LATE HOLOCENE PLANTS, CATAVIÑA, BAJA CALIFORNIA

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ABSTRACT—Thirty-six plant taxa were identified from macrofossils and pollen in a late Holocene (1,770 years B.P.) woodrat (*Neotoma*) midden from a granite boulder field near Cataviña, Baja California, Mexico. The fossils document the presence of Sonoran Desert (Viscaino subdivision) vegetation and a relatively modern climatic regime in the late Holocene. However, abundances and distributions of plants were different from today. Excluding rare *Pinus* pollen (long distance transport), only about 51% of the midden plants still occur within 100 m of the site. Another 8 species have moved into the area. Apparently, greater moisture allowed soil development on boulders and the expansion of plants, especially *Prosopis glandulosa,* away from the mesic washes. The modern climate is drier than 1,770 years ago.

RESUMEN—Treinta y seis taxa de plantas fueron identificados de macrofósiles y polen de un déposito de *Neotoma* proveniente de peñas de granito cerca de Cataviña, Baja California, México. Los fósiles documentan la presencia de vegetación del Desierto Sonorense (Subdivisión Viscaino) y un régimen de clima relativamente moderno en el Holoceno tardío. Sin embargo, la abundancia y distribución de las plantas estaban diferentes del tiempo presente. Excluyendo el polen raro de *Pinus* (transportado de una distancia larga), solamente cerca del 51% de las plantas del depósito de *Neotoma* continuan encontrándose dentro de 100 m del sitio. Otras 8 especies se han movido dentro del área. Aparentemente una humedad mas grande permitió el desarrollo de suelo en las peñas y la expansión de las plantas, especialmente *Prosopis glandulosa,* afuera de los arroyos mésicos. La clima modernos son más secos que hace 1,770 años.

Quaternary woodrat (*Neotoma*) middens often are preserved in dry rockshelters and caves in deserts, and contain remains of plants, invertebrates, and vertebrates that are useful in reconstructing past environments and climates. Middens have been collected and analyzed from numerous localities, especially in the southwestern United States (Betancourt et al., 1990). The 21 living species of *Neotoma* range from northern Canada to Nicaragua, and live in many climates and habitats. Most *Neotoma* species construct houses with enclosed nests, but the type of construction varies with species. Houses are made of sticks, plant fragments, and even dung and bones, and provide shelter, protection against temperature extremes, and especially in deserts, protection from water loss (Vaughan, 1990). Most plant species (62 to 86%) found in these structures grow within an area of 30 to 50 m (Finley, 1990). The desert woodrat (*Neotoma lepida*) lives in the Cataviña area today (Huey, 1964; Hall, 1981; Clark and Sankey, 1999). Although packrat middens may not be unbiased samples of a plant community, they still provide useful information about the past (Vaughan, 1990). Relative abundance of plant species in middens reflect abundance of plants in the local vegetation through the woodrats' dietary biases, which should be similar through time (Van Devender, 1990). Only a few middens from Baja California have been analyzed for this interesting area (Wells, 1976, 1986; Lanner and Van Devender, 1998; Peñalba and Van Devender, 1998). Here we report on a midden that was collected near Cataviña.

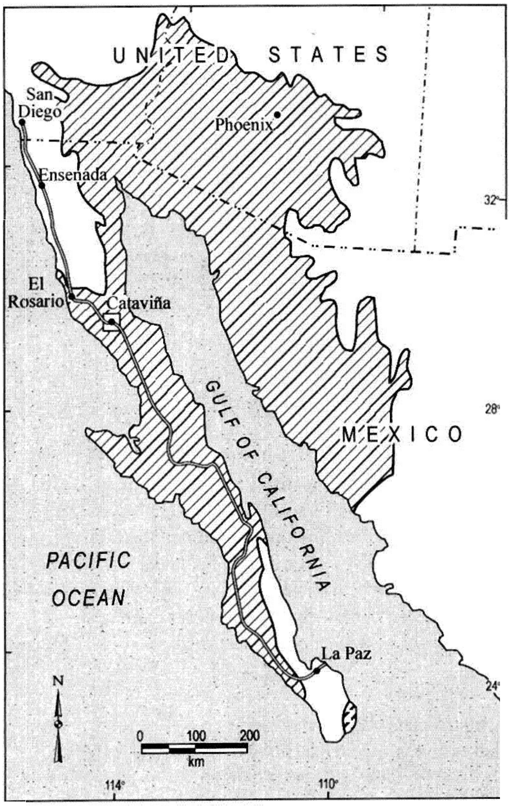

FIG. 1—Map of the peninsula of Baja California, Mexico showing general location of the Cataviña region (square) and an outline of the Sonoran Desert (cross-hatched, after Turner and Brown, 1994).

In Mexico, the Sonoran Desert occurs around the upper two thirds of the Gulf of California, from the lower Colorado River Valley southward to the tip of Baja California, and southward through Sonora, as far south as Guaymas (Fig. 1; Turner and Brown, 1994). The Sonoran Desert is divided into 6 regions, based on differences in vegetation. Cataviña is in the Viscaino subdivision, Baja California (Turner and Brown, 1982). The Viscaino is the second most arid region, receiving average annual precipitation of 49 to 194 mm (Turner and Brown, 1994). Succulent plants such as cardón cactus (*Pachycereus pringlei*), *Agave*, *Yucca valida*, and *Dudleya* dominate the Viscaino. Other common plants are the boojum tree (*Fouquieria columnaris*), elephant tree (*Pachycormus discolor*), goatnut (*Viscainoa geniculata*), and ocotillo (*Fouquieria splendens*; Shreve and Wiggins, 1964).

During the 1.8 million years of the Pleistocene, there were 15 to 20 glacial/interglacial cycles (Imbrie and Imbrie, 1979). Ice age climates with woodland and chaparral in desert lowlands typical of ca. 12,000 years ago persisted for 80 to 90% of this period (Porter, 1989; Winograd et al., 1997). For example, singleleaf pinyon (*Pinus monophylla*) and California juniper (*Juniperus californica*) in a series of 5 middens dated at 30,950 to 11,190 years B.P. from limestone near Misión San Fernando velicata and Parry pinyon (*P. juarezensis*) at nearly 18,000 years old from the granite boulders near Cataviña (Wells, 1986) were growing in areas that are now dominated by boojum tree and cardón. During the warmer, drier interglacial periods, ranges of woodland and chaparral plants such as juniper contracted northward and to higher elevations as they retreated from the deserts (Van Devender, 1990). Relatively modern desertscrub communities were developed for only about 5 to 10% of the Pleistocene. Range expansions and contractions of plants recorded in middens may help explain their present distributions. For example, the boojum presently occurs in 2 disjunct areas, in the Viscaino subdivision of Baja California and on the west coast of Sonora. When did they reach these areas? Were they previously more widely distributed? Here we report the plants in a late Holocene midden from Baja California and compare them to present-day vegetation at the same locality.

MATERIALS AND METHODS—The midden reported here (Cataviña midden #3) was collected in January 1989 from the Cataviña Research Site, a 20 year-old ecology field area for Albertson College of Idaho's (ALBRCIDA) Biology Department and Orma J. Smith Museum of Natural History. The midden was located in an extensive Cretaceous granitic (tonolite) boulder field of the Jaraquay block (Gastil et al., 1975) at a site 9 km northwest of Rancho Santa Inés (29°46′N, 114°46′W, elevation 550 m). The area contains plants, arthropods, and vertebrates typical of the Viscaino subdivision of the Sonoran Desert (Bratz, 1976; Blom and Bratz, 1976; Farley and Clark, 1976; Blom and Clark, 1984; Yensen and Clark, 1986). Average annual rainfall for the Cataviña site was 96 mm for the past 15 years. Average annual temperature is 18.4°C (June to September: 24.5°C and December to March: 13°C; Hastings and Humphrey, 1969). The extensive boulder field in the Cataviña area is ideal for woodrat middens because

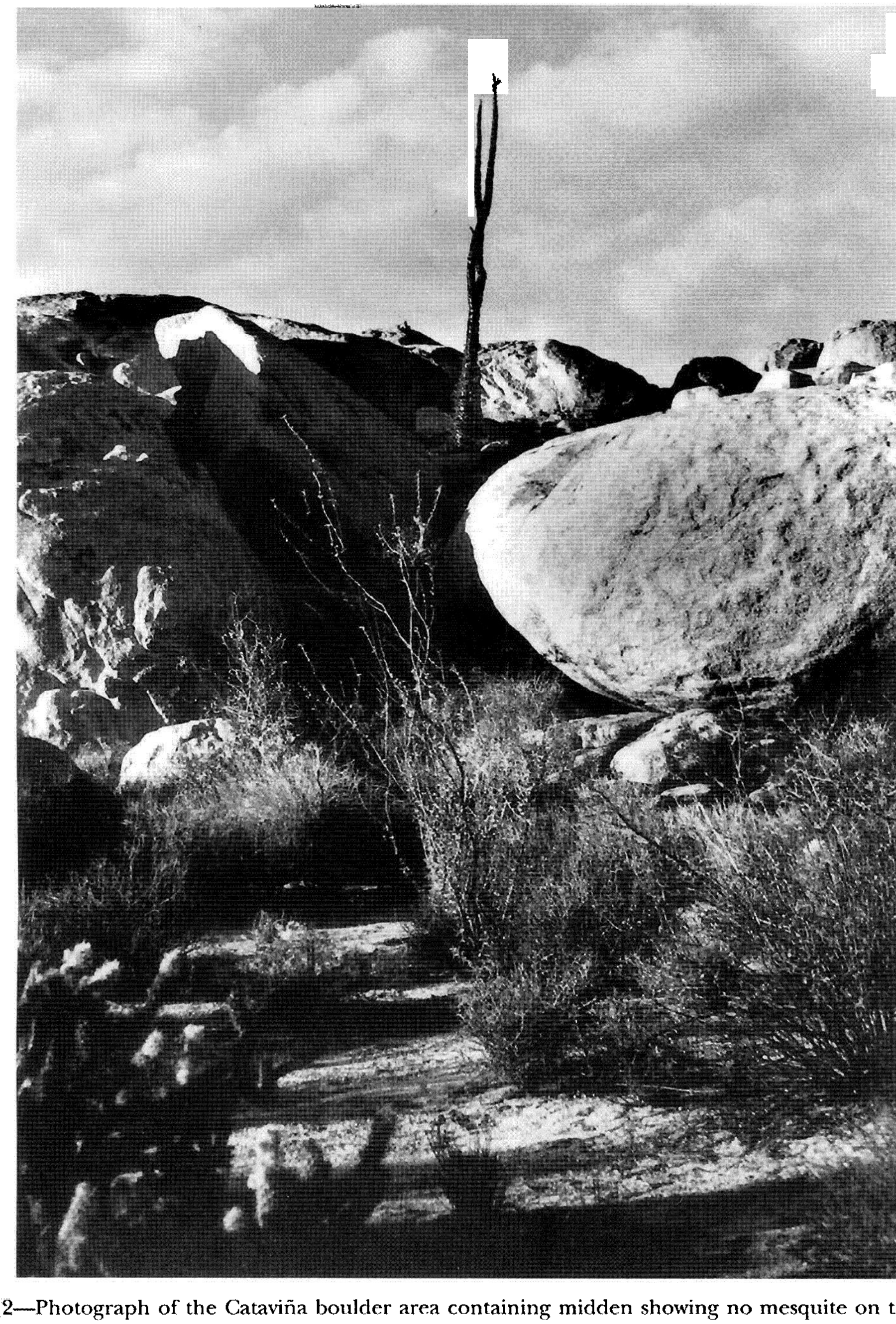

FIG. 2—Photograph of the Cataviña boulder area containing midden showing no mesquite on the boulders.

the granite weathers rapidly into various shapes including dry pockets that preserve middens.

The midden was wedged in a crack ca. 3 m below the top of a boulder pile that is ca. 10 m above a sandy wash (Fig. 2). The front of the midden was exposed to light from an opening above, but protected from precipitation. The midden was 2 m long, 1 m wide, and 20 to 25 cm deep. The upper 0.5 cm was unindurated, pale yellow plant material, and the remaining 20 to 25 cm was indurated and compacted stratified plant material. These 2 layers were separated by a thin layer of dark, hardened urine. Pollen from the upper 0.5 cm of the midden sample was analyzed separately from the remaining 20 to 25 cm portion.

A 652 g sample of the midden was soaked in distilled water for 4 days until completely disaggregated. Wet plant material was screened through a Tyler soil sieve (number 20 mesh, 0.84 mm). Plant material was dried and the liquid was saved for pollen analysis. Total dry weight after washing was 237 g, 36.3% of the original mass. Woodrat feces and large plant remains were picked out, leaving 115 g of matrix that were sorted for plant and arthropod remains. Arthropods are reported in Clark and Sankey (1999). A date of 1,770 ± 60 years B.P. (radiocarbon years before 1950; Beta Analytical-30453) was obtained, using standard radiocarbon methods, from a composite of many woodrat feces. This provides an average age for the deposit. Pollen was sampled from both layers of the midden and processed following standard acetolysis techniques (Faegri and Iversen, 1975; Davis and Anderson, 1987; Anderson, 1990).

Plant remains were identified using Munz (1968), Wiggins (1980), Benson and Darrow (1981), Roberts (1989), and the plant and seed collections in the Orma J. Smith Museum of Natural History, Bilby Research Center, and the University of Arizona Herbarium. Nomenclature follows Munz (1968). All voucher specimens are held in the Arizona-Sonora Desert Museum. Plant fragments were ranked from rare to abundant (1 to 5), where 1 specimen is 1, the most abundant specimen is 5, and the remainder are between 1 and 5, following Van Devender (1990).

RESULTS AND DISCUSSION—Thirty five plant taxa were identified from the woodrat midden based on macrofossil remains (Table 1). Mesquite (*Prosopis glandulosa*) was the most abundant plant in the midden. Creosotebush (*Larrea divaricata*), desert lavender (*Hyptis albida*), goldeneye (*Viguiera deltoidea*), jojoba (*Simmondsia chinensis*), joint fir (*Ephedra californica*), wishbone bush (*Mirabilis*), and *Encelia californica* also are common, with all, except wishbone bush and goldeneye, occurring within 100 m of the midden site today. One annual from the midden, *Chorizanthe brevicornu*, has not been recorded in the Cataviña area. Eight taxa that grow within 100 m of the midden today, the woodrat's presumed foraging range (Van Devender, 1987), were absent from the midden: boojum tree, California buckwheat (*Eriogonum fasciculatum*), cardón, desert broom (*Baccharis sarothroides*), ocotillo, San Diego goldeneye (*Viguiera laciniata*), senita (*Lophocereus schottii*), and *Acalypha californica*. Packrats eat all of these plants (Van Devender et al., 1994), so their absence from the midden presumably is not due to dietary biases. Additionally, 12 taxa in the midden today are not found within 100 m of the midden. Three of these taxa are uncommon in the area today: fairy duster (*Calliandra californica*), winter fat (*Krascheninnikovia lanata*), and *Menodora spinescens*.

Seven plant taxa were identified from pollen (Table 2). As in the macrofossils, *Prosopis* was the most abundant taxon present in the pollen samples. A long-spined Compositae and *Ephedra* were the most abundant species. A single fragmentary pollen grain of *Pinus* surely represents long distance transport of this easily-dispersed pollen. In the late Holocene as today, *Pinus* was likely restricted to high elevations in the mountains of Baja California.

Mesquite pollen and macrofossils dominate the midden's assemblage. In the Cataviña area today, mesquite is occasional in sandy washes but absent from the boulders. Abundant mesquite in the midden probably reflects more mesic conditions in the late Holocene that allowed soil development on the boulder surfaces and colonization of longer-lived plants that are now restricted to the more mesic sandy washes. Further evidence that the late Holocene plant community was different is that only 51.4% of the plant taxa in the midden grow within 100 m of the midden today. The 17 plant taxa from the midden that no longer grow near the midden site include several species that are now uncommon or have more restricted distributions in the Cataviña area (*Baccharis sarothroides, Bursera microphylla, Calliandra californica, Krascheninnikovia lanata,* and *Menodora spinescens*). Additionally, 8 plant taxa (*Acalypha californica, Eriogonum fasciculatum, Fouquieria columnaris, F. splendens, Lophocereus schottii, Pachycereus pringlei, Viguiera laciniata*) that grow within 100 m of the midden today are absent from the midden. Although this absence may partly be due to difficulty identifying some of the twigs, their absence from the midden is probably real.

Conclusions—Evidence from the midden suggests that the composition of the plant community in the Cataviña area during the late Holocene was similar to today's, but that species distributions and abundances were different on local scales. The abundance in the mid-

TABLE 1—Plants present in the midden, identified from macrofossils and pollen. Plants growing today within 100 m of the midden (*) and not known from the Cataviña area (**). Relative abundance scores discussed in Van Devender (1990).

Scientific name	Common name	Material	Relative abundance
Trees and shrubs			
**Atriplex polycarpa*	Saltbush	leaf	2
Bursera cf. *microphylla*	Elephant tree	twig	1
Calliandra californica	Fairy duster	seed	2
Krascheninnikovia lanata	Winter fat	leaves	1
**Encelia californica*		achenes, phyllaries	4
**Ephedra californica*	Joint fir	seeds, twigs	3
**Euphorbia misera*		twig	1
**Hyptis albida*	Desert lavender	seeds, fruit, leaves	3
**Larrea divaricata*	Creosotebush	fruit, twigs, leaves	3
Krameria cf. *grayi*	White ratany	bracts, twigs, leaves	2
Menodora spinescens		twigs	2
**Pachycormus discolor*	Elephant tree	leaves	2
**Prosopis glandulosa*	Honey mesquite	seeds, leaves, twigs	5
**Simmondsia chinensis*	Jojoba	flowers, fruit, leaves	3
**Solanum hindsianum*		seed	1
$n = 15$			
Subshrubs			
**Ambrosia dumosa*	White bursage	leaves, twigs	2
Bebbia juncea	Sweetbush	achenes	2
**Lotus rigidus*	Desert rock pea	seeds, fruit	2
Pleurocoronis ?pluriseta	Arrowleaf	achenes, heads	2
**Trixis californica*		leaves	2
Viguiera deltoidea	Goldeneye	achenes	3
$n = 6$			
Succulents			
**Agave* cf. *cerulata*		seeds, leaves	2
Ferocactus cf. *cylindraceus*	Barrel cactus	seeds, bracts	2
$n = 2$			
Herbaceous perennials			
Mirabilis sp.	Four-o'clock	seeds, fruit	3
Physalis sp.	Tomatillo	seeds	2
**Sphaeralcea* sp.	Globe mallow	fruits, twigs	2
$n = 3$			
Annuals			
Amaranthus sp.	Quelite	seed	2
Amauria rotundifolia		achenes	2
Caulanthus lasiophyllum		fruit	2
***Chorizanthe brevicornu*		fruit	1
Cryptantha maritima	Nievitas	fruit	2
Cryptantha muricata	Nievitas	nutlet	2
Eschscholtzia sp.	Poppy	seed	2
Pectocarya sp.	Combbur	fruit	2
**Perityle emoryi*	Rock daisy		1
$n = 9$			
Total $n = 35$			

TABLE 2—Pollen from midden sample. A is from the top 0.5 cm layer. B is from the remaining 20 to 25 cm. Known quantities of *Lycopodium* grains were added to the sample in order to calculate pollen concentrations (Stockmarr, 1971). (X), present; (—), absent.

Plant taxa	A	Percent of total	B	Percent of total
Total grains counted	384		315	
Concentration of grains/cc	(1/1616) × 10		8.47 × 10	
Lycopodium (24,400 grains added)	8	2.1	9	2.9
Amaranthaceae	5	1.3	5	1.6
Cactaceae	2	0.2	—	—
Compositae				
Ambrosia	2	0.5	6	1.9
Long-spined grain	27	7.0	32	10.2
Ephedraceae				
Ephedra	18	4.7	18	5.7
Leguminosae				
Prosopis	275	71.6	220	69.8
Pinaceae				
Pinus	—	—	X	—
Hidden from view	17	4.4	1	0.3
Unidentified	30	7.8	20	6.3

den of mesquite and other taxa which today live over 100 m from the midden suggests that these plants were growing on the boulders during the late Holocene (1,770 years B.P.) indicating greater soil development on boulder surfaces. Relatively more mesic climate likely allowed these plants to expand into more marginal habitats.

K. Glenn discovered the first woodrat midden in the Cataviña area in 1984. A Sigma Xi Grants In-Aid of Research to J. Sankey funded this research at Northern Arizona University, Flagstaff. C., E., and K. Clark, T. Burgess, and J. Wiens helped search for middens. R. Weedon and his students helped collect the midden. S. Sharpe and B. Barton helped with the pollen processing and R. S. Anderson helped with the pollen identification. P. Koehler helped with some of the macrofossil identifications. E. Mead illustrated the maps. S. Sharpe reviewed an earlier version of the manuscript. The Resumen was translated by A. L. Reina G.

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