MADROÑO, Vol. 47, No. 3, pp. 189–194, 2000

PLEISTOCENE MACROFOSSIL RECORDS OF FOUR-NEEDLED PINYON OR JUNIPER ENCINAL IN THE NORTHERN VIZCAINO DESERT, BAJA CALIFORNIA DEL NORTE

PHILIP V. WELLS
Department of Ecology and Evolutionary Biology, University of Kansas, Lawrence, KS 66045

ABSTRACT

Two late-Pleistocene *Neotoma* (wood rat) middens have been dated by four radiocarbon analyses at 10,000–10,200 and 17,470 radiocarbon years. Both deposits document by numerous macrofossils the abundance of *Juniperus californica* Carrière, but in the older deposit dominance is shared with *Pinus quadrifolia* Parl. Both deposits contain lesser quantities of the principal dominant shrub of the California chaparral, the chamise (*Adenostoma fasciculatum* Hook. & Arn.) together with the shrubby oak, *Quercus turbinella* E. Greene, and other chaparral genera at about 30°N in the northern part of the Vizcaino desert. The existing desert vegetation at both sites is dominated by giant columnar xerophytes and several species of low, desert shrubs, no trace of which has been detected in either of the dated middens. Although abundance of macrofossils of woodland trees with lesser amounts of chaparral shrubs, in conjunction with absence of any species of desert shrub, document a modest displacement of desert vegetation at moderate elevations (550–594 m) in the northernmost Vizcaino desert, this evidence cannot be extrapolated to include the entire peninsula of Baja California. Very substantial biogeographic and ecologically pertinent physiographic evidence suggest a major desert barrier in the central part of the peninsula that also may explain the high degree of endemism in the desert flora.

RESUMEN

En Desierto Vizcaino, Baja California del Norte, Mexico, en 550–594 m, dos depositos de epoca tardo-Pleistocene con datos 10,000–10,200 y 17,470 anos, documentan con macrofosiles numerosos la presencia de *Pinus quadrifolia* y/o *Juniperus californica,* con arbustos de encinal (*Quercus turbinella, Adenostoma fasciculatum*). Sin embargo, arbustos de desierto moderno ausente en los dos depositos.

Some of the most spectacular desert vegetation in North America occupies a relatively restricted sector of northern Baja California, north of the Vizcaino Plain in the central part of the peninsula. Shreve (1951), who was very familiar with all the North American deserts, referred to it as a desert wonderland (on p. 108). This unique assemblage of bizarre xerophytes of gigantic stature extends from just south of the lofty Sierra San Pedro Martir, east of El Rosario on the Pacific Coast, south to about San Borja, a distance of about 250 km. The most spectacular scenery is more localized, reaching a peak in areas of weathered granitic rocks, such as the extensive tract north of Santa Ines or farther south near Portezuelo.

The unique plant is the cirio tree (*Idria columnaris* Kell.), a remote relative of the common ocotillo (*Fouquieria splendens* Engelm. also present) of the same family, but the cirio attains a height of more than 16 m and has a single main trunk with spongy wood that stores water. It has been likened to an inverted, spiny carrot with innumerable short branches arranged in dense spiral phyllotaxy. Although it resembles a giant columnar cactus, it has ordinary C3 photosynthesis, unlike most cacti which have crassulacean acid metabolism (CAM). The cirio is practically endemic to this sector of Baja California, reaching its southern limit on the high Tres Virgenes volcanoes at over 1600 m, east of San Ignacio. The equally impressive cardon cactus (*Pachycereus pringlei,* (S. Wats.) Britt. & Rose) has about the same northern limit on the Pacific slope, but extends south to the Cape in Baja California del Sur, where it is the ubiquitous dominant giant of desert elevations.

Another pachycaul with a swollen trunk, the elephant tree (*Pachycormus discolor* (Benth.) Coville) is prominent in the cirio area but extends south with the cardon, though not nearly to the Cape. Closer to the cardon in distribution is another distinctive quasi-endemic tree, *Viscainoa geniculata* (Kell.) Greene, which associates with cirio in its more limited range. Sprawling beneath the vertical cardons is another large cactus, but of a horizontal mode of growth, the endemic *Machaerocereus gummosus,* (Engelm.) Britt. & Rose, with a windswept appearance and tart fruits ("pitahaya agria"). The lesser cacti include various species of *Opuntia,* especially chollas (*O. cholla* Weber, *O. molesta* Brandegee). A lesser succulent is the euphorbiaceous *Pedilanthus macrocarpus* Benth. The dominant understory shrubs are mainly dull gray like *Ambrosia chenopodiifolia* (Benth.) Payne, enlivened by weedy patches of *Encelia californica* Nutt. with its masses of sunflowers, and punctuated by the scarlet flowers of *Beloperone* shrubs (seen after the winter rains).

TABLE 1. PLANT COMPOSITION OF *NEOTOMA* MIDDENS FROM THE CIRIO-CARDON DESERT OF BAJA CALIFORNIA DEL NORTE. Locations shown on Fig. 1: site 1 = northwest of Mision San Fernando at ca. 30°N; site 2 = northwest of Rancho Santa Ines at 29°46′N. Relative abundances: +++ = major constituent; ++ = lesser; + = trace.

	SITES: San Fernando, at 594 m	Santa Ines, at 550 m
	AGES: 10,000–10,200 ± 135 (UCLA: 1365, 1366, 1367)	17,470 ± 200 (Beta 9372)
MACROFOSSILS		
CONIFERS		
Pinus quadrifolia (intact leaf fascicles)	absent	+++
Juniperus californica (leafy twigs, seeds)	+++	+++
CHAPARRAL		
Adenostoma fasciculatum var. *obtusifolium* (leaves)	++	++
Quercus turbinella (acorns, leaves)	++	++
Prunus lyonii (leaves, endocarps)	+	+
Arctostaphylos glandulosa (nutlets of drupe)	+	
Eriodictyon angustifolium (leaf)		+

It was in this most spectacular part of Baja California that I first sought for evidence of Pleistocene vegetation early in 1968. The *Neotoma* method (Wells 1976) had already proven fruitful in the Mohave, western Sonoran ("Colorado" desert, California), and Chihuahuan deserts (Wells 1966; Wells and Berger 1967). Equipped with a ¾ ton 4 × 4 pickup and camper, my lifetime friend, Jack Yrizarry, and I crawled down the thousand-mile desert track to the Cape. "The Baja Run" was then little more than a very rough, rocky trail with incredibly steep grades in places and was strictly one lane in the best stretches, where a speed of 15 mph might be briefly reached! The average speed with a big, rocking camper was about 5 mph. That there was any "road" at all was due to a sparse procession of big-wheeled trucks driven by native truckers, who provided "servicio particular" to isolated local rancheros.

METHODS AND MATERIALS

The *Neotoma* macrofossil method (first monographed in Wells 1976) is deceptively simple, but requires thorough training in taxonomic and morphological botany and proficiency with existing floras over wide areas of North America. Furthermore, it is essential that proficiency extends to minute details exhibited by numerous tiny macrofossils. Interpretation of the results requires training in ecology of the vegetation of North America and detailed knowledge of its physiography, geology, and climatology.

Skilled sampling of the deposits is even more essential. The key to critical stratigraphic analysis is a focus on friable, macrofossil-rich layers. The friable stratigraphic layers are split off as separate units that disintegrate in the dry state into their constituent macrofossils. Thus, bulk-processing of middens in homogenizing water baths is avoided. Instead, the method of dry-processing provides a copious yield of macrofossils from discrete stratigraphic units that are carefully sorted on a multiple-mesh seive set. The macrofossils are sorted as to species, weighed, and reported as percent biomass, or with simpler assemblages assigned relative abundances. Most species are present as mere traces. There is often an overwhelming dominance of woody plants that fully justifies the vernacular name "wood rat," coined by mammalogists for the genus *Neotoma.* Aliquots of the same friable stratigraphic layers burned for carbon dating are curated separately as vouchers for documentation and further study.

RESULTS

Less than a week of crawling south of Ensenada got us well within the northern part of the great cirio desert, northwest of Mision San Fernando. Exploring all of the rock shelters we could spot with 10× binoculars en route, we finally found an old wood rat (*Neotoma*) midden in a cavelet located in volcanic rocks. The midden was about one meter thick and well within a secure shelter, large and dark enough to harbor a few bats. I knew it was old because it contained none of the desert plants mentioned above, but rather was composed of woodland or chaparral trees and shrubs, predominantly *Juniperus californica,* accompanied by leaves and acorns of a shrubby live-oak (*Quercus turbinella*) and tiny but numerous leaves of chamise (*Adenostoma fasciculatum*), a principal dominant of the California chaparral (Table 1). Also present were a few nutlets of *Arctostaphylos glandulosa* Eastw. More remarkable were the large leaves and endocarps (cherry pits) of *Prunus lyonii* Eastw., the Catalina cherry.

A thorough reconnaisance of the area showed a desert vegetation characterized by dominance of all of the giant columnar xerophytes and a profusion of lesser cacti and Agavaceae, notably *Agave shawii* Engelm., *A. deserti* Engelm., and *Yucca whipplei* Torrey. There were no chaparral shrubs except for one individual of the xerophytic monotype, *Xylococcus.* A fly in the ointment was the presence of a few, live *Ju-*

niperus californica Carrière about 200 m from the midden site at an elevation of 610 m (2000 ft). This somewhat vitiated the significance of the juniper record, but the chaparral sclerophylls justified the three radiocarbon dates kindly provided by Rainer Berger: 10,000 to 10,200 radiocarbon years before present from top to bottom of the midden. This was cetainly not a pleniglacial date, but rather late-glacial to Holocene transition (Table 1).

Proceeding slowly south for another few days, we entered the extensive granitic area north of Santa Ines, where we explored many *Neotoma* middens in cavities within the small exfoliation domes of the granitoid rocks. Unfortunately, all we saw were records of desert plants. This set a pattern of more desert records all the way to La Paz. Needless to say, I was discouraged with the prospects, but later switched to mainland Mexico, where I have more unpublished records. Still later, I decided to concentrate on the Great Basin (Wells 1983).

Shortly after the 1983 paper appeared, William H. Clark of Albertson College, Caldwell, Idaho, kindly sent me samples of an obviously ancient wood rat midden from the Santa Ines granitic area. It contained *Pinus quadrifolia,* a four-needled pinyon pine species previously unrecorded in the *Neotoma* fossil record anywhere, so I had the stratum dated: 17,470 ± 200 radiocarbon years before present (Beta 9322). In 1988, I responded to Bill's generous invitation to visit the site to collect more material. Instead of a week's drive below Tijuana, I made it in the afternoon of the same day, blacktop all the way! Additional material from the dated sector of the midden provided much more *Pinus quadrifolia* and *Juniperus californica* and a similar assemblage of chaparral sclerophylls previously recorded in the 10,000 yr old midden, plus *Eriodictyon angustifolium* Nutt. Consistently absent from both the 10,000 and 17,400 y-old deposits were any xerophytes of the existing desert vegetation (Table 1).

The combination of chaparral shrubs, junipers, and pinyons was called *encinal* by Forrest Shreve, using a Spanish word for an oak community. The west slope of the Sierra San Pedro Martir at middle elevations has chaparral, partly dominated by *Quercus turbinella* and *Adenostoma,* associated with *Pinus quadrifolia* and *Juniperus californica* but minus any desert xerophytes, aside from the chaparral *Yucca, Y. whipplei.* Thus, the encinal recorded in late-glacial and pleniglacial middens in what is now cirio desert has a nearly exact analog in the San Pedro Martir mountains to the north.

Discussion

The contrast between the spectacular modern desert vegetation dominated by giant xerophytes like cirios and cardons at both *Neotoma* sites and the midden macrofossil evidence for a Pleistocene encinal, lacking desert xerophytes, staggers the imagination (Table 1). The recorded displacement was complete at this latitude, ca. 30°N.

Pinus quadrifolia, the four-needled pinyon, is one of the more mesophytic pinyon pines. At present it is restricted to moderately high elevations (ca. 1100 to 2100 m, or 3500 to 7000 ft), mainly on the western or Pacific slopes of the Peninsular Range as far south as the San Pedro Martir. In contrast, the one-needled *P. californiarum* D.K. Bailey (1987) occurs on the rain-shadowed eastern slope of the Peninsular Range (Bailey, personal communication 1975–1990; Wells 1995). Where the two distinct species occur on the same mountain, as on Mt. San Jacinto, California, *P. quadrifolia* forms a zone well above *P. californiarum.* The latter, one-needled, pinyon alone has a far southern disjunction on Cerro San Luis (to 1550 m) in the Sierra de Calamajue at about 29°N, an isolated peak not far north of the high San Borja Mountains (to 1700 m +), where no pinyon pines have ever been recorded (Fig. 1). The nominate subspecies of *Pinus californiarum* also extends disjunctly far to the north of *P. quadrifolia* on low, isolated mountains in arid parts of the Mohave Desert, e.g., the Coxcombs, Eagle, Old Woman, and northeast in the Providence; it dominates the pinyon-juniper zone in all of these ranges (Wells 1995).

From the distribution maps of Critchfield and Little (1966), one would have hypothesized *P. californiarum* (then under the Great Basin species *P. monophylla* Torrey & Frémont) to have extended farther south on the peninsula than *P. quadrifolia* during the Ice Ages, because they show the southerly outlier of the former on Cerro San Luis. This may well have been true on the east or Gulf of California slope, where we have no *Neotoma* records. The macrofossil record of *P. quadrifolia* we do have is from the Pacific side of the peninsular divide in the cirio zone at the substantial elevation of 550 m (1800 ft), less than 500 m below its modern lower limit (Wells 1986).

The assemblages of evergreen sclerophylls (*Adenostoma fasciculatum,* or chamise, a principal dominant of California chaparral, *Prunus lyonii, Arctostaphylos glandulosa* or Eastwood manzanita, etc.) are consonant with the presence of *Juniperus californica* or *Pinus quadrifolia* in the same strata of the *Neotoma* middens. Today, the juniper and four-needled pinyon both associate with a broad zone of chaparral below montane forest of *Pinus jeffreyi* Grev. & Balf. that is mainly above 2500 m; the chaparral belt (largely dominated above by *Arctostaphylos peninsularis* Wells) extends down to <1000 m.

Chaparral extends southward from California in the Peninsular Range to Cerro Matomi (to 1370 m), the southern extremity of the San Pedro Martir. Aside from small populations of manzanitas (*A. peninsularis*) on isolated peaks: Cerro San Juan de Dios (to 1300 m at 30°N) and Cerro San Luis (1550 m: the southern limit of *Pinus californiarum* at 29°19′N) there is a major disjunction of chaparral species to the high San Borja Mountains (to 1700

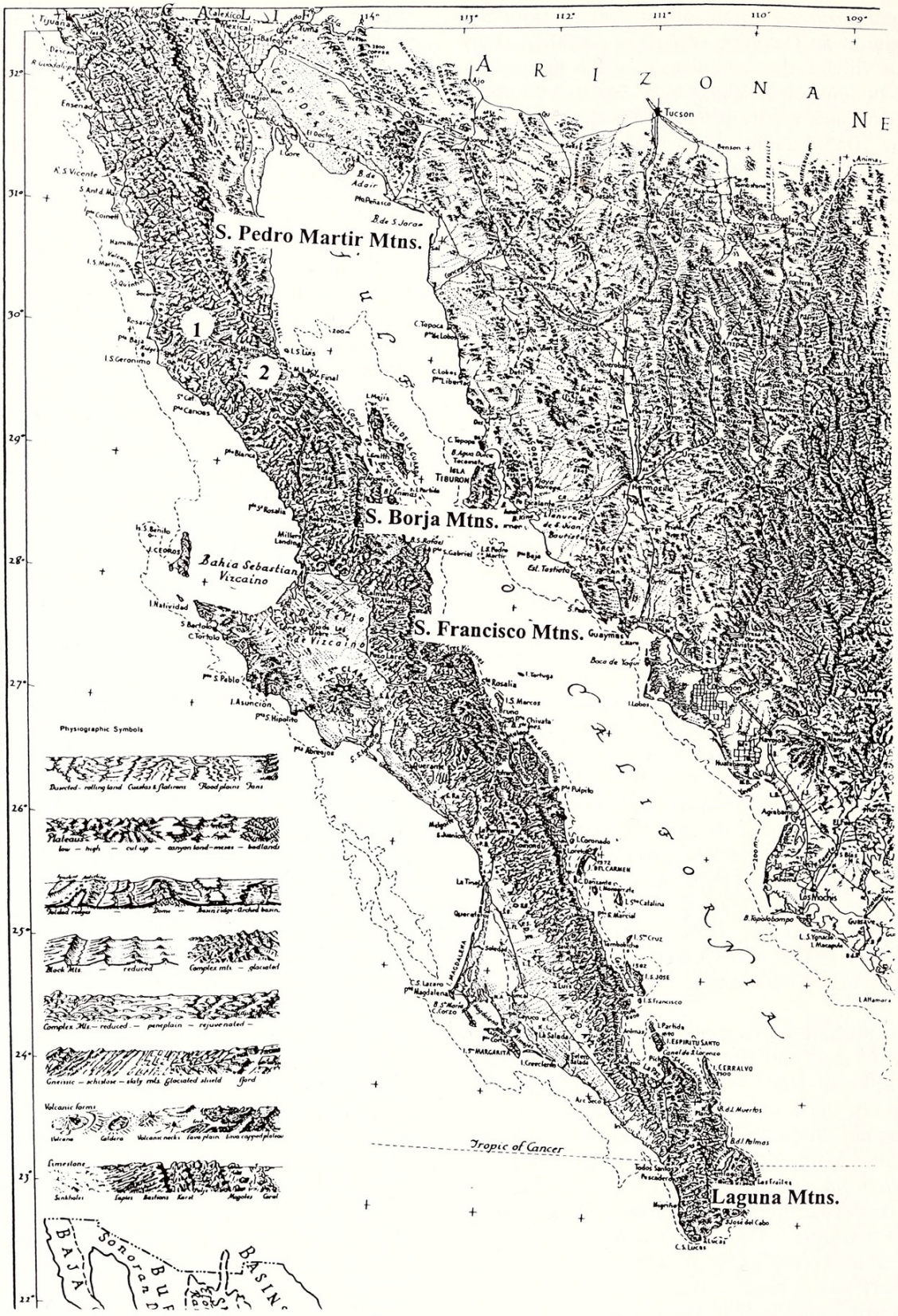

FIG. 1. Map of Baja California, showing principal mountains mentioned in text and numbered wood rat (*Neotoma*) midden sites of Pleistocene age in white circles: 1 = northwest of Mision San Fernando, 30°N, at 594 m (1950 ft). 2 = northwest of Rancho Santa Ines, 29°46′N, at 550 m (1800 ft).

m) rising above the Gulf of California at 28°47′N (Fig. 1). The San Borjas are the southern limit of *Juniperus californica* and *Arctostaphylos peninsularis,* but lack pinyon pines (Reid Moran, personal communication 1969; Wells 1972). Still farther south at 27°30′N there is a southern outpost of chaparral on the lofty Tres Virgenes volcanoes (to 2000 m) above Santa Rosalia on the Gulf; the Tres Virgenes are also a southern outpost for cirio trees.

Possibly the most unexpected macrofossil occur-

rence in the northern cirio desert at both *Neotoma* sites (Table 1) is the Catalina cherry tree (*Prunus lyonii*). This large-leaved cherry occurs in California on the larger Channel Islands, but not on the mainland. In Baja California, however, this evergreen cherry has widely disjunct stations in deep canyons of the isolated and inaccessible Sierra de San Francisco (or Francisquito) of northern Baja California del Sur at ca. 27°30′N (Fig. 1). The two Pleistocene records of *Prunus lyonii* in the northern part of the cirio zone suggest (but do not prove) a former continuity of range.

A major biogeographic anomaly that might shed light on the Pleistocene location of the Sonoran Desert with its rich array of endemic plants (about 30% of the 2500+ species are endemic: cf. Wells 1970), is posed by the distribution of pinyon pines (cf. Wells 1986). As discussed above, *Pinus quadrifolia* is presently restricted to the Sierra San Pedro Martir south to about 30°20′N, and the *Neotoma* record at Santa Ines extends that to 29°46′N, a scant 80 km farther south. The one-needled *Pinus californiarum* has an isolated southern outpost on Cerro San Luis (to 1550 m) at 29°19′N. Neither of these pinyon pines is known from the higher Sierra San Borja (to 1700 m +), where *Juniperus californica* reaches its southern limit. None of these three conifers occurs in Baja California del Sur, the southern half of the peninsula, which has suitably high mountains such as Tres Virgenes (to 2000 m), Sierra de Santa Lucia (to 2000 m), Sierra de la Giganta (to 1770 m), and Sierra de la Victoria (to 2070 m) = Laguna Mountains (Fig. 1). Instead, the Laguna Mountains support an extensive zone of the three-needled Mexican pinyon, *Pinus cembroides* Zucc. (subsp. *Lagunae* Bailey), which has very distinctive pink "endosperm" (gametophytic tissue). In all other species of pinyon pines the food reserves of the seed are white. *Pinus cembroides* has a very wide distribution on the mainland of Mexico. There are also some live-oaks in the Lagunas identical to mainland species (*Quercus reticulata* H. & B., *Q. tuberculata* Liebmann).

Other broad sclerophylls in the isolated Lagunas include the toyon, *Heteromeles arbutifolia* (Lindley) Roemer, *Arbutus peninsularis* Rose & Goldman, and *Garrya salicifolia* Eastw. Most remarkably, no taxa of *Arctostaphylos, Ceanothus,* or *Adenostoma* are known from any mountains of Baja California del Sur (S. de la Giganta, S. de Laguna). Absence of these three most characteristic genera of the California chaparral, including the two most speciose genera, *Arctostaphylos* and *Ceanothus,* is strong evidence of a major isolating barrier in the central sector of the peninsula. The southernmost known occurrence of *Arctostaphylos peninsularis* is in the high Sierra de San Borja at 28°45′N (Wells 2000).

The isolated Sierra de la Laguna pinyon-oak woodland is mainly above tropical deciduous forest, which occupies the lower slopes and surrounding foothills of the Lagunas that are on the Tropic of Cancer (23 ½°N). The absence of *Juniperus californica* or either of the two northern pinyons may mean that these conifers never migrated this far south. Almost certainly, had *Juniperus californica* colonized any of the high mountains of Baja California del Sur, possibly even the summer-rainy Lagunas, it may have survived to the present, inasmuch as its niche is vacant, there being no other species of *Juniperus* in Baja California.

Although the *Neotoma* macrofossil evidence from the northern cirio zone documents a modest displacement of desert vegetation by a mesophytic pinyon pine and evergreen chaparral, there is as yet no evidence as to how far south this Pleistocene climatic effect extended. Even if all the elevated areas north of the Vizcaino plain in the central sector of Baja California were affected, there would be ample room for desert vegetation farther south (Fig. 1). The peninsula is immensely long, extending far into subtropical latitudes. The apparent failure of even the relatively xerophytic *Juniperus californica* to colonize any of the mountains of the southern half of Baja California (it stopped far short in the San Borjas at 28°45′N) suggests a major desert barrier in the central sector of the peninsula, where temperature-sensitive giant cacti, and quasi-endemics like *Idria* (cirio), *Pachycormus, Viscainoa* and others may have survived the long Pleistocene periods of climatic displacement unscathed.

Acknowledgments

Research supported by grants from the National Science Foundation: GB-5002, DEB 78-11187. Special thanks are extended to William H. Clark and his long-term research team at Santa Ines, chiefly from Caldwell, Idaho, who generously shared their discovery of the ancient pinyon midden near their annual camp at Santa Ines.

Literature Cited

Bailey, D. K. 1975. Personal communication 1975–1990.

———. 1987. A study of *Pinus,* subsection Cembroides: the single-needed pinyons of the Californias and the Great Basin. Notes Royal Botanic Garden, Edinburg 44:275–310.

Critchfield, W. B. and E. L. Little. 1966. Geographic distribution of the pines of the world. U.S.D.A. Forest Service Misc. Publ. 991.

Moran, R. 1969. In letter.

Shreve, F. 1951. Vegetation of the Sonoran Desert. Carnegie Institute of Washington Publication 591, Vol. 1.

Wells, P. V. 1966. Late Pleistocene vegetation and degree of pluvial climatic change in the Chihuahuan Desert. Science 153:970–975.

———. 1970. Historical factors controlling vegetation patterns and floristic distributions in the Central Plains region of North America. Department of Geology, University of Kansas, Special Publ. 3.

———. 1972. The manzanitas of Baja California, including a new species of *Arctostaphylos.* Madroño 21: 268–273.

———. 1976. Macrofossil analysis of wood rat (*Neotoma*) middens as a key to the Quaternary vegetational

history of arid America. Quaternary Research 6:223–248.

———. 1983. Paleobiogeography of montane islands in the Great Basin since the last glaciopluvial. Ecol. Monogr. 53:341–382.

———. 1986. Systematics and distribution of pinyons in the late Quaternary, Pp. 104–108. *in* R. L. Everett compiler. Proceedings: Pinyon-Juniper Conference.

———. 1995. Recognizing the new single-leaf pinyon pine (*Pinus californiarum* Bailey) of southern California. The Four Seasons 10:53–58.

———. 2000. The Manzanitas of California, Mexico and the World. Published by the author; 151 p., 150 figs.

———, AND R. BERGER. 1967. Late Pleistocene history of coniferous woodland in the Mohave Desert. Science 155:1640–1647.