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MURRAY SPRINGS, A MID-POSTGLACIAL POLLEN RECORD FROM SOUTHERN ARIZONA*

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ABSTRACT. The pollen record from Murray Springs (Martin, 1963) indicated a mid-postglacial moist interval. Because of the importance of determining the nature of the Altithermal climate in southern Arizona and to verify, if possible, initial pollen and dating results, samples were recollected and further stratigraphic and dating studies were initiated. The results indicate slightly greater relative numbers of pollen grains of mesic and hydric species, especially pine, sedge, and cattail, in beds deposited 4000 to 5000 radiocarbon years ago. The southern Arizona pollen record between 5000 and 7000 years ago remains unknown as critically dated exposures of this age have yet to be discovered.

INTRODUCTION

Southwestern flood plains are renowned for their complex history of postglacial cutting and filling. As much as 10 meters of superimposed fills, broken by soil surfaces or erosion cuts, lie exposed in arroyo walls throughout parts of the desert grassland and Chihuahuan Desert of southeastern Arizona. From 7500 to 4000 years ago, an age obtained by extrapolation from Europe to the Southwest (Antevs, 1955, p. 324), the climate of western North America was supposedly unusually dry, accounting for extensive dissection of flood plains at that time and for other phenomena which led Antevs (1955, p. 328) to designate this interval the "Long Drought".

The concept of the mid-postglacial as a relatively dry interval in much of western North America can be supported by pollen records showing at least minor minima in the tree pollen sum in the Northern and Central Rocky Mountains, the Great Basin, and the Mohave Desert (Hansen, 1951; Pennak, 1963; Maher, ms; Sears and Roosma, 1961; Mehringer, in press). But in the areas close to the Mexican border Martin (1963) encountered conflicting evidence. Arguing partly on meteorological grounds, Martin concluded that the Altithermal in the Southwest along the Mexican border, and presumably also in Mexico, was relatively wet, not relatively dry, at least in summer. One of Martin's key localities regarding the nature of the Altithermal pollen record in southern Arizona is Murray Springs, part of a small arroyo entering the Upper San Pedro River in Cochise County.

In addition to the continuing question of the nature of the Altithermal climate in southern Arizona, it seemed desirable, for the following reasons, to recollect and reanalyze the Murray Springs profile.

1. Replication sometimes yields serious discrepancies, as shown in counts by Potzger and by Graham from the lower 5 feet of Gause Bog,

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Texas (Graham and Heimsch, 1960). In paired counts from the alluvial sites in Arizona, Martin and Schoenwetter commonly obtained significant differences in their counts (Martin, 1963, p. 35, 40). Could the initial profile, counted by Schoenwetter and illustrated in Martin (1963), be duplicated?

2. At the Lehner Ranch arroyo, 20 kilometers upstream from Murray Springs in a similar tributary of the San Pedro River, Mehringer failed to find a pollen zone comparable to units 2 and 3 in the original Murray Springs count. Why was the Murray Springs rise in pine and in hygric species not seen at the Lehner Site?

3. Counts of the pollen obtained in samples of the soil surface by Martin (1963), by Hevly, Mehringer, and Yocum (1965), and by Mehringer, Adams, and Martin (in preparation) indicate that in the southwestern deserts the relative abundance of pine and other tree pollen is probably a function of the pollen-producing efficiency of the local vegetation. Where local vegetation is dominated by heavy pollen producers, such as *Atriplex, Amaranthus,* certain Gramineae, or *Ambrosia,* the relative frequency of pine will be low. Where the local desert vegetation is dominated by poor pollen producers, such as the zoophilous shrubs *Larrea, Acacia, Prosopis,* or *Flourensia,* or where local vegetation is absent over many square kilometers, such as in the middle of a dry lake bed, the pine pollen count will be proportionately high. In the case of Murray Springs, it might be argued that an increase in pine pollen simply reflected drought-initiated expansion of desert scrub communities at the expense of desert grassland, a hypothesis that would be entirely in accord with the concept of a hot-dry Altithermal climate. In brief, could a slight rise in pine pollen at this locality signify drier rather than wetter conditions?

4. Stratigraphy at the original collecting site had been only casually considered. Would a detailed reexamination of the stratigraphy yield an alternative explanation for the age of the beds and would additional radiocarbon dating substantiate the earlier dates which indicated a late Altithermal age?

LOCALE

Murray Springs is located in a tributary arroyo to the San Pedro River in the San Pedro Valley, Cochise County, Arizona, 46 kilometers south of Benson and 2.7 kilometers west of Lewis Springs, at an elevation of 1260 meters (Martin, 1963, fig. 1). Above a small terrace cut by the stream, the vegetation is characterized by desert scrub elements, such as *Acacia vernicosa, Larrea divaricata, Flourensia cernua, Koeberlina spinosa,* and *Ephedra trifurca* (Lowe, 1964, figs. 3, 4, 5). On recent arroyo fill set within the older terrace, grasses such as *Muhlenbergia rigens* and *Sporobolus wrightii* occur in dense localized stands, and cottonwoods (*Populus fremontii*), willows (*Salix gooddingii*), *Rhus microphylla,* and mesquite (*Prosopis juliflora*) line the arroyo in the vicinity of the site and indicate a shallow water table. While water flows in the arroyo only after heavy rains, the sand in the arroyo floor at a point about 50 meters upstream from the site is damp throughout the driest months of the year.

DEPOSITIONAL HISTORY

A description of the stratigraphic units at pollen locality I is given in table 1. Photographs of the deposits are shown in plate 1, A and B.

The sand and gravel of unit A represent the coarse bed load of a former stream. The occurrence of rolled lumps of clayey peat in this channel fill (pl. 1-B) suggests that the coarse load was not transported very far and that it was buried by unit B soon after deposition.

The horizontal laminations of fine sand, silt, and clay and the abundance of cattail and sedge in the pollen analyses substantiate a shallow pond origin for units B, C, and D. Contacts between units B, C, and D are believed to be minor, but the sharp contact between units A and B suggests an abrupt change from a through-flowing stream to a pond. Antevs (1952, p. 381) has suggested beaver dams as the cause of this type of pond sediment accumulation in Arizona; however, this remains unproven.

Unit D is truncated by an erosional contact indicating desiccation and subaerial erosion before deposition of the sandy clay of unit E on a flood plain intermittently occupied by people of the Cochise culture. The contact between units E and F is obscure, but the stronger soil structure in E suggests that a hiatus of sufficient time to allow weathering of unit E is represented.

Units F and G indicate a repetition in the deposition of flood-plain alluvium similar to E but are less weathered. Unit H is an accumulation of slope wash sediments of the past 100 years or less and is widely represented in the southern San Pedro Valley. The erosion represented by the contact between G and H is minor, whereas the entrenchment of the present arroyo after unit H is a major event of Recent time and probably occurred early in this century.

RADIOCARBON DATING

For the lack of ideal materials, radiocarbon dating (table 2) of the Murray Springs section at pollen profile I was only partially successful, charcoal sample A-617 yielding what we regard as a reliable date. Previous experience has shown that fine grained sediments bearing indigenous organic matter can provide reasonably accurate results if (1) recent contaminants, such as rootlet fragments, are removed by re-

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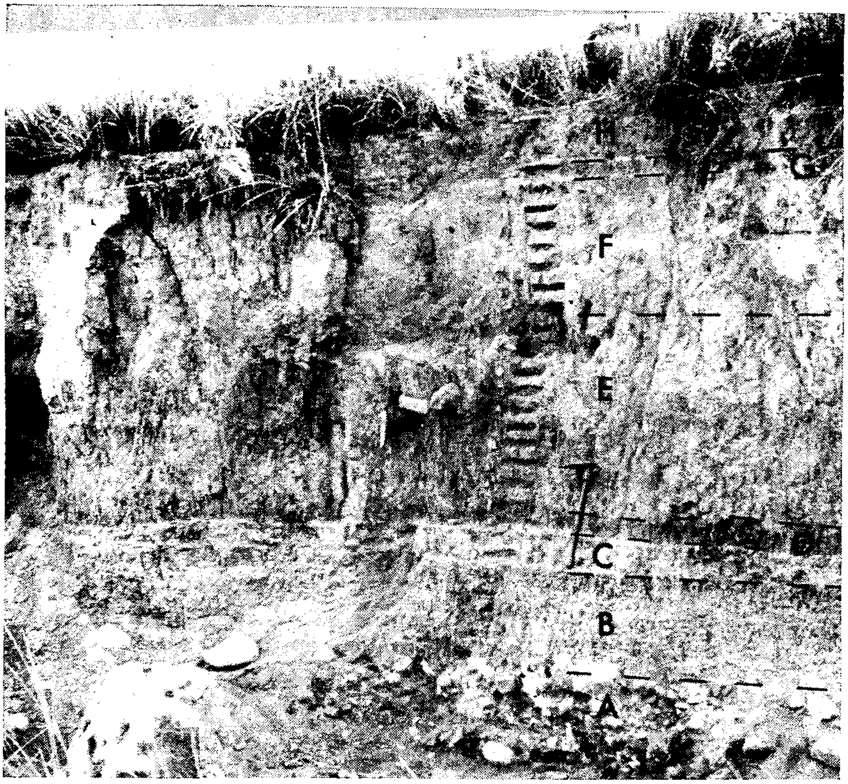
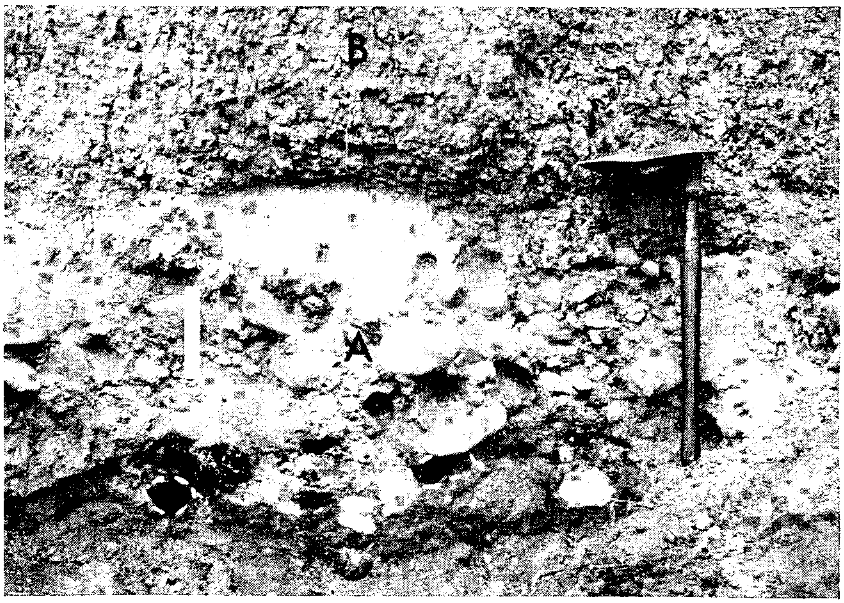
PLATE 1

A. The arroyo wall at Murray Springs pollen locality I, showing stratigraphy, location of pollen samples, and milling stones. Charcoal from directly beneath the milling stones in unit E was dated at 1550 ± 190 B.P.

B. The beds of the lower portion of Murray Springs pollen locality I, showing the lumps of organic clay (outlined), dated at 8270 ± 180 B.P.



A.



B.

TABLE I

Description of stratigraphic units

Unit	*Description*	*Maximum thickness (meters)*	*Accumulated thickness (meters)*
H	Sand—pale tan, finely laminated, soft, friable, silty sand with weak coarse prismatic structure. Caliche, grit, and small pebbles at the base. Upper surface is the tread of a 3.5-meter terrace.	0.28	0.28
G	Silt—red, weakly laminated, coarse, sandy silt with weak coarse blocky structure. A 2.5 centimeter thick gray clayey silt layer occurs above and below the red sand. Sharp erosional upper contact.	0.06	0.34
F	Silt—pale brownish-gray, soft, friable, poorly sorted, sandy, clayey silt with dispersed small pebbles and coarse sand grains. Medium to coarse, moderate prismatic structure. A 5.0 centimeter thick sand layer with dispersed grit and pebbles occurs at 30 centimeters below top of unit. Sharp upper contact.	0.71	1.05
E	Clay—brownish-gray, hard, sandy clay with dispersed grit and small caliche pebbles. Contains weak calcareous rootlet molds and strong medium prismatic structure breaking to angular. Charcoal, hearth, and Cochise milling stones occurred at about 1.5 meters below the surface. Obscure upper contact.	1.00	2.05
D	Clay—gray, hard, weakly laminated, sandy clay with dispersed grit and pebbles. Strong medium blocky structure with iron stains and calcium carbonate coatings of root molds and ped surfaces. Obscure upper contact becomes a sharp erosional contact 10 meters upstream.	0.10	2.15
C	Sand—tan, weakly laminated, silty fine sand with calcareous root molds and ped surfaces and moderate to weak, coarse blocky structure. Carbonaceous clay band near the top of the unit. Sharp depositional upper contact.	0.15	2.30
B	Clay—grayish-brown, hard, laminated, silty clay and clayey silt (pale brown) with numerous calcareous root molds; carbonaceous flecks; weak iron stains (1-4 mm); and strong medium, irregular blocky structure. Sharp depositional upper contact.	0.50	2.80
A	Sand and gravel—Loose sand and cobbles (channel fill?) with slump blocks of hard clay or sandy clay and rolled clayey peat lumps. Sharp uneven contact with unit B. Base of unit not observed.	1.00+	3.80+

peated flotation and decantation, and (2) organic residue and humate fractions yield dates in statistical agreement.

Samples A-186 (4120 ± 500) and A-187 (5280 ± 350), both silty clay of unit B, were cleaned of rootlets but not separated into residue and humate fractions during earlier attempts at dating (Damon, Long, and Sigalove, 1963, p. 292). A-580, A-696, and A-697 were collected in order to evaluate the dates on the basis of analyses on separate fractions. Only one of these (A-696) yielded sufficient carbon from both fractions, but the dates are not in statistical agreement. The date on humates could be correct or it could be contaminated by extraneous humic acids which are commonly derived from overlying soils and hence younger than the sample. But humic acids more ancient than the sample can be carried by ground water and absorbed by younger organic matter. Therefore, without other evidence, it is impossible to know whether the humate fractions are too young, too old, or the true age of the sediment.

Laboratory experience reveals that root contaminants have sufficiently less bulk density than indigenous carbonized plant remains and peptized humic acids and can be readily separated by the flotation and decantation treatments, and only a few hundredths of a percent of rootlet fragments are easily detected by the unaided eye while the sample is being handled. Even so, the treatment is not 100 percent efficient. While it can be assumed that dates on the organic residue are a minimum for the age of the sediment, they are probably not more than a few hundred years in error.

TABLE 2

Murray Springs pollen locality I radiocarbon dates (in stratigraphic order)

Number	*Material and description*	*Age (B.P.)*
A-617	Charcoal Charcoal from hearth in unit E, 1.55 meters below surface, under two Cochise milling stones, and between pollen samples 14 and 15.	1550 ± 90
A-186	Earth Silty clay from 2.1 meters below surface was combusted to yield CO_2 after washing and leaching with HCl.	4120 ± 500
A-697B	Humates Silty clay (unit B) containing decomposed plant remains washed to decant rootlets and pretreated to yield organic residue (A-697A, inadequate) and humate fractions. Sample equivalent to pollen sample 23 at 2.4 meters below surface.	4230 ± 290
A-696A	Organic residue	4340 ± 250
A-696B	Humates Silty clay (unit B) containing decomposed plant remains washed and treated to yield organic residue and humate fractions. Sample equivalent to pollen sample 26 at 2.7 meters below surface.	5890 ± 270
A-187	Earth Silty clay (unit B) from 2.7 meters below surface was combusted to yield CO_2 after washing and leaching with HCl.	5280 ± 350
A-580B	Humates Clayey peat occurring as discrete rounded lumps in channel gravel fill of unit A at the base of the section. These peat lumps are redeposited.	8270 ± 180

From this discussion, it is obvious that a definitive statement cannot be made as to the age of unit B. If the humate fractions are older than corresponding residue fractions, as suggested by A-696, then the residue fraction of A-697 would have dated less than 4230 B.P., which would suggest that A-186 is too old. By making a weighted average of A-696A and B, according to the proportion of carbon recovered, we find that a date of 4670 B.P. would have been obtained from the whole earth sample. The difference between this and the residue date is 330 years, which is a reasonable, if not high, estimate for error that might be expected due to younger organic matter in the residue.

Approximately 2 percent of the clayey peat (A-580) was carbon, almost all in the form of humates. Peat is mostly composed of humic acids so the date of 8270 B.P. is probably approximately correct for the time of formation of an organic mat upstream before erosion led to its disruption and redeposition in unit A. A buried organic mat, which could be the source of the peat lumps, is exposed in the arroyo wall approximately 100 meters upstream. This would also be a source of older humic acids which may be contaminating the carbon-14 samples from unit B. Because there are masses of this peat only a few centimeters below unit B (pl. 1-B), contamination by older humic acids is to be expected whenever the local water table stands above unit B.

If these interpretations are correct, then unit B was deposited between 4000 and 5000 years ago. From a geological point of view, a thousand years for the time the shallow pond sediments accumulated is probably too high, and it is more likely that the 40 centimeters of unit B were laid down in less than 500 years.

THE POLLEN DIAGRAM

The pollen types recovered are typical for southeastern Arizona pollen profiles and have been discussed previously (Martin, 1963; Hevly, Mehringer, and Yocum, 1965). Pollen was counted using double fixed sums (Mehringer and Haynes, 1965). The first count includes all pollen types and is represented by the solid portion of the diagram. The second count excludes cheno-ams and composites and is represented by the hatched portion of the diagram (fig. 1). The pollen profile has been broken where there is an erosional hiatus. At any such break, there is the probability of a time gap in the sediments (Mehringer, 1965, p. 179); to continue the pollen diagram across such a break without indicating this possibility can increase the danger of mis-

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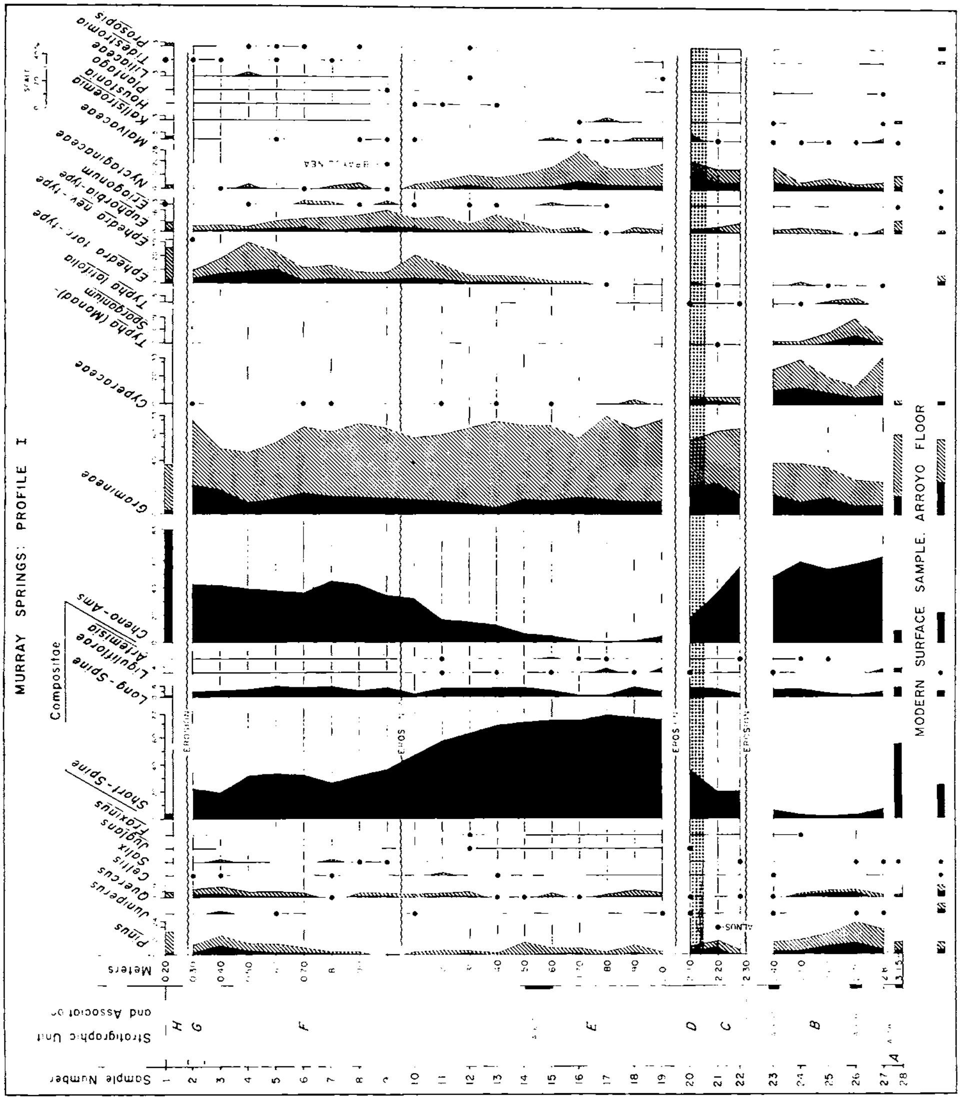
Fig. 1. Murray Springs pollen profile I. The solid portion of the pollen diagram represents the first count, which includes all pollen types. The lined portion indicates the second pollen count, excluding cheno-ams and composites. The dots (·) indicate 1 percent or less in the first count or less than 2 percent in the second count. Both counts are plotted to the same scale and are read from the zero percent line at the left. The first count is a 200-grain count. The second count is a 100-grain count with the exception of the surface sample and samples 23 through 27, which are 200-grain counts. Stippled zone indicates possible mixing of pollen across erosional contact.


MURRAY SPRINGS: PROFILE I
MODERN SURFACE SAMPLE, ARROYO FLOOR
Compositae
Prosopis
Malvaceae
Nyctaginaceae
Ephedra
Typha latifolia
Sparganium
Cyperaceae
Gramineae
Cheno-Ams
Artemisia
Liguliflorae
Long-Spine
Short-Spine
Fraxinus
Juglans
Salix
Celtis
Quercus
Juniperus
Pinus
Meters
Stratigraphic Unit
Sample Number

interpreting the record. The shading on the pollen diagram indicates the possibility of mixing of pollen from two different units across an erosional contact.

Unit B is characterized by the abundance of cheno-ams, Cyperaceae, *Typha,* and pine pollen. The mesic pollen types along with the geology of the deposit suggest ponding. Pollen preservation in unit B was unusually good for southwestern alluvial sediments. In units C and D there is change to short-spine composite dominance and a decrease in Cyperaceae. The site may still have been relatively mesic during the deposition of units C and D, but the decrease in Cyperaceae and *Typha* is indicative of drying conditions. It is possible that sample 20 (unit D) is contaminated with pollen from the base of unit E. Mixing of pollen within 10 centimeters of an erosional contact separating different stratigraphic units is a common occurrence at the Lehner Site (Mehringer, unpub. data).

In unit D the abundance of short-spine composite pollen may be compared with the modern soil surface samples from the cienegas of southeastern Arizona (Martin, 1963, fig. 13) and is indicative of a higher than present water table. Sample 28 (organic clay of unit A) is similar to pollen spectra of the composite dominated portion of unit D. The increase in *Ephedra* pollen, which is dated at about 1500 B.P., is comparable to the increased relative frequency of *Ephedra* encountered in pollen soil-surface transects from the desert grassland to desert scrub communities. In soil-surface samples from grass-dominated communities of southeastern Arizona *Ephedra* pollen usually accounts for less than 1 percent of the pollen even in the second count (exclusive of cheno-ams and composites). In the desert scrub communities, as in the San Pedro Valley at the Murray Springs locality, *Ephedra* pollen usually accounts for at least 3 to 5 percent of the pollen in the second count.

The pollen of Nyctaginaceae gradually decreases as the *Ephedra* increases. Most, if not all, of the Nyctaginaceae pollen is referable to *Boerhaavia.* In the pollen records from the Lehner Site, changes involving a decrease in Nyctaginaceae (mainly *Boerhaavia*) and an increase in *Ephedra* pollen are accompanied by a decrease in the relative frequency of grass and mesic species. The decrease in Nyctaginaceae and the increase in *Ephedra* pollen are probably the result of decreasing effective moisture. Samples 11 through 1 show a change from short-spine composite to cheno-am dominance and are within the range of variation that would be expected along arroyos in the desert scrub communities in the San Pedro Valley today. The increase in pine pollen in samples 6 through 1 is accompanied by high values of *Ephedra* pollen rather than by the pollen of mesic species as in unit B. At least 10 percent blown-in arboreal pollen is expected in the soil-surface samples of the present southwestern desert where local pollen production is low. The increase in arboreal pollen in samples 6 through 1 is indicative of decreased effective moisture and a reduction in local pollen production.

DISCUSSION

The lower portion of Schoenwetter's diagram was not recollected because of obvious redeposition. Otherwise, there is general agreement in the fluctuations of cheno-am, composite, and pine pollen between the first counts in our new diagram and the original one by Schoenwetter (Martin, 1963, p. 43). The differences in the pollen counts are minor and would require no change in the pollen units originally proposed at this site. The main source of new information comes from the second count. In it grass is the dominant pollen type, and the record of the less abundant types is magnified.

The interpretation of arboreal pollen counts, especially pine, in the alluvial profiles of southeastern Arizona is in part dependent upon other pollen types accompanying the pine. In the soil surface samples from grassland communities (Lowe, 1964, figs. 23, 30), the pine pollen values are lower than in those from the desert. Even though the grassland communities are closer to the source of pine pollen, the local pollen production is higher, and therefore there is a lower relative frequency of pine pollen from long-distance transport. In the sparser vegetation of the deserts there is less local pollen production and the relative frequency of blown-in pine pollen is greater.

In the modern surface samples from desert scrub vegetation of the San Pedro Valley the higher pine values are accompanied by the presence of *Ephedra* pollen, a type that is rare in southern Arizona grassland surface samples. Applying this observation to fossil pollen spectra

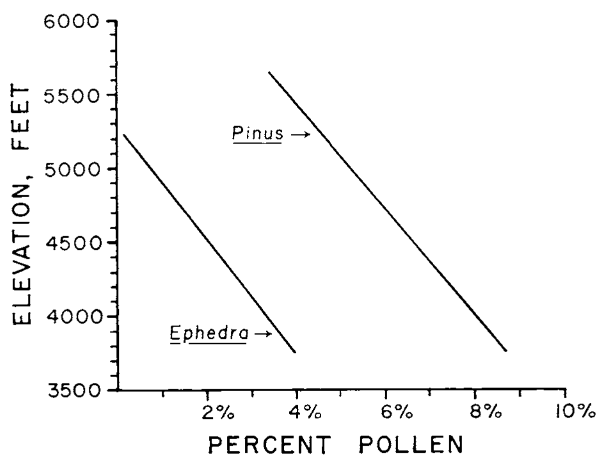


Fig. 2. Regression lines for soil-surface pollen percentages plotted against elevation and based on 100-grain pollen counts exclusive of cheno-ams, composites, and grasses. The data are from 42 soil-surface samples collected between 3750 and 5650 feet from the desert scrub, grassland, and oak grassland of southeastern Arizona. Pine pollen again becomes increasingly abundant above 5500 to 6000 feet. A statistical treatment of southeastern Arizona soil-surface samples from which these data were taken is in preparation (Mehringer, Adam, and Martin, in preparation).

from the San Pedro Valley, 4 percent pine with little or no *Ephedra* pollen indicates more effective moisture and a grassland vegetation whereas spectra with 10 percent pine pollen and 3 percent or more *Ephedra* would indicate desert scrub vegetation (fig. 2). These differences are not always apparent in the first pollen count, but they become more obvious in the second.

When high pine frequencies are accompanied by aquatic indicators and *Ephedra* pollen is rare, we assume that there has been an increase in the production of pine pollen relative to the local pollen production. If there were no absolute increase in pine pollen, one would expect the relative frequency of pine pollen to decrease because of the increase in local plant cover and local pollen production due to a locally higher water table or ponding. Therefore, it is assumed that the *Typha* and Cyperaceae pollen plus the higher pine frequencies in unit B represent a change in the regional upland vegetation as well as the local flood-plain community. This change could involve either an expansion of pine communities in the surrounding ranges or an increase in production of pollen by existing trees. Increased effective moisture seems probable in any case.

With these stratigraphic studies and new radiocarbon dates, the age of the Murray Springs deposit has been verified within the limits of the potentials of the material dated. The new dates substantiate Martin's original conclusion for the age of unit B of the Murray Springs deposits. The Lehner Site (Mehringer and Haynes, 1965; Mehringer, unpub. data), studied in more detail than any of the other alluvial deposits in southern Arizona, has not yielded pollen-bearing sediments of equivalent age.

SUMMARY

The main reason for returning to the Murray Springs locality was to verify the evidence for a relatively moist period in southeastern Arizona about 4000 to 5000 radiocarbon years ago. Because of the presence of *Typha* and Cyperaceae pollen in unit B, we are confident that during this time period there was ponding at the Murray Springs locality and presumably greater local pollen production. The high frequencies of pine pollen are difficult to explain without inferring greatly increased absolute pine pollen production, brought about by a regional climatic shift to more effective moisture. The pollen evidence indicates that there was an areal expansion of the grassland and woodland communities in the upper San Pedro Valley. A downward displacement of the present vegetation zones by about 300 meters seems sufficient to explain the pollen record from unit B. The southern Arizona pollen record between 5000 and 7000 radiocarbon years ago remains unknown as critically dated exposures of pollen bearing sediments of this age have yet to be discovered.

References

Antevs, E. V., 1952, Arroyo-cutting and filling: Jour. Geology, v. 60, p. 375-385.

——— 1955, Geologic-climatic dating in the West: Am. Antiquity, v. 20, p. 317-335.

Damon, P. E., Long, Austin, and Sigalove, J. J., 1963, Arizona radiocarbon dates IV: Radiocarbon, v. 5, p. 283-301.

Graham, Alan, and Heimsch, C. W., 1960, Pollen studies of some Texas peat deposits: Ecology, v. 41, p. 751-763.

Hansen, H. P., 1951, Pollen analysis of peat sections from near the Finley site, Wyoming, *in* Moss, J. H., and others, Early Man in the Eden Valley: Univ. Pennsylvania Mus. Mon., p. 111-118.

Hevly, R. H., Mehringer, P. J., Jr., and Yocum, H. G., 1965, Modern pollen rain in the Sonoran Desert: Arizona Acad. Sci. Jour., v. 3, p. 123-135.

Lowe, C. H., ed., 1964, The vertebrates of Arizona: Tucson, Arizona, Univ. Arizona Press, 259 p.

Maher, L. J., Jr., ms, 1961, Pollen analysis and postglacial vegetation history in the Animas Valley region, southern San Juan Mountains, Colorado: Ph.D. thesis, Univ. Minnesota, 85 p.

Martin, P. S., 1963, The last 10,000 years, a fossil pollen record of the American Southwest: Tucson, Arizona, Univ. Arizona Press, 87 p.

Mehringer, P. J., Jr., 1965, Late Pleistocene vegetation in the Mojave Desert of southern Nevada: Arizona Acad. Sci. Jour., v. 3, p. 172-188.

——— in press, Pollen analysis of the Tule Springs site area, Nevada, *in* Wormington, Marie, ed., Pleistocene studies in southern Nevada: Carson City, Nevada, Nevada State Museum.

Mehringer, P. J., Jr., and Haynes, C. V., Jr., 1965, The pollen evidence for the environment of Early Man and extinct mammals at the Lehner mammoth site, southeastern Arizona: Am. Antiquity, v. 31, p. 17-23.

Pennak, R. W., 1963, Ecological and radiocarbon correlations in some Colorado mountain lake and bog deposits: Ecology, v. 44, p. 1-5.

Sears, P. B., and Roosma, Aino, 1961, A climatic sequence from two Nevada caves: Am. Jour. Sci., v. 259, p. 669-678.