Late Quaternary Vegetation History and Paleoclimate of the U.S.A.-Mexico Borderlands Region From Packrat Midden Series

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Fossil Packrat Middens

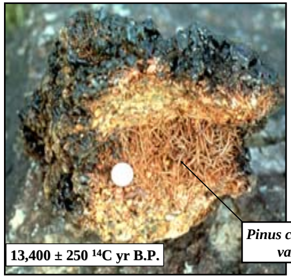


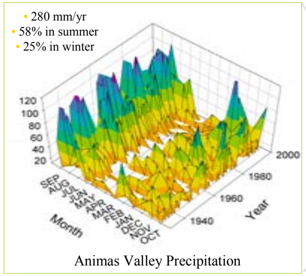
Figure 1. Packrat (*Neotoma)* and an example of a midden showing preservation of macrofossils.

1. Introduction:

Two new packrat midden (*Neotoma* spp.) series reveal glacial to interglacial changes in vegetation and climate in the Playas and San Simon Valleys in the U.S.A.-Mexico Borderlands. The Borderlands, where the states of Arizona and New Mexico intersect with each other and the Mexican states of Chihuahua and Sonora, are characterized by several northwest-southeast trending and tilted fault-block ranges separated by closed topographic basins. These basins now contain ephemeral playas, but held pluvial lakes (Animas, Cloverdale, Cochise, Goodsight, Hachita, Palomas, Playas) during the Pleistocene and lesser lakes sporadically in the Holocene. The valleys receive an annual average of 240-380 mm of precipitation, roughly half of which occurs during summer, while winter precipitation contributes < 20% of the annual average precipitation. Seasonal and interannual precipitation variability is evident in a three-dimensional graph of historical monthly precipitation for Animas, New Mexico near the northern end of Playas Valley (Figure 2).

Packrat middens are deposits of plant materials (seeds, leaves, twigs), bones, pollen, and fecal pellets representing the den of *Neotoma* spp. (Figure 1). These deposits are abundantly preserved in rock crevices and caves in arid areas of the western U.S.A. where pollen is poorly preserved. Series of middens are collected from an area and dated via radiocarbon, providing a "snapshot" of floral assemblages through time. Our study provides insight into key questions about the vegetation history and paleoclimate in the Borderlands:

- How has vegetation changed from the late Pleistocene to present?
- What was the timing of major vegetation/climate changes?
- What was the importance of C_4 grasses and summer annuals in glacial woodlands, and hence the extent of summer rainfall?
- When did modern desert scrub species appear on the landscape?



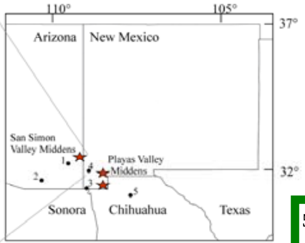
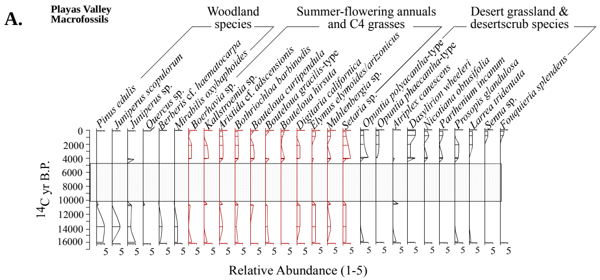


Figure 2. Map of sites and three-dimensional graph of monthly precipitation for Animas, New Mexico. Sites are: (1) Willcox Playa/Paleolake Cochise, (2) Murray Springs, (3) Paleolake Cloverdale, (4) Paleolake Animas, (5) Paleolakes El Fresnal and Santa Maria. Red stars indicate midden sites.

2. Methods:

Nine middens from Playas Valley, NM and 60 middens from the Peloncillo Mountains in San Simon Valley, AZ were collected from areas that currently support desert scrub vegetation. Middens were extracted with a hammer and chisel and the external weathering rind removed. Middens were soaked in water to disaggregate the matrix of crystallized urine and release the macrofossils. Midden materials were wet-sieved, dried, sorted, and macrofossils identified. Macrofossil abundances were quantified using a relative abundance scale of 1 to 5, where 0 = 0 fragments, 1 = 1 fragment, 2 = 2-25, 2.5 = 26-50, 3 = 51-75, 3.5 = 76-100, 4 = 101-150, 4.5 = 151-200, and 5 ≥ 200 fragments. Macrofossils were radiocarbon dated to provide chronological control.



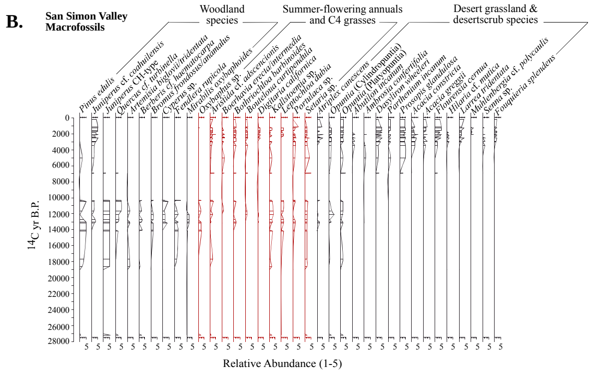


Figure 3. (A) Plant macrofossil relative abundance through time for select species from Playas Valley, NM. Stippled area indicates period from which no middens were found. (B) Plant macrofossil relative abundance through time for select species from San Simon Valley, AZ. Short horizontal bars within the abundance curves indicate midden dates.

5. References:

- Castiglia, P. J. and Fawcett, P. J. (2003). Holocene lakes and Late Quaternary climate variability in the Chihuahuan Desert, Mexico. XVI INQUA Congress Abstract.
- Haynes, C. V. (1991). Geoarchaeological and Paleohydrological evidence for a Clovis-age drought in North America and its bearing on extinction. *Quaternary Research* **35**, 438-450.
- Paruelo, J. M. and Lauenroth, W. K. (1996). Relative abundance of plant functional types in grasslands and shrublands of North America. *Ecological Applications* **6,** 1212-1224.

3. Results & Discussion:

- Pleistocene plant macrofossil and pollen assemblages from middens indicate vegetation along pluvial lake margins consisted of open pinyon-juniper communities dominated by *Pinus edulis, Juniperus scopulorum, Juniperus* cf. *coahuilensis*, and a rich understory of C_4 annuals and grasses.

- The Pleistocene middens contain several summer rainfall indicators including the mid-summer annuals *Boerhavia, Kallstoemia, Mirabilis*, and *Portulaca* and the C_4 grasses *Bouteloua curtipendula, Bouteloua eripoda, Bouteloua hirsuta, Bothriochloa barbinodis, Digitaria californica*, and *Leptochloa dubia*. Although both lake and pinyon-juniper expansion across the lowlands have been attributed to greater winter precipitation, the summer-flowering understory, characteristic of modern desert grassland in the Borderlands, indicates at least moderate summer precipitation during the late glacial.

- A transition to a warmer, drier climate is inferred from the extirpation of *Pinus edulis* from the lowlands of the Playas and San Simon Valleys by 10,300 ¹⁴C yr B.P. The disappearance of pinyon and change to more xeric oak-juniper communities is contemporaneous with other midden sites in the northern Chihuahuan Desert and may have occurred abruptly during the "Clovis-aged Drought" when the water table at nearby Murray Springs dropped to unusually low levels just before 10,900 ¹⁴C yr B.P. (Haynes. 1991).

- Few in our series dated from the middle Holocene (8000 – 4000 ¹⁴C yr B.P.), a period during which middens are scarce across the Southwest. The gap was previously attributed to hydrologic drought during the middle Holocene and declines in woody perennials and packrat populations. However, beach ridge and lacustrine deposits from Laguna El Fresnal and Laguna Santa Maria indicate wetter than present conditions in the Borderlands during the middle Holocene (Castiglia and Fawcett, 2003).

- The late Holocene is marked by the arrival of Chihuahuan Desert scrub elements and few departures. Desert scrub elements begin to appear by about 4000 ¹⁴C yr B.P., marking the transition to present-day vegetation. *Larrea tridentata* and *Fouquieria splendens,* two of the dominant desert species present at the sites today, both appear later than in surrounding areas.

Relative abundance patterns of C_4 grasses, C_3 grasses C_3 shrubs

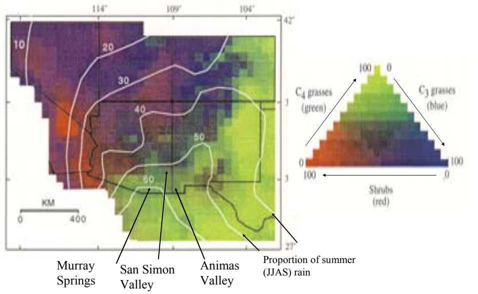


Figure 4. Relative abundance patterns of C_4 grasses, C_3 grasses, and C_3 shrubs across the Great Basin and American Southwest as modeled by Paruelo and Lauenroth (1996). Annual proportions of rainfall in summer months (JJAS) are indicated by isolines.

4. Conclusions:

The midden sequence indicates that pinyon-juniper woodland with a C_4 understory expanded downslope to the margins of pluvial lakes in Playas Valley and surrounding basins during the late Pleistocene, suggesting increased effective moisture with at least moderate summer rainfall. The timing of pinyon-juniper woodland extirpation conforms to other regional records, and may have occurred during the "Clovis-aged Drought." By about 4000 ¹⁴C yr B.P., desert scrub elements begin to appear, marking the transition to present-day vegetation. Future work will include study of pollen samples from the Peloncillo Mountains middens to identify regional vegetation, including vegetation from the valley floor. Climate envelopes for key C_4 and summer-flowering annuals will be constructed in an attempt to quantify the amount of summer precipitation that fell during the Pleistocene.