Report to: Dr. David Breternitz   Date: March 1965

From: J. Schoenwetter

Title: Pollen Analysis of Sediments from Northeastern Colorado: Preliminary Report

Erratum

On Figure 2, read 5LO1-19 for 5LO1-17 and Artemisia for Artemesia

Introduction

Pollen samples were gathered in 1964 from a series of localities north and west of Westplains, Colorado, in Townships 11 and 12 North, Ranges 55 and 56 West. Collections were made in stratigraphic series below, within, and above archaeological horizons at sites 5WL32, 5WL33 and 5LO1, and a single sample was collected from a burial at site 5LR99. Seventy-one subsurface and nine surface samples were submitted to this laboratory of which sixty-eight were processed and analyzed.

The objective of the project was two fold: first, to obtain a pollen chronology which might be useful in the relative cross-dating of future archaeological work in the area; second, to obtain paleoecological information which might have a relevance for the interpretation of the archaeological data. Both objectives have been fulfilled in large part, but the relatively small number of pollen samples of any given paleoecological horizon necessitates the recognition that the interpretations set forth in this report as yet require a respectable measure of further substantiation.

Because this is a pioneer research project in this area, and because this report is destined for modification before publication, I have purposely attempted a liberal approach to the interpret of the palynological data. A rigid conservatism, while respectably scientific, would seem to little serve our present purposes. We are here searching out the potentialities of new approaches in an attempt to gain new perspectives and investigate new problems. If the interpretations come to be seen, in future, as erroneous because based upon too little data it should not be surprising.

Extraction and analysis procedures

The method used in extracting the pollen from the sediment samples is that with which this laboratory has had wide success on alluvial and colluvial materials in the Southwest. It basically consists of four steps:

(1) passage of material through 80 micron mesh screening

(2) removal of majority of the minerals with HCL and HF

(3) heavy liquid flotation to remove the light, organic, fraction of the sample

(4) standard acetolysis and KOH treatment.

Of the sixty-eight samples processed in this manner, sixty yielded sufficient pollen for an analysis. Five of the recalcitrant samples were from one particular stratigraphic horizon., so it appears that the extraction method was not at fault in this case, but the samples actually did not contain much pollen.

Counting and identification of the pollen taxa was done at 450 magnifications. The small number of pollen taxa recognized may partly be a function of the poorly preserved condition of much of the ancient pollen. The category Gramineae probably incorporates a few Cyperaceae pollen grains, for scabrate grass pollen and crushed, battered and broken Cyperaceae pollen sometimes are much alike. The total lack of Cyperaceae pollen in the fossil record, then, is probably not meaningful, but I would doubt that more than a dozen Cyperaceae pollen grains were included in the Gramineae in any case.

In the Southwest the size of pine pollen is an index to species within the genus; smaller grains are usually referred to the pinyon pines and larger grains to the other Southwestern pines. There is a large range of variation in the size of the Pinaceae pollen in these samples, with most grains being of a small size, but I have been reluctant to assume that the size-frequency statistics worked out for Arizona species (Martin, 1963, p. 20) are applicable in northeastern Colorado. Incorporated in the Pinaceae taxon is an occasional occurrence of spruce (Picea) pollen--undoubtedly a matter of long-distance transport.

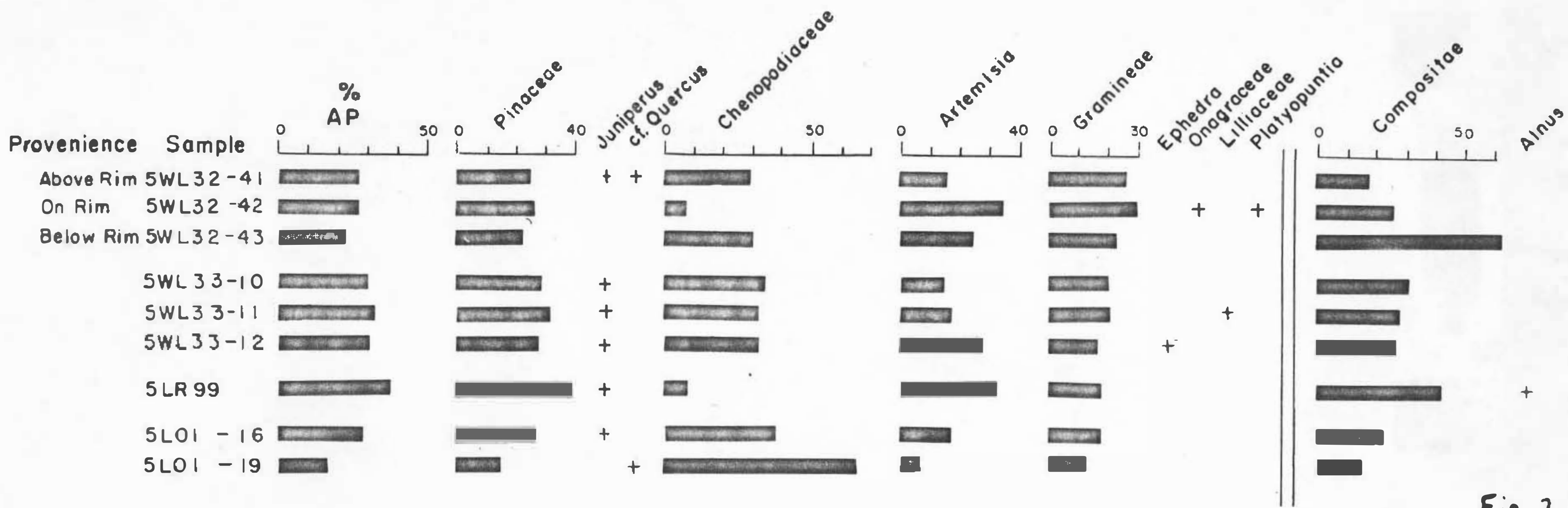
In poorly preserved material the pollen of Artemisia exhibits a great range of morphological variation and has caused no little trouble to Southwestern palynologists. I have been rather liberal in allocating poorly preserved pollen to this taxon, and have undoubtedly made a number of errors in this regard. Some of the grains I have called

Artemisia are probably Compositae grains of the other category, and others are probably of completely different families, for the tricolporate scabrate-microreticulate morphology is a very common one.

The morphology of oak (_Quercus_) pollen is variant and pollen of completely unrelated taxa closely resembles it. The "cf. _Quercus_" category, then, relates to pollen grains which look like those of oak but may not actually be so. Grains of this type were found in the surface samples, though no oak was reported for the area on the vegetation forms.

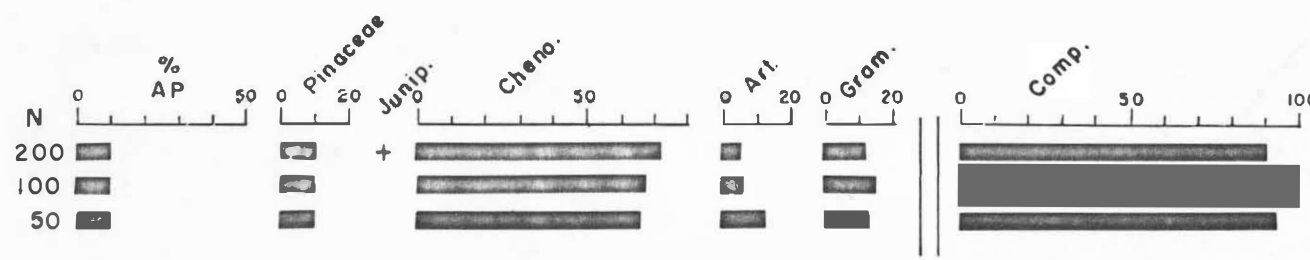
The pollen diagrams are somewhat unorthodox. The double bar segregates taxa included in the pollen sum, on the left, from taxa excluded, on the right. The pollen sum is the number on which the percentages have been based; taxa excluded from the sum are diagrammed on the same percentage basis as those to the left of the double bar. Thus if the pollen sum of the included taxa was 200 grains--the usual figure--the percentage of an excluded taxon would be greater than 100 per cent if more than 200 grains of that type were observed. The diagrams also include a shaded area for certain taxa which is the confidence interval at the 95 per cent level of confidence. This confidence interval is based on the assumption that pollen statistics follow a binominal distribution, as has been indicated in a number of studies (Faegri and Ottestad, 1948; Mciseman, 1962). The bar representing the frequency of the pollen of a taxon will fall below, within, or above the shaded area. As is discussed below, the shaded area represents the present condition, so the pollen frequency may be evaluated as less than present, like present, or more than present immediately from the diagram. A cross on the diagram indicates a pollen frequency of less than 2.5 per cent, unless otherwise indicated in the text.

All of the surface samples, and the majority of subsurface samples, were "counted" until 200 grains of the taxa included in the pollen sum were observed. This has become the standard fixed count of both this laboratory and that of the University of Arizona. However, not all samples were equally pollen productive, and it seemed that this might be an important variable which could be used as a horizon marker. I accepted one 22 x 22 mm area on the microscope slide as a standard. If more than 200 pollen grains could be observed on this area a 200-grain count was made; if more than 100 but less than 200 grains could be observed the count was stopped at 100; if more than 50, but less than 100, the count was stopped at 50; if less than 50 grains occurred the sediment was considered sterile. There has been some concern in the palynological literature that counts of less than 150 grains may be statistically meaningless. It is true that the more grains that are observed the more meaningful are the resultant frequencies by any standard, but when few taxa are involved this rule seems to lose its force. I soon recognized that the frequencies of the pollen taxa were remarkably stable even with small counts, so I put the rule to the empirical test. Figure 1 shows the variation in pollen frequencies for counts of 50, 100 and 200 grains on the same sample (Site 5WL32, sample 2).



Provenience
Sample
% AP
Pinaceae
Juniperus
cf. Quercus
Chenopodiaceae
Artemisia
Gramineae
Ephedra
Onagraceae
Liliaceae
Platyopuntia
Compositae
Alnus
Above Rim 5WL32-41
On Rim 5WL32-42
Below Rim 5WL32-43
5WL33-10
5WL33-11
5WL33-12
5LR99
5LO1 - 16
5LO1 - 19

Fig. 2



% AP
Pinaceae
Junip.
Cheno.
Art.
Gram.
Comp.
N
200
100
50

Fig. 1

I feel that this demonstrates fairly well that the smaller counts are reliable in the case of these materials. The confidence limits, of course, widen as the sample size decreases. This is expressed on all diagrams.

The Surface Samples (Fig. 2)

One of the inherent difficulties of any pioneer effort is the lack of comparative data. In a pollen study this difficulty is compounded by the realization that pollen analysis is essentially a statistical technique, dealing with the relative frequencies of pollen taxa, and as such is open to all of the problems of sampling and mathematical manipulation that the field of statistics is heir to in addition to the botanical problems of identification and the physical problems of extracting pollen from the sediment. To overcome the factor of lack of comparative data, and to indicate what statistical problems were involved, it was necessary to analyze a respectable series of samples representing known, modern, pollen rain-vegetation associations. This was the only available control on the subsurface samples.

The surface samples were collected in the area of the sites themselves. Thus conditions of topography, drainage and sediment type should be roughly approximate for the surface and subsurface samples from any given site, and the major fluctuating variable through time should be the vegetation pattern itself. Also, variation in pollen content between surface samples from a given site should be a function of variations in the immediate vegetation of the sample area. Since records are available of the vegetation of the sampled areas, we can define the "present" condition and see how it varies at a site and for all sites.

Observing the pollen spectra from all the sites (Fig. 2) it is evident that some taxa are quite consistent in frequency while others vary from one sample to the next. Clearly, those that vary least must be most reponsive to regional ecological factors while those that vary most are more responsive to local ecological factors. Our major concern is with regional, not local, paleoecology since we wish to relate to the regional archaeological record. Local ecological variation, while of import, may be considered "noise". Because we perforce deal with the frequencies of pollen taxa, however, and because the total of all frequencies must equal 100 per cent, each pollen frequency affects all the others. If all of the taxa were considered equally, the "noise" taxa might be so important as to drown out the meaningfulness of the "regional" taxa. The simple solution to this problem is to segregate the obvious "noise" taxa from the others and treat them separately. The "noise" taxa cannot be ignored altogether because they have some ecological significance; thus their variation through time may be useful in the paleoecological reconstruction. But too many taxa cannot be included in the "noise" category for this will (1) leave us with very few pollen grains to observe in the "regional" category, making the analysis long and tedious, and (2) affect the statistics of the "regional" category in a drastic manner.

For the "noise" category then, I have selected only the few taxa which vary most drastically: Compositae, *Cleome*, Cereals, *Alnus*, and *Betula*. *Alnus*, *Betula*, *Cleome* and Cereals only occur once each in the entire pollen record. The former two are specialized riparian plants, Cleome is an insect-pollinated plant whose occurrence is probably a direct function of this single sampling situation, and the cereal pollen is a function of the man-influenced environmental condition. Compositae is the taxon which shows the greatest variation in the surface samples and is also the one which shows the greatest variation in the subsurface samples. These taxa are diagrammed to the right side of a double bar on the figures. Their percentage frequencies do not affect the taxa on the left side of the bar, whose percentages are calculated on the basis of the pollen sum--usually 200.

The best indices to the present regional condition are the Pinaceae and the Gramineae values. At the 95 per cent level of confidence all of the Pinaceae and Gramineae values for the surface samples fall within the same statistical range. All of the Artemisia values except those from 5WL32-42 and 5LR99, which are higher, and 5L01-19, which is lower, fall into the same range. 5WL32-42 is from a locality which has more Artemisia coverage than the others; 5LR99 is from a locality of above average elevation; 5L01-19 yields an Artemisia value significantly lower than 5L01-16, from the same site, and thus seems very anomalous. From the present distribution of Artemisia it is clear that this plant has a relationship to the areal ecology. It is normally found in unusual frequency at either higher elevations or north facing slopes and thus can be recognized as a cold-preference element in the areal vegetation pattern. Like any living plant, it must respond to the local conditions of the site, but it may be considered as occupying a niche in the regional ecology.

The Chenopodiaceae, of the "regional" taxa, varies the most widely from sample to sample. This is in part, of course, due to its local ecological requirements, but it is also a function of the mathematical system of the pollen analytic technique. As the total percentage of all of the "regional" taxa must equal 100 per cent, the frequencies of some taxa must vary if the frequencies of other taxa vary. Pinaceae and Gramineae vary within statistical limits, but they do vary; Artemisia varies significantly; Juniperus, Quercus, Ephedra, Liliaceae, and other taxa also have some affect on the total of 100 per cent. Some taxon, or taxa, must take up the statistical slack; in these samples it is the Chenopodiaceae.

What interpretations of paleoecological significance can be derived from the variations in the surface samples? First, the present conditions are best demonstrated by Pinaceae and Gramineae values. Any statistically significant variation in these taxa through time can be reliably accepted as "different from present". As a family the Gramineae have a very wide range of ecological tolerance. If we could determine what genera or species of grasses were involved we might know the direction of ecological variation indicated by a greater or lesser frequency of Gramineae pollen, but pollen identification will not allow this refinement.

The Pinaceae, on the other hand, has a less wide ecological range. Granting that we are not here dealing with other genera than now occur in the western plains area, a significant decrease in the number of Pinaceae should be indicative of a significant decrease in effective moisture, while a significant increase should be indicative of a significant increase in effective moisture. Of course effective moisture is a complex variable. It is at once a function of competition, amount of water available at the roots of the trees, and temperature. The amount of water available is itself controlled by the nature and periodicity of the rainfall, the amount of rainfall, and the height of the water table. Thus variations in Pinaceae frequency are meaningful, but only in a general way.

Variations in *Artemisia* frequency through time should be a reliable index to temperature values, since this plant is today temperature sensitive in this area. However, it can be expected that sites which presently support more *Artemisia* might well have supported more *Artemisia* in the past. This must be taken into account in determining the statistical "present" condition at each site. More *Artemisia* than present should then be an index of cooler conditions; less than the present should be an index to warmer ones.

There is a valuable clue to the ecological significance of the Compositae taxon in the distribution of maximal and minimal frequencies in the surface samples. Compositae values are maximal at the high elevation site and in the canyon bottom; they are minimal in the rock shelter locality and above the canyon rim. When it is realized that these Compositae pollen grains are shed primarily by annual, rather than perennial, plants it is clear that this taxon must represent local

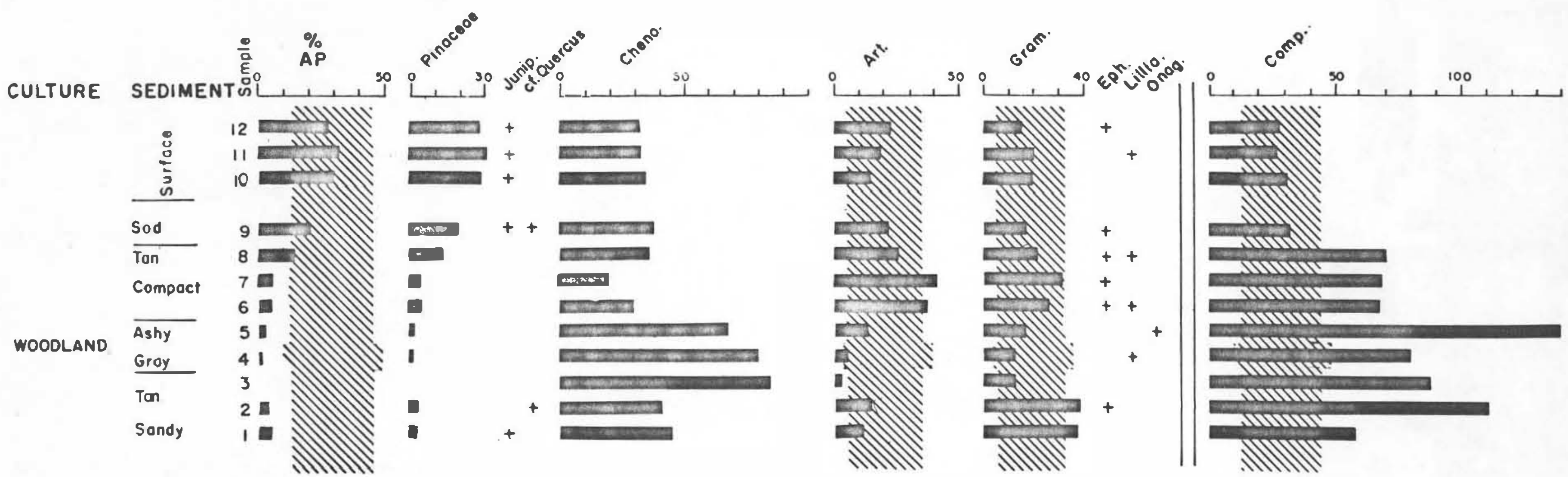

CULTURE
SEDIMENT
Sample
% AP
Pinaceae
Junip.
cf. Quercus
Cheno.
Art.
Gram.
Eph.
Lillia.
Onag.
Comp.
0
50
30
100
40
Surface
Sod
Tan
Compact
Ashy
Gray
Tan
Sandy
WOODLAND
12
11
10
9
8
7
6
5
4
3
2
1

Fig. 3

ecological conditions during the summer growing season only. The maximal values come from the wettest localities; the minimal values from the dryest ones. Thus Compositae values should be a reliable index to wetter than present summers if statistically higher values are found, and dryer than present summers if statistically lower values are found. The value for "present" will be different at each site since the Compositae are a local ecological index.

5LR99

The single subsurface sample from this site did not yield sufficient pollen for analysis. While this is disappointing, a successful analysis of this sample might have raised more problems than it resolved. The sample was of sediment associated with a burial. Extremely few sediment samples from burials have been successfully analyzed for pollen content anywhere in the world, and those which have been successful in the Southwest have sometimes yielded comparable results to others of the same age, and other times have not.

5WL33 (Fig. 3)

In the surface samples from this site *Artemisia* values range from 13.5 to 22.5 per cent. These frequencies do overlap at the 95 per cent level of confidence, and indicate a single "present" condition with frequencies ranging between 6.0 and 35.0 per cent. Subsurface *Artemisia* frequencies below 6.0 per cent would then indicate warmer conditions than present and values above 44.0 per cent would indicate wetter summer conditions than present. As with the other sites, AP values below 12.0 per cent would indicate less effective moisture areally than at present, and AP values above 45.0 per cent would indicate more effective moisture areally than at present.

The sample from the sod layer thus shows conditions like the present existing at the time of deposition. The uppermost sample from the tan compact layer is significantly different from the present in its Compositae frequency but in other ways is like the present, thus at the time of its deposition there was more water available during the summer but no other variation.

The lower two samples from the tan compact layer have significantly lower AP values than the surface samples, as well as significantly higher Compositae values and significantly higher Artemisia values. The indications are, then, that during the earlier deposition of the tan compact layer cooler conditions than present occurred with wetter summers, but lessened effective moisture values.

In the samples from the ashy gray layer, the AP frequency is significantly lower than present, the Compositae frequency is significantly higher, and the Artemisia frequency not significantly different. The interpretation of the pollen statistics is one of a condition with the same lessened effective moisture and high summer season moisture values evidenced in the lower tan compact layer but no cooler or warmer than present.

In the tan sandy layer the uppermost sample differs from those of the ashy gray layer in its significantly lower Artemisia values, an indication of warmer conditions. The lower two samples of this sediment have significantly low AP values, significantly high Compositae values, and Artemisia values like those of the present. Thus, like the ashy gray layer, they indicate a condition of less effective moisture but higher summer season moisture values yet similar temperature relationships to the present. The lower tan sandy layer samples differ from those of the ashy gray layer and the surface in having significantly higher Gramineae values. Because the Gramineae values do not vary significantly in the surface samples, we have no controls to determine the meaning of their variation in the subsurface samples; all we can recognize is that the variation must have some meaning. So it becomes clear that the ecological condition evidenced in the lower tan sandy layer samples is distinct from the ecological condition evidenced in the ashy gray layer, even though the AP, Artemisia and Compositae values are indicative of the same phenomena. Just what the distinction is, we do not know.

Sediment	Effective mois-ture values	Wetness of summers	Temperatures
Surface	Present	Present	Present
Sod	"	"	"
Tan Compact	" Lower	Greater "	" Cooler
Ashy Gray	"	"	Present
Tan Sandy	" " "	" " "	Warmer Present "

TABLE I

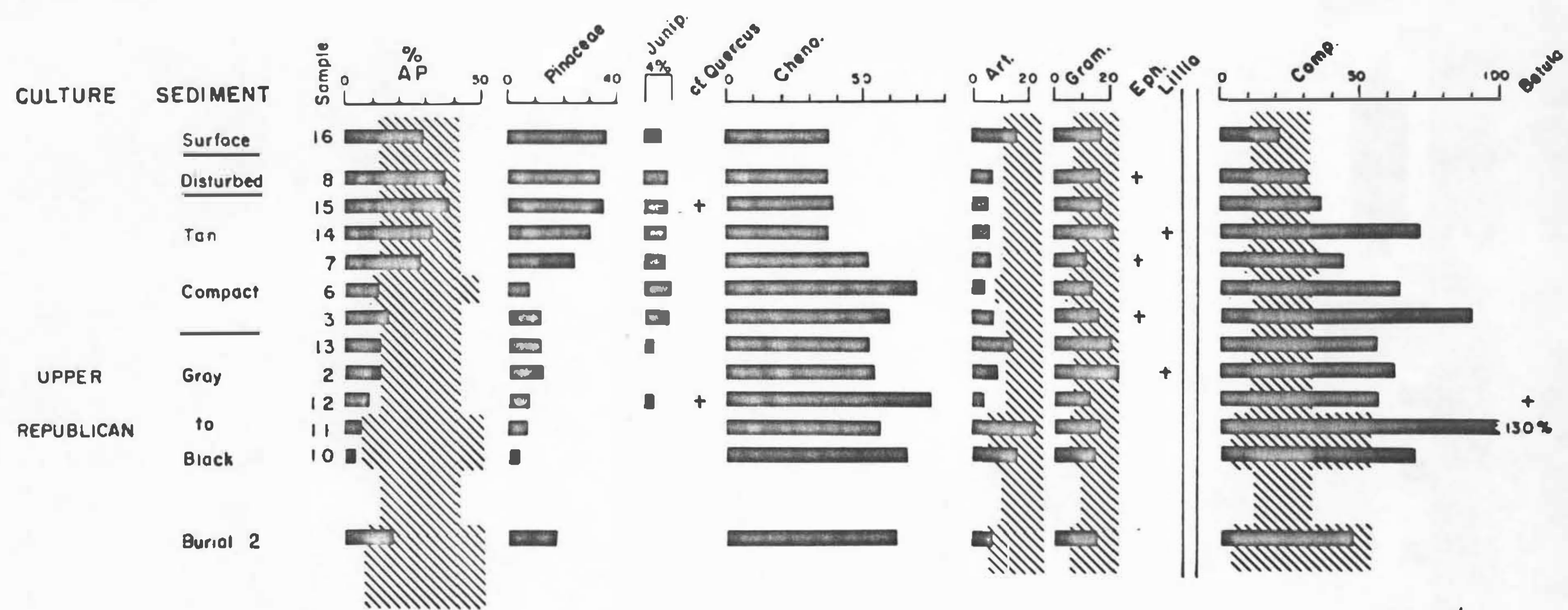

CULTURE
SEDIMENT
Sample
% AP
0
50
Pinaceae
0
40
Junip.
4%
cf Quercus
Cheno.
0
50
Art.
0
20
Gram.
0
20
Eph.
Lillia
Comp.
0
50
100
Betula
Surface
Disturbed
Tan
Compact
Gray
to
Black
Burial 2
UPPER
REPUBLICAN
16
8
15
14
7
6
3
13
2
12
11
10
130%

Fig. 4

5L01 (Fig. 4)

It was pointed out in the discussion of the surface samples that surface sample 5L01-19 was anomolous in its significantly low *Artemisia* record. My suspicions regarding this sample were heightened when sample 8 from this site was analyzed and it also evidenced a significantly low *Artemisia* frequency. Sample 8 is a subsurface sample from a disturbed sedimentary horizon such as quite commonly occurs at the top of rockshelter sequences. It seems highly probable that 5L01-19 is not representative of the modern condition but is a sample of the disturbed layer, like 5L01-8. Therefore, only 5L01-16 is utilized as the standard for "present" conditions at this site.

The stratigraphy of the rockshelter sediments (see stratigraphic profile) is complicated by the mass of rock fall which occurred sometime in the past. The absolute depth from the surface in this case is not necessarily a reliable index to the relative age of the sample. The relative ages of samples 1 to 8 are proven by their stratigraphic relationships, as are the relative ages of samples 10 to 15, but the two series are not necessarily synchronous. The oldest sample may be either 1 or 10; samples 11 to 13 may be older, younger, or synchronous with samples 1 and 2; and samples 14 and 15 may be older, younger, or synchronous with samples 3 to 8. The only reliable stratigraphic event is the rock fall. Some of the samples are younger than the rock fall and others are older--nothing more is known to be true. The Upper Republican horizon is below the rock fall.

On the basis of similarity in pollen content with the surface sample, I have grouped samples 8, 15, 14 and 7 as the youngest of the series above the rock fall and samples 3 and 6 as the older of the series above the rock fall. All of the samples of the tan compact sediment above the rock fall have AP frequencies within the statistical range of present values, and Artemisia frequencies below the range of present values. The reconstructed environmental conditions during the deposition of this unit would be one of effective moisture values like the present, but warmer and with wetter summers. Samples 3 and 6 have lower AP frequencies than the others, and may be considered transitional to the older samples, but fall within the statistical range of "present" conditions. Samples 4 and 5 were not processed but they may be presumed to have been similar to samples 3 and 6.

Of the samples collected below the rock fall sample 13 must be the youngest and samples 12, 11 and 10 must be increasingly older. Samples 11 and 10 yielded only 50-grain counts; it therefore seems reasonable to suppose that sample 2, which yielded a 200-grain count, is more of an age with samples 13 and 12 than with 11 and 10. Sample 1, which may be older or of a similar age as samples 11 and 10, was pollen sterile. So there are two, possibly three, horizons below the rock fall: the youngest, evidenced in samples 13, 12 and 2, yields 200-grain counts; an older one, evidenced in samples 11 and 10, yields 50-grain counts; an oldest one may be represented by the sterile sample 1. While the AP frequencies are significantly less than present values and the Compositae frequencies are significantly more than present values in both the younger and older horizons below the rock fall, the Artemisia frequencies are less than present values in the older one. Thus for the earliest horizon evidenced by pollen in the rockshelter series we may reconstruct an environment of less effective moisture, more summer moisture, and temperatures like the present, while somewhat later there are conditions of less effective moisture, more summer moisture, and temperatures warmer than the present.

Five samples were collected at 5L01 in association with Upper Republican artifacts. All but one were pollen sterile as that term is used in this report. It would seem that there is a horizon at the site in which this is a characteristic condition, as in sample 1. Perhaps the pollen sterile condition is itself some kind of an artifact of the early cultural horizon. A sample contains fewer pollen grains because (1) the pollen in it has been destroyed, presumably by oxidation or micro-organisms, or (2) because the sediment was deposited too rapidly to entrap pollen in reasonable quantity. Cultural modification of the rockshelter sediments could have thus produced the pollen sterile condition as an artifact.

The sample from burial 2 at this site yielded a 50-grain pollen count. The AP, Artemisia and Compositae frequencies fall within the range of present values, indicating the occurrence of environmental conditions not demonstrably different from those of the present day. In this regard, this sample is quite anomalous, relating to no other subsurface sample from the site.

There are a series of alternative conclusions that might be drawn. First, that the sample has been contaminated in the collection and represents present conditions because present pollen was incorporated. It would otherwise have been pollen sterile like the other samples associated with artifacts. Without supporting evidence acceptance of such a conclusion throws doubt upon all of the samples and so should only be thought of as a last resort. Second, that this sample is statistically non-representative; that it is that one-in-twenty defiance of the odds that can be expected to occasionally occur. This conclusion is incredibly naieve, but remains a possibility. Third, that the sample--being from the disturbed provenience of burial fill--blends pollen from different horizons and is not comparable to samples which were deposited under "natural" conditions. Fourth, that the sample accurately represents environmental conditions occurring at the time the burial was interred.

If the third alternative were true, the only blend of horizons that could occur would be of horizons as old or older than the true horizon of the burial. All data available agrees that from the beginning of deposition in the rockshelter through the end of the Upper Republican period AP values were low and Compositae values were high. It seems improbable, then, that any blend of such horizons would produce the higher AP values and the lower Compositae values obtained in this burial sample. Higher AP values are recognized in the samples above the rock fall, so it is possible that

TABLE II

Sediment	Effective Moisture	Summer Moisture	Temperature
Surface	Present	Present	Present
Disturbed	"	"	Cooler
Tan Compact	"	Greater	"
Burial 2		Present	Present
Gray to Black	Lower " "	Greater " "	" Cooler Present

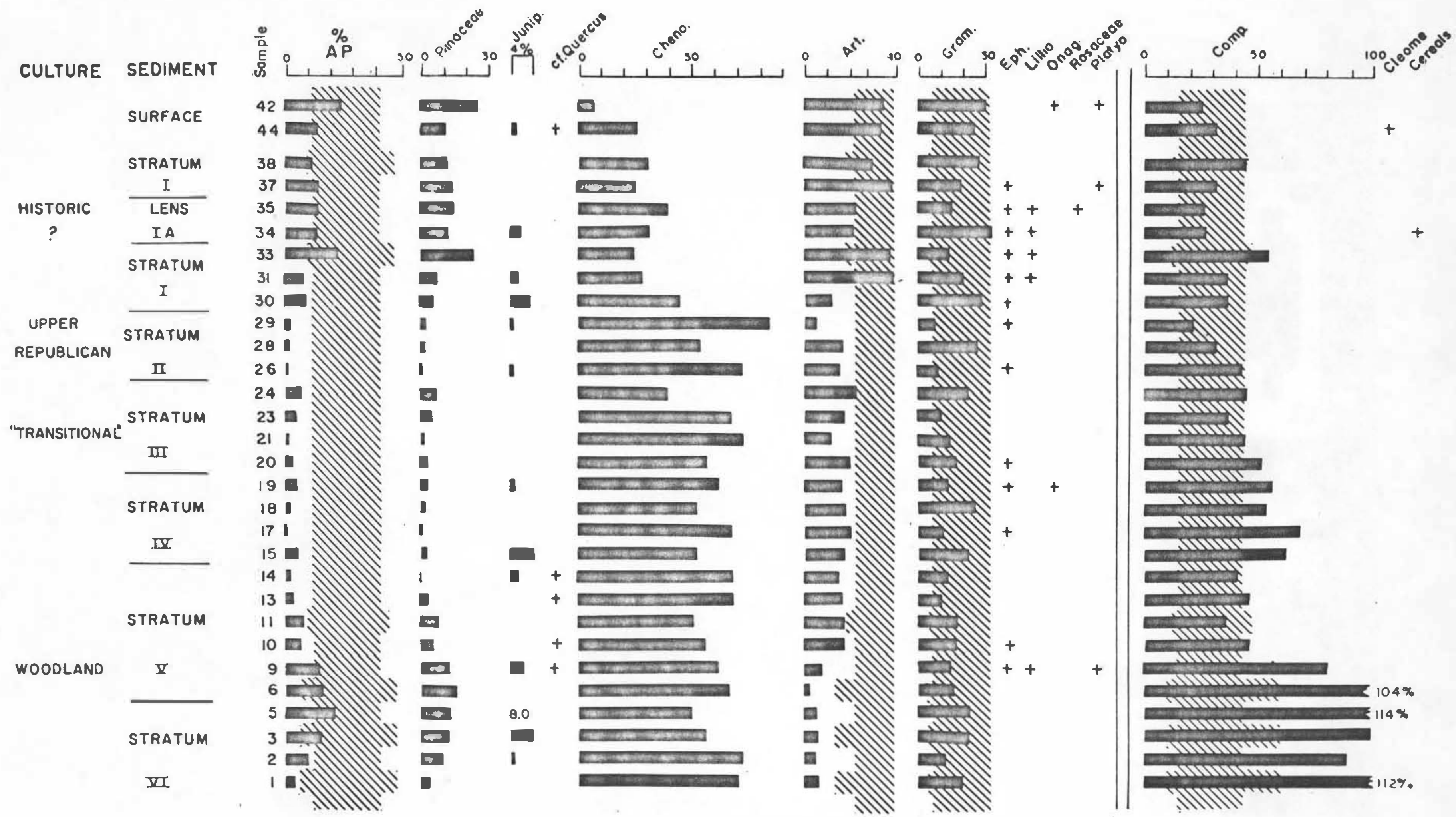

CULTURE
SEDIMENT
Sample
% AP
Pinaceae
Junip. 4%
cf. Quercus
Cheno.
Art.
Gram.
Eph.
Lilia
Onag.
Rosaceae
Platyo
Comp.
Cleome
Cereals
HISTORIC ?
UPPER REPUBLICAN
"TRANSITIONAL"
WOODLAND
SURFACE
STRATUM I
LENS IA
STRATUM I
STRATUM II
STRATUM III
STRATUM IV
STRATUM V
STRATUM VI
8.0
104%
114%
112%

Fig. 5

the Burial 2 sample represents a period later than the other Upper Republican samples, but the blend of horizons hypothesis is still inadequate to explain the low Compositae frequency.

It would thus seem that this sample must be granted as much acceptance as any other and taken at face value as truly representative of an environmental condition which did occur on the Upper Republican horizon. It seems probable that it occurred very late in Upper Republican time, about the time of the rock fall at this site, for it is only after the period of the rock fall that samples contain AP frequencies in the range of those of this sample. It seems important that the frequency of Artemisia in sample 13 is significantly higher than the other Upper Republican samples except for the one from Burial 2.

5WL32 (Fig. 5)

Of the three surface samples from this site illustrated on figure 2, that from the canyon rim most closely approximates the vegetation condition at the site (sample 42). When sample 44 was analyzed it was immediately apparent from the quantity of pollen and the quality of preservation that this was a surface sample also, and the presence of Cleome pollen was an excellent indication that it had been collected from the site proper. These two surface samples were utilized to establish the confidence intervals for the "present" condition as evidenced in the Artemisia and Compositae values.

Stratum I is composed of two parts, above and below Lens IA.

Three samples, 39, 38 and 37, were processed from the upper part. Sample 39 was pollen sterile and sample 38 yielded only a 100-grain count. Samples 38 and 37 illustrate no variation from present indications.

The two samples from Lens IA have significantly lower Artemisia values than the surface samples, indicating a warmer condition than now occurs but otherwise similar. Sample 34 also contained ten pollen grains of some cultivated cereal. Differentiation between maize and wheat pollen is possible by phase contrast microscopy and size-frequency analysis but neither seemed important in this case. The grains average about 58 microns and are more probably those of wheat than maize. Late artifacts are recovered from Lens IA, and thus are probably of historic age.

Three samples were analyzed from the lower part of Stratum I, 33, 31 and 30, and they are all different. The youngest has AP and Artemisia frequencies within the range of present values, but a Compositae frequency which is significantly higher. Sample 31 has Artemisia and Compositae frequencies within the range of present values but an AP frequency which is significantly lower. Sample 30 has Compositae frequencies within the range of present values but both AP and Artemisia frequencies which are significantly lower. It would thus appear that environmental conditions varied widely through the deposition of this sediment unit. At the end of the deposition the present effective moisture values were first established, temperatures were like the present, and summer moisture was greater. In the earlier part of deposition, however, effective moisture values were lower, temperatures were higher, and summer moisture was as at present.

All samples from Stratum II, the Upper Republican horizon, and all but sample 20 from Stratum III, the "Transitional" horizon, illustrate the same environmental condition. AP frequencies are below the range of present values, as are Artemisia frequencies, and Compositae frequencies are within the range of present values. The environment throughout this period seems to have been one of less effective moisture, summer moisture values like the present, and warmer temperatures.

The lowermost sample from Stratum III is distinct from those of Stratum II, but like those from Stratum IV in its significantly higher Compositae values. Stratum IV contains low frequencies of AP and Artemisia pollen and frequencies of Compositae pollen above the range of present values. It appears that throughout the deposition of this unit conditions were of lower effective moisture, higher temperatures and similar summer moisture relative to the present.

Stratum V, which contains Woodland artifacts, can be divided into an earlier and a later horizon on the basis of its pollen content, the later horizon evidenced in samples 10, 11, 13 and 14 and the earlier horizon evidenced in samples 6 and 9. The later horizon is characterized by low AP and Artemisia frequencies and by Compositae frequencies which fall within or just above the range of present

Sediment	Effective Moisture	Summer Moist.	Temperature
Surface	Present	Present	Present
Upper Stratum I	"	"	"
Lens IA	"	"	"
Lower Stratum I	" Lower "	Greater Present "	Present " Warmer
Stratum II	"	"	"
Stratum III	" "	" Higher	"
Stratum IV	"	"	"
Stratum V	" Present	Present Higher	" "
Stratum VI	" Lower	" "	" "

TABLE III

Cross-Site Correlations

Cross-site correlation is accomplished by consideration of the best-known horizons, Woodland, Transitional and Upper Republican, in their stratigraphic contexts at the various sites. Pollen horizons are smaller discrete units than the cultural horizons and may be expected to be absent at one site and present at another. Close attention to stratigraphic details, however, should allow the development of an integrated pollen chronology.

The earliest horizon at 5WL32 is pre-Woodland in age and is interpreted as representing conditions of less effective moisture, more summer moisture, and warmer temperatures than the present. The next oldest horizon, also pre-Woodland in age, differs only in having effective moisture values like the present. The only other pre-Woodland pollen spectra are those from the Tan Sandy layer at 5WL33. These agree with those of the earliest horizon at 5WL32 in effective moisture and summer moisture interpretation but are not in agreement in regard to temperature values. Also, the spectra from 5WL33 illustrate an unusual condition in respect to Gramineae pollen. For purposes of cross-site correlation, only the reconstructions concerning the areal environmental conditions can be reliably utilized. The local temperature and summer moisture reconstructions form valuable adjuncts for cross-site correlations but cannot be expected to be in as good agreement as the areal environment indicators. The distinction in Gramineae values seems a reliable indication that the Tan Sandy deposit at 5WL33 is actually not correlative with Stratum VI at

5WL32 and therefore of a different age. Because the pollen statistics of the youngest pre-Woodland samples in Stratum VI agree so well with those of the oldest Woodland samples in Stratum V at 5WL32, it seems improbable that the pre-Woodland conditions evident at 5WL33 could be younger than those at 5WL32. Thus, it would appear that the Tan Sandy sediment at 5WL33 is the oldest pre-Woodland sediment sampled.

The Woodland horizon at 5WL32 is divided into two pollen horizons; an earlier one in which AP frequencies are within the range of present values, and a later one in which AP frequencies are below the range of present values. In both horizons, as in all horizons at this site, Gramineae frequencies are within the range of present values. In both horizons, as in all horizons at this site, Gramineae frequencies are within the range of present values. The Woodland horizon samples from 5WL33 have low AP frequencies and Gramineae frequencies within the range of present values. They cannot, then, be correlative with the earlier Woodland pollen spectra from 5WL32. But they need not necessarily be correlative with the upper spectra from Stratum V on cultural, stratigraphic, or palynological grounds.

On cultural grounds, the Woodland horizon at 5WL33 could be correlative with either the Woodland or the Transitional horizons at 5WL32, since recognition of the Transitional horizon is based on the addition of culture traits to the Woodland horizon, and such traits might have simply been missing at 5WL33 at a late period. On stratigraphic grounds there is no direct correlation that can be made by virtue of lithology or index fossils between 5WL32 and 5WL33, so there is no evidence that the ashy gray layer at the latter site relates to any given stratum at the former site. On palynological grounds the combination of lower AP frequencies and "present" Graminea frequencies occurs in Strata I, II, III and IV as well as Stratum V, so there is no reliable indication of which unit the Woodland horizon at 5WL33 is correlative to.

But complete cynicism is not necessary. The pollen records of Strata II-V vary in response to local conditions as well as areal ones, and it is not impossible that local conditions at the two sites could be responses to some single, regionally operative, factor. The local temperature evidenced by the Woodland horizon samples at 5WL32 is within the range of present values, and the summer moisture evidenced is above the range of present values. On cultural grounds we can argue that the Woodland horizon at 5WL32 may be equivalent to the Woodland through Transitional horizons at 5WL32 but cannot be as late as the Upper Republican horizon. Within this span of the pollen chronology from 5WL32 there are no periods evidenced in which temperature values are similar to the present, but there is a period--that of the deposition of Stratum IV--when summer moisture values are higher than the present. Though it cannot be considered as conclusively proven, it would appear probable on palynological grounds that the Woodland horizon at 5WL33 is equivalent in age to Stratum IV at 5WL32. Thus the Woodland artifacts at 5WL32 would be younger than those from 5WL33, and the entire Woodland horizon in the area would be recognized in the environmental chronology as beginning during a period when effective moisture values and summer rainfall values were high, progressing through a period when both effective moisture values and summer moisture values decreased (later horizon of Stratum V), and ending with a period of low effective moisture values but increased summer moisture.

The environmental conditions evidenced in the Transitional horizon, Stratum III, at 5WL32 (lower effective moisture and summer moisture like the present) are not illustrated in spectra from 5WL33 above the Woodland horizon. Since the lower samples from the Tan Compact layer at 5WL33 seem correlative with Stratum I samples at 5WL32, as is discussed below, it appears that the period of time encompassed by Strata III and II at 5WL32, and by the Upper Republican horizon at 5L01, is missing in the 5WL33 sequence.

The Upper Republican horizon, Stratum II, at 5WL32 is not differentiated,palynologically, from the Transitional horizon of Stratum III. The environment seems to have continued as one with less effective moisture and summer moisture like the present. At 5L01 the stratified upper Republican horizon samples which were not pollen sterile illustrate a slightly different condition: less effective moisture but higher summer moisture values and cooler temperatures. Because the temperature and summer moisture variables may be locally controlled, the discrepancies between the Upper Republican horizon samples at the two sites cannot be said to definitely relegate them to different periods of absolute time. But on this basis the whole of the later Stratum V through early Stratum I period is homogenous palynologically, so it cannot be said that the Upper Republican horizons at the two sites are of the same absolute time, either.

There are some interesting correspondences between samples 31 and 33, from lower Stratum I at 5WL32, and the older Upper Republican horizon samples from 5L01. The oldest samples at 5L01 have AP frequencies below the range of present values and Artemisia frequencies within the range of present values--as does sample 31--but has high Compositae values, which sample 31 does not have. Sample 33 has the high Compositae values and the high Artemisia values--as do the oldest samples from 5L01--but has high AP values, which those samples do not. The discrepancies between the two sites are, interestingly enough, the same discrepancies which occurred between the stratigraphic samples at 5L01 from the Upper Republican horizon and the sample from Burial 2. In other Upper Republican samples AP frequencies are below the range of present values, but in the Burial 2 sample and in sample 33 from Stratum I the AP frequencies are within the range of present values. In most Upper Republican samples Compositae frequencies are above the range of present values but in the Burial 2 sample and in sample 31 from Stratum I the Compositae frequencies are with the range of present values. I do not believe that these correspondences are due to chance; there is no reason to suspect that the lower Stratum I sediment was deposited much later than the

Upper Republican horizon on the basis of cultural evidence, and there is no reason to suspect that similarities of potentially time-equivalent pollen samples from different sites are inexplicable. I believe that at the period of absolute time involved a change in environmental conditions was occurring. The interval between samples 31 and 33 might encompass a respectable length of time, and I think it probable that both samples 31 and 33 represent the transition period in collapsed form which is more adequately sampled in the Upper Republican horizon at 5L01.

Thus, Stratum II, and sample 30 from Stratum I, evidence the environmental conditions at the beginning of the Upper Republican horizon: low effective moisture values, high temperatures, and summer moisture values like the present. The succeeding condition was one of low effective moisture values also, but with high summer moisture values and cooler temperatures. Before the end of the Upper Republican horizon temperatures reverted to the warmer condition, and in very late Upper Republican time conditions like those of the present became established. The lower samples from the tan compact layer at 5WL33 (samples 6 and 7) seem to be correlative with the oldest Upper Republican samples from 5L01 and thus be of the middle Upper Republican series.

The post-Upper Republican horizon is characterized at all sites by AP frequencies illustrative of effective moisture within the range of present values. By integration of the samples from the various sites we can subdivide this horizon into an earlier conditin with higher temperatures and higher effective moisture values (Site 5L01, samples 3-15), and a Historic horizon with temperature values and summer moisture values like the present (Site 5WL32, lens IA and upper Stratum 1; 5L01, Sample 8; 5WL32, sample 9).

Table IV integrates the resultant paleoecological chronology. The effective moisture reconstruction is the most secure. ~~The summer moisture reconstruction is the most secure.~~ The summer moisture reconstruction is made possible by agreement between two or more sites in regard to Compositae values for any given horizon, but is less secure. The temperature reconstruction is made possible by agreement between two or more sites in *Artemisia* values on any given horizon and seems only applicable on post-Woodland horizons. It is the least secure reconstruction.

		Eff. Moisture	Summer Moist.	Temperature
Historic		Present	Present	Present
Post Upper Republican		Present	Greater	Higher
Upper Republican	very late	Present	Present	Present
	late	Less	Greater	Higher
	middle	"	"	Present
	early	"	Present	Higher
Transitional		"	"	"
Woodland	late	"	Greater	?
	middle	"	Present	?
	early	Present	Greater	?
Pre-Woodland	late	"	"	?
	middle	Less	"	?
	early*	"	"	?

TABLE IV

* Evidencing different, but unknown, conditions on the basis of Gramineae values.

Absolute Dating of the Chronology

Absolute dating of an environmental chronology is possible by (1) direct association of the samples of which the chronology is composed with radiocarbon, tree-ring or cross-dated ceramic dates; (2) association of the samples with serriated artifact types which have been given dates independently; or (3) correlation of the reconstructed environmental conditions with similar ones which have been independently dated by (1) or (2) elsewhere. At present, C-14 dates are not available for the sites involved though they will be available shortly. There is no assurance, however, that the C-14 dates will have sufficiently narrow confidence intervals to be of much direct benefit in defining the absolute age of particular sections of the reconstructed chronology, and any independent dates will be very useful as checks on the radio--carbon analyses.

Method (2) has yielded some generalized dates for parts of the chronology. Estimated dates for the entire Woodland horizon are AD 500-1000, for the Transition horizon AD 1000-1200, and for the Upper Republican horizon are AD 1200-1500.

Palynological investigations in North America covering the period of AD 500 to the present are not rare. Few of those from the United States which have been published, however, have been successfully cross-correlated since most are dependent upon radio-carbon analyses for an absolute chronology and have few dates for any given horizon. In general, the last two millenia have been rather neglected of dated alluvial units, with variations in periodicity of rainfall and variations in total annual rainfall. The Southwestern chronology is well dated by association of the pollen samples with datable ceramic styles. In the Mississippi Valley a few pollen samples of the chronology were associated with radiocarbon dates and others could be dated by association with early, versus late, Mississippian artifact styles. The environmental reconstruction in that area is proferred in vegetational terms (wet prairie, dry prairie, disturbed prairie) because there was insufficient data to reconstruct the causal environmental factors.

In the Mississippian chronology, a major shift in vegetative cover from wet prairie (late) to dry prairie (early) is bracketed by radiocarbon dates as necessarily occurring sometime between AD ~~1465~~ 1485 and ~~1465~~ 1365. In the Southwestern chronology a major shift in effective moisture values from more moisture (late) to less moisture (early) is bracketed by ceramic and tree-ring dates as necessarily occurring between AD 1410 and 1375 in response to a shift in rainfall periodicity from a winter-dominant storm pattern (late) to a summer-dominant storm pattern (early). Closer correlation between these disparate regions could hardly be expected. Considering the estimated date for the Upper Republican horizon, and considering that the direction of the shift in effective moisture values at the end of the Upper Republican horizon is in the same direction as the AD 1410-1375 shift in the Southwest, it is almost a surety that the two are correlative by the paleobotanist. With the recent concern of North American archaeologists in pollen analysis, more work has been accomplished on the last two millenia; unfortunately for this report the majority of the relevant data is yet unpublished.

Published pollen chronologies for the American Southwest for the time span of the past two millenia were recently integrated by Schoenwetter and Eddy (1964). It was shown that a gap existed in the chronology between AD 1100 and 1550, with only slight information--poorly dated and scanty--for the 1550 to present horizon. More recent work (Hevly, 1964; Schoenwetter, n.d.; Schoenwetter, MSa; Schoenwetter, MSb; Schoenwetter, MSc) has closed the 1100 to 1550 gap in the Southwestern chronology and has added to our understanding of the early historic period to 1775 but is unavailable in published form. Another yet unpublished study which is of critical value to this report is concerned with the pollen analysis of Middle Mississippian sites on the American Bottoms near Cahokia (Schoenwetter, MSd). This report cannot attempt to recapitulate more than the highlights of argument of these unpublished studies, but must utilize the conclusions drawn in them in attempting absolute dates for the chronology developed in the preceeding section of this report.

In the Southwest, environmental reconstruction on the basis of pollen analysis has reconstructed the sequence of variations in effective moisture (Schoenwetter and Eddy, 1964, 1964, pp. 73-108; Schoenwetter, MSa), and these have been correlated, through a consideration phenomena. Since the shift in effective moisture values in these Colorado sites occurs at the end of the Upper Republican horizon sampled, the Upper Republican horizon evidenced probably did not last far into the 15th Century. A good terminal date would be AD 1425.

Dating of other phenomena in the Colorado chronology by correlation is more difficult. Increases in effective moisture in the Southwestern chronology are dated at AD 1250-1200, 1150-1050 and 750-300. A return to wet prairie conditions is recognized in the Mississippi Valley chronology, but undated except by association with early ("Old Village") Mississippian artifacts. From the estimated dates on the Woodland horizon it seems unlikely that the shift to higher effective moisture values on the late pre-Woodland horizon would be correlative with either the ~~AD 1250~~ 13th century or the ~~AD 1150~~ 12th century variations in the Southwestern chronology. It is not too unlikely, however, that it does correlate with the ~~AD 750~~ 8th century fluctuation in the Southwestern chronology, and whatever its actual absolute age it seems likely that it is correlative with the shift occurring in early Mississippian times in the Cahokia area. Accepting the AD 750 date for the early Woodland-middle Woodland shift in effective moisture values allows recognition that something over 600 years of time is involved in the known Colorado cultural sequence in this area.

The amount of time elapsed between the end of the early Woodland horizon and the beginning of the late pre-Woodland horizon would be--if the Southwestern chronology was accepted--about 450 years.

This might seem excessive were it not for the fact that samples 6 and 9 at 5WL32 are separated from samples 3 and 5 by a break in stratigraphy so a seperation in absolute time of unknown duration is evident. The middle pre-Woodland horizon, then, is likely to be as old as AD 300 and the early pre-Woodland horizon may well date before the beginning of the Christian era.

It may be noted that despite the reconstruction of summer moisture values for both Colorado and the Southwest in the AD 750-1395 period, no attempt has been made at correlation. While such correlation might be possible, the underlying assumption would be that increases and decreases in summer moisture in the two areas would be functions of similar climatic causes. As this assumption is hardly demonstratable with available meteorological data I have preferred the cautious approach in this case. It is a lead that might be followed up in future paleo-ecological inquiry on the Plains, however.

Cultural Ecology

Perhaps the most important piece of cultural ecological data recovered in this study was the complete lack of any indication of agriculture on the prehistoric horizons. About 3450 pollen grains of the Upper Republican horizon, 1150 of the Transitional horizon, and 3175 of the Woodland horizon were observed without noting one of a cultivated type. By contrast, 10 grains of cereal pollen were observed in a count of 500 grains from lens IA. This lack of prehistoric agricultural orientation seems substantiated by the lack of cultural indications of settled existence. As the evidenced effective moisture values in the area were below those now occurring, it seems unlikely that the Upper Republican or Woodland cultures would have had a reliable economic basis in agriculture.

The presence of grinding implements in greater quantity in the Woodland than the Upper Republican horizons is not clearly related to environmental conditions on the basis of available data. If it could be shown that most of the Woodland grinding implements were recovered from the early Woodland horizon, it might be argued that the people were preparing food from a plant which was more plentiful under such conditions. Alternatively, if the occurrence of grinding tools is correlative with the indications of greater summer moisture values, the plant involved might well be a member of the Compositae such as sunflower, marsh elder or ragweed. In any case, an explanation of simple cultural preference could always be invoked. Environmental conditions often offer economic opportunities which are not culturally exploited.

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