INTRODUCTION

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Bonnie Fine Jacobs, Pat Fall, and Owen K. Davis have collected and edited 11 new articles on fossil pollen from the southwestern U.S.A. Still very much a frontier for historical ecologists, this region is famous for its many climates, from the winter gales blasting alpine glaciers in the central Rockies to the fierce heat of summer baking creosote bushes in Death Valley. When long, gray fronts roll south across the Mojave in winter, or summer thunderheads soar above the desert mountains of Arizona and New Mexico, it may rain. More expectable is dry air, dry weather, and a temperature range of 40 to 50°F between the early morning low and the mid-afternoon high.

With or without aridity, extremes of relief guarantee extremes of climate and a great variety of plant communities. North of the Mexican border, Brown and Lowe map 21 major biotic communities in the region south of 38° and west of 103°. For the Santa Catalina Mountains in southern Arizona, Whittaker and Niering (*Ecology*, 1965, 65:436) recognized 10 community types and a maximum of species diversity compared with other mountains they had studied.

Historical ecologists need a different concept, an index of species turnover with time, which certainly was greater for most of the world during the Quaternary than during the Tertiary. It remains to be seen whether Ice Age biotic change was greater in the Southwest than in the East. In the absence of many fossils, the desert and its vegetation was once believed to have been quite stable, a notion challenged by pollen analysis, then put to rout by the peculiar technique of fossil packrat midden analysis pioneered 25 years ago by Wells and Jorgensen (*Science*, 1964, 143:1171).

The study of fossil packrat middens captured the interest of a new group of Quaternary ecologists; many more discoveries can be expected as the midden method is refined. Would the packrat middens themselves yield high quality fossil pollen? Yes, indeed, as far as pollen preservation goes. Interpretation of the counts from fossil packrat middens, however, is less satisfactory. Here Thompson reports that intersample variability may be high, as in those cases in which the packrats are suspected of adding flowering branches to their middens. More often than in the case of fossil pollen, the midden macrofossils are identifiable to species. Now with the aid of TAMS (tandem accelerator mass spectrometer) technology, individual plant fragments may be dated to resolve matters of contemporaneity. The packrat midden revolution is having an inevitable effect on palynologists of the arid west.

"If you could start your research again, wouldn't you switch to fossil midden analysis?" Jacobs was asked at

her dissertation defense. Jacobs' pollen profile from Hay Lake on the Mogollon Rim of Arizona held one answer, along with others to be found elsewhere in this book. In the moist mountain environments where middens rapidly rot, there is no substitute for the fossil pollen cored from the muddy bottoms of natural lakes. With over five meters of sediment radiocarbon dated beyond 37,000 years, Jacobs had no need for regrets. By careful examination and measurement of the morphological variations found in the best preserved pine pollen grains, she concluded that some came from *Pinus aristata* (foxtail pine), a modern relict on Humphries Peak outside Flagstaff, Arizona. Apparently the tree had entered the state from the southern Rockies to establish itself with the full glacial refuge of high-elevation pines and spruces along the Colorado Plateau of Arizona and New Mexico.

This view is supported by Hevly's lengthy record from Walker Lake. The site outside Flagstaff is now surrounded by *Pinus ponderosa* (ponderosa pine). During the last glaciation, it was a spruce or spruce-pine refugium.

Perhaps the first hint of the major change to be found in the Ice Age pollen record of the Southwest came from Roger Anderson's analysis of Kaetan Cave in the inner gorge of the Grand Canyon. At a depth of only 12 inches, abundant pollen of *Abies* (fir) and *Picea* (spruce) appeared (Schwartz *et al.*, *American Antiguity*, 1958, 23:267). To learn more about the remarkable inner gorge caves, O'Rourke and Mead studied several, including Kaetan. There the pollen is beautifully preserved, although infilling was very slow. One shrinks from thinking of sedimentation "rates" when a surface of Kaetan Cave was radiocarbon dated at 14,000 yr B.P.! Spruce was then more widespread at higher elevations in the Grand Canyon, in accord with Jacobs' and Hevly's findings for the region, and *Artemisia* (sagebrush) was more abundant, suggesting Great Basin influence.

Below the Colorado Plateau lakes are scarce. Pecks Lake, an oxbow of the Verde River, is nestled at the edge of the desert beneath the historic mining town of Jerome, Arizona. In a western Washington lake, Davis had detected the effects of sheep grazing, including the rise of the coprophilous fungus, *Sporomiella*. Collaborating with Hevly and Frost, he found the expected signature of *Sporomiella*, along with a rise in *Juniperus* (juniper), a weed tree to cows and ranchers. The new technique of TAMS dating also helped by showing that plant macrofossils from Pecks Lake were 1000 years younger than standard dates on lake muds. Apparently, erosion had dislodged old carbon from the soil and artificially "antiqued" the rapidly accumulating historic lake sediments, as Flenly and King recently found under similar circumstances following human arrival on Easter Island (*Nature*, 1984, 307:47).

In the busy corridor between Tucson and Phoenix, Fish undertook the analysis of soil samples for salvage archaeologists. Disturbance pollen showed up in quantity, as one might expect in flood plains cultivated 900 years ago by the ancient ones, the Hohokam. Fish also sampled rocky terraces of steep hills above the flood plain where no modern farmer would dream of operating a tractor and where few archaeologists had bothered to dig. In fine soils lodged behind rock terraces, she found more disturbance in the form of high percentages of weedy herb pollen (*Tidestromia*, *Boerhaavia* [spiderling], and Chenopodiaceae-*Amaranthus* [Cheno-ams]). The result was dis-

turbing indeed, since one of her study sites was the very ground of Tumamoc Hill where desert ecology had had its beginnings (and where many chapter authors have or have had their laboratories). Turn-of-the-century botanists had selected the Tumamoc Hill site in part for the natural condition of its *Cercidium-Cereus* (palo verde-saguaro) Sonoran Desert plant community. Thanks to the evidence provided by fossil pollen, it seems that some of the "natural" desert vegetation must be more invasive than had been recognized.

Other clues to prehistoric activity emerged in the southern Colorado Plateau and Great Basin where archaeologists dig in dry caves that were formerly the domain of prehistoric hunting and gathering peoples. Ethnographers report that pinyon nuts were a major food source for the Paiute and Shoshone. Pollen analysts are increasingly alert to methods for distinguishing pinyons from the other pines. In the central Great Basin, Madsen reported pinyon as early as 6000 years ago. In southwestern Colorado, Petersen noted its arrival in abundance only after 3500 years ago, rather late, it would seem, in view of Jacobs' records throughout the late Pleistocene not far south in central Arizona and Betancourt and Van Devender's 8300 yr B.P. midden records from Chaco Canyon, New Mexico (*Science*, 1981, 214:656-658). Middle to late Holocene arrival is noted in pollen and packrat midden records of pinyon throughout Colorado.

All this might be passed over as a classic case of delayed migration to match Margaret Davis' records of chestnut and hickory in the eastern U.S. (*Ann. Missouri Bot. Gard.*, 1983, 70:557), if it were not for the new Holocene pollen records provided for the central Rockies by Fall and Short. They have sampled lakes above 3000 m, above the local range of pinyon. Their Holocene profiles suggest warming to at least 4500 yr B.P. or later, followed by cooler climates and a retreat of tree line. Fall concludes, "Neoglacial cooling and drying (ca. 4000 to 3000 yr B.P.) constricted the subalpine forest at both its upper and lower elevations." It would seem that by waiting out the first half of the Holocene, pinyon was surprisingly tardy in attaining its present Colorado range. Did prehistoric people have more to do with the late Holocene spread of pinyon than either climate or pinyon jays?

There is more. Even the pristine high-elevation forests of the West may not have been entirely safe from prehistoric impact. Anderson and his co-workers' Balsam Meadow pollen record from central California includes an increase in charcoal, suggesting increased burning ("fire stick farming") in the pine forests of the late Holocene. Were anthropogenic fires as important as climate in constricting the treeline?

Further clues to these and other matters of interest to ecologists are emerging from the subalpine lakes and bogs above the desert rim where the Pleistocene pollen analysts find the richest opportunity to practice their craft. Even within the desert proper, there is much more opportunity for pollen analysis than has been thought. One result is the waning of classical biogeography. The ranges of modern animals and plants no longer must bear the burden of all our thoughts on the last Ice Age and its aftermath. When Ed Deevey wrote his seminal "Biogeography of the Pleistocene" (*Bulletin of the Geological Society of America*, 1949, 60: 1315-1416), he correctly inferred dynamic changes in the Ice Age biota of western North America largely on the basis of relict distributions in Great Basin fish and from chromosome

inversions in fruit flies. Such indirect methods, no matter how inventive, have been forced into the wings and the stage is filling with radiocarbon-dated fossils!