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SHORT PAPER

Early Holocene Vegetation Record from the Salton Basin, California

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Plant and vertebrate macrofossils in an early Holocene fossil packrat (*Neotoma* sp.) midden with a radiocarbon age of 8640 ± 100 ^{14}C yr B.P. are reported from the Chocolate Mountains, near the Salton Sea, Riverside County, California. An inventory of the midden has permitted a comparison of the modern flora and fauna of the site with that extant during the early Holocene. Whereas the biota had assumed most aspects of its modern Sonoran desert aspect by this date, statistically significant evidence of differences is attributed to an increased flow of surface water in Salt Creek, a high-standing, low-salinity Lake LeConte, and the late arrival of some characteristic Sonoran desert plants. These observations are consistent with models of significant fall–winter precipitation in the Sonoran Desert, although we cannot exclude alternative explanations. ©1995 University of Washington.

Packrat midden analysis is an important tool in the study of Late Quaternary climate change, timing, and causation in arid western North America (e.g., Betancourt *et al.*, 1990). Within the Sonoran Desert, 209 fossil middens have been reported (Van Devender, 1990; Van Devender *et al.*, 1990), although only two California sites are included: Picacho Peak (Cole, 1986), in extreme southeastern California, and the Whipple Mountains (Van Devender, 1990), close to the California–Arizona border. The Salt Creek site reported here is therefore the most westerly of known Sonoran Desert fossil packrat middens, except for specimens from the Viscaino Subdivision of Baja California briefly reported by Wells (1976).

The fossil midden sample was collected from a shallow rockshelter on the south side of Salt Creek, approximately 500 m east of the Bradshaw Trail railroad crossing (33°30″ N, 115°40″ W), 3.3 m above the floor of Salt Creek Wash, 250 m above sea level, and 320 m above the 1993 level of the Salton Sea (Fig. 1). The modern climate of the site is typical of the western Sonora Desert (Shreve, 1964). Precipitation is mostly in the form of winter rain, with occasional fall storms from the tropical Pacific (Huning, 1978), in contrast to the eastern Sonoran desert of Arizona which experiences significant summer monsoonal precipitation. Precipitation decreases with elevation so that the Lower Colorado Valley/Salton Basin receives less than 100 mm yr^{-1} (Ezcurra and Rodriguez, 1986). The midden is located astride the interface of true creosote bush scrub and the modified vegetation of the desert wash (Shelford, 1963). A survey of the extant vegetation in March 1992 identified four shrubs as the dominant species: *Bebbia juncea* (sweetbush), *Ambrosia dumosa* (bursage), *Hyptis emoryi* (desert lavender), and *Chilopsis linearis* (desert willow). In the adjacent creosote bush scrub, *Larrea divaricata* (creosote bush), *Opuntia basilaris* (beavertail cactus), *O. ramosissima* (pencil cholla), and *Encelia farinosa* (brittle bush) were dominant.

The fossil midden consists of a heterogeneous mass of amberat (Emerson and Howard, 1978; Spaulding *et al.*, 1990) and plant debris cemented to the rear wall and roof of a shallow, north-facing rock shelter. On the basis of textural differences and perceived discontinuities in the deposit, the midden was mapped as five units, coded in stratigraphic order from A (basal unit) through E. Unit C is the focus of this report, from it approximately 500 g of the deposit was removed with a hammer and chisel. The bulk of the deposit has been left *in situ* for future study. Plant remains were identified by reference to herbarium specimens held at the Rancho Santa Ana Botanical Gardens and at the University of Arizona, Tucson. Vertebrate remains were identified by reference to specimens in the collections of the Natural History Museum of Los Angeles County and T. R. Van Devender. Thorough collections of extant vegetation were made in September 1991 and May 1992, with species being assigned dominance values on a scale of 0 (absent) to 5 (abundant). Conventional radiocarbon dating was used to establish the age of Unit C, based on 13 g dry weight of *Neotoma* fecal pellets. The radiocarbon age was reported as 8640 ± 100 yr B.P. (with ^{13}C correction; Beta Analytic No. 49184), which yields a calibrated age of 7580 cal yr B.C. (1 σ range 7873–7538 cal yr B.C.; Stuvier and Reimer, 1993).

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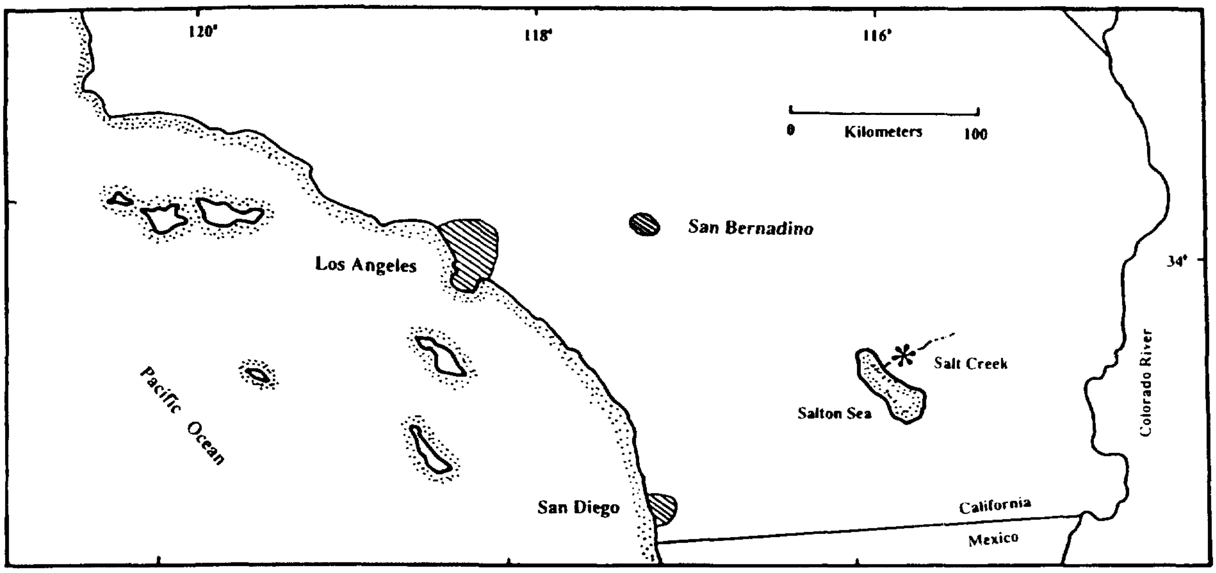

FIG. 1. Map showing location of the early Holocene Salt Creek packrat midden, southern California.

Collections of the modern flora within 50 m of the midden site yielded 31 native and 2 introduced species (Table 1), compared with 23 plant taxa identified from unit C of the midden. Seven vertebrate taxa from the midden were also identified. At least 22 (71%) of the modern plant taxa were not identified in the fossil midden, and 13 (59%) of the midden plant taxa were not identified in the modern flora (Table 1). The most widely used similarity coefficient in packrat midden studies has been Sorensen's Index (Sorensen, 1948), which typically yields values in the range of 0.65–0.85 for comparisons of modern vegetation with modern packrat midden samples (Spaulding, 1985). The Salt Creek fossil midden shares only 9 species with the modern native flora, equivalent to a Sorensen's Index of 0.26. Sorensen's Indices computed from 20 published comparisons of modern middens with extant vegetation at their respective sites (Cole and Webb, 1985; Spaulding, 1981, 1985; Vaughan, 1990) yield a mean and standard deviation of 0.75 ± 0.13, respectively. The Salt Creek midden flora is therefore shown to be significantly different from the modern flora ($P < 0.0001$) with respect to shared species.

It has long been recognized that the transition from full-glacial conditions of the Late Wisconsinan (ca. 18,000 yr B.P.) into the modern climatic regime, which began ca. 11,000 yr B.P. in the American West, was not smooth or even continuous, but broken by repeated and significant climatic fluctuations (Pielou, 1992). These Holocene fluctuations are more poorly known than developments in the late Pleistocene, in part because of research bias ("the lure of the Pleistocene"; Webb and Betancourt, 1990) and in part because of the complexity of local variation. In the American Southwest, detailed studies of late Pleistocene and early Holocene vegetational and climatic shifts in the Mohave (Spaulding, 1990) and Sonoran (Van Devender, 1990) deserts, as well as the Chihuahuan and Great Basin deserts and the Colorad Plateau have recently been reported, based on packra midden analysis. These studies lead us to conclude tha the Salt Creek midden was emplaced (8640 ± 100 yr B.P. late during the transition from glacial to interglacial veg etation, a process that was largely complete by 800 yr B.P.

Comparison of the Salt Creek fossil midden with th extant flora of the site by similarity coefficient analysi demonstrates that the site supported a significantly, bu not radically, different biome at 8640 ± 100 yr B.P. Thes differences might reflect any or all of the following: th relatively small size of the midden sample (500 g), selec tive foraging by packrats (Dial and Czapelewski, 1990) or modest differences in local climate; these alternative cannot be addressed by similarity indices alone. Fort nately, extralocal plant and vertebrate remains recovere from the fossil midden provide additional insight into th problem.

Eleven plant taxa identified from the midden (48% o the total assemblage) were absent within a 50-m radius o the site in 1991–1992. Ten of these taxa are typical So noran Desert species, although cacti of the genus *Mam milaria* are not common in the modern Salt Creek env ronment and *Atriplex hymenelytra* is locally absent, pr sumably as a result of the lowered modern water table The remaining taxon (*Yucca cf. brevifolia*, the Joshu tree) is represented by a fragment. Joshua trees are er demic to the modern Mohave Desert, with the close extant stand some 40 km to the northwest in the Cotto wood Mountains of Joshua Tree National Monumen Nevertheless, *Y. brevifolia* macrofossils have been r ported from the Late Wisconsinan (13,000–11,000 y B.P.) lowland Sonoran Desert site of Picacho Peak, c

TABLE 1
Relative Abundances of the Modern and Fossil Flora

Taxon	Modern relative abundance	Fossil relative abundance
Yucca cf. *brevifolia*	0	1
Ambrosia dumosa	3	0
Bebbia juncea	3	0
Calycoseris wrightii	2	0
Encelia farinosa	3	0
E. californica	0	1
Hofmeisteria pluriseta	2	4
Hymenoclea salsola	4	0
Monoptilon belloides	2	0
Peucephyllum schotti	4	4
Trixis californica	0	2
Chilopsis linearis	5	5
Cryptantha barbigera	2	0
C. holoptera	0	2
C. ramosissima	2	0
Crypthantha sp.	—	2
Brassica tournefortii[a]	3	0
Lepidium fremonti	0	1
L. virginicum	2	0
Opuntia basilaris	3	0
Opuntia ramosissima	3	2
Mammillaria grahamii	0	3
M. tetrancistra	0	3
Atriplex hymenelytra	0	4
Euphorbia polycarpa	2	0
Cercidium floridum	3	0
Lupinus arizonicus	3	0
Acacia greggii	0	5
Prosopis glandulosa	0	2
Psorothamnus spinosus	0	2
Nemophila sp.	2	0
Phacelia tanacetifolia	2	0
Hyptis emoryi	3	2
Salvia columbariae	2	0
Mirabilis tenuiloba	2	0
Camissonia claviformis	1	0
Clarkia elegans	3	0
Eschscholzia sp.	2	0
E. parishii	2	0
Plantago insularis	3	0
Plantago sp.	—	2
Schismus barbatus[b]	2	0
Muhlenbergia microsperma	0	1
Chorizanthe brevicornu	2	0
Lycium sp.	2	0
Physalis sp.		2
Nicotiana trigonophylla	2	3
Larrea divaricata	5	4

[a] Introduced from North Africa.
[b] Introduced from Europe.

110 km southeast of Salt Creek (Cole, 1986; Van Devender, 1990) and are considered indicative of cool summer temperatures (Rowlands, 1978).

The vertebrate fauna of the midden included the rodents *Neotoma* sp., *Onchomys torridus*, *Peromyscus* sp., and *Reithrodontomys cf. megalotis;* the reptiles *Sceloporus cf. occidentalis* and *Sonora semiannulata;* and abundant vertebral remains of the giant minnow *Gila cf. elegans*. *Gila elegans* is an endangered species now found no closer to the site than Lake Mohave on the Colorado River, ca. 225 km NNE of Salt Creek. The species is salinity-intolerant, and can have reached Salt Creek from the Colorado River only via pluvial Lake Le Conte. Its presence in the midden is strong evidence for a relatively high-standing, low-salinity Lake Le Conte and a much more active Salt Creek at 8640 ± 100 yr B.P. The presence of the reptiles *Sonora semiannulata* and *Sceloporus occidentalis*, neither of which are common at such low elevations in the Lower Colorado River Valley today, provide additional circumstantial evidence for cooler, more mesic conditions at the site as late as 8640 yr B.P.

Van Devender (1990), in summarizing the evidence derived from 199 packrat middens in the Sonoran Desert, concluded that Joshua Tree woodland was present at Picacho Peak since at least 13,000 yr B.P., disappeared about 11,200 yr B.P. and was replaced by creosote bush scrub of modern aspect by 10,500 yr B.P. The establishment of the modern Mohave–Sonoran Desert boundary is thought to date from 8000–9000 yr B.P., when junipers and oaks were finally extirpated from what are now desert lowlands (Van Devender, 1990). The Salt Creek midden thus dates from the terminal transition period. We believe that the *Y. cf. brevifolia* and *G. cf. elegans* records, coupled with the 48% extralocal plant taxa in the midden (especially drought-intolerant taxa such as *Acacia greggi* and *Prosopis glandulosa*), provide convincing evidence that a significantly more mesic, latest Wisconsinan flora of "Mohave" aspect persisted on the lower bajadas of the northern Chocolate and southern Orocopia Mountains. This flora probably reflects a higher water table and, in all likelihood, increased flow in Salt Creek. The presence of *Y. cf. brevifolia* implies that early Holocene summer temperatures were lower than are typical of the site today and that the increased precipitation was more likely to have been of Mohave-like winter Pacific origin, rather than Sonoran-like summer monsoonal as suggested by Spaulding and Graumlich (1986). These conclusions are in accord with the demonstrated persistence of woodland assemblages in the Whipple Mountains (520 m altitude; northwest Sonoran desert, 175 km NE of Salt Creek) as late as 8910 ± 380 yr B.P., a date statistically indistinguishable from that of the Salt Creek midden (Van Devender, 1990). We also note the absence of white bursage (*A. dumosa*) and sweetbush (*B. juncea*) in the midden sample, even though they are both very common within 50 m of the site today and characteristic of the Sonoran Desert biome in general. This is consistent with Van Devender's (1990) observation that *A. dumosa* was a late arrival at Picacho Peak (post-4800 yr B.P.), in contrast to its early arrival in Death Valley (10,200 yr

B.P.; Woodcock, 1986), and also evidence for similar early Holocene mesic conditions in the Hornaday Mountains of Sonora, Mexico (Van Devender *et al.*, 1990). We concur with Van Devender *et al.* (1994) that the early Holocene climate of the western Sonoran Desert may have experienced significant fall–winter precipitation from Pacific storms and argue that the Salt Creek data are not easily reconciled with general circulation models indicating an early Holocene southwest warmer than today (e.g., Kutzbach, 1987; COHMAP, 1988). Conversely, the presence of *A. greggi, T. californica, P. glandulosa*, and two species of *Mammilaria* complicate the pattern and lead us to suppose that the increased precipitation may also have included a biseasonal component.

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REFERENCES

Betancourt, J. L., Van Devender, T. R., and Martin, P. S. (Eds.) (1990). "Packrat Middens: The Last 40,000 years of Biotic Change." Univ. of Arizona Press, Tucson.

Cole, K. L. (1986). The Lower Colorado Valley: A Pleistocene desert. *Quaternary Research* 25, 392–400.

Cole, K. L., and Webb, R. H. (1985). Late Holocene vegetation in Greenwater Valley, Mohave Desert, California. *Quaternary Research* 23, 227–235.

Dial, K. P., and Czapelewski, N. J. (1990). Do woodrat middens accurately represent the animals' environments and diets? The Woodhouse Mesa study. *In* "Packrat Middens: The Last 40,000 Years of Biotic Change" (J. L. Betancourt *et al.*, Eds.). Univ. of Arizona Press, Tucson.

Emerson, D. O., and Howard, W. E. (1978). Mineralogy of woodrat, *Neotoma cinerea*, urine deposits from northeastern California. *Journal of Mammalogy* 59, 424–425.

Escurra, E., and Rodriguez, V. (1986). Rainfall patterns in the Gran Desierto, Sonora, Mexico. *Journal of Arid Environments* 10, 13–28.

Huning, J. R. (1978). "A Characterization of the Climate of the California Desert." U.S. Bureau of Land Management, Riverside.

Kutzbach, J. E. (1987). Model simulations of the climatic patterns during the deglaciation of North America. *In* "North America and Adjacent Oceans During the Last Deglaciation" (W. F. Ruddiman and H. E. Wright, Jr., Eds.) Vol. K-3, pp. 425–446. Geological Society of America, Boulder, CO.

Pielou, E. C. (1992). "After the Ice Age. The Return of Life to Glaciated North America." Univ. of Chicago Press, Chicago.

Rowlands, P. G. (1978). "The Vegetation Dynamics of the Joshua Tree (*Yucca brevifolia* Englem.) in the Southwestern United States." Unpub. Ph.D. dissertation, University of California, Riverside.

Shreve, F. (1964). Vegetation of the Sonoran Desert. *In* "Vegetation and Flora of the Sonoran Desert" (F. Shreve and I. L. Wiggins, Eds.). Stanford Univ. Press, Stanford.

Sorensen, T. (1948). A method of establishing groups of equal amplitude in plant sociology based on similarity of species content. *Det Kongress Danske Videnske, Selskab Biologica Skrifter* 5, 1–34.

Spaulding, W. G. (1981). "The Late Quaternary Vegetation of a Southern Nevada Mountain Range." Unpub. Ph.D. dissertation, University of Arizona, Tucson.

Spaulding, W. G. (1985). Vegetation and climates of the last 40,000 years in the vicinity of the Nevada Test Site, South-Central Nevada. *U.S. Geological Survey Professional Paper* 1329, 1–55.

Spaulding, W. G. (1990). Vegetational and climatic development of the Mohave Desert: the glacial maximum to present. *In* "Packrat Middens: The Last 40,000 Years of Biotic Change" (J. L. Betancourt *et al.*, Eds.). Univ. of Arizona Press, Tucson.

Spaulding, W. G., and Graumlich, L. J. (1986). The last pluvial climatic episodes in the deserts of southwestern North America. *Nature* 320, 441–444.

Spaulding, W. G., Betancourt, J. L., Croft, L. K., and Cole, K. L. (1990). Packrat middens: Their composition and methods of analysis. *In* "Packrat Middens: The Last 40,000 Years of Biotic Change" (J. L. Betancourt *et al.*, Eds.). Univ. of Arizona Press, Tucson.

Stuvier, M., and Reimer, P. J. (1993). Extended ^{14}C database and revised CALIB 3.0 ^{14}C age calibration program. *Radiocarbon* 35, 215–230.

Van Devender, T. R. (1990). Late Quaternary vegetation and climate of the Sonoran Desert, United States and Mexico. *In* "Packrat Middens: The Last 40,000 Years of Biotic Change" (J. L. Betancourt *et al.*, Eds.). Univ. of Arizona Press, Tucson.

Van Devender, T. R., Burgess, T. L., Felger, R. S., and Turner, R. M. (1990). Holocene vegetation of the Hornaday Mountains of northwestern Sonora, Mexico. *Proceedings San Diego Society of Natural History* 2, 1–19.

Van Devender, T. R., Burgess, T. L., Piper, J. C., and Turner, R. M. (1994). Paleoclimatic implications of Holocene plant remains from the Sierra Bacha, Sonora, Mexico. *Quaternary Research* 41, 99–108.

Vaughan, T. A. (1990). Ecology of living packrats. *In* "Packrat Middens: The Last 40,000 Years of Biotic Change" (J. L. Betancourt *et al.*, Eds.). Univ. of Arizona Press, Tucson.

Webb, R. H., and Betancourt, J. L. (1990). The spatial and temporal distribution of radiocarbon ages from packrat middens. *In* "Packrat Middens: The Last 40,000 Years of Biotic Change" (J. L. Betancourt *et al.*, Eds.). Univ. of Arizona Press, Tucson.

Wells, P. V. (1976). Macrofossil analysis of Woodrat, *Neotoma*, middens as a key to the Quaternary vegetational history of arid America. *Quaternary Research* 6, 223–248.

Woodcock, D. (1986). The late Pleistocene of Death Valley: A climatic reconstruction based on macrofossil data. *Palaeogeography, Palaeoclimatology, Palaeoecology* 57, 273–283.