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# FIELDIANA

## Anthropology

Published by Field Museum of Natural History

Volume 63, No. 1

March 10, 1972

### Paleoecology of the Hay Hollow Site, Arizona

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#### FOREWORD

PAUL S. MARTIN

CHAIRMAN EMERITUS, ANTHROPOLOGY

In order to make the researches of Dr. Bohrer more meaningful and to place them briefly and roughly in an archaeological setting, I shall attempt to give a general description of the site and of some of the data obtained. My statements are based on information given me by John M. Fritz, who headed up the research. A full treatment of the details I will give will be presented in his doctoral dissertation for the Department of Anthropology, University of Chicago. This is in preparation.

Both Mr. Fritz and Dr. Bohrer have read and corrected the statements herein.

#### INTRODUCTION

Hay Hollow site in Hay Hollow Valley, located about 10 miles east of the contemporary town, Snowflake, Arizona, on the ranch of James Carter, is about 5,750 ft. (pocket altimeter) above sea level and is at 109°55' W. longitude and 34°31' N. latitude. It is situated on an erosional bench about 16 ft. above the flood plain of Hay Hollow Wash. Excavations were started there in the summer of 1965 and research continued through two more summers until the autumn of 1968. The research was supported by the Field Museum of Natural History and grants from the National Science Foundation (GS-245, GS-984, GS-1910, and GS-2381). Grateful acknowledgement is made to the Museum and to the Foundation for this generous support.

The site was chosen for investigation because (1) it appeared to have been occupied before or near the beginning of the introduction

*Library of Congress Catalog Card Number: 73-179170*

of pottery-making and agriculture in the area; (2) it was unlike any other excavated site in the area except the County Road Site (about 1000 B.C.–350 B.C., GX-0274 and GX-0272, Geochron Laboratories) partly dug under the direction of Dr. James N. Hill but not written up for publication; and (3) it provided an opportunity to measure and analyze prehistoric subsistence systems at a time during which crucial changes were taking place—that is, at a time when the people of the area were responding to pressures that caused them to shift from their hunting-gathering subsistence adaptation to one of farming.

The site (houses and pits) represents the structured remains of a hunting-gathering adaptation. It can be referred to as a Desert Culture Site—a term that now signifies a special adaptation of the Indians who occupied Danger Cave (Utah) during a time of gradual desiccation of part of the Great Basin. In reality, it may be that the “Desert Culture” represents not one but many differing adaptations, the shadowy origins of which suggest a genesis around or near pluvial lakes, forests, grassy uplands, and perhaps in less favourable areas—a genesis that may have started about 10,000–12,000 years ago in the Great Basin area. The common denominator of all of these adaptations was fishing, hunting animals (both large and small, extinct and existing), and the gathering of native, wild plants—herbs, roots, seeds, nuts, berries, and fruits. Agriculture was not known or practised until sometime after 3,500 B.C.

Hay Hollow Site may also be referred to as “early Mogollon culture,” a “cultural descendant” of the Desert Culture. If one prefers that sort of taxonomic classification, then one may properly call the site “late Desert Culture” or “early Mogollon Culture.”

The investigator, John M. Fritz; Dr. Vorsila Bohrer, our palynologist; and I prefer not to fix the site in that kind of substructure or scaffolding, but to emphasize the subsistence system and adaptation of the people of that time and place and to explain (derive laws) that system in terms of attributes, resources, technology, ideology, and social organization.

#### BRIEF DESCRIPTION OF THE HAY HOLLOW SITE

The site as outlined by Mr. Fritz occupied an area of about 6,000 sq. m. Excavations were done by means of a phased sampling program which insured a collection of data that reflected the attributes of the whole site without digging the whole site. More explicitly, a grid of 720 squares, 3 m. square, was superposed on the site. Some



areas (areas that were blackened from charcoal(?) and houses) were separately structured in the sample.

After a topographic map was drawn, all surface cultural debris (lithic waste, blades, manos, metates, fire-cracked rock, and sandstone slabs [house walls]) was gathered, sacked by squares, and analyzed.

Then excavations were begun with a crew of six people with Mr. Fritz in charge, assisted by Dr. James N. Hill. Sixty per cent of the entire site was excavated and 90 per cent of all features. Translated into numbers this meant that all nine houses were completely dug; and 250 pits out of a probable total of 265. Sixty-eight thousand artifacts and 13,000 "cooking" stones were recovered. Out of the 68,000 artifacts, we found that about 47,000 (2/3) were unutilized flakes; 18,000 were flakes modified by use and 3,000 were "tools," that is, stones modified over large areas of their surfaces, and that these had been employed for cutting, scraping, and piercing. In addition, we recovered 170 whole or broken milling stones; 460 stones that were used in the manufacture of stone tools, and 30 potsherds, most of which probably came from one pot—a "seed" bowl shape. The pottery is grayish-brownish and blackish, is friable, and not well-fired. It is among the earliest pottery of the area (about 300 B.C.).

Attributes of all artifacts, houses, and pits were classified and tabulated by Fritz and their frequencies placed on IBM punch cards for use in a computer analysis. Factor analyses have been run. As of 1968, patterns of co-variation and association had been worked out for artifacts found in houses, pits, hearths, roasting pits, and storage pits.

Complete analyses, descriptions, associations among artifacts, typological analyses, test implications of his models, and explanations will be set forth in detail in a subsequent report.

In addition to gathering and excavating of cultural items and debitage, Fritz collected about 250 sediment samples for palaeobotanical analysis. Of this number, about 40 per cent or 100 specimens were turned over to Dr. Vorsila Bohrer—palynologist, University of Massachusetts at Boston, for pollen analysis. Her research, presented in this report, gives us basic knowledge of past and present botanic environments and clues as to past climates and available moisture. I will not attempt to summarize her work since it is clearly presented hereafter. I should like to point out the signifi-

cance of one important facet of her research: the ability to distinguish between pinyon and other pine pollen—the first time this has been done.

Another aspect of Fritz's research was to fix the site in time. A total of 22 carbon-14 determinations was run on charcoal and human bone (Geochron nos. GX-0539, 0540; 0578-0582; 0727; 0796-0799; 0800-0809).

This large a series probably reflects the total time range of occupation of the site. The radiocarbon dates span seven centuries: 470 B.C.  $\pm$  115 to A.D. 305  $\pm$  110. The mean of the series is A.D. 37.03  $\pm$  95.6. Fritz dates the site at about 300 B.C. to A.D. 300.

Analysis of the data suggests that the houses and pits fell into several separate clusters of houses surrounded by many pits.

The earliest group consists of three houses and dozens of pits, the mean age of which is 30.7 B.C.  $\pm$  97.5 years.

The next younger group—perhaps two to five houses and associated pits—yields a mean date of A.D. 89.6  $\pm$  94.17 years.

The most striking feature of the site was the large number of pits—some 265, all told. Two hundred fifty were excavated and described. They range in size from 20 cm. to 5 m. in diameter, and in depth from 10 cm. to 1 m.

The pits may have been used for storage, caching foods or materials, roasting or boiling, and thermal treatment of chert.

The houses closely resemble the one well-preserved structure at County Road site (supra). The walls, sloped inward, were of jacal, with posts placed about the periphery or rim of a shallow, bowl-shaped depression, the diameters of which were about 5 m. Each house had been provided with a tunnel entrance that extended eastward about 2 m. Interior house features consisted of at least one small hearth, several pits, and a kind of deflector composed of a series of upright, sandstone slabs about 30 cm. high set end-to-end to form a low partition wall between the entry and the hearth. The floor, the center of which was depressed below the present surface about 10-25 cm., yielded milling stones and tools of chipped stone. One house smaller than the others may have been functionally different from the others.

Given these data and developing models based in part upon ethnographically known hunting and gathering cultures, Fritz has formulated a series of testable propositions:

1. Technology was generalized—that is, tools for food procurement and processing were not elaborated relative to those of more specialized agricultural adaptations which followed in the Southwest.
2. The population consisted of small groups that were dispersed over the area through which resources were distributed.
3. In times of famine individuals or families might have temporarily combined with groups in areas more richly endowed.
4. The nuclear family was the basic unit of social organization. However, aggregation of familial units, or bands, formed periodically when resources concentration occurred.
5. At Hay Hollow site, cooking, butchering, roasting, and broiling were done downwind and at some distance from the houses.
6. At this site food preparation such as milling was done in or adjacent to houses.
7. Hay Hollow site was a base camp which was occupied most intensively during the winter months and from which groups moved to procure resources throughout the area—particularly at higher elevations.
8. The resources used for food included maize. Both cobs and pollen of *Zea* have been found at the site.

In general, then, Fritz employs the data from the Hay Hollow site to reconstruct the subsistence system and other sociocultural phenomena of the people at this site from about 300 B.C. to A.D. 300.

April, 1971

FIELD MUSEUM OF NATURAL HISTORY, CHICAGO

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## Paleoecology of the Hay Hollow Site, Arizona

### ACKNOWLEDGEMENTS

Dr. Richard H. Hevly first aroused my curiosity about the pollen record of economic plants with his research (1964) in the Hay Hollow Valley. Dr. Paul S. Martin, Director of the Southwestern Archaeological Expedition of Field Museum of Natural History, in cooperation with Dr. Paul S. Martin, Chief Scientist, Laboratory of Paleoenvironmental Studies of the Geochronology Department of the University of Arizona, provided an opportunity to satisfy my

curiosity. For the verification of *Typha* pollen and for matters concerning methodology and extraction I gratefully acknowledge the help of Peter J. Mehringer, Jr., Palynologist in the Department of Geochronology. John M. Fritz, University of Chicago, exhibited a sense of purpose and closely correlated sampling plan that greatly enhanced the value of the results. The viewpoint of much of my research reflects the influence of Professor Volney H. Jones, Curator of the Ethnobotanical Laboratory of the University of Michigan.

None of the research could move forward without the financial assistance received under National Science Foundation Grant GS 245, GS 984, GS 1910, and GS 2381, and the Wenner-Gren Foundation Grant 2186 to Dr. Paul S. Martin of Field Museum of Natural History. Assistance from a predoctoral fellowship awarded by the University of Arizona and a National Science Foundation Grant GB 4694 to Dr. Paul S. Martin of the University of Arizona were also essential for the completion of this research.

## INTRODUCTION

Plant macrofossils, such as leaves, seeds, or wood were infrequent in the Hay Hollow excavation. The pollen, as a record of vegetation, consequently increased in importance. Pollen spectra could be procured from apparent replicates of cooking pit types, from similar sections of house floors, and from grinding tools. Pollen investigations focused on revealing the prehistoric utilization of plants, both cultivated and wild, and discerning the nature of the plant communities characteristic of the Hay Hollow Valley during the occupation of the site. I (1968) have presented detailed results which are summarized in this publication.

## POLLEN ANALYTICAL PROCEDURES

The excavators of the Hay Hollow Site gathered the pollen data in the form of sediment samples from the floor and fill of about 40 per cent of the pits and from all definite houses. Samples were removed with a trowel and placed in clean plastic bags tagged with provenience and date. About 250 samples were collected, 234 of which have been catalogued by the Geochronology Department, University of Arizona. Of the 100 samples extracted, 30 samples had sufficient pollen for a 200-grain count. About half came from the floors of outdoor pits and half from house floors.

The interpretation of fossil pollen counts from the Hay Hollow Site was enhanced by studying the modern plant communities in 25 locations together with the pollen spectra derived from soil surface samples. I adapted the quarter method (Curtis, 1950, p. 25) for sampling the modern soil surface among pines. First a topographic map was used to establish a compass direction for a transect that would run at right angles to the prevailing slope. A pair of numbers from a random numbers table determined the paces to each sampling point of four reference trees. Forty double-pinches (one pinch is ca. .7 ml.) of surface soil were accumulated in a single plastic bag and assigned a geochronology catalog number. Except for omitting the four trees as reference points, the same technique was usually followed in collecting soil surface samples among junipers and in grassland. All samples were collected between January 30 and April 9, 1967.

I extracted the pollen following the HC1-HNO<sub>3</sub> schedule of Mehlinger (1968). In addition, I inspected screenings for seeds, acetylated the sample just prior to the treatment with potassium hydroxide, and dehydrated the residue in 95 per cent and 100 per cent ethyl alcohol followed by thiophene-free benzene prior to mounting in silicon oil (Dow Corning 200 fluid, viscosity 12,500 centistokes).

Pollen taxonomic categories conformed to those used by Hevly et al. (1965) with a few modifications. *Short-spine* was substituted for *low-spine* and *long-spine* for *high-spine* in the Compositae. *Opuntia* grains were divided into the *Cylindropuntia* or cholla type and the *Platyopuntia* or prickly-pear type, on the basis of puncti-baculate ektexine in the former and reticulate ektexine in the latter (Kurtz, 1948; Tsukada, 1964). Juniper was omitted from all pollen sums to minimize the effects of differential pollen preservation and the impact of juniper destruction by ranchers on the natural pollen rain.

Pollen measurements from 26 ponderosa pines (*Pinus ponderosa*) and 14 pinyon pines (*P. edulis*) in the Snowflake area were used to evaluate the pine pollen record in conjunction with surface samples. Modern and fossil pine saccus breadth frequencies were based on 100 observations.

The relation of Indian plant uses to pollen deposition was explored through experiments and by the use of the 95 per cent confidence interval of the binomial distribution (Herskowitz, 1965; Fryer, 1966).

## MODERN VEGETATION

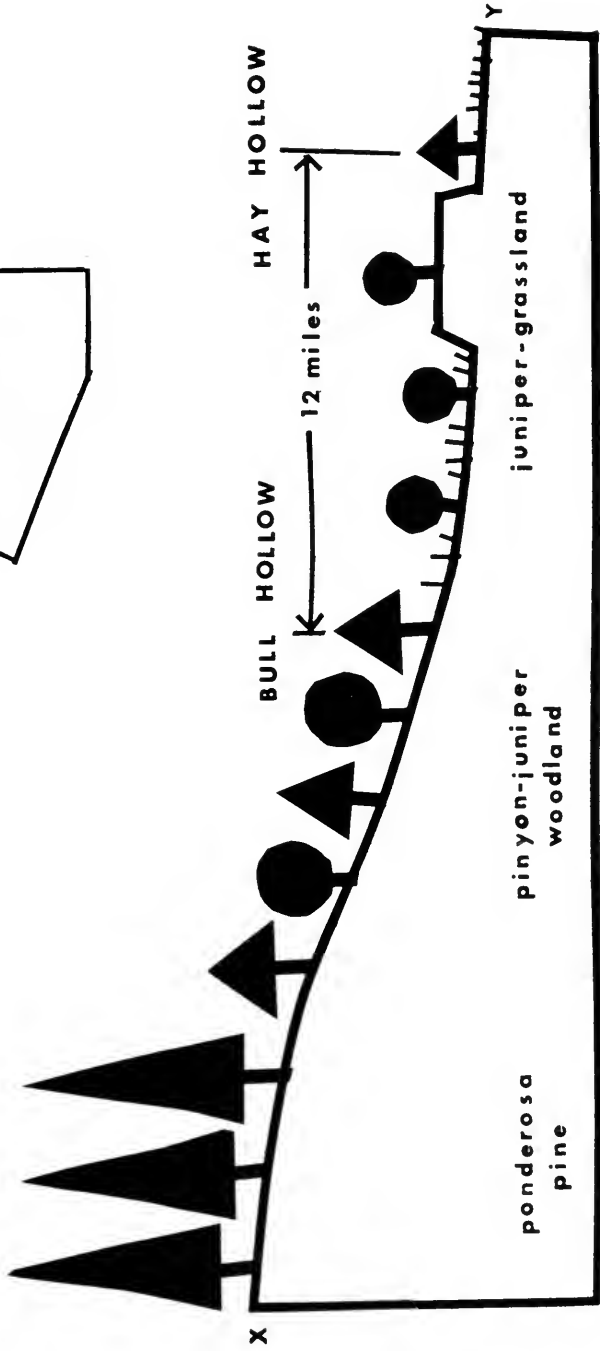
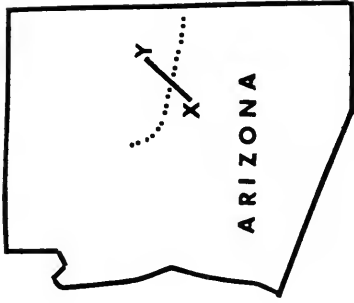
The escarpment known as the Mogollon Rim forms a rugged arc from Flagstaff, Arizona, southeast through central Arizona into New Mexico. It marks the southern edge of the Colorado Plateau, which extends through adjoining portions of New Mexico, Colorado, and Utah. At 7,500 ft. the crest of the rim supports a broad sweep of ponderosa pine forest with occasional admixture of Gambel oak (*Quercus gambelii*), Douglas fir (*Pseudotsuga menziesii*), or aspen (*Populus tremuloides*). The rim also cradles a less stately forest, known as a pinyon-juniper woodland, on its lower slopes that merge with the Colorado Plateau. The woodland interdigitates with the grassland vegetation. Islands of pinyon-juniper woodland cover mesas and eminences; a grassland predominates in the valleys, sometimes as a juniper savanna in the sense of Dansereau (1957) (see fig. 1).

The Hay Hollow Site vegetation probably represents only a relict of a pinyon-juniper woodland. Pinyon pine grows on portions of north-exposed mesa slopes and intermixes with some Utah juniper (*Juniperus osteosperma*) in the rocky, dry channel east of the site. Few pinyon live on the mesa top and none occupies the Hay Hollow site, located on a terrace below a northeastward extension of the sandstone mesa. Broadly spaced one-seed juniper (*Juniperus monosperma*) are conspicuous on the site terrace (fig. 2); the junipers gradually decline in density as they mix with the alkali-sacaton (*Sporobolus airoides*) grassland at slightly lower elevations to the north.

Since the site terrace was devoid of annuals for three years, shrubs and other perennials were especially obvious. They included: squawbush (*Rhus trilobata*), adelia (*Forestiera neomexicana*), banana yucca (*Yucca baccata*), wild buckwheat (*Eriogonum mearnsii*), sagebrush (*Artemisia bigelovii*), and heavily grazed Mormon tea (*Ephedra torreyana*). This sparse cover of primarily entomophilous shrubs helped to account for the high mean pine pollen frequency (36 per cent). Such a high pine percentage in the modern pollen rain would not be expected in the desert grassland of southern Arizona where grasses and annual anemophilous herbs are abundant and where the local pollen rain is presumably heavier (Martin, 1963).

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FIG. 1. (*opposite*). Vegetational transect from the Mogollon Rim to the Hay Hollow Site.



In the summer of 1967 the excavation backfill on the terrace provided a habitat for pioneer species. Nevertheless, despite a moist summer, only three species were observed to colonize the disturbed area. They represented disseminules of nearby perennials such as grama grass (*Bouteloua* sp.), alkali-sacaton grass, and blue gilia (*Gilia longiflora*). The weedy elements one might expect on disturbed ground were missing, perhaps because there was no local seed.

Even if the seed source were closer, weed establishment would be doubtful. One weedy species, *Chenopodium fremontii*, formed sparse rings beneath junipers only in rainy summers in the valley. Populations of *Chenopodium fremontii* might be restricted to such locations because the cattle grazed the inflorescence in spite of otherwise abundant vegetation. On the other hand, another potential weed, prostrate pigweed (*Amaranthus graecizans*), exhibited ungrazed shoot tips but failed to spread beyond the relatively restricted habitats along intermediate-sized drainways. Climatic or edaphic factors, rather than grazing pressure, seemed to influence its distribution.

Many plants of potential economic value are not productive under the present climate. Although banana yucca produced flowers, neither it nor wolfberry (*Lycium pallidum*) bore fruits. In poor years pinyon pine seed production was limited to a few trees in the drainways near the site. Shrubs like squawbush grew only 3 ft. tall and lacked vigor. The low density of weedy annuals mentioned above would not sustain human life even in good years. It is hard to imagine successful maize cultivation at this site under the above conditions.

## PREHISTORIC CHANGES IN PLANT COVER

The Hay Hollow Site received higher effective moisture during the time it was occupied than today. Apparently enough moisture was available when house 17 was occupied to support a pinyon-juniper woodland. The nearest woodland today is 12 miles distant. I do not know if the former woodland was isolated from the present woodland or continuous with it.

The alkali-sacaton grassland probably grew near the site, as it does today. Although salt-bush may have been less abundant than today, the herbaceous Chenopodiaceae and *Amaranthus* (table 1) were certainly more abundant. Populations of other herbs were probably more widespread than today. Among them would be tansymustard (*Descurainia obtusa*), bee plant (*Cleome serrulata*), and





FIG. 2. The Hay Hollow Site during excavation of house 20 in 1965. View looks north and east; the Hay Hollow stream bed is in the middle distance. Photographed from a mesa 30 ft. above the site (Field Museum of Natural History negative 103021).

TABLE 1.—Flora of the Hay Hollow Valley and nearby areas with a list of University of Arizona Herbarium accession numbers.

Vouchers are identified from Kearney and Peebles, 1960.

PINACEAE. Pine Family		
<i>Pinus edulis</i>	pinyon pine	158252
CUPRESSACEAE. Cypress Family		
<i>Juniperus monosperma</i>	one-seed juniper	158249
<i>J. osteosperma</i>	Utah juniper	158253
EPHEDRACEAE. Joint-fir Family		
<i>Ephedra viridis</i>	Mormon tea	163897
<i>E. torreyana</i>	Mormon tea	158191
GRAMINEAE. Grass Family		
<i>Bouteloua gracilis</i>	blue grama	164318
<i>Hilaria jamesii</i>	galleta grass	161745
<i>Lycurus phleoides*</i>	wolf-tail grass	163246
<i>Muhlenbergia torreyi</i>	ring muhly grass	164330
<i>Munroa squarrosa</i>	false buffalo grass	164329
<i>Oryzopsis hymenoides</i>	Indian rice grass	
<i>Sporobolus airoides</i>	alkalai-sacaton grass	163408
<i>S. contractus</i>		164317
<i>Tragus sp.</i>		
LILIACEAE. Lily Family		
<i>Nolina microcarpa</i>	beargrass	158255
<i>Yucca baccata</i>	banana yucca	163909
<i>Y. baileyi</i>		163899
SALICACEAE. Willow Family		
<i>Populus spp.*</i>	cottonwood	
<i>Salix sp.*</i>	willow	
POLYGONACEAE. Buckwheat Family		
<i>Eriogonum alatum</i>	winged eriogonum	
<i>E. jamesii</i>	antelope sage	161738
<i>E. mearnsii*</i>	wild buckwheat	161777
CHENOPODIACEAE. Goose-foot Family		
<i>Atriplex canescens</i>	four-winged saltbush	158217
<i>Chenopodium fremonti</i>	goose-foot	164340
<i>C. graveolens</i>		164333
<i>C. watsoni*</i>		161417
<i>Eurotia lanata</i>		164328
<i>Salsola kali</i>		
AMARANTHACEAE. Amaranth Family		
<i>Amaranthus albus*</i>		161760
<i>A. graecizans</i>	prostrate pigweed	164335
<i>A. powellii*</i>		163210
<i>A. torreyi</i>		164332
NYCTAGINACEAE. Four-o'clock Family		
<i>Mirabilis multiflora</i>	four-o'clock	164324
<i>Oxybaphus linearis</i>		164321

\* Collected between Pinedale and Taylor, Arizona.

TABLE 1.—Flora of the Hay Hollow Valley and nearby areas with a list of University of Arizona Herbarium accession numbers.—*Continued*

PORTULACACEAE. Portulaca Family		
<i>Portulaca oleracea</i>	purslane	164331
<i>P. parvula</i>	purslane	164508
<i>P. retusa</i>	purslane	164316
CARYOPHYLLACEAE. Pink Family		
<i>Drymaria fendleri*</i>		163240
BERBERIDACEAE. Barberry Family		
<i>Berberis haematocarpa</i>	red mahonia	158213
CAPPARIDACEAE. Caper Family		
<i>Cleome serrulata</i>	Rocky Mountain bee-plant	
CRUCIFERAE. Mustard Family		
<i>Descurainia obtusa*</i>	tansy-mustard	163896
<i>Dithyrea wislizeni</i>	spectacle-pod	
<i>Lepidium montanum</i>	pepper-grass	164326
<i>Stanleya pinnata</i>	desert-plume	164325
SAXIFRAGACEAE. Saxifrage Family		
<i>Ribes</i> sp.*	goose-berry	
ROSACEAE. Rose Family		
<i>Chamaebatiaria millefolium*</i>	fern-bush	
<i>Cowania mexicana</i>	cliff-rose	158192
LEGUMINOSAE. Pea Family		
<i>Amorpha fruticosa*</i>	false-indigo	
<i>Astragalus</i> spp.	loco-weed	
<i>Parryella filifolia</i>		158195
POLYGALACEAE. Milk-wort Family		
<i>Polygala alba*</i>	milk-wort	161742
EUPHORBIACEAE. Spurge Family		
<i>Croton texensis</i>		164336
<i>Euphorbia revoluta</i>		164314
ANACARDIACEAE. Cashew Family		
<i>Rhus radicans*</i>	poison-ivy	
<i>R. trilobata</i>	squaw-bush	158256
VITACEAE. Grape Family		
<i>Vitis arizonica*</i>	canyon grape	
MALVACEAE. Mallow Family		
<i>Sphaeralcea</i> sp.		
LOASACEAE. Loasa Family		
<i>Mentzelia pumila*</i>	stick-leaf	
CACTACEAE. Cactus Family		
<i>Echinocereus</i> sp.	hedgehog cactus	
<i>Opuntia whipplei</i>	Whipple cholla	
<i>O.</i> sp.	prickly-pear	

\* Collected between Pinedale and Taylor, Arizona.

TABLE 1.—Flora of the Hay Hollow Valley and nearby areas with a list of University of Arizona Herbarium accession numbers.—*Continued*

ONAGRACEAE. Evening-primrose Family		
<i>Oenothera runcinata</i>	evening-primrose	161818
OLEACEAE. Olive Family		
<i>Forestiera neomexicana</i>	adelia	158214
POLEMONIACEAE. Phlox Family		
<i>Gilia longiflora</i>	blue gilia	164315
<i>G. multiflora</i>		
BORAGINACEAE. Borage Family		
<i>Cryptantha flava</i>		163901
LABIATAE. Mint Family		
<i>Salvia reflexa</i> *	Rocky Mountain sage	161759
SOLANACEAE. Potato Family		
<i>Chamaesaracha coronopus</i>		161902
<i>Lycium pallidum</i>	wolf-berry	
<i>Physalis fendleri</i>	ground cherry	164320
SCROPHULARIACEAE. Figwort Family		
<i>Cordylanthus wrightii</i> *	club-flower	161744
<i>Penstemon linarioides</i>	beadtongue	161741
COMPOSITAE. Sunflower Family		
<i>Artemisia bigelovii</i>	sagebrush	164327
<i>A. filifolia</i>	sand sagebrush	158210
<i>Aster arenosus</i>		158218
<i>Brickellia brachyphylla</i>	brickell-bush	164323
<i>Chrysothamnus</i> sp.	rabbit-brush	
<i>Franseria acanthicarpa</i>	bur ragweed	164399
<i>Gaillardia</i> sp.	blanket-flower	
<i>Gutierrezia lucida</i>	snake-weed	164322
<i>Helianthus</i> sp.*	sunflower	
<i>Pectis papposa</i>	chinchweed	164337
<i>Senecio longilobus</i>	thread-leaf groundsel	164397
<i>Thelesperma</i> sp.		
<i>Verbesina encelioides</i>	crown-beard	164334
<i>Xanthium</i> sp.	cocklebur	
<i>Zinnia grandiflora</i>		164319

\* Collected between Pinedale and Taylor, Arizona.

ground cherries (*Physalis fendleri* and *Chamaesaracha coronopus*). All of the foregoing plants were traditionally gathered for food by the Hopi (Whiting, 1939) and Zuñi (Stevenson, 1915). The use of beeweed and tansy-mustard extends into the prehistoric plant record (Jones and Fonner, 1954; Schoenwetter and Eddy, 1964, p. 74; Martin and Byers, 1965).

The structure of the alkali-sacaton grassland during the occupation of the Hay Hollow Site changed according to the available mois-

ture (fig. 3). Moist summers provided an abundance of alkali-sacaton grass and dry summers allowed expansion of the herbaceous *Chenopodiaceae* and *Amaranthus* populations. In summers of abundant rainfall large stores of alkali-sacaton grass seed could be set aside with relative ease. In dry summers the prostrate pigweed, an amaranth, would spread in the open spaces among the grass and furnish an alternate harvest. Prostrate pigweed could easily invade a cultivated field. Other species of *Chenopodium* and *Amaranthus* would furnish seed in intermediate years. No similar wild harvests in drought years are available today except in limited and widely scattered habitats.

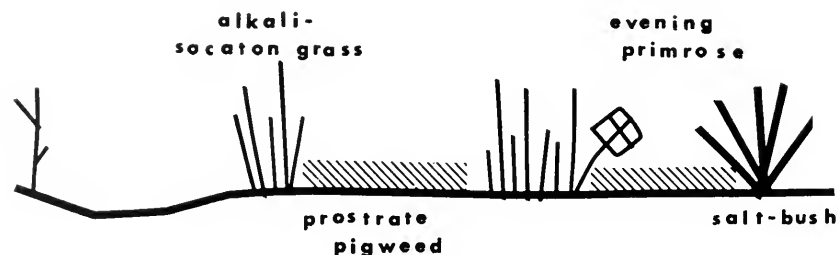
With higher available moisture, yucca, cholla, and pinyon would all bear fruit more heavily. Wolfberry and squawbush would undoubtedly be more productive. Wild grapes might grow in the area and a different species of cholla, although the floristic composition would be essentially similar to the modern one.

Today a relict-stand of pinyon in the midst of a juniper grassland is all that remains of the pinyon-juniper woodland which apparently grew nearby at the time of initial occupancy. Herbaceous *Chenopodium* and *Amaranthus* populations also appear relict at present, and the water table is lower than in times past. While these are valid ecological contrasts, and the average available moisture seems to be low enough to limit *Chenopodium*, *Amaranthus*, and pinyon populations, I do not know the extent to which other factors over the past 2,000 years have contributed to the modern plant ecology.

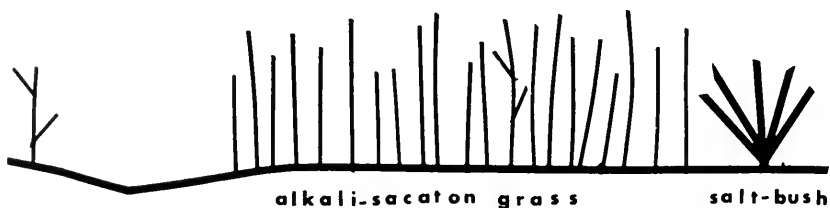
## EVIDENCE FOR HIGHER EFFECTIVE SOIL MOISTURE

### HERBACEOUS POLLEN

Cat-tail (*Typha* sp.) pollen in the prehistoric spectra implies higher ground water levels than today. The cat-tail pollen recovered from the floors of houses 17, 32, and in a cooking pit (68051815) probably originated locally. If the pollen were wind transported, they probably came from less than 7 miles distant (cf. Potter and Rowley, 1960). If man inadvertently introduced the pollen, then we may infer local availability. People who used cat-tail, such as the Acoma, Laguna, Pima, and Paiute, for everyday purposes (Russell, 1908, p. 133; Castetter, 1935, p. 53; Stewart, 1941, p. 375) had the plants available locally. No cat-tail grows near the modern site today, not even in localized habitats.

**A. DURING SITE OCCUPANCY**

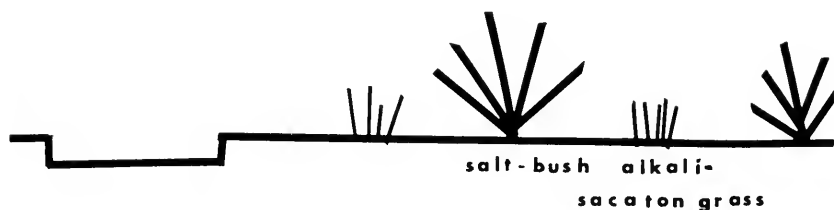
LOW AVAILABLE MOISTURE



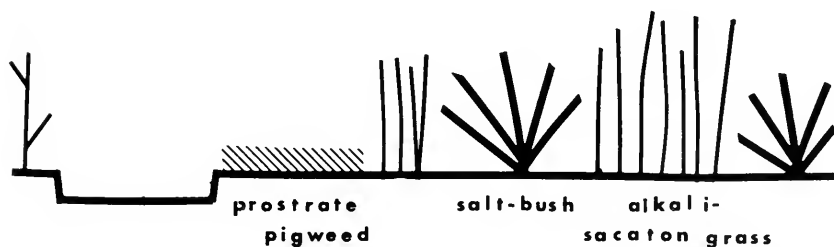
HIGH AVAILABLE MOISTURE

FIG. 3. a. Extreme fluctuations in plant cover (September aspect) adjacent to the Hay Hollow Site as postulated during the site occupation.

The record of the *Chenopodiaceae* + *Amaranthus* pollen type, together with the seed that implied food utilization, pre-supposed an abundance of herbaceous plants. One would either need a jeep or helicopter today to exploit the limited and widely scattered herbaceous *Chenopodium* and *Amaranthus* habitats in the area. During a modern drought year, there may be no herbaceous *Chenopodium* and *Amaranthus* whatsoever. More regularly available moisture in an average summer must have maintained the populations at a broader distribution during the site occupation to make the seed

**B. DURING 1960'S**

LOW AVAILABLE MOISTURE



HIGH AVAILABLE MOISTURE

FIG. 3. b. Extreme fluctuations in plant cover (September aspect) adjacent to the Hay Hollow Site as observed in the 1960's.

collection practical. The shifts in structure within the alkali-sacaton grassland are inferred from the modern ecology of a swale 2 miles west of Snowflake, Arizona. (See section on plants used by prehistoric occupants for a more complete discussion of evidence.)

The recovery of pollen from evening-primrose (*Onagraceae*) in prehistoric pollen spectra is also suggestive of slightly higher levels of available moisture. During my three seasons observing the flora in the Hay Hollow Valley, I found no evening-primrose. *Oenothera runcinata*, one member of the family, did grow in the alkali-sacaton

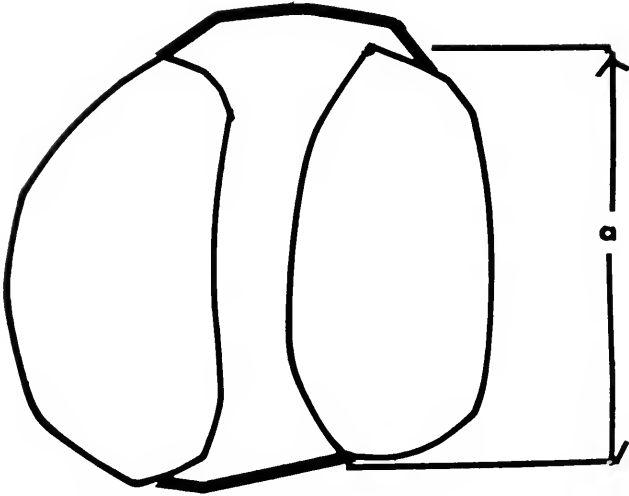


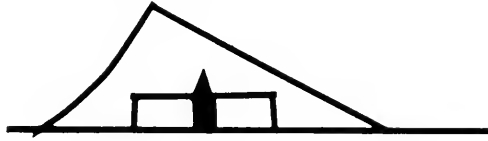
FIG. 4. Pine pollen grain with two sacculi as seen in distal view.  $a$ =sacculus breadth.

swale 2 miles west of Snowflake, Arizona. The same species grew at Window Rock, Arizona, in a similar habitat or in areas that received extra run-off from the road shoulder. Assuming *Oenothera* is not present today, slightly higher moisture values would probably be necessary to maintain a population of evening-primrose in the Hay Hollow Valley.

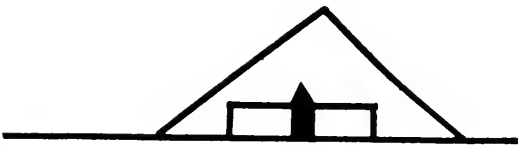
#### ARBOREAL POLLEN

As the artificial introduction of pine pollen into the site was unlikely and as only two naturally occurring pine species (*Pinus ponderosa* and *P. edulis*) were expected, I endeavored to separate the two on the basis of bladder breadth (fig. 4) and to use their pollen frequencies as the estimate of the past position of the pinyon-juniper woodland border. The smaller pinyon pollen bladders formed a normally distributed population that overlapped in its upper size extremes with the larger ponderosa pine pollen (fig. 5). However, bladders  $\leq 30\mu$  seemed to be almost entirely pinyon pollen. A series of modern soil surface samples were analyzed to determine the characteristic frequency of pine pollen bladders  $\leq 30\mu$  in grassland, at the borders of and within the pinyon-juniper woodland, and in a ponderosa pine forest. By using up to 10 soil surface samples from different locations within a given vegetation type, it was possible

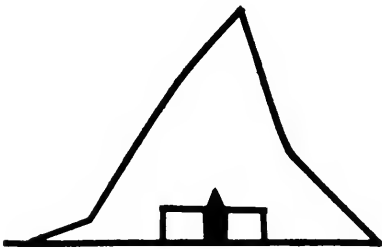




**ponderosa from mesic habitat (n=200)**



**ponderosa from xeric habitat (n=200)**



**pinyon (n=280)**

20                    30                    40                    50                    60  $\mu$

FIG. 5. Graph of pollen saccus breadth frequencies of ponderosa and pinyon pine.

to statistically discriminate between the modern archaeological site, a pinyon-juniper woodland, and a grassland on the basis of the frequency of pine pollen  $\leq 30\mu$  (see table 2).

Pollen extractions from the prehistoric site were measured to obtain the frequency of pine bladder breadth equivalent to  $\leq 30\mu$  in a sample of 100 pine pollen grains (table 3). The frequency of small

TABLE 2.—Summary of small pine pollen saccus breadth ( $\leq 30\mu$ ) frequencies with 95 per cent confidence interval for modern surface samples in major plant communities near Snowflake, Arizona.

Plant community	No. of sub-samples from different geographic locales	Mean frequency	95% confidence interval
Ponderosa pine	4	18	14-23 (N=400)
Pinyon-juniper	10	44.2	41-47 (N=1000)
"Juniper-Grassland" of Hay Hollow Site <sup>1</sup>	2	33.8	31-37 (N=1000)
Grassland	10	29.4	26-32 (N=1000)

<sup>1</sup> The modern Hay Hollow Site is characterized by junipers, an extremely low density of pinyon trees, and a lack of herbaceous cover.

pine pollen from one of the earlier houses (house 17) compared to an equivalent frequency from either the modern environment or from a denser pinyon-juniper woodland. I assumed the latter choice was correct because the previously described independent indicators suggested higher effective moisture values.

The trend in C<sup>14</sup> dates associated with the three prehistoric pollen samples (table 3) analyzed for pine bladder size paralleled an interpretation of increased woodland decimation. The accompanying record of *Typha* pollen in both the oldest and intermediate samples (houses 17 and 32, respectively) seems incompatible with an interpretation of less favorable climatic conditions for the growth of pin-

TABLE 3.—Interpretive summary of prehistoric small pine pollen saccus breadth ( $\leq 27.5\mu$ ) frequencies with C<sup>14</sup> dates.

Description	Frequency of small sacci	95% confidence limits	Plant community	C <sup>14</sup> yrs B.P. 1950
House 17, X1754220	42.5	36-49	pinyon-juniper or modern site <sup>1</sup>	2095 ± 105 1995 ± 100 1895 ± 110
House 32 (composite of X3251, X3253, X3254325)	29	20-39	modern site <sup>1</sup> or grassland	1030 ± 80 1920 ± 75
Pit 30051815	24	16-34	modern site <sup>1</sup> or grassland	
Pit 33853825	18	11-27	grassland	1720 ± 90

<sup>1</sup> The modern Hay Hollow Site is characterized by junipers, an extremely low density of pinyon trees, and a lack of herbaceous cover.

yon. The persistence of *Typha* pollen is more harmonious with an interpretation of woodland decimation under generally favorable climatic conditions. I consider man as the destroyer of the woodland instead of climate.

The contrast of 12.7 per cent pine pollen in house 17 with the 36 per cent pine pollen from the modern surface at Hay Hollow might seem to indicate an early retreat of the number of pine trees in prehistoric times (Schoenwetter and Dittert, 1968, p. 46). Modern Southwestern surface transects show that the pine percentages decrease with elevation and with distance from pines (Hevly, 1964, 1968; Schoenwetter and Eddy, 1964, p. 68). Application of the generalization to all archaeological sites may not be justified. The generalization implies that the herbaceous cover is constant and the arboreal pollen is the variable. Exceptions can be found in modern surface samples (table 4). Samples derived from Bull Hollow, a grassy valley adjacent to a vigorous pinyon-juniper woodland, showed a lower percentage of pine pollen (18.5 per cent) than the modern

TABLE 4.—Percentage of pine in pollen spectra near Snowflake, Arizona, ranked by decreasing density of herbaceous cover.

Rank	Geochron Cat. No.	Description	% pine	Distance to nearest pine and elevation in feet
1	9065	Alkali-sacaton swale	7	No closer than 5 mi. to pinyon; 5,600
1	9066	Meadow	2	$\frac{1}{4}$ - $\frac{1}{2}$ mi. to ponderosa pine; 6,400
2	9141	Juniper grassland	25	No closer than $1\frac{1}{4}$ mi. to pinyon; 5,900
2	9142-2	Border of pinyon- juniper woodland	18.5	100 to 200 feet to pinyon; 5,900
2	9147	Grassland with Morman tea	19	No closer than 8 mi. to pinyon; 5,500
3	9068	Grassland with saltbush	12	No closer than 1 mi. to pinyon; 5,800
4	9148	Eroded grassland	28	No closer than 20 mi. 5,200
4	9061	Hay Hollow Site	34.5	100 to 200 feet to pinyon; 5,800
5	9142-1	Interior of pinyon- juniper stand	58	5,900
5	9057-6	Interior of pinyon- juniper stand	79	6,100
5	9146	Interior of pinyon- juniper stand	68	6,300

Hay Hollow Site with its relict pinyons. I assumed neither the herbaceous or arboreal pollen to be a constant in this study.

My assertion that the cultural introduction of pine pollen is negligible involves the following assumptions: (1) No pine pollen residue adhered to pinyon seeds possibly used as food. This assumption has supporting experimental evidence (table 7). (2) The limited Zuñi practice of eating pinyon and ponderosa pine buds and shoots (Stevenson, 1915, p. 96) concerned an early enough developmental stage of pollen formation to be ignored as a source of pine pollen introduction. (3) No Pueblo Indians gathered pinyon and ponderosa pine pollen for ceremonial use as did the Navajo (Vestal, 1952, pp. 13-14). (4) Any possible pollen distortions resulting from spreading pine needles on the floor where maize was stored can be ignored at the Hay Hollow Site, although excavators at Point of Pines noted the practice at Ariz. W:10:50. (5) The concentrations of pine pollen in an infant burial at Broken K Pueblo near Snowflake, Arizona (Hill and Hevly, 1968, p. 206) resulted from interment on a day within the period of pine pollination. Pollen rain on any one day may be quite different from averages of pollen from living surfaces and may not necessarily indicate cultural introduction. Pine values reach as high as 78 per cent ( $n=54$ ) in weekly June extremes in the San Augustin Basin (Potter and Rowley, 1960, p. 16).

### SEED MACROFOSSILS

The recovery of a seed of *Portulaca retusa* from a prehistoric fire pit (table 5) is perhaps less significant as an indicator of increased available soil moisture, since *Portulaca* grows in the area today. However, no seeds were recovered from two soil surface pollen sampling transects at the site. If available moisture were greater, *Portulaca retusa* would grow more abundantly and increase the probability of recovering the seeds in the modern soil surface.

Considering the small amount of sediment used in pollen analysis (24-36 ml.), the widespread recovery of a minute charred, unknown seed (table 5) was intriguing. The seed was hexagonal in cross-section and oblong in longitudinal view. It measured about .5 mm. long and half as wide. The dark, non-reflective surface of the minute seed discouraged photographic attempts.

Modern surface samples at the Hay Hollow Site did not contain the seed, but I recovered it in a soil surface sample in a mesic tributary of Bull Hollow (12 miles distant). I redeemed the same seed at the Tule Springs Site in southern Nevada, where oxidized seed

TABLE 5.—Seeds screened from prehistoric sediment samples prior to pollen extraction.

Geochron. Cat. No.	Field Museum No.	No. and type of seed; remarks
9068-2	X3252	½ T*; house 32 floor
9069-1	X3253	Herbaceous cheno-am fragment; 90% cheno-am pollen; from under grinder in house 32
9070-2	X3255	1 T*; house 32 entryway
9072-2	X2553	1 T*; house 25 floor
9076	16853815	½ T*; firepit floor
9080	22852815	2 T*; firepit floor
9089-2	29450815	2 T*; firepit floor
9095-1	31253815	½ T*; 1 <i>Chenopodium graveolens</i> , 82.5% cheno-am pollen from firepit floor.
9101-1	44753815	6 T*; 1 <i>Portulaca retusa</i> , herbaceous cheno-am fragments; 81% cheno-am pollen from firepit floor.
9105	53052815	2 T*; firepit floor
9111-2	59251825	1 T*; firepit floor
9116-2	62954825	½ T*; firepit floor
9138	269	1 T*; burial

\* Tule Springs Site, Nevada, unknown. See section on seed macrofossils for description.

clusters, derived from spring mound IV, stratigraphic unit E2s (Mehringer, 1965), were in association with Cyperaceae, *Scirpus* sp., grape (*Vitis* sp.), and ash (*Fraxinus* sp.) macrofossils.

The ecology of the transect in the Bull Hollow tributary and the mesic species composition of the Tule Springs stratigraphic unit imply that this unknown seed is also characteristic of a damp or mesic habitat. Since the seed was not found in modern surface samples at the Hay Hollow Site, I inferred the site must have been more mesic during human occupation.

## PLANTS USED BY THE PREHISTORIC OCCUPANTS

Dr. Hugh C. Cutler, Curator of Useful Plants, Missouri Botanical Garden, recovered maize macrofossils while examining organic matter from the fill of 60 pits. An almost spherical maize kernel (about 4.5 mm. diam.) probably came from a pop or very hard flint type. A cob fragment that seemed to come from the tip of an ear had 12 rows, grains 3.4 mm. thick, and a cupule width of 4.4 mm. The

fragment resembled a popcorn, like Reventador, or a very small form of a hard flint (correspondence).

Pollen evidence suggested that alkali-sacaton grass seed probably was ground on a metate. Seeds from the pollen category of Chenopodiaceae + *Amaranthus* were harvested. The milling stone used in processing the seed as well as an associated baking pit was identified by pollen analysis. Two species of cholla (*Cylindropuntia*) were harvested and at least one cholla roasting pit was identified from the high concentrations of cholla pollen in the pit. High concentrations of pollen from long-spine Compositae on a grinding stone also suggested plant utilization. The pollen spectral distortion of mormon-tea (*Ephedra* sp.), indicative of usage, was associated with one storage pit and possibly a fire pit.

Dr. Hugh C. Cutler identified a portion of the carbonized wild seeds from the site. A few Chenopodiaceae or Amaranthaceae seeds and a partly burned seed of *Opuntia* sp. reinforce conclusions derived from pollen analysis. In addition, carbonized juniper seed, or probable fragments, were recovered from houses 13 and 17. The juniper berries might have been consumed by the inhabitants, as the Hopi do today (Whiting, 1939, p. 63; Nequatewa, 1943, p. 18).

The key to the identification of certain pollen spectral distortions, indicative of plant utilization, lies in the high concentration of a given pollen type. If, for example, food supplies were replenished often enough in a given location, the associated pollen might have reached a concentration that could not be duplicated by the pollen rain sampled in the soil surface. An interpretation of pollen spectral distortion seems justified when a frequency is so high that it fails to come within the 95 per cent confidence interval (binomial distribution) of the highest probability of occurrence in a known normal spectrum. For example, *Ephedra* pollen reached a concentration under natural conditions of 26 per cent with 95 per cent confidence limits of 20 to 33. A fossil spectrum from a cultural context (X1754365) had a frequency of 44 per cent, with 95 per cent confidence interval of 38 to 51. The fossil sample might yet be matched by undiscovered or unanalyzed samples of the modern pollen rain. But a plant community exhibits sufficient homogeneity that I do not expect very many new samples to exceed the confidence limits of the extreme sample used above as an illustration. One could not conclude that a fossil *Ephedra* sample statistically exceeding the confidence limits of the modern sample will never be matched by the natural pollen

TABLE 6.—Pollen spectral distortion at the Hay Hollow Site.

Pollen type	%	Field Museum No.	Provenience
Cheno-Am <sup>1</sup>	80	X3251	NE quadrat, house 32
Cheno-Am	90	X3253	SW quadrat beneath hand grinder, house 32
Cheno-Am	79	X3253	SW quadrat, house 32
Cheno-Am	80	X325335	SW quadrat, floor of pit in house 32
Cheno-Am	79.5	22852815	Outdoor cooking pit type 2b from area 1
Cheno-Am	82.5	31253815	Outdoor cooking pit
Cheno-Am	81	44753815	Outdoor cooking pit
Cheno-Am	80	52951825	Outdoor cooking pit
Cheno-Am	86	53052815	Outdoor cooking pit type 2b from area 2
Cheno-Am	79	57252825	Outdoor cooking pit
Cylindropuntia <sup>2</sup>	9	31351865	Outdoor cooking pit
<i>Ephedra torreyana</i> type <sup>3</sup>	44.5	X1754365	Floor of pit in house 17

<sup>1</sup> Chenopodiaceae + *Amaranthus*. Modern maximum was 59% with 95% confidence interval from 52–65. Prehistoric mean of 79% has 95% confidence interval of 72–84.

<sup>2</sup> Unless sampling directly beneath cholla, the modern frequency is 0% with 95% confidence interval 0–2. Prehistoric mean of 9% has 95% confidence interval of 6–14.

<sup>3</sup> Modern maximum was 26% with 95% confidence interval 20–33. The prehistoric 95% confidence interval is 38–51.

rain. One could conclude that this will rarely happen and that the distorted nature of the fossil *Ephedra* sample probably had a cultural cause.

The identification of pollen spectral distortion (table 6) led to experiments to ascertain how pollen concentrations might accumulate. When one considers that pollination precedes seed formation, the assertion that pollen spectral distortion may be created by the use of seeds seems paradoxical. However, experiments suggest that pollen adheres to the seeds, fruits, and husks in six of the seven species of plants tested (table 7). The nature of the blossom, or the collective blossoms (inflorescence), provides a possible explanation.

In the case of maize, husks enclose the cob from pollination to maturity. Pollen accumulates on the husk exterior and may be transferred to thekerneled cob by the person doing the husking. Cholla (*Opuntia whipplei*) and sunflower (*Helianthus* sp.) have blos-

TABLE 7.—Relative abundance of pollen washed from modern seeds, fruits, and husks.

Name of plant	Plant part	Pollen		
		Abundant	Common to rare	Absent
Pinyon ( <i>Pinus edulis</i> )	seed*			X
alkali sacaton grass ( <i>Sporobolus airoides</i> )	caryopsis*	X		
maize ( <i>Zea mays</i> )	husk caryopsis	X	X	
goose-foot ( <i>Chenopodium dessoratum</i> )	seed*	X		
Prostrate pigweed ( <i>Amaranthus graecizans</i> )	seed*		X	
Whipple cholla ( <i>Opuntia whipplei</i> )	fruit and stem		X	
sunflower ( <i>Helianthus</i> sp.)	achene*	X		

\* Winnowed prior to treatment

soms which shrivel and dry but persist at the apex of the ripening ovary or fruit (fig. 6). Wind and moisture may transfer pollen from the old flower to the developing fruit beneath it. The pollen of flowers arranged in the indeterminate inflorescence as in grass, *Chenopodium* and *Amaranthus*, was unintentionally collected in the same container as the mature seed while beating the inflorescence for seeds (fig. 7).

The foregoing experiments raise the question of whether the use of seeds or flowers created pollen spectral distortion. The alternatives are difficult to weigh in the case of the long-spine Compositae pollen type. Sunflower (*Helianthus* sp.) blossoms might be ground for ceremonial purposes (Stevenson, 1915, p. 93) or the achene might be cracked on the milling stone to facilitate separation of the shell from the seed (Cushing, 1920, p. 252). Either situation might contribute to the long-spine Compositae pollen concentration. The use of many other genera in the same family would produce similar results.

The recovery of small, black seed-fragments resembling *Chenopodium* or *Amaranthus* in association with distorted frequencies of the Chenopodiaceae + *Amaranthus* pollen type indicated that the prehistoric pollen probably was originally introduced along with the seed (table 5).



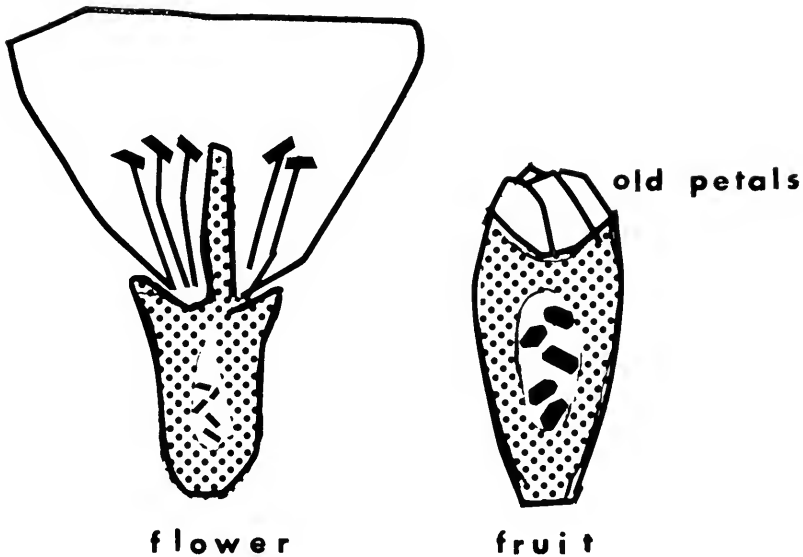


FIG. 6. Flower with inferior ovary and developed fruit. Old stamens with pollen residue are retained with the old petals in cholla (*Opuntia whipplei*) and in sunflower (*Helianthus* sp.).

In the case of grass, I infer that it was the seed ground on the stone, since I know of no modern use of blossoms of grass that entails grinding or crushing. Normally, prehistoric pollen of grass genera seldom shows consistent differences at magnifications of 400 $\times$ , except in size range. Because certain small grass pollen occurred in clumps, in suspiciously large amounts, and conformed in size to pollen of modern *Sporobolus airoides* ( $23\mu \pm 1.6$  n=50) which grows nearby, inference on the use of this species was postulated. It was assumed no other small grass pollen now absent (i.e., *Leersia oryzoides*, *Phragmites communis*, *Calamagrostis* sp.) produced the pollen record in question.

Although only one species of cholla (*Opuntia whipplei*) now grows in the Hay Hollow vicinity, knowledge of former utilization of an additional species is based on significant differences in the prehistoric cholla pollen diameters ( $58.5\mu \pm 22.2$  n=24) from the diameters of modern Whipple cholla pollen ( $63\mu \pm 6.0$  n=24). It is a matter of speculation if people traveled long distances to collect the other species of cholla or even traded for it. Cholla joints are considered more of a starvation food than a delicacy (Castetter, 1935, p. 35). Cholla buds are favorably regarded (Nequatewa, 1943, p. 19), but I am

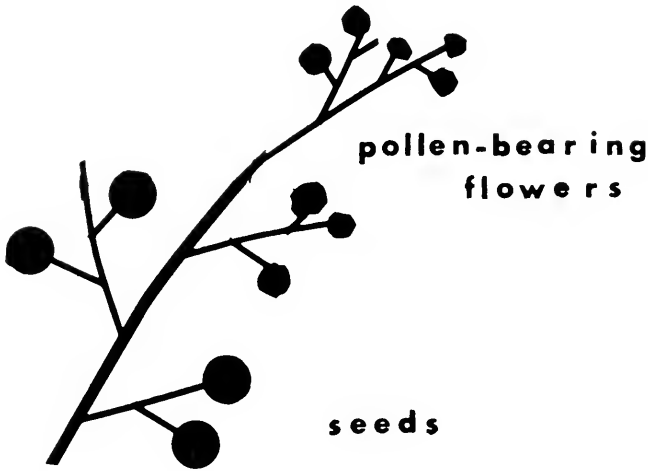


FIG. 7. Indeterminate inflorescence typical of *Chenopodium*, *Amaranthus*, and members of the grass family.

acquainted with no modern records of extended travel or trade for cholla. This leads to speculation that cholla was locally exploited until only one species survived.

#### POLLEN INDICATORS OF SEASONAL OCCUPANCY

If pollen spectral distortion has been accurately assessed, the seasonal presence of the creator of the distortion, man, may be recognized in certain cases. For example, I would assume that the people who lived in house 17 were present in the spring when *Ephedra* pollinates and in late summer when maize, alkali-sacaton grass, and prostrate pigweed, mature. Cholla pollen should probably be disregarded as evidence of seasonal occupation at the Hay Hollow Site since it is possible to gather the fruit or vegetative portions of *O. whipplei* in winter, and still retain pollen (table 7). Pollen spectral distortion will tell the investigator little or nothing in regard to winter occupancy. On the other hand, it may provide important clues to occupancy during certain portions of the growing season.

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