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SPATIAL AND TEMPORAL DISTRIBUTION OF RADIOCARBON AGES ON RODENT MIDDENS FROM THE SOUTHWESTERN UNITED STATES

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INTRODUCTION

The analysis of rodent middens, principally deposited by packrats (*Neotoma* sp), has rapidly become the most important paleoecologic and paleoclimatologic tool in the southwestern United States. The recent discovery of rodent middens created by stick-nest rats (*Leporillus* sp) and rock wallabies (*Petrogale* sp) in Australia (Green *et al,* 1983; P S Martin, oral commun, 1984) and by dassie rats (*Petromus typicus*) in South Africa (L Scott, oral commun, 1984) portends the use of midden analysis in arid regions worldwide. Several recent reviews of southwestern paleoecology (eg, Spaulding *et al,* 1983) rely heavily on rodent middens for ecologic and climatic reconstructions.

Here I provide a compilation of the spatial and temporal distribution of ^{14}C dates on rodent middens from the Southwest, superseding that of Mead, Thompson, and Long (1978). Packrat middens are usually unstratified, are possibly occupied at different times, and commonly require multiple ^{14}C dates (Spaulding, 1983). Therefore, the chronology of rodent middens depends entirely upon ^{14}C dates. The sampling bias and statistical distribution of ^{14}C dates in time and space strongly affect regional paleoecologic interpretations derived from rodent middens.

METHODS

^{14}C dates and the latitude, longitude, and elevation were collected from all published and selected unpublished studies of rodent middens in the southwestern United States and northern Mexico (see Bibliography). "Rodent middens" refers to predominantly indurated deposits formed by packrats (*Neotoma* sp) and also include several porcupine (*Erethizon dorsatum*) middens from New Mexico, Arizona, and Colorado (Van Devender, Betancourt & Wimberly, 1984). Unpublished dates were obtained from the files of the Paleoenvironmental Laboratories at the University of Arizona and from many individuals associated with midden research. Multiple ^{14}C dates for several middens were included as separate samples because each date, not necessarily each midden, is the basis for age determinations.

RESULTS

A total of 910 ^{14}C dates on rodent middens was obtained for analysis and an additional 42 "modern" middens were dated by the presence of chlorophyllous materials. The University of Arizona analyzed 57% of the dates; 15 other laboratories analyzed the remaining 43%. During 1983–84, researchers obtained 39 of the 910 ^{14}C dates from small samples using the University of Arizona tandem accelerator mass spectrometer (TAMS) (Donahue *et al*, 1983).

A histogram of ^{14}C dates (fig 1) indicates a bimodal distribution with sharp peaks at 0 and 10,000 yr BP. This distribution decays asymptotically towards a frequency of 0 at 50,000 yr BP, the oldest date obtained. "Infinite" dates beyond the age range of ^{14}C analysis are plotted at their minimum age. The >10,000 yr BP section of the histogram can be modelled with the exponential decay function

$$N = 38e^{(-0.92\,(T-10{,}000))},\ r^2=0.79 \qquad (1)$$

where N = the number of samples in the age interval T.

The >10,000 yr BP section is suggestive of a Gamma probability distribution (Haan, 1977). The Gamma distribution is a two parameter distribution with a shape factor n and a scale factor Y; the distribution resembles an exponential-decay curve for $n < 1$. The cumulative Gamma distribution, fit to the >10,000 yr BP data using standard procedures (Haan, 1977), closely matches the cumulative frequency of ^{14}C dates with $n = 0.81$ (fig 2A).

A Gamma probability distribution was fit to the >10,000 yr BP frequency distribution after the 34 "infinite" dates were removed. The resulting cumulative Gamma distribution (fig 2B), with $n = 0.78$, compared favorably with the resulting cumulative frequency of ^{14}C dates. The sum of squared differences between the cumulative Gamma and the empirical cumulative frequency distributions decreased by one half after the "infinite" dates were removed, indicating a better fit. Both the exponential-

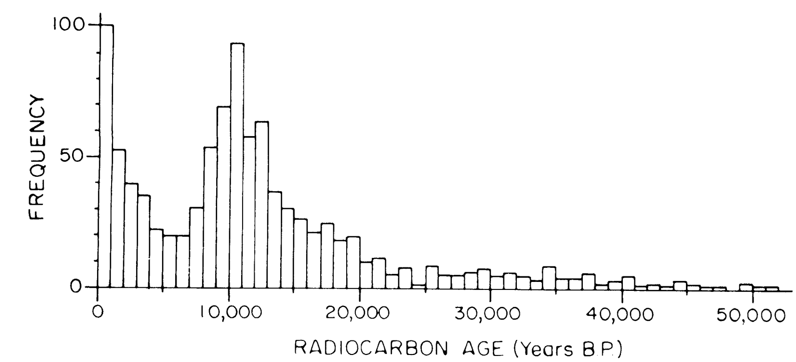

Fig 1. Histogram showing the distribution of 910 ^{14}C dates and 42 "modern" rodent middens from the southwestern United States.

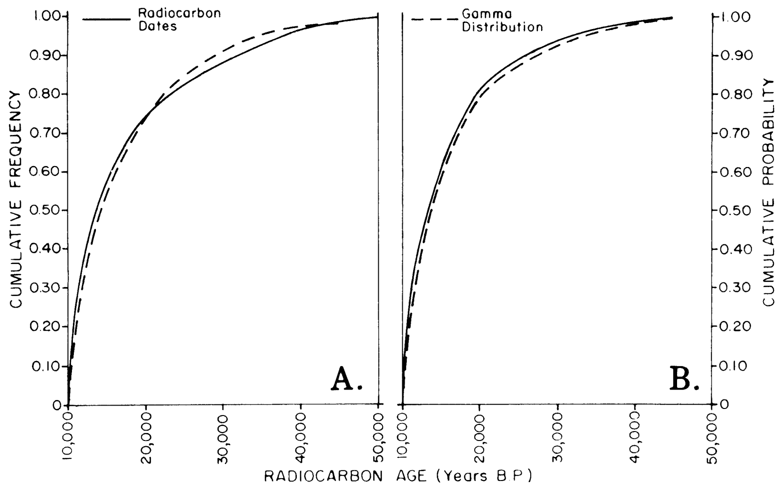

Fig 2. A. Comparison of cumulative frequency of all >10,000 yr BP ^{14}C dates on rodent middens and a cumulative Gamma probability distribution with n = 0.81 and Y = $1.03*10^{-4}$. B. Comparison of cumulative frequency of >10,000 yr BP ^{14}C dates (without "infinite" dates) and a cumulative Gamma probability distribution with n = 0.78 and Y = $1.21*10^{-4}$.

decay model and the Gamma probability distribution of >10,000 yr BP ^{14}C dates support the expectation that the probability of preservation of middens should exponentially decrease with increasing age.

The spatial distribution of ^{14}C dates (fig 3) reveals a concentration of research in several regions. The histogram of dates by latitude and longitude showed a strong bias around latitudes 32° N ± 30′ and 36° N ± 30′ wherein 19 and 36% of the middens were collected, and between longitudes 114°W ± 30′ and 116°W ± 30′ wherein 50% of the middens were collected. Nevada has yielded more ^{14}C dates on macrofossil middens (28%) than any other state. However, few middens have been collected from central Arizona, central and eastern New Mexico, most of Utah, and western Colorado, and only 9 middens have been dated from northern Mexico.

Little bias was present in either elevation or aspect which could not be attributed to the natural topography of the Southwest. Although middens were collected from sea level to 2700m elevation, 95% were collected between 300 and 2100m. The aspect, available for 526 middens, showed no preferential azimuth. Scatterplots of elevation and aspect *vs* ^{14}C age (not shown) revealed no significant relationship which could not be attributed to the spatial distributions of dates by age class.

The ^{14}C dates were divided into age classes to check for sampling bias as a function of age (fig 4). The late Holocene (0–4000 yr BP) age class, which contained 179 dated middens and 42 "modern" middens, had a scattered pattern. Fifty-two percent of these middens were collected from Nevada and the lower Colorado River area (fig 4A) and 72% were collected between 1400 and 2000m elevation. The middle Holocene (4000–8000 yr BP) contained 90 ^{14}C dates, few from any site or region (fig 4B). The early Holocene (8000–11,000 yr BP) age class contained 217 ^{14}C dates, 60% of

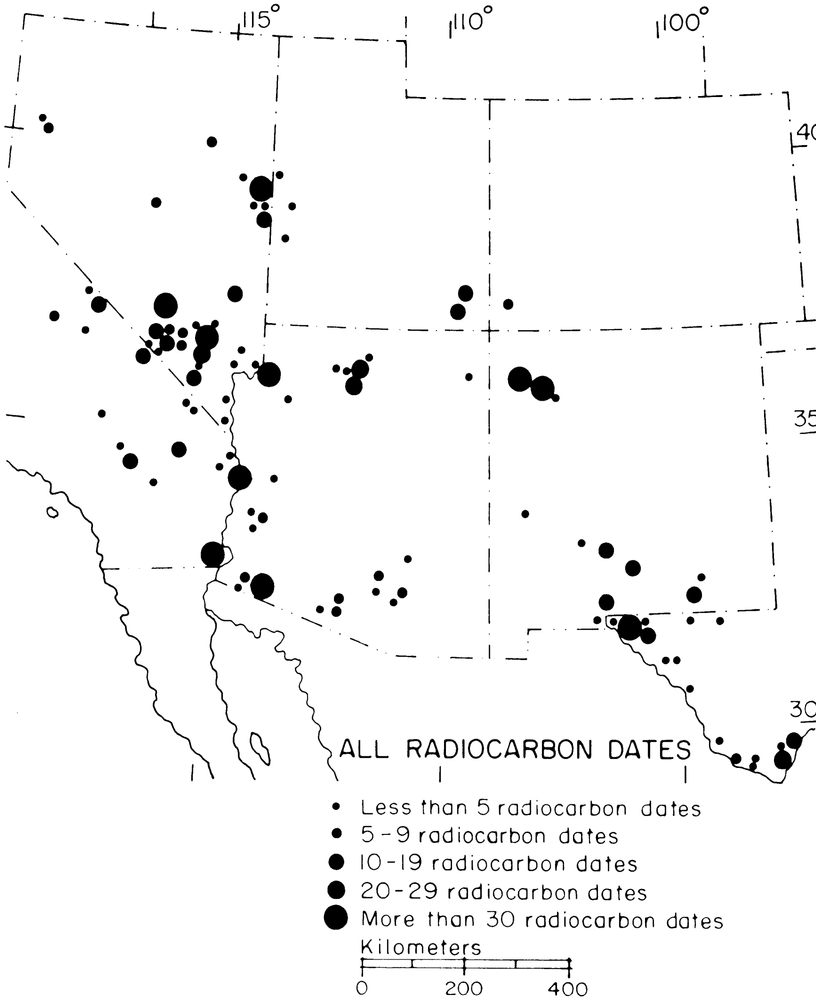

Fig 3. Map of the southwestern United States showing the spatial distribution of all ^{14}C dates on rodent middens.

which were from the lower Colorado River area and southern Nevada (fig 4C).

The distribution of Pleistocene middens reflects specific midden studies. The latest Pleistocene (11,000–15,000 yr BP) age class, with 186 ^{14}C dates, and the full glacial (15,000–22,000 yr BP) age class, with 128 ^{14}C dates, were predominantly collected from southern Nevada (eg, Spaulding, 1983) or the Grand Canyon (eg, Cole, 1982, Mead & Phillips, 1981). The interstadial and infinite (>22,000 yr BP) age class contained 111 ^{14}C dates, 34 of which were of infinite age. These middens were collected primarily from Nevada (61%) and Big Bend National Park (21%), with 33% from replicate dating of two middens from Nevada (Spaulding, 1983).

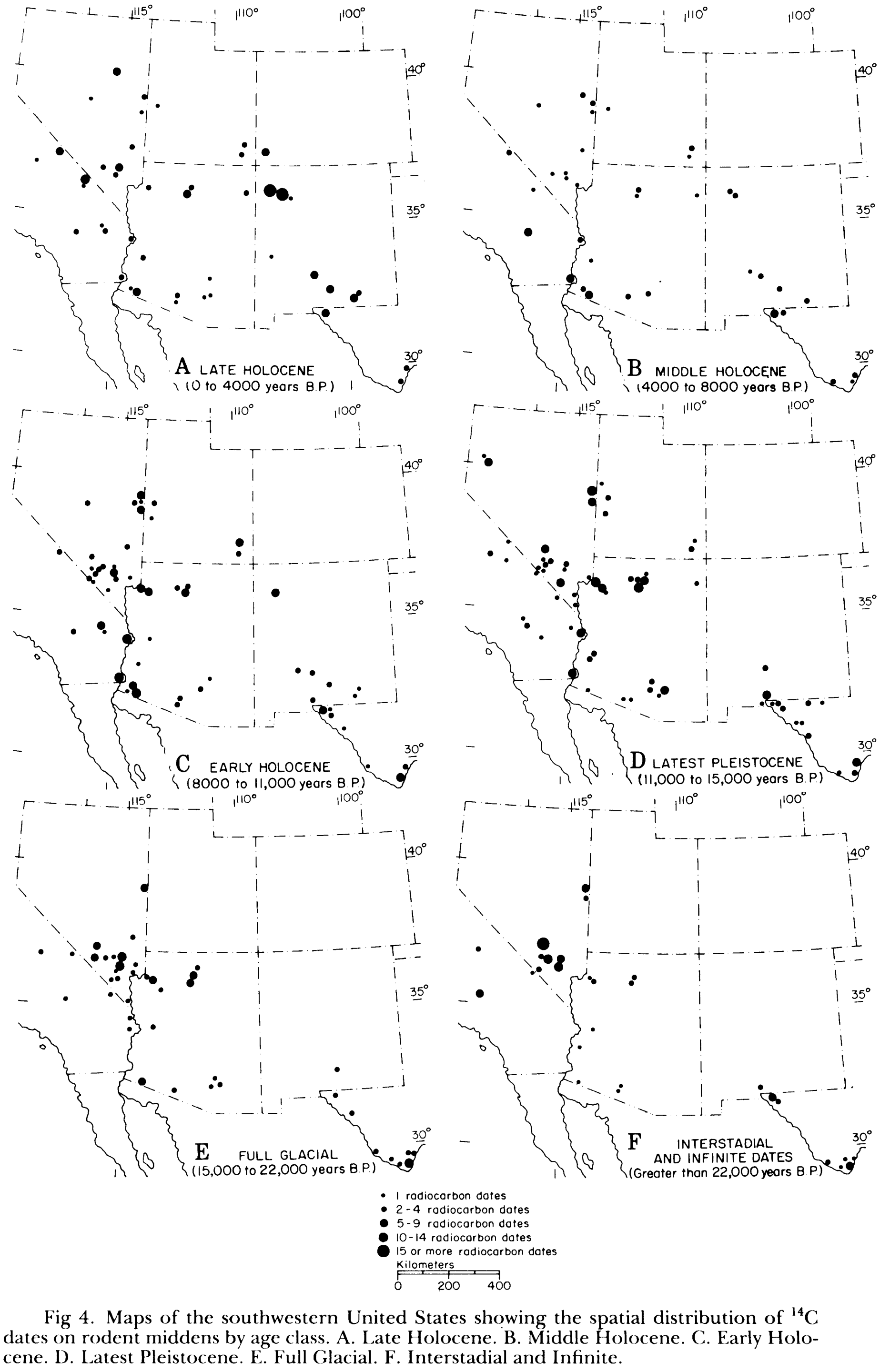

Fig 4. Maps of the southwestern United States showing the spatial distribution of ^{14}C dates on rodent middens by age class. A. Late Holocene. B. Middle Holocene. C. Early Holocene. D. Latest Pleistocene. E. Full Glacial. F. Interstadial and Infinite.

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DISCUSSION

The temporal and spatial distributions of ^{14}C dates on rodent middens raise questions concerning preservation of middens, inherent sample bias, and sample design for future midden research. The temporal distribution of ^{14}C dates >10,000 yr BP suggests that the probability of occurrence of a ^{14}C date in a given age class decreases exponentially with increasing age. Indeed, the observed dates can be fit with an exponential-decay model (eq 1) or Gamma probability distribution (fig 2).

The bimodal distribution of ^{14}C dates (fig 1) can be best explained using researcher bias and the Gamma probability distribution. The shape of the histogram from 0 to 6000 yr BP is suggestive of the Gamma distribution of a lesser number of samples (284) compared with the number of pre-10,000 yr BP samples (520). However, a Gamma distribution cannot be fit because a different statistical population of ^{14}C dates begins at 7000 yr BP. The peak centered on 10,000 yr BP, and the gradual rise from 7000–10,000 yr BP could be caused by selective midden collection, because many studies had a goal of determining biogeographic displacements during the Pleistocene and early Holocene (eg, Van Devender & Spaulding, 1979). The collection of middens containing macrofossils of species now at higher elevations, and rejection of all other middens, created a selective bias towards middens older than 8000–10,000 yr BP. If two sampling populations of ^{14}C dates are assumed, then their bimodal distribution (fig 1) can be interpreted as two Gamma probability distributions with different starting age classes at 0 and ca 10,000 yr BP.

Future research on rodent middens will benefit from the recognition of the present sample bias. Until now, midden sampling has been heavily biased spatially towards the lower Colorado River (including Grand Canyon National Park), southern Nevada, southern New Mexico, and Big Bend National Park regions (figs 3 and 4), and temporally towards >10,000 yr BP ^{14}C dates. While this type of sampling allows intensive site-specific analyses and the comparison of, eg, late Pleistocene plant assemblages in the Mojave, Sonoran, and Chihuahuan Deserts, it does not allow reconstruction of a paleoclimatic "gradient" between these areas (Wells, 1979). Systematic midden collection in central Arizona, Utah, and New Mexico is needed before any regional paleoecologic gradients across the Southwest can be quantified.

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ERRATUM

MOSCOW MV LOMONOSOV STATE UNIVERSITY RADIOCARBON DATES II SEA LEVEL INDICATORS FROM COASTAL USSR

N I GLUSHANKOVA, O B PARUNIN, A O SELIVANOV, A I SHLUKOV, and T A TIMASHKOVA

(Radiocarbon, Vol 25, No. 3, 1983, P 892–898)

An error in the geographic coordinates appears throughout the date list. All the data recorded as minutes should have been tenths of a degree. For example, the first date, MGU-IOAN-129 should read 78.6° N rather than as published, 78° 6′ N.

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