POLLEN AND OTHER MICROFOSSILS IN PLEISTOCENE SPELEOTHEMS, KARTCHNER CAVERNS, ARIZONA

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Pollen and other microfossils have been recovered from six carbonate speleothems in three Kartchner Caverns rooms: Grand Central Station (samples T2, T3, T4), the Bathtub Room (T11, T12), and Granite Dells (T16). The carbonate samples were dated from 194-76 Ka. The pollen concentration is greatest (~2 grain/cm³) in sample T11, which has many layers of clastic sediment, and the concentration is least in T4 (~0.05 grain/cm³), which has few mud layers. Therefore, the pollen was probably present in sediments washed into the cave, perhaps during floods. Although the pollen abundance in sample T4 is too low for confident interpretation, modern analogs for the five other samples can be found on the Colorado Plateau in areas that today are wetter and colder than the Kartchner Caverns locality. Agave pollen in samples T2 and T4 indicates that this important source of nectar was in the area during at least the latter part of the Pleistocene. Two orobatid mite exoskeletons recovered in speleothem T4 were probably washed into the cave with the pollen and mud trapped in the speleothems.

Kartchner Caverns is at ~1400 m msl on the eastern slope of the Whetstone Mountains in Cochise County, Arizona. Six speleothem samples for pollen analysis were selected from the samples dated by Derek Ford at McMaster University using uranium-series techniques (Hill 1992; Ford & Hill 1999). The samples were from three locations in the cave (Fig. 1): Grand Central Station (sample T2, T3, T4), the Bathtub Room (T11, T12), and Granite Dells (T16).

The vegetation near the cave is desert grassland with abundant mesquite (*Prosopis juliflora*) and yucca (*Yucca elata*). The cave entrance is near an intermittent stream with woody riparian vegetation including mesquite, hackberry (*Celtis reticulata*), and acacia (*Acacia* spp.). The mean monthly temperature at nearby Benson, Arizona, is 17.1° C and the average annual precipitation is 290 mm, over half falling during July and August (Sellers & Hill 1974).

METHODS

A large fragment of each speleothem sample was crushed, and pollen was extracted from 60 cm³ of the cleaned pea-sized fragments (Table 1.) Low pollen content of the Kartchner Caverns speleothems necessitated the large sample size. Pollen samples from lakes, cienegas, or packrat middens contain tens of thousands of pollen grains per cm³ of sediment. In contrast, the entire 60 cm³ speleothem samples usually contained <100 pollen grains.

RESULTS AND DISCUSSION

SOURCE OF POLLEN

The concentration of pollen in the speleothems is 2 grains/cm³ or less (Table 2). In contrast, the pollen concentration in sediment from Saint David Cienega, ~10 kilometers to the southeast and in similar vegetation, is 17,000 - 20,000 grains/cm³ (Davis 1994). Such low concentrations in the speleothems indicate that pollen was transported into the cave in much lower abundance than it occurred at the surface.

Brook *et al.* (1990) have reported good concentration of pollen (~1000 grains/cm³) in African cave deposits. They infer an airborne source for pollen in speleothems located near cave entrances. The much lower concentrations of pollen in the Kartchner Caverns speleothems probably reflects a different pollen transport mechanism. The pollen concentration is greatest (up to 2 grains/cm³) in T11 and T12, which have many layers of sediment (mud inclusions), and the concentration is least in T4 (~0.05 grains/cm³), which has few mud inclusions. T11 and T12 are from the Bathtub Room, near a submerged conduit for water coming into the cave. This avenue may have been the source of pollen and sediment to those speleothems. All samples are in rooms far from the modern natural cave entrance.

This study suggests that flowing water washed the pollen along with mud into the cave where the growing speleothems

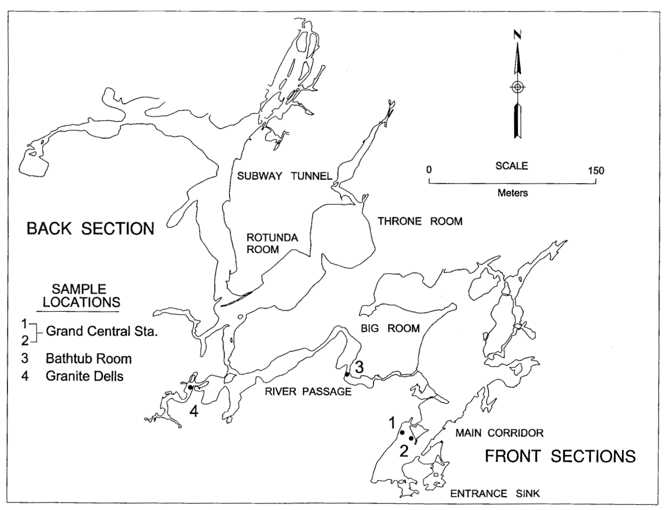

Figure 1. Map of Kartchner Caverns showing location of samples taken for pollen analysis.

Table 1. Pollen extraction procedure.

a. Speleothem sample crushed into pea-sized fragments.
b. Fragments washed over 250 µm screen and rinsed thoroughly to remove smaller fragments and pollen contaminants
c. 60 cm³ of speleothem fragments placed in Nalgene® beakers and covered with dilute HCl. Concentrated HCl added periodically until speleothem fragments completely dissolved (~3 weeks).
d. Residue transfer to 50 ml Nalgene® test tubes and centrifuged.
e. 40 ml HF overnight and 1 hr in boiling water bath centrifuge, decant, water rinse, transfer to 15 ml centrifuge tubes.
f. Acetolysis*
g. 10 ml 10% KOH 2 minutes in boiling water bath centrifuge, decant, rinse with hot water until clear.
h. Stained with safranin "O".
i. Transferred to labeled 1 dram shell vials.
j. Few drops of glycerin added, mixed thoroughly, desiccated over anhydrous clay.

*ACETOLYSIS
a. 5 ml glacial acetic acid centrifuge and decant.
b. Stir sample, add 5 ml acetic anhydride (volumetric dispenser)
c. Add 0.55 ml H_2SO_4 to acetic anhydride solution (volumetric pipet), mix centrifuge, decant into glacial acetic acid.
d. 5 ml glacial acetic acid centrifuge and decant.

incorporated it. This interpretation is supported by the relatively high percentages of pollen from streamside plants (*Populus*, Cyperaceae, and *Urtica*) within the speleothems (Table 2 & Fig. 2). The abundance of poorly preserved pollen and fungal spores, which are characteristic of soil horizons that could have been eroded from nearby uplands and washed into the cave, also supports the hypothesis.

AGE OF POLLEN SAMPLES

The uranium-series radiometric ages of the speleothems analyzed for pollen range from 194 ± 50 to 78 ± 8 Ka (Ford & Hill 1999; Table 2). This age spans the Illinoian glaciation, the Sangamon interglacial, and the beginning of the Wisconsin glaciation. The age of individual speleothems (T3, T4, & T11) span tens of thousands of years, and the position of the pollen within these speleothems is unknown. Thus, the exact age of the pollen sample is undetermined. The sequence shown in Figure 2 is based on the median age of speleothems with multiple dates.

ENVIRONMENTAL INTERPRETATION

Sample T4 has too little pollen to confidently interpret, but the other 5 samples are similar in composition to the pollen rain found in the area today (Davis 1995; Hevly & Martin 1961). The percentages of some herbs (Gramineae, Chenopodiaceae-*Amaranthus*, Compositae, and *Ambrosia*) are lower than in modern vegetation, whereas the percentages of trees (*Quercus* and *Cupressaceae*) and sagebrush (*Artemisia*) are higher. Mesquite (*Prosopis*), which currently dominates the vegetation near the cave, is absent. The winter precipitation indicator *Plantago* is present in sample T3, but summer precipitation indicators like *Boerhaavia*, *Kallstroemia*, and *Euphorbia* are absent (Table 2; Fig. 2). Overall, the pollen assemblage indicates more trees than in the modern vegetation, possibly due to greater precipitation and lower temperature

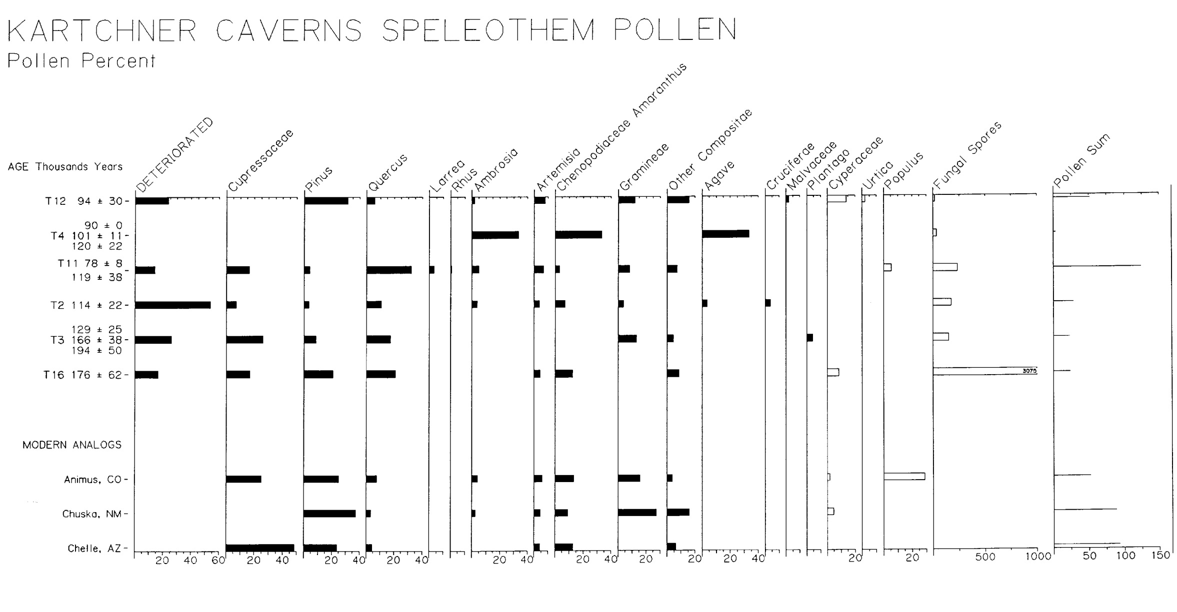

Figure 2. Percentage pollen diagram of the Kartchner Caverns pollen samples (upper) and 3 modern analogs from the Colorado Plateau: Animus, Colorado (Maher 1963), Chuska, New Mexico (Bent & Wright 1963), and Chelle, Arizona (Fall 1987).

Table 2. Percentages of pollen and spores form Kartchner Caverns speleothems. Speleothem labels and ages are from Hill (1992).

SAMPLE	1	2	3	4	5	6
SPELEOTHEM	T2	T3	T4	T11	T12	T16
U-Series Age (Ka)	114±22	129±25 166±38 194±50	90±0 101±11 120±22	78±8 119±38	94±30	176±62
SUM	28	23	3	124	51	24
DETERIORATED	53.6	26.1	0.0	13.7	23.5	16.7
Pinus	3.6	8.7	0.0	4.0	31.4	20.8
Cupressaceae	7.1	26.1	0.0	16.1	0.0	16.7
Quercus	10.7	17.4	0.0	32.3	5.9	20.8
Larrea	0.0	0.0	0.0	3.2	0.0	0.0
Rhus	0.0	0.0	0.0	0.8	0.0	0.0
Ambrosia	3.6	0.0	33.3	4.8	2.0	0.0
Artemisia	3.6	0.0	0.0	6.5	7.8	4.2
Other Compositae	0.0	4.3	0.0	7.3	15.7	8.3
Gramineae	3.6	13.0	0.0	8.1	11.8	0.0
Cheno-Am	7.1	0.0	33.3	3.2	0.0	12.5
Agave	3.6	0.0	33.3	0.0	0.0	0.0
Cruciferae	3.6	0.0	0.0	0.0	0.0	0.0
Malvaceae	0.0	0.0	0.0	0.0	2.0	0.0
Plantago	0.0	4.3	0.0	0.0	0.0	0.0
Populus	0.0	0.0	0.0	5.6	0.0	0.0
Cyperaceae	0.0	0.0	0.0	0.0	13.7	8.3
Urtica	0.0	0.0	0.0	0.0	2.0	0.0
Fungal Spores	175.0	147.8	33.3	236.3	17.6	3075.0

when the samples were deposited 194-75 Ka (Fig. 2).

A numerical comparison between the Kartchner Caverns samples and modern pollen samples in the western United States used the squared chord distance (scd) statistic (Overpeck 1985). Close modern analogs (scd < 0.14) for the speleothem pollen samples were found on the Colorado Plateau. These modern samples are shown in the lower portion of Figure 2. The climate where the modern samples were collected is wetter (300-900 mm/yr *v.* 290 mm/yr) with a much colder mean annual temperature (6-10°C *v.* 17°C) than at Kartchner Caverns today.

Low pollen concentration of the speleothem pollen samples makes this climatic interpretation tentative. Also, the original pollen assemblage may have been altered by water transport into the cave. The modern analogs shown in Figure 2 all have a squared chord distance of <0.15, which is considered a close match (Overpeck 1985). However, the higher percentage of oak (*Quercus*) than in any of the analog samples (Fig. 2) and the two *Agave* grains suggest less than the 10°C cooling indicated by the Colorado Plateau analogs.

AGAVE POLLEN

An important feature of the modern ecology of Kartchner Caverns is the presence of a nesting colony of bats (Buecher & Sidner 1999). Two samples (T2 & T4) each contain single grains of *Agave* pollen, thus confirming that this important source of nectar for the bats was present in the past when the speleothems were deposited (~194-76 Ka).

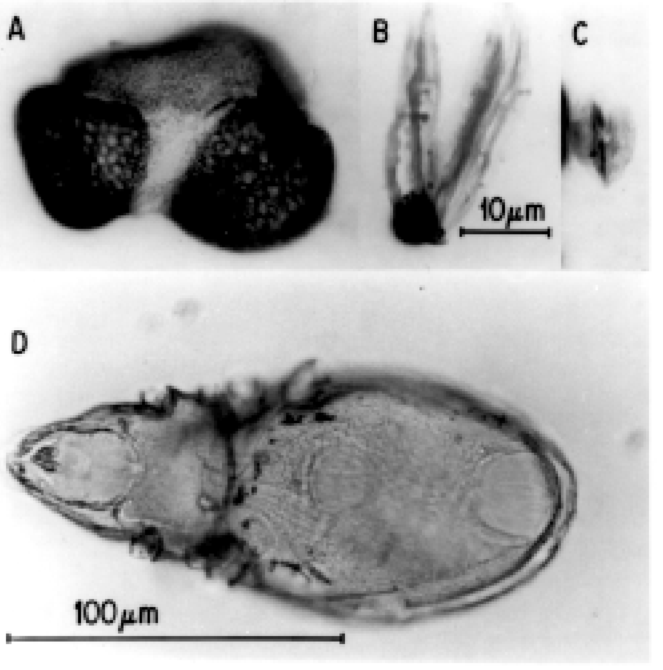

Figure 3. Photomicrographs of Kartchner Caverns microfossils. A. Pine (*Pinus*) pollen from sample T12. B. Deteriorated joint fir (*Ephedra*) pollen from sample T12. C. Creosote bush (*Larrea*) pollen from T11. D. Orobatid mite from sample T4. Magnification of A, B, and C, use upper scale (10 µm); D use lower scale (100 µm).

OROBATID MITES

Two exoskeletons of orobatid mites were recovered in sample T4 (Fig. 3). Although living mites have been photographed on modern speleothems (Welbourn 1999), this is the first report of a fossil occurrence of these organisms in speleothems. They are common as fossils in some archeological samples, but their paleoecological significance is uncertain (Davis & Buchmann 1994).

CONCLUSIONS

Pollen is present in low numbers in six speleothems at Kartchner Caverns, probably because it was washed into the cave from the surface. Modern analogs for the fossil pollen percentages can be found today on the Colorado Plateau, where the mean annual temperature is 10°C cooler than at Kartchner Caverns State Park. However, the climate from 194-76 Ka was not too cool for *Agave*, whose pollen is present in two samples.

ACKNOWLEDGMENTS

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