Pollen Analysis in the Glen Canyon*

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Introduction

Through pollen analysis the archeologist may hope to uncover stratigraphic or paleoecological evidence inaccessible by other methods. At the same time the results can be inconclusive, equivocal, or negative. There are many uncertainties in deciding on proper procedure. Should one attempt a palynological survey, scattering samples widely and thinly to learn a little about as many archeological sites as possible? If sites are to be flooded is it important to concentrate on sample collecting, letting the extraction and analysis wait for a later time? Is a routine percentage count undesirable--should the analyst simply scan his material for noteworthy pollen types such as Zea, Cucurbita, or an abundance of pine, examining a far larger number of samples in this way than is possible if he attempts a systematic pollen count? Is a detailed study of a single locality that can serve as a master profile the best way to begin?

My procedure has been to count all samples to a sample size of 200 grains, each assigned to a rather small number of pollen types with little or no effort made at the identification of unknown or unfamiliar grains. If fewer than 200 grains can be found on two slides, no data on that sample are given. The 200 grain count provides a satisfactory estimate of both the dominant and the less common pollen types (Martin, 1963). Because of uncertainty about which types to subtract as "local overrepresentation" second counts exclusive of one or several items were seldom attempted. An exception is the count minus "Cleome" from 42Ka172, FS 58. In an effort to learn more about Zea and other large grains likely to be present but rare, certain slides were scanned at low power. No pine bladder measurements were made, although this technique might allow separation of ponderosa from pinyon pollen in the fossil record. A rich record of fossil spores of many types is available in many of the preparations, including some that lack more than a few grains of pollen. Other techniques would certainly have been adopted by another pollen analyst; in the absence of standard procedures for arid land palynology there is room for many innovations.

The result of pollen analysis of Glen Canyon scats, including dry human feces, is presented elsewhere (Martin and Sharrock, 1964). The present account summarizes the results of study of alluvial, aeolian, lacustrine and cave earth samples collected mainly in Lake and Moqui canyons. The largest number of samples were obtained by William Byers in the summer of 1962; many others came from the Glen Canyon salvage crew; a few were collected by John F. Lance in the late summer of 1962. Among the sample lots in storage in

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the Geochronology Laboratories and unextracted to date are the following: 42Sa367, 42Sa585, 42Sa633, 42Sa369, 42Sa364, 42Sa444, and 42Sa697. All extractions followed a schedule including KOH, HCl, HF and Nitric Acid treatments, a reasonably effective means of clearing mineral matter from arid land sediments. I am indebted to Floyd W. Sharrock for assistance in interpreting provenience of certain samples, to William Byers, Bernard C. Arms and William Brooks for assistance in the extractions, to Henry Tucker for statistical help in analyzing the counts from Red Ant Kiva, and to Peter J. Mehringer, Jr. for advice on the interpretations.

A major disappointment of the Glen Canyon pollen project was the number of samples that proved sterile or otherwise uncountable. Samples from the lacustrine sediments of Lake Pagahrit, from Escalante River site 42Ka172, and from many of the prehistoric dry feces of the rock shelters were rich in well preserved pollen. However, the alluvial-aeolian sands that filled downstream parts of Lake and Moqui canyons in prehistoric times and now contain many archeological remains were not. In 16 samples from Lyman Flat, 42Sa623, collected by William Byers, countable pollen was present only in samples from the top and bottom levels. Two samples from this site collected by John F. Lance, one from an organic layer with snails, contained many spores but little pollen.

From Dead Tree Flats, 42Sa627, samples FS140/1 to 140/7 yielded insufficient pollen recovery for a complete analysis. Lance also submitted two samples from this site, which proved uncountable, one from a dark bed on the terrace edge and pre-dating occupation, the other from level 3, structure 1. Five samples from Creeping Dune, 42Sa701, FS 203/1, 204/1, 205/1, 122/1 and 132/1, were extracted without positive results.

As mentioned above the five samples from Lake Pagahrit contained well preserved and easily counted pollen. All but one sample from Horsefly Hollow were productive and the upper levels were easy to count. In the case of Red Aunt Kiva (42Sa675) samples below two meters depth were largely sterile. Those above two meters were countable with some effort.

Pollen identifications were made at 500 or in some cases 200 power. Ephedra was separated into two types (see Martin, 1963); the local representative of the nevadensis type is E. viridis (Lindsay In Woodbury, et. al., 1959: 64). In addition to separate counts of the Liguliflorae and Artemisia the Compositae were divided into long- and short-spine types, the latter including the wind-pollinated ambrosia group. For ecological interpretations I have relied on floristic and vegetational descriptions of the Glen Canyon presented in Woodbury, et al. (1958, 1959) and in Woodbury, Durrant and Flowers (1959) plus field notes of William Byers and Floyd W. Sharrock.

Escalante River, 42Ka172, Elevation 1170 m.

Seven pollen counts from this site in the juniper woodland provide the only good record of Zea of any of the stratified Glen Canyon cave deposits examined to date (see Table 1). Zea pollen is present in the upper five samples and was not found in the lower two, which may pre-date occupation. The relatively high grass pollen count may also reflect cultural use, at least in the case of the large grass pollen grains (40 to 56 microns). Although they are too small to represent Zea these grains are decidedly larger than the pollen of native grasses commonly found in alluvial or lacustrine beds that are not associated with man. Grass pollen of large size was very common in certain human fecal samples from Lake and Moqui alcoves (Martin and Sharrock, 1964). The abundance of small tricorporate, reticulate, pollen grains resembling Cleome in FS 58 is also likely to represent man's use.

Pollen from the Escalante River profile is quite well preserved; broken pine pollen grains did not exceed three per sample and averaged only 3% for the entire profile. Large numbers of spores were present at and above the 48 in. level. They may reflect cultural disturbance, although similar high frequencies of spores also occur in certain alluvial deposits not associated with prehistoric man.

Scans of some slides were made for Zea pollen, which is large enough (over 60 microns, usually 80-100 microns) to spot under low power. At 100x an entire slide can be examined for Zea and other large pollen grains in a small fraction of the time it would take to complete a count at 400x or 600x. Cucurbita and Opuntia pollen grains are also large enough to be spotted at 100x, but none were found. The estimates of pollen on the slide were obtained by multiplying the average number of grains counted in at least three passes at high power by the number of rows needed to cover the entire 22 mm. cover slip at that power. The following results were obtained:

> FS 109, 1400 pollen grains, 12 Zea, 1 Cereus-type Cactaceae, 1 Abies. This sample came from a gourd bowl at a depth of 6 in. FS 2, no scan made. There were two large grasses, 50 microns and 56 microns in dia. in the regular count. FS 115, 640 pollen grains, 19 Zea, 1 Abies. FS 43, 960 pollen grains, 2 Zea, 1 Picea, 1 large grass, 51 microns in dia. FS 58, no scan; one large grass, 40 microns in dia. in the regular count. FS 66, 800 pollen grains, 5 Picea. FS 68, 520 pollen grains, 1 Picea. A sample marked "FS 23, level II" contains Cleome and Zea and resembles FS 58 in total count. It is not listed in Table 1.

In the high frequency of Artemisia the Escalante profile differs from any of those taken in Lake and Moqui canyons. The pine and juniper curves fluctuate but the number of samples counted is too small to establish their stratigraphic reliability as pollen units or to use the counts in an effort at demonstrating vegetation change. In view of good preservation of the plant microfossils, and the good record of *Zea*, further pollen study at this site could certainly be justified.

Red Ant Kiva (42Sa675), Moqui Canyon, Elevation 1219 m.

Buried in the top of the main alluvial terrace in Moqui Canyon, here 22 m. high, lies Red Ant Kiva. Immediately above it is Flatrock House (see Sharrock, *et al.*, 1963). Because trash and fill deposits in Southwestern kivas commonly contain a pollen record extending from the time of occupation through part or all of the post-occupation interval, the prospect for a pollen profile at this site seemed especially favorable.

Four pollen samples collected by Lance (1963) from his units A B, D and E proved uncountable after extraction. In late July of 1962 William Byers collected a 560 cm. pollen profile at 4 in. (10 cm.) intervals from the level of the kiva floor near the deflector to the top of the terrace. Thirty-two of Byers' samples were extracted; 15 were uncountable or sterile, as follows: 100, 130 200 210, 240, 270, 300, 330, 360, 390, 420, 450, 480, 520 and 550 cm. With the exception of a sample from 500 cm., associated with Pueblo II-III occupation, the productive samples all lay between the surface and 240 cm. above the kiva and its contents, in the alluvial sands and humus that mantle the terrace.

The 500 cm. sample is dominated by cheno-ams and pine; pine is equally common between 60 and 160 cm., reaching an anomalous proportion in levels 180 and 220. High values of juniper, *Ephedra* of the *nevadensis* type, and *Shepherdia* are seen between 60 and 160 cm. The upper levels, from the surface to 50 cm., are dominated by pollen of the Chenopodiaceae with *Sarcobatus* in abundance between 50 and 120 cm. A small tricorporate, reticulate pollen grain with wall structure closely resembling species of *Descuraina* and *Dryopetalon* (Cruciferae) was encountered at 230 cm. *Zea* was sought but not found; all counts are shown on Table 2 and most are plotted in Fig. 1. Long distance transport undoubtedly accounts for the occasional records of *Picea* and *Alnus*. Presumably *Populus* pollen is not properly preserved in the terrace pollen record.

Unlike the case of the Escalante River counts, scans of large numbers of pollen on certain slides yielded very few large grains. Scans were made as follows: 30 cm., 18,400 pollen grains 1 *Opuntia*; 220 cm., 500 pollen grains--no unusual types; 500 cm., 750 pollen grains, no unusual types.

During the analysis the following clumps or clusters of pollen in broken anthers were encountered. Each clump was tallied as a single grain in the pollen sum. An estimate of the total number of grains in clumps is given for each occurrence, as follows:

pine -	10 cm., 1 clump, 6 grains.
	60 cm., 1 clump, 6 grains.
Shepherdia -	60 cm., 1 clump, ca. 9 grains.
Sarcobatus -	40 cm., 1 clump, ca. 25 grains.
	60 cm., 12 clumps, ca. 130 grains.
	70 cm., 4 clumps, ca. 110 grains.
	120 cm., 5 clumps, ca. 50 grains.
cheno-ams -	40 cm., 2 clumps, ca. 16 grains.
	50 cm., 3 clumps, ca. 47 grains.
	70 cm., 8 clumps, ca. 140 grains.
	80 cm., 6 clumps, ca. 75 grains.
	120 cm., 3 clumps, ca. 20 grains.
	180 cm., 1 clump, ca. 30 grains
long-spine Compositae -	40 cm., 2 clumps, ca. 20 grains.
Sphaeralcea -	120 cm., 1 clump, 6 grains.

Clumps of pollen are seldom found unless the source plant is growing in the immediate vicinity. Since each clump may disintegrate to a varying degree during extraction, thus affecting the apparent number of "single grains" in the count, any quantitative interpretation of counts from strata with pollen clusters is especially hazardous. In the case of Red Ant Kiva the number of clumped grains may reflect terrace burial by aeolian sands. Similar clumps of cheno-am pollen are found in low aeolian mounds on the Willcox Playa, southeastern Arizona, which contain buried stems of *Suadea* (Chenopodiaceae).

With one exception, the productive pollen samples at Red Ant Kiva should entirely post-date occupation. According to Sharrock the youngest cultural material they overlie is of Pueblo III age, thus no younger than the 1300's. Canyon cutting is known to have occurred in many parts of the Southwest at that time, but evidence of late 13th century cutting in Lake and Moqui canyons was not detected by Lance, who concluded that no important geological events followed the completion of the aggrading interval and aboriginal abandonment (Lance, 1963, 369). We cannot be certain that the subsequent 300 cm. of deposition at Red Ant Kiva, including 230 cm. of productive pollen samples, represents a continuous sedimentary record of the last 600 years between 13th century abandonment and post-1880 canyon incision. If it were continuous, the average rate would have been 0.5 cm. per year, considerably less than the 2.5 cm. per year estimate of Gregory for the region and the 1.8 cm. per year estimate of Lance (1963, 368) based for the fill deposited between older and younger occupations of Red Ant Kiva itself. An important point is that aeolian dust and sand is continually blowing into the canyon in sufficient quantity to bury cottonwood logs and other plants on the upper terrace (Sharrock, Day and Dibble, 1963, 10); thus, a sediment source is available for continual terrace growth during the last few hundred years, even though rapid alluvial filling at an average rate of 2 cm. per year no longer occurred.

The first batch of four samples from Red Ant Kiva included the 220 cm. level with its unusual pine pollen count (Table 2). Pollen was scarce in the preparation but pine accounted for 197 of the 200 grains in the sample. To reduce the possibility that this count was the result of some laboratory error a second extraction was made. Two HF treatments were necessary to obtain a count of 77 pollen grains, of which 72 were pine, 4 were Compositae of various sorts and 1 a cheno-am. With the exception of the sample at 230 cm. pollen was very scarce in other samples above and below the 220 cm. level; even the 180 cm. level, which contained 82% pine pollen, was barely countable.

Pine counts similar to those at 180 and 220 cm. are typical only of full-glacial sediments from certain parts of the Southwest. An effort to learn more about these peculiar pine counts led to a more thorough study of Red Ant Kiva than was originally planned when it appeared that countable samples largely post-dated beds of greatest interest to the archeologists. The entire set of counts (Table 2 and Fig. 1) was more variable than most alluvial profiles I have counted, not only in the presence of strong trends seen in pine, juniper, *Ephedra*, *Shepherdia*, Cheno-ams, and *Sarcobatus* but also in the presence of much interlevel variation. The latter involves a change of up to 49% between adjacent counts of *Sarcobatus*, 71% between adjacent counts of cheno-ams and 43% between adjacent counts of pine (not including the record from 220 and 230 cm.

To compare interlevel variation between the upper counts from Red Ant Kiva and a less variable, "more typical" late postglacial pollen profile, 13 counts of 200 grains each were used from the fill of Kiva G at Mug House, Wetherill Mesa between 0.35 and 2.44 cm., mainly above the last period of occupation of the kiva by Pueblo III Indians. The profile will be published in a report on pollen analysis at Wetherill Mesa (Martin and Byers, MS). Differences between adjacent counts for six pollen groups at Red Ant Kiva are shown in Table 3 those for adjacent counts from Mug House Kiva G are shown in Table 4. It may be worth restating that while the counts from Kiva G come from fill of local origin those from Red Ant Kiva represent terrace sands of combined alluvial and aeolian origin which buried the kiva and its contents. Despite the difference in origin of sediments the sedimentary columns are approximately equal in thickness. They may or may not extend through the same period of time, approximately the last 600 years.

Results of computations from the two sets of counts are shown in Table 5. In the case of Pinus, Ephedra, Cheno-ams + Sarcobatus + Gramineae, and Compositae, variances of each set are significantly higher ($P < .01$) for the counts from Red Ant Kiva. In part this difference may reflect the much higher means for difference in counts between adjacent levels in Red Ant Kiva. When coefficients of variation are computed (standard deviation divided by mean) the values appear to be less divergent than the variances alone.* Perhaps the most interesting statistic is the mean of the differences (column 2 in Table 5), which is higher in each case for Red Ant Kiva. If this mean is compared with that obtained on the original counts themselves (column 1) the resulting ratio (column 3) is high, greater than 0.50, for each pollen type from Red Ant Kiva and is exceeded by the values from Mug House only in the case of Ephedra, in which the ratio for the means is 0.79. Mug House ratios for the other five pollen types are considerably less than 0.50.

The selection of the six pollen types for study was slanted so that means for each would not be too divergent. Thus Sarcobatus, which is virtually absent at Mug House, shows extreme interlevel variation at Red Ant Kiva. The net effect of grouping it with cheno-ams and grass was to reduce somewhat the apparent difference in interlevel variance between the two profiles.

The main point is that even though counts from both Red Ant Kiva and Mug House Kiva G show trends, from low to high values for juniper and pine at Mug House and from high to low at Red Ant Kiva, interlevel counts of the Red Ant Kiva profile are far more variable. The source of this variation is unknown, but may be related to the pollen clumping noted above.

The high interlevel variance makes hazardous any attempt at climatic interpretation of Red Ant Kiva counts. Yet the counts lend themselves to a division into three pollen units, with the second divisible into three subunits. As man was presumably absent from Moqui Canyon at the time, cultural disturbance can be dismissed as an explanation for the changes in the pollen proportions. I am indebted to P. J. Mehringer for calling my attention to the possible meaning of the correlation between pine, juniper, Shepherdia and Ephedra of the nevadensis type in units 2a and 2b. These four pollen types would be

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*Variances and coefficients of variation for interlevel differences in pollen counts are seldom computed; they should provide useful estimates of the degree to which pollen profiles have been smoothed. The presence of trends will not affect these values.

expected to reach a maximum within the juniper-pinyon woodland of the Four Corners area. Their decline toward the top of the profile and the rise of *Sarcobatus* followed by cheo-ams in unit 1 could signal a drying out, or at least a falling water table along the flood plain with a reduction in spring seeps along the canyon walls, the most plausible habitat for scattered juniper and pinyon in the vicinity at the time. The expansion of juniper and pinyon with *Shepherdia* and *Ephedra viridis* would be expected locally if there were a notable climatic cooling with increased moisture associated with the Little Ice Age. I have inferred that the post-13th century pine rise could be attributed to abandonment alone, with a subsequent increase in pine and juniper pollen production as secondary plant succession converted Pueblo III fields in the Four Corners area back into pinyon-juniper woodland. (see Martin, 1962; Leopold, *et al.*, 1963). However, the Red Ant Kiva record indicates an *increase* followed by a *decrease* in tree pollen. The decrease is not readily laid to secondary plant succession.

It is very unlikely that the high pine counts in level 180 and 220 represent the natural pollen rain at Red Ant Kiva at that time. Scarcity of pollen in these levels, the peculiar record of Cruciferae(?) in level 230, and the complete absence of pollen on other adjacent samples suggest that the pine concentration is the result of some unknown but post-depositional alteration. At the same time the relatively high pine counts in pollen unit 2b, which is better preserved and is accompanied by relatively high numbers of those pollen types to be expected in juniper-pinyon woodland near its lower limit, present the possiblity that pinyon itself grew near the site in the recent past. This possibility is enhanced by the presence of clumps of pine pollen in levels 10 and 60 cm. Such clumps are not expected unless the source is close at hand. In the absence of replicated pollen records from Moqui Canyon the matter seems best left in abeyance, with lots of room for other interpretations, hopefully based on additional and better evidence.

Horsefly Hollow, Lake Canyon, 42SA544, Elevation 1243 m.

Unfortunately, dirt samples for pollen analysis, including the content of complete pottery vessels and dust from storage cists, were not collected at Horsefly Hollow when it was excavated in 1960. In July of 1962 William Byers collected 17 samples in a profile about 16 ft. south of structure 2 (see Sharrock, *et al.*, 1960, Fig. 10). Byers' choice of sampling point offered a maximum depth of deposit but was apparently too far from the storage cists and other structures to indicate the nature of their contents.

In addition to pollen counts of seven samples at 20 to 30 cm. intervals shown in Table 6, the following observations were made with low power scans in certain levels: level 0, 30,000 pollen grains including 3 *Picea* and 1 *Pseudotsuga*. Level 50 cm., 8000 pollen grains scanned. 1 Onagraceae, 1

Nyctaginaceae. Level 90 cm., 4960 pollen grains, 1 Nyctaginaceae, 1 *Selaginella*. Level 120 cm., 4640 pollen grains, 1 Onagraceae, piece of anther containing roughly 200 cheno-am pollen grains. Level 150 cm., clump of 6 *Quercus* grains, too little pollen for a scan. Level 170 cm., 100 grains only counted. Level 180 cm., insufficient pollen for a count.

The pollen profile can be divided into two units. The upper is relatively homogeneous, extending to a depth of 120 cm., dominated by cheno-ams and resembling unit 1 of Red Ant Kiva. No economic pollen types were seen in the counts or scans and the strata probably post-dated occupation. Pollen in unit 2 (levels 150 and 170 cm.,) is poorly preserved; it contains relatively more short-spine Compositae and grass pollen. Although no *Zea* or other unmistakable economic pollen types were counted, the slight rise in grass suggests a cultural introduction since this type is of low frequency in sediments not associated with man's prehistoric activities in the canyons.

Horsefly Hollow illustrates the formidable problem faced by the archeologist in attempting to determine the age of a peripheral region yielding, in a single occupation, sherds that were being manufactured in cultural centers elsewhere at various times over a 200 year span (Sharrock, *et al.*, 1961, 64). Sharrock (personal communication, 1964) interprets the site as stratified but essentially representing a single, possibly long term, occupancy, Pueblo II-III in date. The pollen spectrum from 500 cm. in Red Ant Kiva may be of the same age. It contains more pine and *Ephedra torreyana* pollen than the two counts from Unit 2 of Horsefly Hollow but it is quite similar otherwise in pollen proportions.

Lake Pagahrit, Lake Canyon

Under Hutchinson's (1957) classification type 60 is a lake basin dammed by aeolian sand. Examples can be found on topographic maps of northeastern Arizona--for example the unnamed dry lake 1.7 km. in length on the Agathla Peak quadrangle in the Little Capitan Valley northeast of Kayenta. It is not certain that Lake Pagahrit was a type 60 lake. Lance (1963, 365) also considered the possibility of alluvial damming by flushout of sand from a tributary canyon, but felt that the latter mode of origin would not account for the depth, apparently tens of feet, reached by Lake Pagahrit. In 1915 the lake was breached, its buried marl and peat beds exposed, and cottonwoods, sedges and other riparian vegetation replaced by xerophytes (Sharrock, *et al.*, 1961).

The pollen counts (Table 7) come from different exposures of the lake beds and are inadequate for stratigraphic purposes. Separation of the peat from sand fractions might have yielded different counts; this was not attempted. Both peat and marl samples (samples 1, 2, 4 and 5) contain pollen of various aquatic or marsh plants including sedges, *Myriophyllum*, narrow-leaved cattail and the hard water algae Botryococcus. The latter and Myriophyllum are typical of permanent bodies of water and would not be expected in a marshy flood plain occupied by sedges and cattails.

A slide prepared of sample 5 contained an estimated 6000 pollen grains. When scanned at low power, 1 Oenothera, 1 Abies and 1 Picea were found, in addition to many large goblet-shaped spores, 100 microns or more in length.

Sample 4 from light gray sand is utterly unlike the lacustrine samples; it must represent a time when flood plain soils were covered by greasewood (Sarcobatus); the greasewood proportion is quite high, with cheno-ams accounting for most of the rest of the 200 grain pollen count. Conceivably this level correlates with unit 2a at Red Ant Kiva.

Considering the present occurrence of hackberry near the site, the absence of Celtis pollen, a wind-pollinated tree or shrub, is notable. Here, as elsewhere in Lake and Moqui canyons, oak pollen is low in number despite the present of Quercus gambelii, which is common on terraces and hillsides in the area.

Conclusions

Pollen analysis from a site along the Escalante River and from three localities within Lake and Moqui canyons, tributaries of the Glen Canyon, were carried out as part of the University of Utah's Glen Canyon archeological Salvage Project. Upper levels from the Escalante River profile contained relatively large numbers of Zea pollen grains associated with prehistoric occupation.

A 230 cm. profile from Red Ant Kiva in Moqui Canyon contained a record largely post-dating occupation of the site. Appreciable interlevel variations in counts and the occurrence of pollen clumps (pieces of anthers) made interpretation of the counts somewhat uncertain. The presence of over 90% pine pollen in two levels is likely to represent artificial concentration of this type by some unknown process. Nevertheless, trends evident in the Red Ant Kiva record suggest a maximum of pinyon-juniper-Shepherdia and Ephedra viridis pollen in the area soon after abandonment, with more recent drying out resulting in a relative increase first in the local pollen rain of Sarcobatus and later of other Chenopodiaceae.

A profile from Horsefly Hollow in Lake Canyon shows little change; five samples from sediments of Lake Pagahrit in Lake Canyon indicate the nature of its aquatic flora. Unlike the prehistoric human and animal feces, the alluvial-aeolian samples from Lake Canyon and Moqui Canyon contain little evidence of the pollen of economic plants. Many of them proved uncountable, including 19 of 36 samples extracted from Red Ant Kiva and most of 31 samples extracted from Lyman Flats, Dead Tree Flats and Creeping Dune.

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Table 1. Escalante River, 42Ka172. 200-grain pollen counts exclusive of unknowns. Second count of FS58 is exclusive of the Cleome type.

FS no.	Depth	*Picea*	*Pinus*	*Juniperus*	*Quercus*	*Ephedra*, *torreyana* type	*Ephedra*, *nevadensis* type	*Shepherdia*	Cheno-ams	*Sarcobatus*	Long-spine Compositae	Short-spine Compositae	*Artemisia*	Gramineae	*Sphaeralcea*	*Zea*	*Euphorbia*	Unknowns	Other
109	6"		20	28	2		2	1	84		2	22	22	10		2	1	6	cf. Leguminosae 1, *Salix* 1, *Ribes* 2
2	10-12"		27	47	4		3	1	37		6	41	14	14	1	3		7	*Juglans* 1, Caryo Phyllaceae 1
115	30-40"		15	52	1		4	2	36		4	40	25	13		8		4	
43	48"	1	32	19	2		3	1	48	2	3	25	30	33		(S)	1	5	
58	48-60"		26	22			2		14		8	15	8	6				13	cf. Cleome 99
58	48-60"	1	51	40	4		7		29		12	28	16	11	1	1		18	
66	65-70"	2	34	21	2	1	8		30		7	60	11	22			2	1	
68	84"		31	59	2		8		42		4	37	13	4				2	

(S) = Seen in scan of slide.

Table 2. Red Ant Kiva, 42Sa675, Moqui Canyon. 200-grain pollen counts exclusive of unknowns.

Pollen Unit	Depth in cm.	Pinus (entire)	" (thirds)	W Pinus	Juniperus	Quercus	Populus	Ephedra (torreyana type)	Ephedra (nevadensis type)	Shepherdia	Opuntia	Cheno-ams	Sarcobatus	Long-spine Compositae	Short-spine Compositae	Liguliflorae	Artemisia	Gramineae	Sphaeralcea	Eriogonum	Others	Unknowns
	10	16	2	16	22	2	5	8	2		2	89	1	36	9		4	1			cf. Cleome 1, Picea 1, Alnus 1	
	20	6	4	7	8			6	1	1	(S)	145		15	13		1	1			Euphorbia 2	
1	30	5	6	7	2			4	2	(S)	(S)	157	(S)	12	6		1	8			Salix 1	2
	40	4		4	1		2	1	1			123	22	38	6			1	1			1
	50			9			1		2			178	5	3	1			1				
	60	32	24	40	5				17	6		25	103		2	1		1				
2a	70	15	7	17	2				5	6	1	65	91	3	1		2	1		4	Rhus 1	
	80	35	13	39	1	1		1	9	4		138	2	1	2		2				Tidestromia 1	7
	90	29	30	39	27				34	18		31	27	3	12	1	5	2			Onagraceae 1	1
	110	45	29	52	43			2	33	27		21		6	11	1	2	1	1			
2b	120	18	1	18	5			5	5			71	70	12	2	2		1	8		Salix 1	
	140	63	34	74	31			1	26	13		35		4	12		4					1
	160	85	30	95	23	1		8	15	1		46		4	3		1	3				
	170	8	5	9	23			4	15	11		115		9	9		3	1		1		
	180	145	66	167	3			1	10	1		15			1		1	1				
2c	220	173	72	197					1			1		1								
	230	14	9	17								5	1							5	Cruciferae 173	
3	508	40	28	49	6			11	2			101	1	5	13	1	3	6			Gilia 1, Picea 1	1

Table 3. Differences between adjacent counts, surface to 2.2 m., at Red Ant Kiva.

Level in m.	Pinus	Juniperus	Ephedra	Cheno-ams, Sarcobatus, Gramineae	Compositae	Others
0.10-0.20	9	14	3	55	20	9
0.20-0.30	0	6	1	19	10	3
0.30-0.40	3	1	4	19	25	2
0.40-0.50	5	1	0	38	40	2
0.50-0.60	31	5	15	55	1	6
0.60-0.70	23	3	12	28	3	8
0.70-0.80	22	1	5	17	1	7
0.80-0.90	0	26	24	80	16	15
0.90-1.10	13	16	1	38	1	9
1.10-1.20	34	38	25	120	4	18
1.20-1.40	56	26	17	106	4	4
1.40-1.60	21	8	4	14	12	11
1.60-1.70	86	0	4	67	13	10
1.70-1.80	158	20	8	100	19	11
1.80-2.20	30	3	10	15	1	1

Table 4. Differences between adjacent counts, surface (2.44) to 0.36 m. at Wetherill Mesa, Mug House Kiva G. (Lower two samples coincide with end of Pueblo III occupation.)

Level in cm. (from datum at bottom)	*Pinus*	*Juniperus*	*Ephedra*	Σ Cheno-ams, *Sarcobatus*, Gramineae	Compositae	Others
2.28-2.44	17	6	2	13	8	0
2.13-2.28	14	18	1	7	16	12
1.98-2.13	5	3	0	23	13	2
1.83-1.98	9	1	7	18	19	2
1.52-1.83	9	28	5	20	2	6
1.36-1.52	2	5	3	4	9	5
1.09-1.36	10	4	5	7	7	5
1.00-1.09	2	5	4	21	8	2
0.91-1.00	9	3	2	19	10	13
0.82-0.91	3	7	2	0	10	2
0.55-0.73	22	3	1	18	14	16
0.36-0.55	1	8	0	7	2	2

Table 5.

Pollen Type	Profile	$\bar{X}o$	$\bar{X}d$	$\frac{\bar{X}o}{\bar{X}d}$	Sd^2	$F_{14, 11}$	Cd^2
Pinus	R.A.	49.4	32.7	0.66	1727.1	40.35*	1.27
	M.H.	35.9	8.6	0.24	42.8		0.76
Juniperus	R.A.	12.3	11.2	0.91	136.6	2.28	1.04
	M.H.	31.2	7.6	0.24	60.1		1.02
Ephedra	R.A.	13.7	8.6	0.63	65.5	13.65*	0.94
	M.H.	3.4	2.7	0.79	4.8		0.82
Cheno-am	R.A.	99.9	51.4	0.51	1289.2	21.59*	0.70
Gramineae	M.H.	55.8	13.1	0.23	59.7		0.56
Compositae	R.A.	16.8	11.3	0.67	126.7	4.83*	0.99
	M.H.	49.9	9.8	0.20	26.2		0.52
Others	R.A.	8.3	7.7	0.93	24.2	1.13	0.63
	M.H.	23.8	5.6	0.24	27.4		0.94

Variation of difference in 200-grain pollen counts for Red Ant Kiva and Mug House Kiva G. $\bar{X}o$=mean of observations, $\bar{X}d$=mean of difference between adjacent observations, Sd^2=variance of observations, F=variance ratio (significant values at 99% level are marked with asterisk), Cd=Coefficient of variation for differences. The latter numbers have not been multiplied by 100.

Table 6. Horsefly Hollow, 42Sa544, 200-grain pollen counts, exclusive of unknowns except for the 170 cm. level, which is a 100-grain count.

Pollen Unit	Depth in cm.	*Pinus*	*Juniperus*	*Quercus*	*Populus*	*Ephedra*, *torreyana* type	*Ephedra*, *nevadensis* type	*Shepherdia*	Cheno-ams	*Sarcobatus*	Long-spine Compositae	Short-spine Compositae	Liguliflorae	*Artemisia*	Gramineae	*Sphaeralcea*	*Euphorbia*	*Eriogonum*	Unknowns
	0	7	10		11	2	1		152	2	1	12		2					14
	30	5	12				6		146	4	7	8		11	1				1
1	50	3		1		1	3		154	12	14	4		5	2	1			
	90	3	2		1		26		138	9	4	7		5	3		1	1	
	120	3	1				2	1	160	5	6	8		9	5				
	150	6	5	1		3	3	4	84	9	12	51	3	2	15	1	1		2
2	170	2	6		1		6	3	43	2	11	15	2	3	5			1	

Table 7. Lake Pagahrit, Lake Canyon, 200-grain pollen counts exclusive of unknowns and Botryococcus. Samples 1-3 collected by Allen Howard at site 42Sa540, samples 4-5 collected by J. F. Lance.

Description	Pinus (entire)	Pinus (thirds)	ΣPinus	Juniperus	Quercus	Populus	Ephedra, torreyana type	Ephedra, nevadensis type	Opuntia	Cheno-ams	Sarcobatus	Long-spine Compositae	Short-spine Compositae	Liguliflorae	Artemisia	Gramineae	Sphaeralcea	Eriogonum	Typha angustifolia	Cyperaceae	Myriophyllum	Alnus	Others	Unknowns
1. Sandy Peat 10 cm.	17	10	20	5	3	7	4	2		31	8	8	14	1	12	6	1			44	28	1	Picea 2 Salix 1 Pseudotsuga 1 Polemoniaca 1	
2. Sandy Peat 40 cm.	17	11	20	4	1	1	1	6	1	39	2	44	2		6	13			20	40				2
3. Light gray sand 100 cm.	1	5	2							56	131	1	3		1	6								
4. Peat Bed	56	43	70	5	7		1	4		29	10	28	15		22	4			2				Euphorbia 2 Rosaceae 1 Botryococcus 19	5
5. Marl	42	28	51	11	3		2	12		45	11	17	23		18	1		1		3		2	Botryococcus 4	3

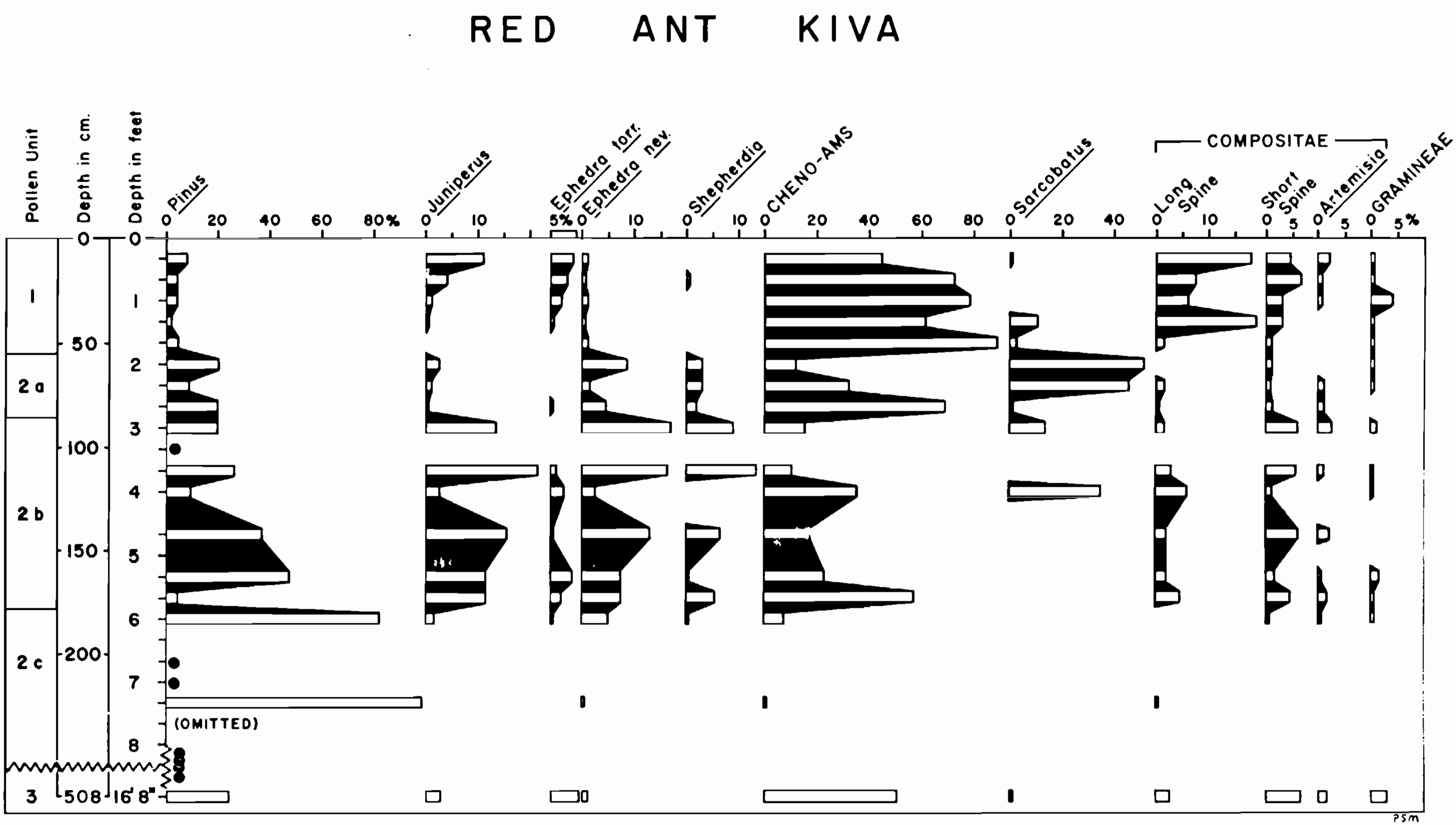

Figure 1. Pollen profile of Red Ant Kiva, percentages based on 200 grain counts shown in Table 2. Dots within the pine curve indicate distribution of unproductive samples. Ephedra torr. = torreyana type, Ephedra nev. = nevadensis type, the latter contributed mainly by Ephedra viridis. The sample from 508 cm. is associated with Pueblo II-III remains; other samples lie above Pueblo III cultural deposits.