Correlation of Archeological and Palynological Data

Abstract. *Analysis of a series of pollen samples and artifact materials, taken from the same excavation units in prehistoric sites in the Middle Pecos River valley of central eastern New Mexico, shows meaningful correlations between some major pollen groups and categories of artifacts. The correlations suggest the use of relative quantities of artifact materials to correct the distortion, resulting from cultural activity, in pollen samples from archeological sites.*

A major problem in attempts to reconstruct sequences of climatic change from pollen samples derived from archeological deposits is the effect of human activity in the vicinity of the site on the vegetation, and hence on the pollen rain. Recent analysis of samples of pollen and of cultural materials from the Pecos River valley indicates that, under restricted circumstances, it may be possible to predict the effects of cultural activities on the pollen rain. The samples were taken from along the Pecos River, about 24 km south of Fort Sumner, New Mexico; all are from small test trenches in desposits of midden debris. On the basis of radiocarbon evidence and the presence of ceramics dated elsewhere by dendrochronology, the sequence of samples spans the period from about 900 to 1250 A.D. Because the middens were shallow (less than 45 cm) and the cultural material from the full depth of each test appeared to be essentially uniform, the total subsurface yields of artifacts and pollen on each test were compared.

The present flora near the sites is relatively impoverished and local erosion is common, probably because of intensive grazing during the late 19th and early 20th centuries; the dominant shrub is now *Prosopis* (mesquite). The extent of recent erosion is reflected by pollen samples taken from the surface on each test to check recent pollen rain; although frequently from within centimeters of mesquite branches, none contained mesquite pollen and all contained remains of obviously ancient *Zea* pollen. Thus my interpretation has been made without data on the modern pollen rain.

Table 1. Relative percentages (and total numbers of fragments) of stone, bone, and sherd fragments at seven loci.

Locus	Stone	Bone	Sherd	*N*
P4C-1	18.9	73.8	7.5	2198
P4B-1	28.6	44.5	27.0	1160
P4B-2	30.1	44.0	26.0	366
P4B-3	47.2	16.2	36.6	142
P24-1	32.3	23.8	43.9	749
P4A-2	38.6	8.1	52.8	209
P4A-3	56.8	15.4	27.9	240

The sequence of pollen samples from the six tests is ordered (Fig. 1*A*) on the basis of cultural chronology. The radiocarbon age from test P4B-2 (M1466, A.D. 1130 ± 110) was determined from the collagen fraction of a sample of *Bison* bone. The most striking feature of this pollen sequence is the heavy predominance of Chenopodiaceae and *Amaranthus*, with dramatic rise at the end of the sequence in the Gramineae. *Zea* is remarkably abundant in several horizons; its presence throughout the sequence is evidence of cultivation as a partial source of subsistence for the ancient inhabitants.

The cultural evidence consists of fragmentary animal bone, ceramic sherds, and implements of chipped stone; the materials indicate a relatively sudden change in subsistence activities shortly after 1200 A.D., when a predominantly bison-hunting economy appears to have replaced an earlier mixed-subsistence pattern of cultivation, small-game hunting, and collection of wild plants. Martin, in reporting results of the pollen analysis, stated that "none of the changes seen in the pollen record require a climatic explanation and all the changes, the drop in cheno-ams, the decline of *Zea*, the rise of *Pinus*, can readily be explained in terms of cultural change" (*1*).

During analysis of the cultural materials, the specimens of each of these classes of material in each stratigraphic test were counted to determine their relative abundances (Table 1). Throughout the sequence the ratios of sherds to other cultural materials and of chenopod + amaranth pollen to other pollen types, varied in the same manner as did the ratios of Gramineae and bone fragments.

Correlation of the ratios of chenopod + amaranth pollen to sherd fragments was tested (Fig. 2). The correlation coefficient for the samples from seven localities (*2*) (r = .7944) indicates significant association beyond the .05-p level (F = 8.544, with 1 and 5 df). The correlation coefficients and probabilities of the relations of all pairs, within the three major pollen groups and the three classes of artifact materials for the seven tests, are shown in Table 2. There are strong correlations between bone and grasses and between sherds and cheno-ams; there are negative relations between most of the variables in these two pairs. There is also significant negative correlation between stone and bone materials. Thus, within the pollen data, grasses and cheno-ams seem to share a reciprocal distribution which is paralleled by similar distribution of bone and sherd materials in the cultural data.

In evaluating the archeological materials, one may assume that the animal bone is a product of hunting, the chipped stone reflects hunting and collecting activities, and the ceramics reflect the relative intensity of sedentary (including cultivating) activities. Within the pollen data, the cheno-ams presumably represent disturbed conditions that could result from erosion, prolonged occupation of the site, or cultivation. Present patterns of vegetation

Table 2. Correlations of archeological and pollen materials.

Matter (*N*, 7)	Stone			Bone			Sherd			Cheno-am			Gramineae		
	r	*F*	*p*	*r*	*F*	*p*	*r*	*F*	*p*	*r*	*F*	*p*	*r*	*F*	*p*
Bone	−.8022	9.03	.05												
Sherd	.3162	1.05	> .25	−.8693	15.48	0.25									
Cheno-am	.1135	0.07	> .25	−.5410	2.07	.25	.7944	8.55	.05						
Gramineae	.5475	3.50	.25	.8722	15.96	.025	−.8932	19.74	.01	−.8686	15.35	.025			
Compositae	.3029	0.51	> .25	−.0117	0.00	> .25	−.0265	0.00	> .25	−.6109	2.98	.25	.2276	0.28	> .25
Compositae + artemesia	.3810	3.08	.25	.1265	2.76	.25	.0173	0.00	> .25	.0374	0.01	> .25	−.0557	0.02	> .25

Table 3. Correlations of archeological and pollen materials on the assumption that cheno-ams = 40 percent and *Zea* = 0.

Matter (N, 7)	Stone r	Stone F	Stone p	Bone r	Bone F	Bone p	Sherd r	Sherd F	Sherd p	Gramineae r	Gramineae F	Gramineae p
Gramineae	−.6735	4.15	.10	.8870	18.45	.01	−.8074	9.36	.05			
Compositae + artemesia	.6516	3.69	.25	−.7269	5.60	.10	.5694	2.40	.25	−.8594	14.13	.025

indicate that the grasses probably represent relatively undisturbed vegetation under favorable conditions of moisture, while the Compositae represent similarly undisturbed vegetation under somewhat drier conditions.

Two significant (*3*) negative correlations occur within the cultural materials. The first, between samples of bone and sherd, shows an expected mutually exclusive distribution between sedentary and hunting activities. The second, between chipped stone and bone, appears to indicate that chipped stone was not associated with hunting activities but probably with the processing of plant materials. Since there is no reported instance in the Southwest of the use of chipped stone to process domestic plants, we assume that it reflects collection of wild plants. This pattern is consistent with the known behavior of many primitive groups, by whom stone butchering and skinning tools were manufactured at the site of the kill (in areas where stone was readily available, such as the Pecos valley), while collected plants were taken to the camp for processing.

Within the pollen groups, the only significant relation is negative correlation between the cheno-ams and grass pollen, indicating that under less disturbed conditions in the vicinity of the sites the cheno-ams were replaced by grasses. The Compositae show no significant relations to either the Gramineae or the cheno-ams, although their distribution (Fig. 1*A*) generally resembles that of the grasses.

The high correlation between animal bone and grasses could indicate either an increased supply of game, resulting from more abundant grasses, or greater reliance on game during periods of less-intensive human activity, or perhaps both. On the other hand, the high correlation between cheno-am pollen and sherds seems to reflect a direct relation between the proliferation of vegetation, resulting from disturbed conditions, and the amount of sedentary cultural activity, as shown by the abundance of sherds.

Thus one may conclude that the variation in sedentary cultural activity caused the variation in cheno-am pollen throughout the sequence; if we allow for the culturally induced variation in cheno-am pollen, we can isolate climatically significant relations in the remaining pollen groups, which can be assumed to represent the natural pollen rain.

As a test of this hypothesis, the pollen percentages were recalculated for each sample, with the assumption that all grains of cheno-am exceeding 40 percent (the point of intercept of the regression) reflected cultural activity, as did all *Zea* pollen. It was expected that, if closer approximation to the natural pollen rain resulted from this recalculation, the correlation of animal bone with grasses would be higher, and this effect is present. Assuming that the higher correlation reflected better approximation of the natural pollen rain, I constructed the pollen profile seen in Fig. 1*B*; here a gradual increase in grasses is matched by decline in Compositae and *Artemesia*, with one major grass peak preceding the 1130 A.D. date and another following.

The present pattern of vegetation and rainfall suggests that this trend represents a shift toward slightly more moist conditions. The present potential vegetation of the area (*4*) includes a grama-galleta steppe 24 to 32 km to the west of the sites, while the po-

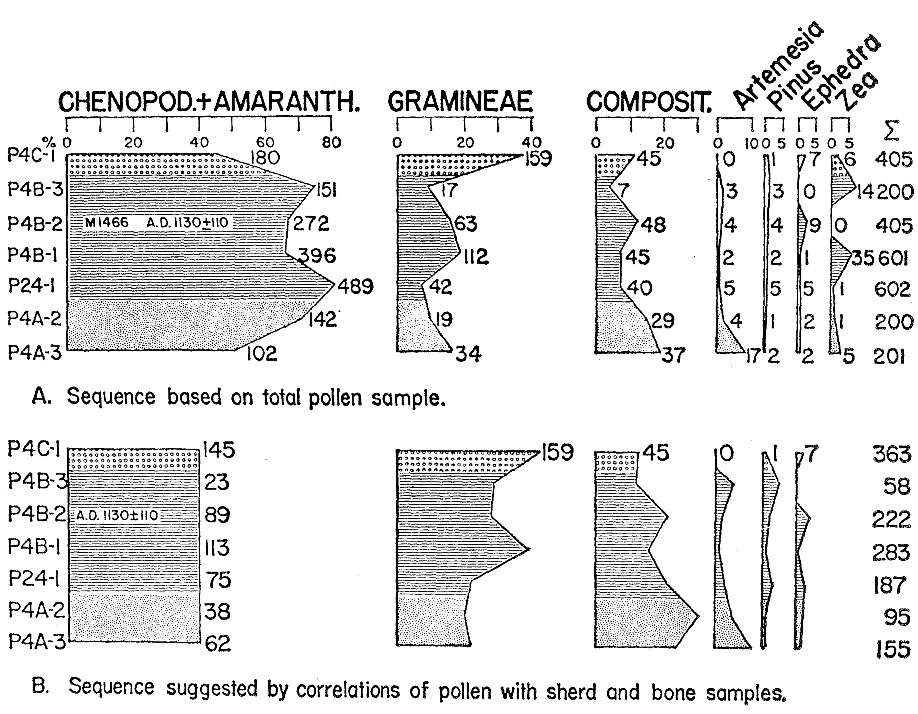

Fig. 1. Initial and revised pollen sequences.

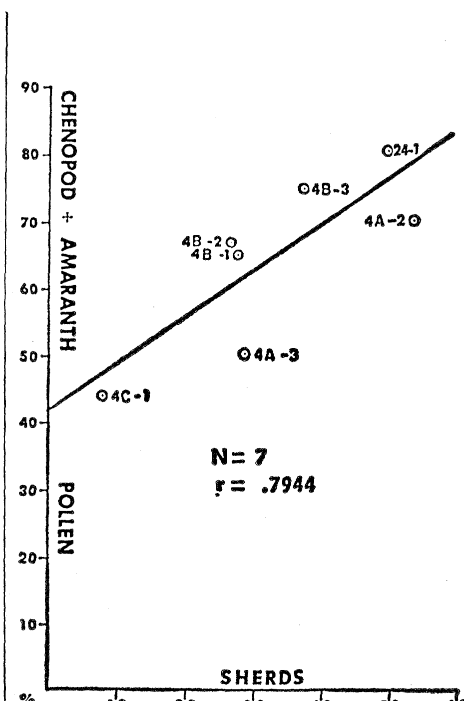

Fig. 2. Correlation of chenopod + amaranth pollen with sherd fragments.

tential vegetation near the sites is grama-buffalo grass. This distribution coincides with a slightly lower rainfall to the west of the area, with the contact between the two potential-vegetation zones approximately equal to the present 36-cm isohyet (*5*). The steppe includes a number of the floral elements that characterize the early levels of the sequence, such as grasses, chenopods, *Artemesia*, and *Ephedra*. The relatively high percentages of Compositae in these early levels may indicate somewhat more arid conditions similar to those of the desert grassland (*6*) to the south of the area. In contrast, the zone of grama-buffalo grass appears typical of the latest portion of our sequence, lacking such genera as *Artemesia* and *Ephedra* and abundant in grasses (*4*).

The recomputed pollen profile also appears to coincide well with specific faunal evidence from the cultural sequence. The first appearance of significant fragments of bone identifiable as of *Bison* is in test P4B-2, following the first Gramineae peak; it appears to indicate the first major intrusion of bison into the area, and, with the second peak in Gramineae, bison bone becomes the dominant element in faunal refuse. This fact strongly suggests that the pollen changes seen in the revised diagram reflect a valid sequence of climatic changes that resulted in replacement of a slightly more arid flora by the present potential-vegetation pattern.

The significance of these correlations, even within this small sample, indicates that this type of analysis may be widely applicable to problems of paleoclimatic interpretation. Such correlations probably could be most successfully utilized in marginal areas in which diversified economic activities were practiced, rather than in areas of more intensive cultivation where the relatively great quantities of sherds might obscure the relations of the other materials. Further testing will be possible on recovery of adequate samples of fragments of the three classes of cultural materials and pollen from uniform excavation units in midden debris.

ARTHUR J. JELINEK
Museum of Anthropology, University of Michigan, Ann Arbor

References and Notes

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3. Certainly the "significance" of a correlation coefficient between quantities expressed as percentages of the same total is subject to constraint, in contrast with correlations between proportions of independent systems (that is, pollen and artifact). Therefore the significance of the correlations within the artifact group and within the pollen group should be viewed with caution.
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7. The archeological and palynological collections were made in 1960 with the support of NSF grant G-13037, which also enabled analysis of the pollen samples by P. S. Martin, Geochronological Laboratories, University of Arizona. For assistance or advice I thank W. S. Benninghoff, M. B. Davis, R. I. Ford, D. E. Helmich, F. B. Livingstone, P. S. Martin, and James Schoenwetter. An earlier version of the report was presented before the 30th annual meeting of the Society for American Archaeology at Urbana, Ill., 8 May 1965.

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Ultracentrifuge Schlieren Photographs: Automatic Analysis

Abstract. *Schlieren photographs can be digitized and stored in a computer's memory. A computer program then interprets and measures the Schlieren curve and calculates molecular properties.*

The analytical ultracentrifuge is frequently employed to determine the various molecular parameters of large molecules (*1*). Concentration gradients are photographed on a spectroscopic plate by means of a schlieren optical system. The schlieren image is then measured on the microscope with a micrometer stage, and the pairs of values of the coordinates of the sequence of points along the curve are used, together with experimental constants, to calculate desired molecular properties such as sedimentation coefficient, weight-average molecular weight, diffusion coefficient, friction factor, and activity of solute. The work of measuring the spectroscopic plates, the calculations, and making the associated graphs usually takes much longer than the time required for the experiment itself. We now describe a method of shortening some of this work.

The image to be scanned is recorded on film of 35 mm or equivalent size, which is placed in a flying-spot scanner —a FIDAC (*2*). A beam of electrons excites a small spot on the face of a cathode-ray tube, from which spot the light is focused through the film and measured by a sensitive phototube. The amount of light transmitted from the spot, through the film, to the phototube is stored in the computer's core memory at a location that corresponds to the location of the spot on the film; the amount is coded by a number between 0 and 6, corresponding to seven different gray levels in the film. The spot is moved across the face of the cathode-ray tube to produce a raster, thus scanning the entire photographic image.

Once the entire image is in the memory, the picture is interpreted by a program written in a computer-programming language called BUGSYS (*3*); the program creates hypothetical "bugs" at points in the picture stored in the memory, which are such that they can read the number corresponding to the gray level at any point and perform simple motions on command—such as moving up, down, left, or right; finding the center of a thick line; or finding the end of a line. Two such bugs were used, acting together, to locate the origin of axes and coordinates of more than 100 pairs of points on the picture, which points represent values for x_i and the corresponding Δy_i between solution and solvent curves on the schlieren image (see Fig. 1). This schlieren curve represents the solution of the transport equation. The contrast on the spectroscopic plates is such that the photographic image does not have a sharp black-white edge; it changes gradually from dark to light to dark again. The BUGSYS program determines the gray level of each point of the image and the coordinate value for the center of the line (midway between the locations of points of equal gray level). The pairs of values of the coordinates thus determined are used in the same fashion as would be the data obtained by manual measurement of the spectroscopic plate with a comparator: the measured distances are converted to centimeters and used, together with constants for the temperature, angular velocity, and partial specific volume and the ideal gas constant, for numerical solution of the transport equation.

The advantage of this method is in reducing time spent on the work to less than 1 second; it also makes it practicable to pool computer programs and algorithms (or soft ware) from several laboratories and to have these used correctly, even though the investigator may not be in constant touch with