SOME CLIMATIC INDICATORS IN THE PERIOD A.D. 1200-1400 IN NEW MEXICO

by

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GENERAL STATEMENT

Three centuries before Columbus landed in America, the alluvial valleys of the south-western United States teemed with activity. The indigenous peoples had been building for 300 years a culture centred around community life based on flood-water farming and on hunting. A large number of pueblos had developed on sites earlier occupied by pit-house people. Community organization had brought advances in the ceramic and decorative arts, and changes in these artistic activities were sufficiently rapid that accurate chronologies have become available through the work of archaeologists during the twentieth century.

These chronologies were at first unrelated to absolute dates, but the excavations of the 1920s at Chaco Canyon (New Mexico) provided the materials through which absolute dates could be established. This was accomplished by matching the changes in tree-ring width backward in time from living trees through successively older samples. Trees overlapping in age provided, by unique successions of distinctive tree-ring widths, a calendar by which individual logs could be dated. Beams found in the excavations at Chaco Canyon gave the first material by which the cultural developments culminating about A.D. 1300 could be dated.

As a result of the time sequence provided by the tree-ring calendar, the dates within which different pottery types were developed could be accurately established. The dates of pottery types have been checked at a sufficiently large number of sites throughout the south-western United States that absolute dating of a large number of distinctive patterns can be considered unassailable.

The sequence of tree-ring widths gives some climatic indications of great interest both to archaeologists and to climatologists. A relatively large number of logs spanning the period from A.D. 1200 to 1300 and, in particular, the years between 1276 and 1299, indicate that this period was generally characterized by smaller tree-ring widths than in the centuries immediately before and after. As a first approximation, the hundred years of narrow tree-ring widths were interpreted as a time of relative aridity, and have been referred to as the "Pueblo Drought".

More recent studies of tree-ring widths using sophisticated statistical techniques have thrown some doubts on any direct correlation of tree-ring widths with rainfall. Such doubts have been put forward before by Glock (1955) whose studies have been aimed at separating the various effects of seasonal occurrence of precipitation, the amount falling in various seasons, and other climatic factors in their relative influence on tree-ring widths. At present, then, tree-ring widths may be considered more satisfactory for reading chronology than for reading climate.

It is this concern about direct correlation of tree-ring width with climate that led to initiation of the present study. This work is a preliminary attempt to obtain independent evidence from pollen concerning the probable nature of the vegetation and thus the climate in a period known to be characterized by narrow tree rings.

CORRELATIVE EVENTS

The indication of relative aridity during the period A.D. 1200-1300 provided a generalized explanation of a marked change in cultural patterns which took place about the same time. Flourishing pueblos were rapidly abandoned; communities centred in cliff dwellings similarly declined.

Correlative geologic work indicated that the time of pueblo abandonment coincided with the development of trench-like arroyos that gutted many alluvial valleys through the south-west. From the dating available

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through the use of potsherds, it is believed that the arroyo-cutting episode was relatively brief. Though not all alluvial valleys were so eroded, there were a sufficient number to justify the geological interpretation that the period A.D. 1200-1400 was characterized by a change in the rainfall-run-off relations (Hack, 1942). Subsequent to the trenching of alluvial valleys, there began in most areas a much longer period of aggradation during which the trenches became alluviated, and by the middle of the nineteenth century most alluvial valleys were characterized by flat floors only occasionally interrupted by discontinuous gullies. There followed a period, centred about 1880, of another epicycle of valley trenching, this time complicated by the effects of intensive grazing accompanying the development of western lands under the American flag.

THE PROBLEM OF CLIMATIC INTERPRETATION

The general simultaneity of arroyo cutting, the abandonment of pueblos, the decline of Pueblo civilization, and the two centuries of narrow tree-ring width made it plausible to interpret these phenomena as interrelated and as indicative of two centuries of relative drought. With regard to the geologic evidence, however, it remains difficult to prove by any available observations the exact nature of the change in rainfall-run-off relations which would be necessary to cause the observed epicycle of erosion in alluvial valleys.

It would be not only of hydrologic interest but also of concern to archaeologists and climatologists to be able to identify what climatic parameters must have changed, and in what degree, in order to reverse a trend of valley alluviation and replace it by valley degradation. It would be logical to suppose that indications of the type and degree of climatic change required for this could be ascertained from a study of the more recent epicycle of erosion centred around the year 1880. However, this later epicycle has been interpreted by many to be the result of man's activities alone—that is, the effect of grazing. In such a view it is not necessary to call on any change in climatic factors to explain the period of arroyo trenching that characterized the end of the nineteenth century. There were others (Bryan, 1941) who interpreted the erosion epicycle of the nineteenth century to be similar in cause to that of immediately pre-Columbian times, and to be related primarily to variations in climatic factors. An intermediate view (Leopold, 1951) is probably more generally accepted now. He provides evidence that there was a change in the intensity of heavy rains during the period of the recent erosion epicycle. This view emphasizes the importance of both grazing use and the simultaneous change in effective climatic parameters.

This brief review emphasizes, then, both the importance and the difficulty of finding ways of separating the individual effects of climatic change from the varying effects of man's activities on the land. The simultaneity of these two factors, both of which would tend in the same direction, reduces the usefulness of observations on the epicycle of erosion in the nineteenth century in ascertaining the individual effects of a changing climate uncomplicated by the effects of man.

Indeed, changes at present observed in the position and form of river channels, in the amount and types of sediment load, and in species and density of native vegetation cannot be clearly ascribed only to the effects of man's use. Meteorological evidence indicates that there has been in much of the Northern Hemisphere a tendency toward greater aridity throughout the first part of the twentieth century. So, the problem of ascertaining the effects of climatic change alone on the hydrologic cycle and on rainfall-run-off relations stands as one of the salient problems in both hydrology and in climatology.

POLLEN AS AN INDEPENDENT CLIMATIC INDICATOR

There is an inherent importance, therefore, of making use of whatever independent evidence can be brought to bear on the question of the nature of the supposed climatic variation occurring in the period A.D. 1200-1400. One possibility for the accumulation of independent evidence is the pollen associated with deposits which can be dated through pottery types stratigraphically associated. With this in mind, the authors collected soil materials in stratigraphic sections containing identifiable pottery types, in the hope that changes in pollen composition would add some information on the nature of vegetation and thus, indirectly, the climate characterizing a span of centuries, including the supposed drought.

The stratigraphic sections are of two general types. The Pueblo Indians characteristically made circular rooms known as kivas, mostly underground, roofed with timbers and soil, which were used as ceremonial rooms. The roofs of these kivas often collapsed, either through abandonment of the structures or lack of maintenance, leaving holes in the earth adjacent to the village. Such holes would logically be used as trash pits by the local inhabitants. The bulk of the trash was composed of soil materials, presumably from deteriorated house walls and from sweepings, including broken pottery, ashes, bones, and other debris. Natural run-off also washed alluvial materials into these holes and tended to fill them up gradually.

Because of the admixture of pottery, stratigraphic lines in earth materials accumulated in kivas can be dated accurately. A sequence of samples obtained at different depths within such kivas constituted one of the sources of the pollen which was analysed. A similar stratigraphic deposit was provided by material that filled pit-houses, early forms of habitation prior to the

construction of the more complicated community apartments. Alluvial materials filling pit-houses are, therefore, analogous to those in kivas.

The second main type of deposit from which pollen was obtained is the alluvial valley fill. Owing to the arroyo trenching of the nineteenth century, there are unending miles of vertical arroyo walls in which the stratigraphic sections of alluvial deposits can easily be seen. It is not uncommon, then, that the sections exposed in the sides of the valley trenches provide artifacts, hearths, charcoal lenses, bones, and other evidence by which dating may be accomplished.

THE SITES AND THEIR INCORPORATED POLLEN

The present paper presents the pollen evidence from a limited number of kivas, pit-houses, and alluvial sections in the vicinity of Santa Fé (New Mexico). Owing to the small number of sites sampled and the restricted geographic area of their occurrence, the evidence presented must be considered preliminary in character and indicative rather than conclusive. Three pit-houses, one kiva, and one alluvial section in an arroyo bank occur in the vicinity of Tesuque (New Mexico) along a 5-mile reach of the valley of Rio Tesuque, elevation 6,500 feet. A kiva was investigated on an unexcavated pueblo site standing on a high ridge at elevation 7,000 feet, one-half mile due north of the village of Chupadero. In contrast to the alluvial section, the pueblo and pit-house sites all have the advantage of being topographically isolated from any possible source of pollen carried from the mountains by streamflow.

Both the Chupadero site and the sites in the Tesuque Valley are located on remnant outliers of unconsolidated sand and gravel of Miocene age, the Santa Fé formation, and extend well above the valley floor. The alluvial deposits of the Tesuque Valley are derived primarily from the weathering of the same Santa Fé formation, but were deposited principally during the period from about 250 B.C. to about A.D. 1300 (Miller and Wendorf, 1958).

The area near Tesuque is presently characterized by a woodland association dominated by piñon pine (*Pinus edulis*) and juniper (*Juniperus utahensis*). These woodland types represent a crown density of perhaps 10 per cent. Grasses and shrubs, including various species of grama (*Bouteloua*), snake weed (*Gutierrezia*), mountain mahogany (*Cercocarpus montanus*), characterize the hills and slopes. The same grasses and shrubs occur in the alluvial valley flats but there, in addition, grow cottonwood (*Populus* sp.), willow (*Salix* sp.), and some salt bush (*Atriplex conescens*).

The dates indicated in Fig. 2 for the pit-houses and kivas include the probable time ranges of the group of pottery types found in the structures. There is no way of determining, however, whether these deposits accumulated during most of the indicated time range.

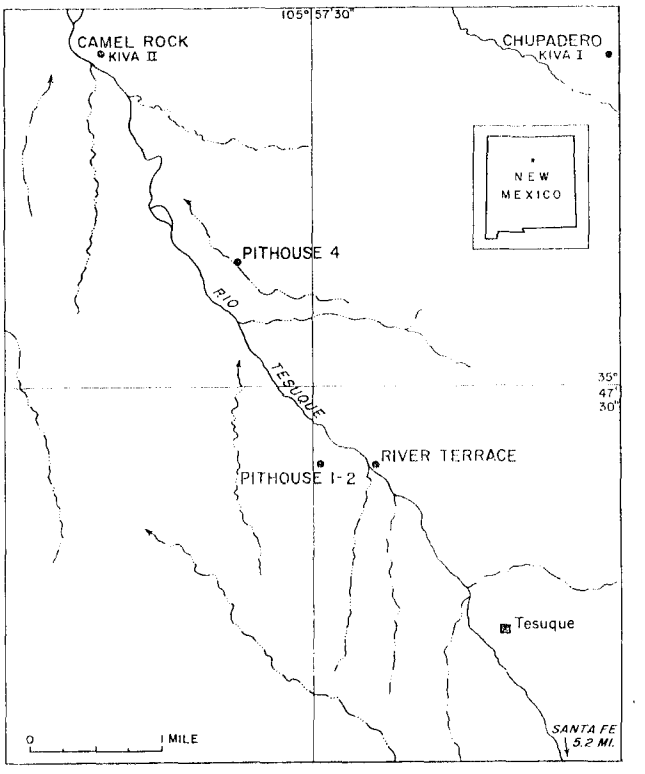

FIG. 1. Location of sampling sites, New Mexico.

The kiva may have filled rapidly, and thus would record only a comparatively brief span within this interval.

DESCRIPTION OF POLLEN DATA

Pollen data are arranged in the diagram (Fig. 2) according to percentage-total pollen and with amounts of *Pinus* and other trees on the left, shrubs in the middle, and herbaceous and cultivated forms on the right. The total number of pollen grains in each count is shown on the far right. The chief forms in the pollen samples and the ones that show the primary variation here are *Pinus*, Chenopodiaceae, and Compositae. The family Chenopodiaceae in the south-western United States is represented mainly by small salt-tolerant shrub genera adapted to arid conditions, such as *Sarcobatus*, *Atriplex*, and *Allenrottea*. Except for *Sarcobatus*, these Chenopodiaceone genera cannot be distinguished by their pollen, unfortunately. The family Compositae, of which the shrub genus sage or *Artemisia* is noted here, is considered to represent either woody or herbaceous forms in the present assemblage, and cannot otherwise be identified by pollen to genera.

The six sections are arranged on the diagram according to their inferred archaeologic age, the youngest at the top.

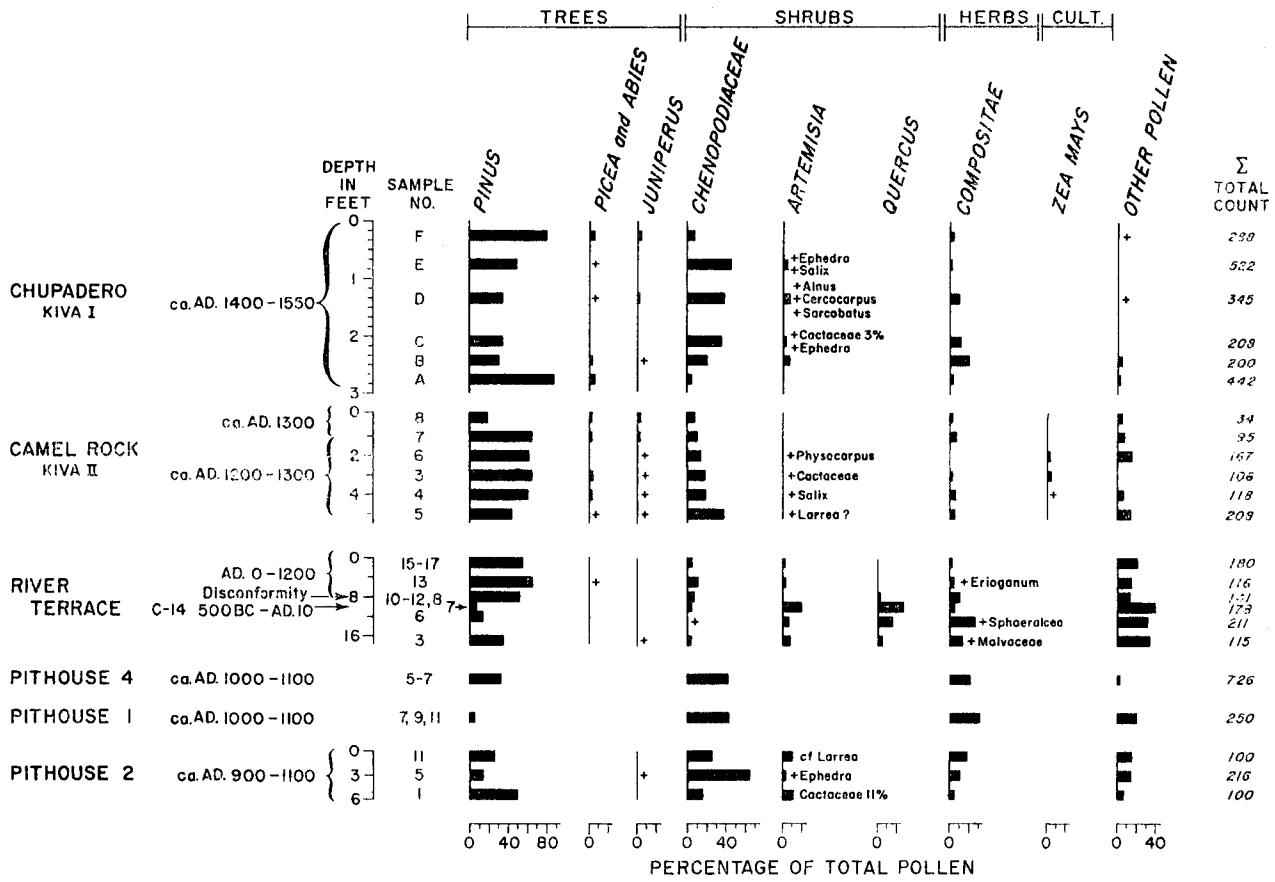

FIG. 2. Pollen diagram of sites near Santa Fé, New Mexico.

It should be noted first of all that the older sections at the bottom of the diagram, including pit-houses 2, 1, 4, and the lower part of the river terrace, are all thought to be older than A.D. 1100, and are as a whole comparatively poor in tree pollen. They contain, instead, various amounts of Chenopodiaceae, Compositae, *Quercus* (which will be scrub oak in New Mexico) and other non-tree forms.

On the other hand, the younger materials dating from A.D. 1200-1300, as in the Camel Rock kiva, contain comparatively large amounts of tree pollen, mainly *Pinus*, and with small amounts of *Picea* and *Abies*.

A section which cannot be dated very well because it contains little archaeologic evidence, and is mainly dated by correlation with other fluvial sequences, is the top part of the river terrace. By inference, it is thought to represent fluvial deposition some time between A. D. 0 and 1200. It contains relatively large amounts of tree pollen and is therefore like the samples from Camel Rock rather than the older materials that are known to be pre-A. D. 1100.

The youngest section, the kiva from Chupadero ridge (top part of Fig. 2) contains pottery that suggests deposition during the general interval of A.D. 1400-1550. This section is very rich in pollen and permitted larger tallies of pollen than the other less polleniferous sections. Within this 3-foot section there appears an oscillation in the percentage values of *Pinus* pollen. While *Pinus* varies from high to low to high values, there is a concomitant rise and fall of Chenopodiaceae and Compositae pollen.

DISCUSSION OF THE POLLEN AND OTHER DATA

Of stratigraphic interest are the low values of pine in all the pre-A.D. 1100 pit-house samples. The contrast between these and the younger Camel Rock kiva materials is considerable. The difference between the older and younger samples in abundance of tree pollen may reflect changes in pollen rain in the valley during the early part of the Christian era. Assuming that the sequences do reflect changes in pollen rain, we can take two possible interpretations of the pollen percentages. The simplest one is that the more prominent representation of tree pollen in the samples may reflect the occurrence of factors that favour the blooming and propagation of pine pollen, perhaps years of higher than average rainfall during the growing season.

It should be emphasized that there are no data by which one may know whether more rainfall in New Mexico results in more prolific blooming of pine.

The other empirical interpretation of the data might be to suppose that some climatic factor such as low values of precipitation might have inhibited the blooming and propagation of non-tree pollen while pine pollen production and dispersal remained unaffected. Under this interpretation, pine pollen is well represented only because of the failure of the non-tree elements to bloom prolifically.

The logical conclusion of the first hypothesis would contradict the generally held concept of relative aridity in the two centuries of arroyo cutting and pueblo abandonment. The samples that are rich in tree pollen are between A.D. 1100 and 1400 in age.

The other empirical interpretation permits us to suggest that unfavourable rainfall might be inferred during the same interval.

As in the case of the other data concerning this interval in New Mexico, pollen analysis provides evidence that something happened to the climatic environment between A.D. 1100 and 1200 that affected the internal composition of the pollen rain in the Tesuque Valley (New Mexico).

The question of what exactly happened remains at this moment still unanswered. However, there is hope that studies now being carried out will result in better understanding of the factors affecting pollen rain in this arid region. There is, further, the possibility of studying the annual modern pollen rain for several years in the valley and comparing it to the contemporaneous changes in seasonal rainfall. It is already known that in modern pollen rain over short time intervals, absolute numbers of tree pollen may remain constant while absolute numbers of non-tree pollen may increase, thus effecting an apparent percentage decrease in tree pollen in the samples. Because of this possibility and because the interpretation of the whole of the post-pluvial pollen chronology from this area is an important question, we think that modern pollen rain studies must be undertaken in the area in order for some of these questions to be answered.

The relation of geographic distance from dominant vegetation to pollen catch is inadequately known. Recent work (Davis and Goodlett, 1960) sheds further doubt on the usual assumption that pollen catch in any locality is predominantly related to the principal vegetation in the same locality.

Further work must also be done on the differential effects of variation in winter and summer precipitation, in particular as this relates to the growth of trees and the production of pollen. As Martin *et al.* (1961, p. 89) have recently pointed out, the so-called "Pueblo Drought" may have been a period when the winter precipitation was different, but the summer rainfall was increased.

CONCLUSIONS

The principal conclusion of the present preliminary investigation is that climatology and hydrology vitally need whatever new tools can be provided by palaeontology and a more sophisticated study of the dendrochronologic record. The actual findings of the pollen itself must be considered more tentative. These findings indicate that the period A.D. 1200-1300 had more pine pollen and less of the Compositae and Chenopods than in the preceding and succeeding centuries. This finding brings into question the supposition that this period was one of relative aridity. We are not the first to raise this doubt (Martin *et al.*, 1961, pp. 82-94).

All kinds of new independent evidence are needed to help separate the effects of climatic change and the effects of man's activities. The authors hope that this challenge will be increasingly recognized and aggressively accepted.

RÉSUMÉ

La sécheresse de 1200 à 1400 apr. J.-C. dans le sud-ouest des États-Unis (L. B. Leopold, E. B. Leopold et F. Wendorf)

Des études de cercles annuels portant sur des séries d'échantillons dans le Nouveau-Mexique et le Colorado indiquent une période de sécheresse prolongée s'étendant approximativement de 1200 à 1400 apr. J.-C. Cette conclusion, formulée il y a plus de vingt ans, a été utilisée à plusieurs reprises par des savants de différentes disciplines pour expliquer d'autres faits connus. Des études dendrochronologiques ultérieures ont montré l'interdépendance complexe des facteurs qui détermine l'épaisseur des cercles annuels ; il est donc nécessaire d'obtenir des preuves nouvelles et objectives pour confirmer la théorie généralement admise selon laquelle une longue suite de cercles annuels étroits indique une période de sécheresse.

Dans la présente étude, des échantillons prélevés dans des couches qui pouvaient être datées avec précision au moyen de tessons et d'objets façonnés ont été analysés pour rechercher le pollen qu'ils contenaient

dans l'espoir que l'on pourrait comparer le pollen découvert dans ces couches datées avec des dépôts de pollen moderne dans la même région. Bien que les données soient quelque peu contradictoires et qu'il se pose des problèmes d'interprétation, certains des échantillons montrent que la végétation associée avec la période de sécheresse supposée était en fait d'un type plus xérophyte que la végétation existant actuellement dans la même région. Les auteurs présentent et commentent certaines données ainsi que les problèmes d'interprétation qu'elles posent.

DISCUSSION

J. NAMIAS. Drought over the south-west is now known to be associated with a fairly definite pattern of large-scale wind and moisture flow. It is probable that on the basis of studies with recent (30 years) upper air data, meteorologists could suggest areas which had quite opposite (very wet) conditions. Would such predictions of simultaneous abnormalities of climate be of help in suggesting places in which pollen analysts, dendrochronologists, etc., might look for clues for long-term climatic fluctuations?

L. B. LEOPOLD. This is a sound suggestion. The knowledge of places where one might expect either similar or opposite anomalies might spur the archaeologist and other scientists to seek confirmatory evidence. The difficulty we envisage is that a combination of dating tools and climate indicators are unique in the south-western United States, owing particularly to the chronology developed by use of tree rings to date unique pottery decorations. Despite the present lack of these tools, Dr. Namias' suggestion that evidence be sought should be kept in mind.

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