floral problems of the surrounding areas will, to a considerable extent, be inexpressible in years. It would be rash at the moment to assume that the climatic fluctuations more or less estimable in years for northern Europe can, with reasonable accuracy, be similarly applied to portions of America where the ice retreat began 20,000 or 25,000 years ago,

Two Creeks . . . along the Lake Michigan shore. It seems quite certain, therefore, that there were even trees of considerable size . . . before the ice had withdrawn for the last time." (McLaughlin, 1932.) See also Voss, 1937*a*, p. 132. Flint insists that "Vegetation returned abundantly to the Connecticut region while ice still occupied the major valleys." (Flint, 1930.)

[266] Sears, 1935. Bryan, 1928, has also commented that "The extensive and unbroken plains which lay to the south of the ice in the interior United States allowed a free sweep of winds from the Southwest and may have limited the zone of periglacial climate to a very narrow strip." [267] Godwin, 1934, p. 350. [268] Flint, 1930; de Geer, 1933.

possibly with very little tundra intervening. The caution of Godwin in regard to the sloping nature of all such indices should not be forgotten, at least until such time as we can definitely establish that all minor climatic movements in postglacial time are solar in origin and world-wide in extent. There are data pointing in this direction, but it would not be possible to eliminate the regional character of much climatic movement in any case. Even after the successful establishment of a world theory of climate one would still have to distinguish the local from the universal. In this connection it is perhaps worth noting that so prominent a climatologist as Brooks has said: "The material is insufficient to establish the existence of systematic world-wide rhythms or pulsations of climate."[269] The fact that this was a comment made in repudiation of an earlier volume in which the author advanced such theories is an added commentary upon the state of confusion at present existing in this field.

POLLEN AND THE AREAL DISTRIBUTION OF THE FOLSOM COMPLEX

For the purposes of this paper which are essentially botanical, there is no necessity for launching into a long discussion of the typological evolution of Folsom and Yuma artifacts. This is a problem which only more work in the field is likely to solve. We may observe, however, that generally speaking late studies reveal this cultural complex as widely distributed over the United States.[270] Nevertheless, all of those finds actually made *in situ* in association with extinct species of animals have, to date, been made in the region of the high plains and the southwestern United States.

Cotter has shown that from this area "the occurrence of these implements diffuses and diminishes in every direction."[271] The focal point at present seems to lie in this region and by far the greater number of known specimens comes from here. There are a few scattered artifacts reported from the east, but they represent surface finds of an undatable nature. Either the erosion of the loess mantle in the western areas is bringing more sites to our attention or the penetration of the Folsom people eastward in any numbers must have taken place comparatively late. At any rate the Folsom complex does not appear so much a forest culture, as one adapted to the great bison area of the west. This statement is in no wise intended to be dogmatic or to minimize the eastern occurrences of Folsom artifacts. It is not impossible that genuine habita-

[269] Brooks, 1931*a*. [270] Cotter, 1935; Howard, 1935.

[271] *Op. cit.*, p. 88. See also Howard, *op. cit.*, p. 119.

tion levels may someday be found within the forest areas. It cannot be denied, however, that compared with the types of erosion common to the high plains, the eastern woodland offers few possibilities that are likely to affect this conclusion. Of these few, the chances of discovering a site in the actual layers of a peat bog are even more negligible. It is not commonly remembered that one of the major reasons why fairly accurate correlations of archaeological with botanical data are possible for such a large section of middle and northern Europe lies in the nature of at least one of the cultures concerned. Yet such is the case—and to date our native cultures show no precisely similar development.

A large number of important sites representing period II (Boreal) on the Blytt-Sernander scale are settlements, apparently seasonal, on islands or other refuge spots in the midst of the bogs which during this period were so extensive over the whole north European plain.[272] Of these, the most typical culture is that known as Maglemose. Its possessors were dominated by a fishing and fowling economy and lingered in places which made the dating of their culture peculiarly approachable through pollen analysis. One can readily recognize the advantages of their peculiar type of economy to the archaeologist when one considers the hiatus in our knowledge of their winter life. Archaeological information fails us whenever they leave the fens which they frequented during the summers.[273]

It is thus obvious that only the peculiar and local circumstance of a bog culture associated with an area thick in peat bogs and submerged fens has really made possible such an extensive correlation of archaeological horizons with climatic fluctuation. It is true that other cultures have been successfully fitted into this scheme, but only because of culture sequences which can be related to the Maglemose tradition or correlated with such an important geological phenomenon as the Litorine Transgression. Faunal successions are also observable. For cultures not associated with the fens, pollen remains, at best, of indirect assistance only as it bears upon the dating of cultures related to those in other areas.

This divergence from our central topic has been made to emphasize the peculiar advantage enjoyed by the European archaeologist in his employment of the pollen analytical method. The region where most of the investigated American bogs occur, namely in eastern Canada and the eastern woodland of the United States has, to date, supplied no

[272] Clark, 1936, p. 41. [273] *Ibid.*, p. 90.

such human traces as provide a fixed point in time for our contemplation of the postglacial activities of man in the New World. Whatever fluctuations of climate they reveal remain meaningless in terms of human occupation.[274] One can only regret, with a reserved hope for the future, that the men who left the remains of their remarkable lithic industry so thickly scattered in the dead lake basins of the Southwest, did not leave similar fragments in the peat of the Ohio bogs.

If we now survey that area in which our oldest culture seems definitely recognizable, we come to the added realization that the pollen analytical method seems altogether inapplicable—not so much because it is in an embryological state of development as because of the lack of necessary successions of preserved pollen. It is true that attempts have been made by archaeologists impressed with the chronologies developed by Sears in the eastern woodland to secure such material from the sites of the high plains, but each attempt has ended in total failure. It has failed at Signal Butte,[275] at Clovis,[276] and at Ft. Collins.[277] Van Royen has sought tentatively to correlate the vegetation bands of the Cape site with Sears' periods in Iowa.[278] This, lacking pollen, lacking the demonstration of the continuity of these vegetation bands over wide areas, lacking also the definite assurance of Sears that we are yet justified in checking Lane's Iowan successions with observed fluctuations in the Ohio bogs,[279] can but remain, at best, a highly theoretical structure. In the region of the high plains there has been as yet no work of a pollen analytical nature which will stand severe critical examination in so far as the dating of temporally remote cultures is concerned.

The work of Gleason[280] is of peculiar importance in this regard. After

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[274] In this connection it is interesting to note such an experienced European specialist as Auer complaining that "the solving of this problem is rendered more difficult firstly as there are in Canada no archaeological facts to go by,"—an apt revelation of the influence of prehistory on the development of the pollen technique in northern Europe! (Auer, 1927, p. 24.)

[275] Strong, 1935, pp. 237–39. It is true that some attempt is made to correlate certain of the cultural horizons with climatic fluctuation in Iowa, but at present the results are not particularly convincing in view of the difficulties which we have reviewed—a fact with which Dr. Strong has indicated his hearty agreement. It must be emphasized that no pollen was derived from the soils at this site. The same remarks apply to the Cape site described by Bell and Van Royen, 1934. For added comment on the Cape site, see also MacClintock, 1935.

[276] Howard, 1935, p. 88. [277] Roberts, 1936, p. 4. [278] Bell and Van Royen, *op. cit.*

[279] Sears, 1932*b*, p. 4. "The exact relationship of those two periods of apparently semi-arid climate [in Iowa] to the changes in Ohio cannot be settled until further work is done."

[280] Gleason, 1922.

an exhaustive survey of the botanical data bearing upon the possible floral successions in this area, he emphasizes conclusions which present great difficulties to any correlation through pollen statistical methods west of the Des Moines lobe of the Wisconsin ice.[281] It is, he observes, "doubtful if any conifers or associated species occurred west of this lobe."[282] The eastern floral successions beginning with the conifers and passing into deciduous forest which yield the pollen changes upon which pollen statistics are primarily based, both in America and abroad, fail us completely upon the high plains. The xerothermic warm and dry period of climate which Gleason postulates brought about an eastern migration of prairie which greatly restricted the boreal flora in the west.

Gleason comments, in addition, that ponds abundant on the Wisconsin drift fifty years ago in Illinois, were notable for the lack of several types of hardy boreal plants.[283] Moreover they were "characterized by the absence of deep peat deposits, indicating that they had never been occupied by boreal vegetation and were of comparatively recent origin."[284] The figures of actual peat distribution, such as quoted by Auer[285] and others are, particularly toward the southwestern angle of the Wisconsin glaciation, far in excess of the actual distribution of deep peat. The peculiar climatic conditions which contributed to the elimination of the usual floral relicts along the western curve of the Wisconsin ice border have apparently greatly limited, if not nullified, the possibilities of the pollen analytical method throughout the entire high plains. When it is considered, for example, that well over a hundred pollen grains per sample[286] are necessary in order to lower the percentage of error and offset local influences, the chance of obtaining sufficient samples seems scant indeed. Even granting the possibility of fragmentary data from a few individual sites, only data over a wide area can enable us to distinguish between local vegetational succession[287] and widespread change brought about by a fluctuation of climate. Since in ordinary soils pollen is quickly destroyed by fungi, and survives

[281] Auer, 1927, points out that within continental areas the filling up of lakes in poorly drained regions is one of the principal causes of peat formation. It is obvious that such conditions do not obtain westward in the United States save in a few quite recent and transitory cases. [282] *Ibid.*, p. 65.

[283] Bogs are particularly characterized by relict plant communities.

[284] Gleason, 1922, p. 70.

[285] Auer, 1930. [286] Erdtmann, 1931*b*.

[287] Hansen, 1937, indicates that it is not impossible for a forest fire to bring about local ecological changes which would tend to duplicate the appearance of a xeric period.

only under the acid conditions obtaining in bogs, or in alkaline fen peats,[288] the prospects for such remains as have been sought in the plains area and elsewhere seem amazingly slight. The only hope that the pollen analytical method seems definitely to offer is the possible chance of correlating western artifacts with eastern finds which may later be dated by this method. At present, bearing in mind the doubts of Voss, Cooper, and even Sears, it seems wise to leave the whole method to a space of disciplined development at the hands of its proponents.

CONCLUSION

After the somewhat critical survey of the uses of the pollen analytical method in America which we have just completed, it may appear that the writer entertains but little faith in its use. Actually this is not the case. Potentially it promises a great deal, for there can be little doubt that, as has been amply demonstrated for Europe, postglacial climate has fluctuated. The question remains, however, whether we are as yet justified in assuming exactly synchronous movements on both continents. As Sears and others have pointed out, the usefulness of any scale which we may devise really depends on further intensive regional studies and, eventually, regional correlations. Sears has made, almost single-handed, an enviable start in this direction, but his detailed fluctuations have not been substantiated by the work of Fuller and Voss in the Lakes region. We are therefore forced to suspend judgment beyond the somewhat tentative observation that Lennart von Post's generalized scheme of a period of increasing warmth, of maximum warmth and of decreasing warmth seems capable of substantiation up to a certain point.

The recent timberline studies of Dr. Griggs constitute the latest caution on the subject of world climatic rhythms. After long study he observes, "The stability of timberline in the Rocky Mountains, coupled with rapid advance in western Alaska and evidences of increasing cold in northeastern Canada, afford, I think, an important insight into the character of climatic changes in general. In common with most others I used to suppose that the great climatic changes indicated in geologic times were world-wide in scope. Conditions here in North America make it clear that shifts in climate of sufficient magnitude to become of geological significance are not necessarily even continental in extent but may occur in much smaller areas. It will be recognized that this greatly simplifies the problem of accounting for such things as ice

[288] Newbigin, 1936, pp. 68, 84.

'ages' since it may involve merely a redistribution of the heat and rain received by the earth rather than variations in the total amount."[289]

Thus Griggs tends to regard the observed historic warmth maximum enjoyed by the Norse colonies in Greenland as a local climatic "exchange" rather than a world phenomenon.[290] The northward movement of forest in Alaska contrasted with the seemingly southward withdrawal of conifers in the east tends strongly to substantiate this viewpoint.

The fact, however, that climatic fluctuation may have to be dealt with regionally does not necessarily destroy the usefulness of pollen profiles. The conclusion is inescapable, however, that if variation should prove totally or even largely of such a nature the complications would be great. Much care would need to be exercised to avoid fitting similar fluctuations into *hypothetically* similar time scales.[291]

Quite recently, Sears has announced the discovery of pollens preserved in alluvial deposits under semi-arid conditions in the Southwest. Lack of details makes extended comment on these discoveries inadvisable. It may be observed, however, that from the standpoint of technology it is difficult to believe that these soil zones are likely ever to supply pollen in amounts sufficient to eliminate the probability of error[292] to the same degree as peat bogs, or to obtain such unbroken sequences upward. Again, the problem of edaphic change must be decided, and the great distance from the ice front also implies some difficulty in establishing a satisfactory datum point. The relative ability of these alluvial deposits to catch wind-blown pollen as satisfactorily as bogs, as well as the effect of seasonal drying—all of these items suggest difficulties, at least for a long time to come, in correlating the data so gathered with fluctuations in the peat layers northward.[293] At best we may hope to derive information suggestive of the great Pluvial of Antevs. It would be rash, however, too hastily to fit isolated vegetation bands, however interesting, into other than local successions. The remaining picture of the pollen problem as seen at present is one of vast interest and amazing complexity, its future promise shadowed only by ill-advised enthusiasm. A long period of endeavor in the field, not merely

[289] Griggs, 1937. [290] *Ibid.*, p. 252.

[291] Auer, 1933, p. 303 seems fully alive to this danger.

[292] Barkley, 1934, discusses certain of the mathematical problems of pollen analysis.

[293] Adams, 1902, has suggested that the great amount of endemism in both flora and fauna in the Southwest indicates that its present arid condition, at least partially, may have endured for a considerable period of time and extended well into the Pleistocene. Griggs, 1937, p. 254, also gives it as his opinion that the flora of the Southwest has remained static for a long period.

at archaeological sites of importance, but at all points likely to yield correlative information, is the only procedure which promises to give us anything equivalent to the development of the pollen analytical method in Europe.

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