A Late Pleistocene (Rancholabrean) Fossil Assemblage
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ABSTRACT

A fossil assemblage, the Dove Spring Lignites Local Fauna (Whistler and Stewart, 1989), containing mollusks and a diversity of small vertebrates, has been recovered from unnamed stream and pond sediments in Dove Spring Wash on the eastern slope of the Sierra Nevada in the northwestern Mojave Desert, California. The unnamed sediments are discontinuously exposed along Dove Spring Wash, and consist of interbedded sandy lignitic mudstones, calichified arkosic sandstones and cross-bedded pebbly sandstones. The most complete exposure contains over 25 m (82 ft) of sediments, including a distinctive sequence of lignitic horizons in the lowest 5 m to 7 m of section. Charcoal from a conifer branch found within the lignite-rich portion of the sequence has yielded a radiocarbon date of 10,730 ± 110 y BP (Beta Analytical-18449).

The fossil assemblage was obtained from approximately one half ton of matrix from three different lignitic horizons processed using underwater screen sieving. The molluscan species include a clam, four aquatic snails, three terrestrial snails, and a slug. All of these are extralocal taxa. Some of the aquatic taxa indicate permanent water, and several of the terrestrial species may be found living today at moderate to high elevations in the San Bernardino mountains or the Sierra Nevada. The 23 species of vertebrates include frogs and/or toads, lizards, snakes, small birds, and small mammals, representing a mixture of xeric and mesic adapted animals. At least nine species are extralocal, existing today only in areas of permanent, running water or in montane habitats. The other 14 species still occur in the high desert today. Many of the taxa are ecologically incompatible today and the combined assemblage has no modern analog. A moister climate with warmer winters and cooler summers might accommodate such an assemblage.

INTRODUCTION

Pleistocene sediments are common and widely scattered over much of the California deserts (Dibblee, 1967; Hewett, 1954). Continuing tectonism, coupled with pronounced climatic changes, has produced a complex Quaternary depositional history. Arid climate, seasonally heavy downpours and continued tectonism have often led to dissection of even the youngest Quaternary deposits. Many of these dissected
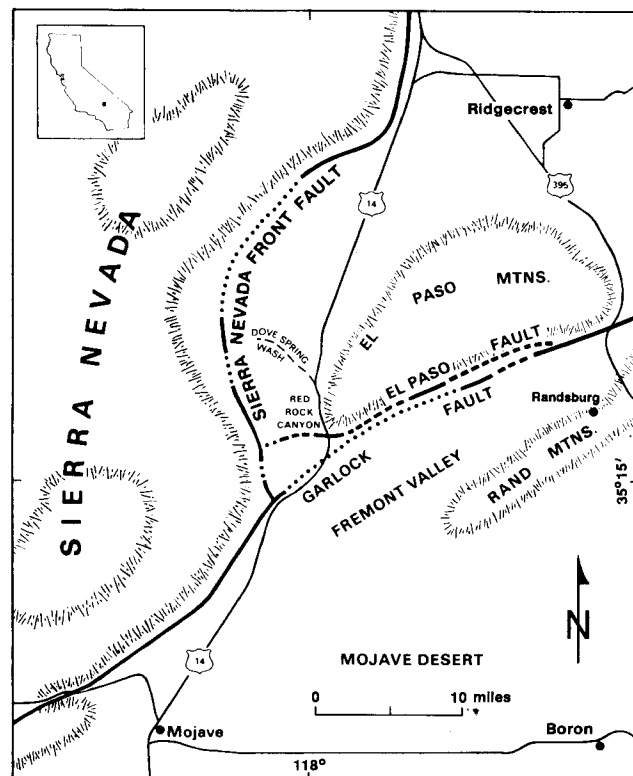

Figure 1. Index map of the northwestern Mojave Desert showing the regional relationships of major faults and mountain ranges to the Dove Spring Wash area.

exposures in the Mojave Desert have yielded fossil assemblages that collectively provide insights into the changing climatic conditions during the last million years (Jefferson, 1989; Reynolds, 1989).

The El Paso Mountains, in the northwestern Mojave Desert, have long been an area of paleontologic interest, primarily due to recovery of diverse Miocene aged vertebrate assemblages in the Ricardo Group (Dibblee, 1952; Merriam, 1919; Whistler, 1969, 1982). There is also a complex history of Quaternary down-cutting and bajada development in the El Paso Mountains that is probably related to periodic uplifts of the emerging Sierra Nevada (Baker, 1912; Dibblee, 1952; Cox, 1982, 1987; Cox and Diggles, 1986; Loomis, 1984; Loomis and Burbank, 1988). In conjunction with studies of the Miocene Ricardo Group, the author and G. T. Jefferson closely examined some of these Quaternary sediments in Dove Spring Wash in 1974. A single rodent femur was discovered in a sandy lignitic bed that was also rich in fossil mollusks. Such mollusk-rich lignitic sediments often yield concentrations of small fossil vertebrates that can be recovered using underwater screen sieving techniques. Two 25 kg samples from superimposed lignitic sandstones were underwater sieved, both yielding samples of mollusks and small vertebrates. This began a sampling program that, to date, has yielded thousands of mollusks, over 100 diagnostic small vertebrate specimens and fossil wood from eight localities scattered along 2 km of outcrops in Dove Spring Wash. No large vertebrate fossils have been found, and all fossil specimens have been assigned to living (extant) species.

METHODS

Geologic mapping was carried out on aerial photographs having an approximate scale of 1:7660. The photographic mapping was transferred to a map base using enlarged, 1:24000 scale, USGS topographic maps to correct for photographic distortions. Columnar sections were measured with a Jacob's staff and direct tape measurements in vertical stream banks. Hand excavated trenches were dug at two locations (Sections A, B, Figure 3) to extend sections below present-day stream base.

Small fossils were recovered from bulk matrix using kerosene and underwater screen sieving with sieve openings of 0.7 mm and 0.5 mm. Additional heavy liquid concentrating was not successful because the fossil vertebrate material had a specific gravity range spanning that of quartz and feldspars, the dominant sand-sized particles. Bulk matrix samples for sieving were taken from lignitic layers, particularly at those levels rich in mollusks. All sampled lignitic horizons yielded at least some bone fragments, but collecting was focused on three horizons that yielded the greatest concentrations (Figures 3, 6).

Fossil specimens were compared with modern osteological collections of the author and the Sections of Herpetology and Mammalogy of the Natural History Museum of Los Angeles County. Standard metric abbreviations are used throughout. Additional abbreviations used are as follows:

LACM = Natural History Museum of Los Angeles County, Los Angeles, California
AP = greatest anterior/posterior dimension
TR = greatest transverse (labial/lingual) dimension
R = right
L = left

All measurements of specimens are in millimeters and are provided only where they are necessary to distinguish species.

GEOLOGIC SETTING

Located near the intersections of the El Paso Fault and Garlock Fault with the Sierran Front Fault, the southern El Paso Mountains are in an area that has had a long history of tectonic activity that continues today (Burbank and Whistler, 1987; Carter, 1986; Loomis and Burbank, 1988). Dove Spring Wash is one of several drainages that developed due to uplift of the southern Sierra Nevada (Figures 1, 4). During the Pleistocene, the eastward flow of the ancestral Dove Spring Wash was intercepted and diverted because of uplift of the El Paso Mountains along the El Paso Fault. Ultimately, Dove Spring Wash drained into Fremont Valley, a major structural basin developed along the trace of the Garlock Fault. Pulses of uplift on the Sierran Front Fault and El Paso Fault have produced periods of both deposition and down-cutting along the route of Dove Spring Wash. In addition, hogback ridges of resistant Miocene
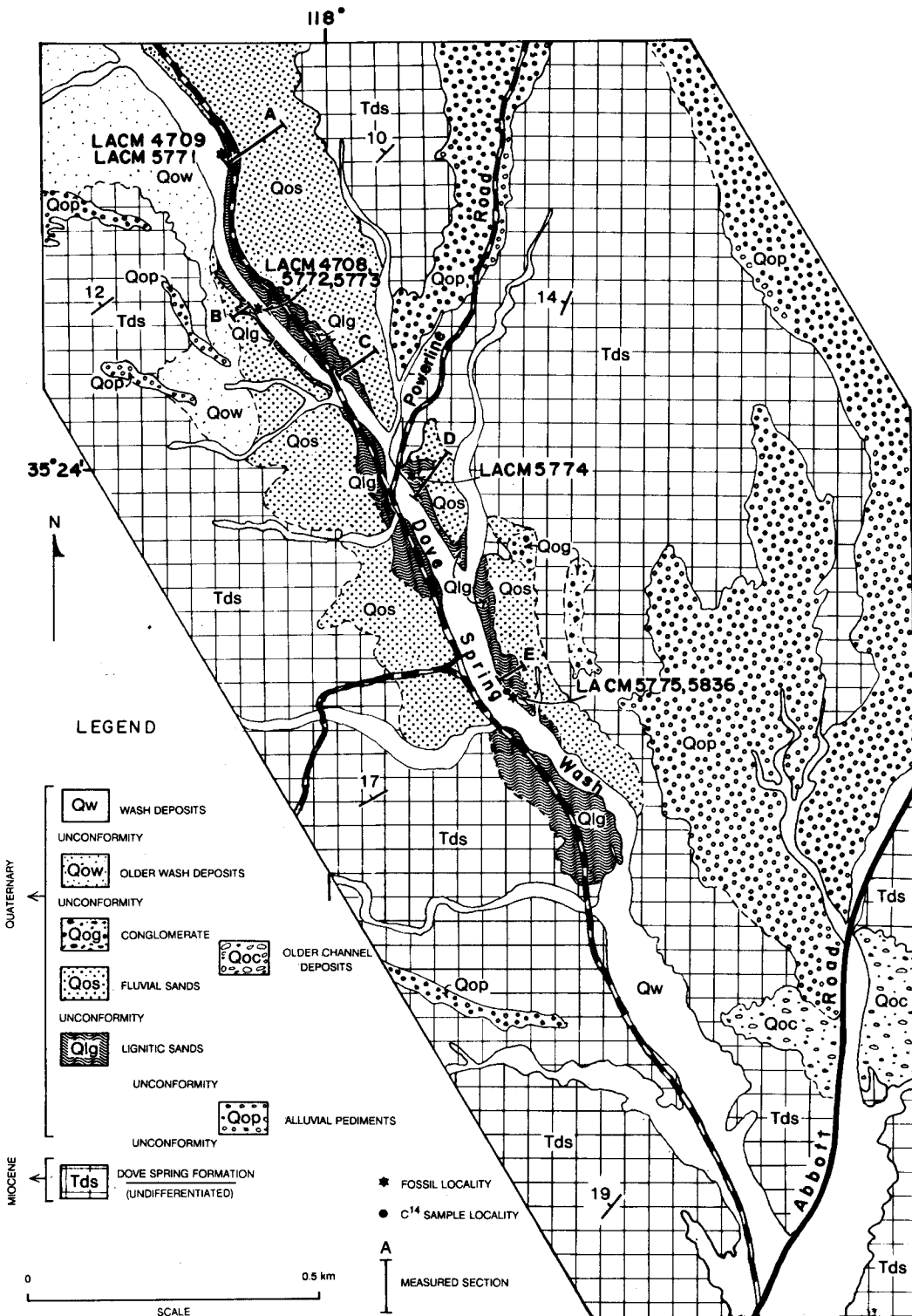
Figure 2 - Geologic map of a portion of Dove Spring Wash showing distribution of Quaternary sedimentary units, locations of measured sections, fossil localities, and the location of fossil wood used for radiocarbon age determination.

strata (Ricardo Group) on the western side of the El Paso Mountains have periodically dammed the drainage and formed ponds in the stream course. The entire area is currently undergoing renewed downcutting, exposing all Pleistocene deposits and the underlying Miocene strata.

The Pleistocene geology along a portion of Dove Spring Wash, and five measured sections, are presented in Figures 2 and 3. In this region of the wash, the Pleistocene sediments are underlain by west-dipping strata of the upper members of the Dove Spring Formation (Dibblee, 1952; Loomis and Burbank, 1988; Whistler, 1969). The Dove Spring Formation in this area is dominated by poorly-sorted alluvial fan deposits, paleosols and silicified hardpans (silcretes). The silcretes are particularly resistant to weathering and form prominent outcrops that produce nick points along the stream course profile.

Older Alluvial Bajada Deposits (Qop)

The oldest Pleistocene deposits form a gently (two degrees to five degrees) dipping bajada developed on the truncated surface of the underlying Dove Spring Formation. The sediments forming the bajada are composed of poorly-indurated, poorly-sorted, massively-bedded, pebbly and boulder-rich arkosic sandstones. These deposits are sheet wash debris derived primarily from the elevated Sierra Nevada to the west, but also contain clasts from erosion of the underlying Dove Spring Formation. The bajada extends from the Sierra Nevada to the western slopes of the El Paso Mountains. Here it merges with less well developed, western-dipping bajadas on the slopes of these lower mountains. During the Pleistocene, resistant volcanic breccias and andesite and basalt flows of the Dove Spring Formation protruded above the bajada surface as northeast/southwest trending hogback ridges. All other pre-Quaternary rocks
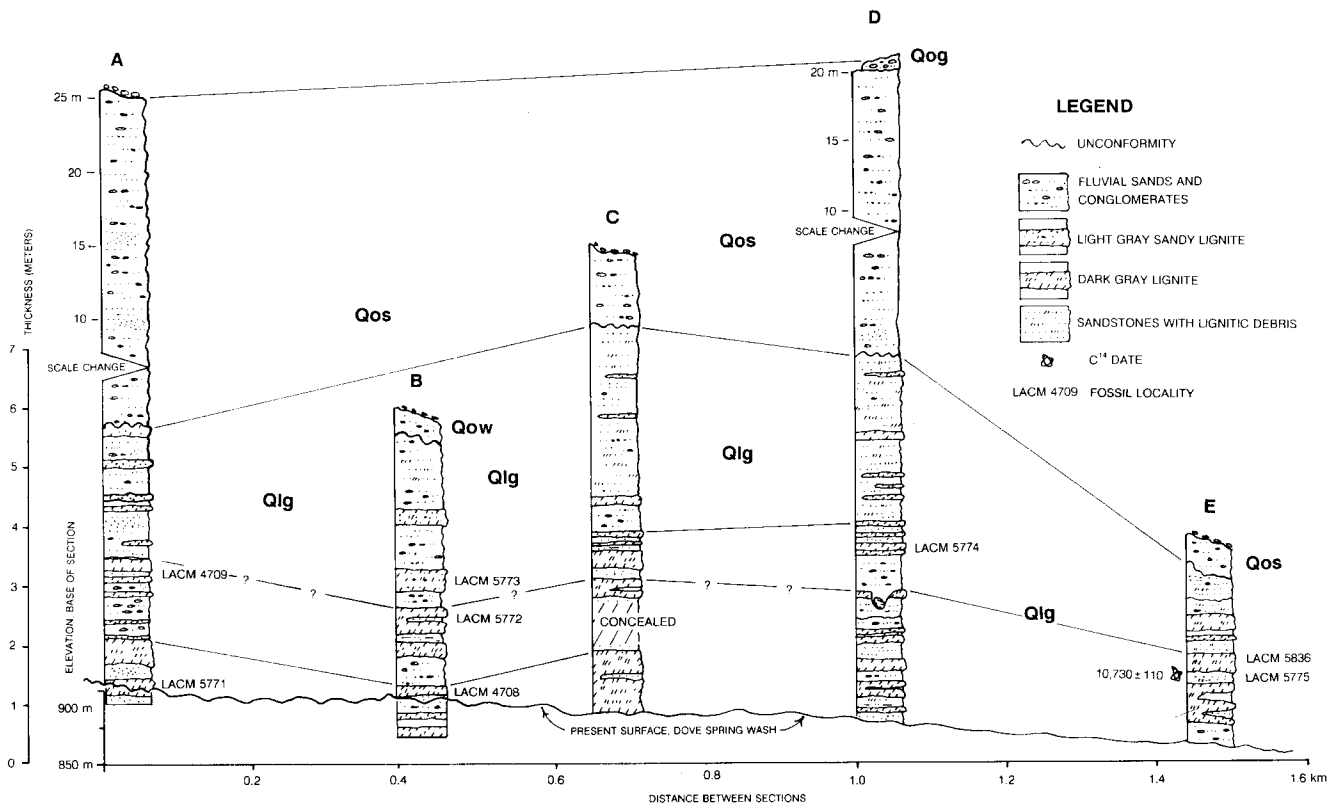

Figure 3 -   Measured sections in the Pleistocene sediments in a portion of Dove Spring Wash showing relationships of the mapped units and stratigraphic positions of fossil localities and the radiocarbon sample locality.

between the El Paso Mountains and Sierra Nevada were buried. These bajadas represent an early to middle Pleistocene episode of relatively stable tectonic conditions. Subsequent erosion, and renewed uplift of the El Paso Mountains, has led to deep dissection of both the bajadas and the underlying older rocks. This dissection may have been enhanced by stream capture of drainages penetrating from Fremont Valley across the southern end of the El Paso Mountains (for example, the main gorge of Red Rock Canyon - Figures 1, 4). The previously-coalesced bajadas are represented today by scattered and isolated patches between actively downcutting drainages and deeply dissected badlands.

Most of the remaining sequence of Pleistocene sediments was deposited in the canyons downcut through the older Pleistocene bajadas (Qop) and into the Miocene Dove Spring Formation. This down-cutting continued 20 m to 30 m further than the down-cutting preceding the bajada development.

Lignitic Sandstones (Qlg)

The oldest unit within the later Pleistocene deposits is a succession of interbedded, very dark gray to lighter gray, sandy lignitic mudstones, pink, light yellow, and white, coarse-grained, arkosic sandstones to pebbly arkosic sandstones, and white, calichified, pebbly sandstones, with a collective thickness up to 7 m. Individual lignitic bands range from less than 1 cm up to 80 cm thick, but most bands average between 10 cm and 20 cm thick. Some bands are continuous for as much as 0.5 km along strike, but others are discontinuous lenses. Several of the more prominent lignitic bands (localities LACM 4709, 5772; Figures 2, 5) grade upward into a very light gray calcareous and gypsiferous sandy mudstone that is very rich in succineid mollusks. Bedding planes are abrupt and well developed in these (Qlg) sediments. Some units, particularly the pink sandstones, display fluvial cross-bedding.

Carbonized plant debris are sufficiently abundant in the lignitic horizons to give the beds a dark gray to black color. Pieces of charcoal up to 5 mm long and pieces of intact, burned wood are also present. One particularly well-preserved specimen of burned conifer branch, up to 3 cm in diameter and over 50 cm long, was collected and submitted for radiometric dating (locality LACM 5575, Figures 2 and 3). A date

of 10,730 ± 110 radiocarbon years before present (1950) with the statistical error representing one standard deviation was reported by Beta Analytical, number 18449 (Florida). This date is consistent with correlations of the fossil assemblage with other dated Late Pleistocene assemblages from the Mojave Desert (Jefferson, 1989; Reynolds and Reynolds, 1985).

This lignitic-rich succession represents fluvial and pond deposits. The ponds were formed by temporary damming of the drainage by resistant hogbacks of silcretes and volcanics within the Dove Spring Formation. In several exposures, the lignitic pond surface has been locally downcut and large (1 m across), stream-bank caved blocks of lignite are incorporated into the non-lignitic arkosic sandstones (Section D, Figure 2). The calcareous and gypsiferous mudstones at the tops of some of the lignite bands represent temporary dessication of ponds.

Old Fluvial Sandstones (Qos)

The lignitic sandstones are unconformably overlain by a succession of less well indurated and poorly cemented, more massive, yellow arkosic sandstones, pebbly sandstones, and poorly sorted, sandy boulder conglomerates with individual granitic boulders up to 20 cm in diameter (Figure 5). This succession is up to 17 m thick in the mapped area. These sandstones represent fluvial, sheet wash, and aeolian reworked fan deposits derived from the granitic Sierra Nevada to the west.

Older Channel Deposits (Qoc)

One half kilometer downstream from the main mapped area, the fluvial sandstones (Qos), and possibly the lignitic sandstones (Qlg), grade into massively bedded, poorly sorted, coarse bouldery sandstones. These deposits (Qoc) are poorly indurated and poorly exposed, but are deposited in a downstream continuation of the erosional channels that were filled with the lignitic (Qlg) and fluvial (Qoc) sandstones in the main drainage of Dove Spring Wash. A direct association between the older channel deposits (Qoc) and the other units has been removed by subsequent erosion and downcutting of Dove Spring Wash.

Older Conglomerate (Qog)

The older fluvial sandstones (Qos) are
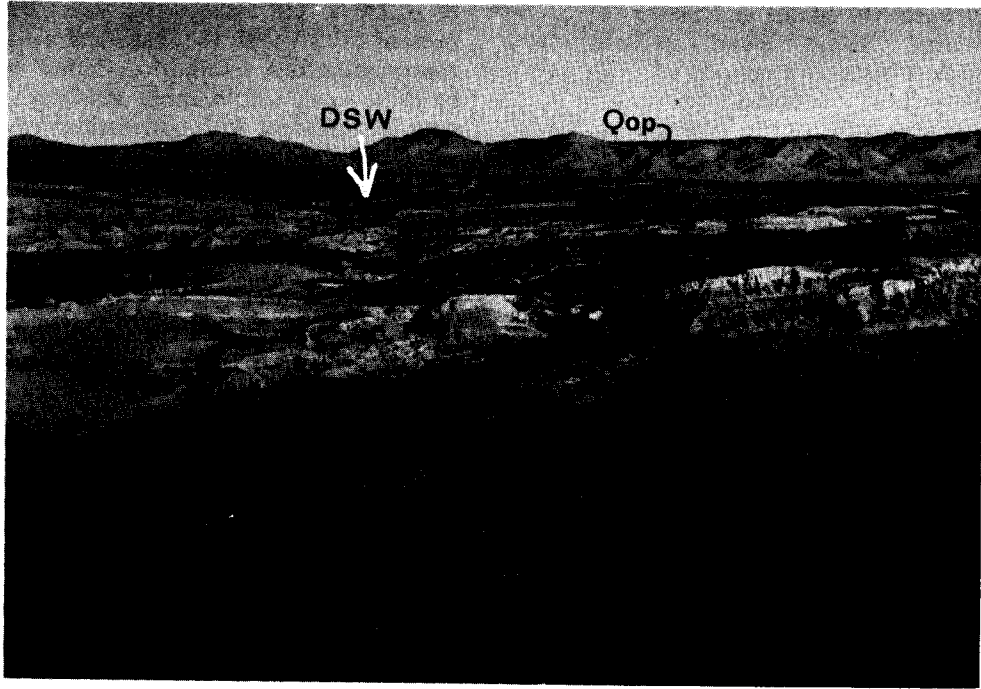
Figure 4 - Oblique photograph looking northwest from the top of the El Paso Mountains toward the Sierra Nevada in the far distance. Dove Spring Wash is the main drainage in the center of the photograph (DSW, white arrow). Notice the flat upper surface of the bajadas (Qop) extending from the Sierra Nevada and deep dissection of this surface in the middle distance. Note also the resistant ridges of Miocene volcanics (dark units = basalts, light units = lithic tuff breccias) in middle distance.
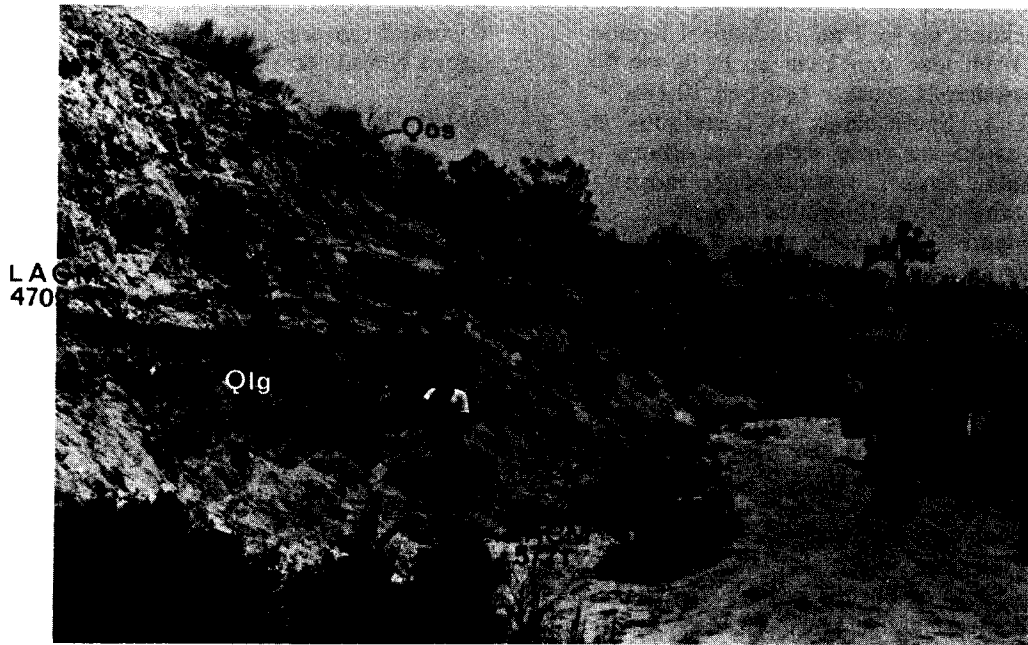
Figure 5 - Photograph at locality LACM 4709 and LACM 5771. Note the distinct lignitic bands (darker gray beds) (Qlg), and the unconformably overlying, more massive, coarse arkosic sandstones (Qos).

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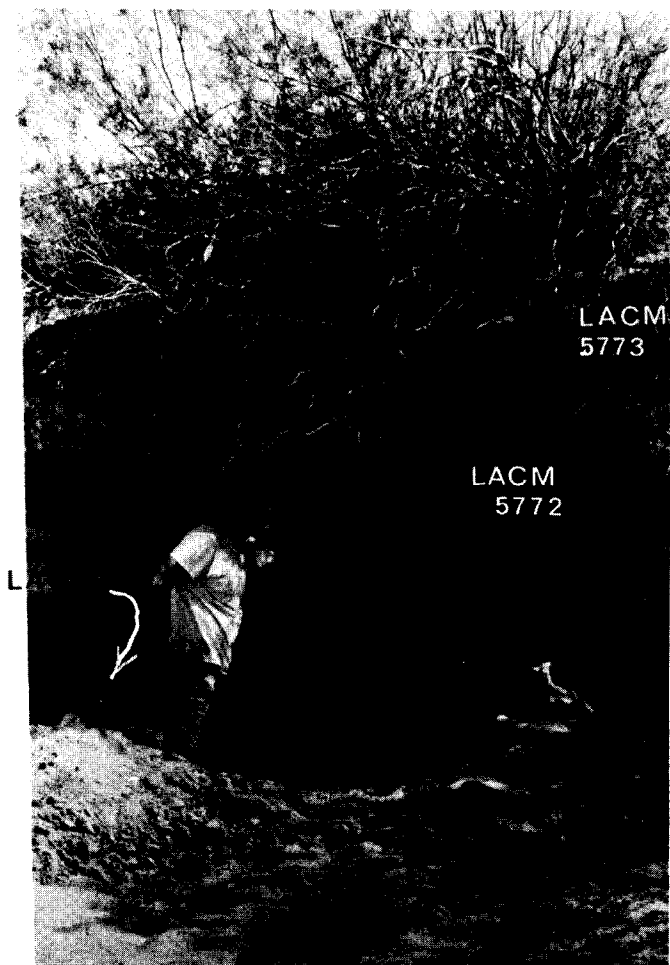
Figure 6. Photograph at locality LACM 4708, LACM 5772 and LACM 5773 Note darker lignitic bands in the bank, each of which has yielded mollusks and small vertebrate fossils.

apparently conformably overlain in one area near the center of the mapped area (Figure 2) by a poorly sorted boulder conglomerate (Qog) composed dominantly of well-rounded boulders (up to 40 cm in diameter) of dark orange quartzite, pink, gray, and purple porphyritic volcanic breccias, dark basalts and andesites, and gray porphyritic granites. All these clast types

are found in Miocene, Paleocene, and late Paleozoic rocks in the El Paso Mountains (Cox, 1982, 1987; Dibblee, 1952; Loomis and Burbank, 1988). This older conglomerate (Qog) represents the western margin of alluvial fans that developed on the western slopes of the El Paso Mountains at the same time that the alluvial fans and older fluvial sediments (Qos) were extending eastward from the Sierra Nevada. The coarseness of the El Paso-derived boulder conglomerate is due to the proximity of the El Paso Mountains and reworking of these large boulders from Tertiary units in the source area.

Older Wash Deposits (Qow) and Wash Deposits (Qw)

The tops of the preceding, later Pleistocene units (Qos, Qoc and Qog) are not preserved in the mapped area. The sediments were downcut to the present grade in the very late Pleistocene or Holocene and are overlain, in part, by Holocene wash deposits (Qow, Qw) composed of unconsolidated arkosic sands containing boulders from the older Pleistocene deposits.

PALEONTOLOGY

A composite faunal list of the fossil assemblage of the Dove Spring Lignites Local Fauna is given in Table 1. The assemblage contains a diversity of small-sized taxa, but no larger animals have yet been recovered. Although all taxa have been referred to extant species, further collecting may yield sufficiently large samples to demonstrate the presence of extinct species. Identifications of mollusks given in Table 1 were provided by R. Lamb and J. D. Stewart, but detailed descriptions of this material are not provided here. The following descriptive discussions of the fossil vertebrate material are not intended to be exhaustive, but provide information on the diagnostic elements recovered and the bases for the specific determinations.

Class Amphibia
Order Anura

The anurans are represented by ungual phalanges, fragments of radio-ulnae, shaft fragments of long bones (femora, tibia-fibulae) and vertebral fragments. All these bear the characteristic punctate bony structure of anuran bones, but none are diagnostic at even the family level.

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Table 1: Dove Spring Lignites Local Fauna

Phylum Mollusca
  Order Veneroidea
    Family Pisidiidae
      Pisidium casertanum (Poli, 1791)
      (clam)
  Order Mesogastropoda
    Family Hydrobiidae
      Pyrgulopsis sp. (aquatic snail)
  Order Basommatophora
    Family Physidae
      Physella concolor (Haldeman, 1841)
      (aquatic snail)
    Family Lymnaeidae
      Fossaria cubensis (Pfeiffer, 1839)
      (aquatic snail)
      Fossaria parva (Lea, 1841) (aquatic
      snail)
  Order Stylommatophora
    Family Vallonidae
      Vallonia cyclophorella Sterki, 1892
      (land snail)
    Family Pupillidae
      Vertigo berryi Pilsbry, 1919 (land
      snail)
    Family Succineidae
      succineids (land snails)
    Family Discidae
      Discus cronkhitei (Newcomb, 1865)
      (land snail)
    Family Limacidae
      Deroceras laeve (Muller, 1774)
      (slug)
Class Amphibia
  Order Anura
    (frog or toad)
Class Reptilia
  Suborder Lacertilia
    Family Iguanidae
      Phrynosoma sp. (horned lizard)
      Sceloporus occidentalis Baird &
      Girard, 1852 (fence lizard)
    Family Anguidae
      Gerrhonotus sp. (alligator lizard)
  Suborder Serpentes
    Family Colubridae
      Pituophis cantenifer Holbrook, 1842
      (gopher snake)
      Lampropeltis getulus (Linnaeus,
      1766) (California kingsnake)

Class Aves
  Order Passiformes
    Species A (perching bird)
    Species B (perching bird)
Class Mammalia
  Order Insectivora
    Family Soricidae
      Sorex palustris (Richardson, 1828)
      (water shrew)
  Order Chiroptera
    Family Vespertilionidae
      Pipistrellus hesperus (Allen, 1864)
      (western pipistrelle)
  Order Lagomorpha
    Family Leporidae
      Sylvilagus, cf. *S. audubonii* (Baird,
      1858) (cottontail)
  Order Rodentia
    Family Sciuridae
      Tamias minimus (Bachman, 1839)
      (least chipmunk)
      Ammospermophilus, cf. *A. leucurus*
      (Merriam, 1889) (antelope ground
      squirrel)
    Family Geomyidae
      Thomomys monticola J.A. Allen,
      1893 (mountain gopher)
      Thomomys ? *townsendii* (Bachman,
      1839) or *T. bottae* (Eydonx and
      Gervias, 1836) (gopher)
    Family Heteromyidae
      Perognathus longimembris (Coues,
      1875) (little pocket mouse)
      Chaetodipus penicillatus
      (Woodhouse, 1852) (spiny pocket
      mouse)
      Dipodomys, cf. *D. merriami* Mearns,
      1890 (kangaroo rat)
      Dipodomys, cf. *D. panamintinus*
      (Merriam, 1894) (kangaroo rat)
    Family Cricetidae
      Peromyscus maniculatus (Wagner,
      1845), or *P. crinitus* (Merriam,
      1891) (deer mouse)
      Reithrodontomys, cf. *R. megalotis*
      (Baird, 1855) (harvest mouse)
      Neotoma fuscipes Baird, 1858 or *N.
      cinerea* (Ord, 1815) (wood rat)
      Microtus californicus (Peale, 1848)
      (vole)

Class Reptilia
Suborder Lacertilia
Family Iguanidae
Phrynosoma sp.

Material: right squamosal with spines (LACM 129754), axis vertebra (LACM 129755).

The squamosal bears large spines that are similar to those of both *Phrynosoma platyrhinos* Girard, 1852, and *P. cornutum* Harlan, 1825. The spines are not as large as those in *P. coronatum* Blainville, 1835, but are distinctly larger than those in *P. douglassi* Bell, 1829.

Sceloporus occidentalis
Baird and Girard, 1852

Material: premaxilla (LACM 129759), right maxillary fragment (LACM 129761), left dentary fragments (LACM 129757, LACM 129758) and left articular (LACM 129760).

The maxillary and dentary fragments bear weakly to moderately tricuspidate teeth typical of many iguanids such as *Callisaurus, Sceloporus, Uma* and *Urosaurus*. The premaxilla and articular are most similar in morphology to species of *Sceloporus*. Among the many species of *Sceloporus* in western North America, the fossil premaxilla is most similar to *S. occidentalis*, with a broad nasal projection including expanded antero-labial flanges encompassing forward projecting foramina (for the terminus of the maxillary artery). The nasal projection is narrower in all other genera and species examined. The articular is also distinctive of *S. occidentalis* in the shape of the articulating surface and the development of the flange posterior to the articular surface.

Family Anguidae
Gerrhonotus sp.

The anguid lizards are unambiguously represented by a single, characteristic osteoscute (LACM 129756).

Suborder Serpentes
Family Colubridae
Lampropeltis getulus (Linnaeus, 1766)

Material: trunk vertebrae (LACM 129762 and LACM 129763) and anterior trunk vertebra (LACM 129764).

All three small vertebrae have short centra, well developed haemal keels, deep subcentral ridges, flattened neural arches and thin, moderately high dorsal spines. The shortened centrum distinguishes these small vertebrae from many small colubrids that would be present in the habitat inferred from the associated assemblage: *Arizona, Leptodira, Hypsiglena, Chionactis*, and *Salvadora*. Several other common genera, such as *Pituophis, Elaphae, Phyllorhyncus*, and *Rhinocheilus*, have much higher dorsal spines than the fossils. Although these small vertebrae are more in the range of the smaller kingsnake species found in western North America, *Lampropeltis zonata* (Blainville, 1835), the short centrum and high dorsal spine are more similar to those of the generally larger, common kingsnake, *L. getulus*.

Class Aves
Order Passeriformes
Family or Families not determined

Birds are represented by two right quadrates (LACM 130271, LACM 130272), fragments of proximal and distal right tibiotarsae (LACM 130267, LACM 130268), and a manubrium of a sternum (LACM 130269).

All specimens are from small, sparrow-sized birds. The two quadrates are sufficiently different to represent at least separate genera.

Class Mammalia
Order Insectivora
Family Soricidae
Sorex palustris (Richardson, 1828)

Material: left maxilla fragment with M^1 (LACM 129769). AP = 1.40, TR = 1.41.

The large size, heavy pigmentation and long, posterolingualy expanded hypocone identify this as the water shrew, *S. palustris*. The only other shrew in western North America as large as the water shrew is *S. pacificus* of the northwestern coast redwood forests, but this coast redwood species lacks the expanded hypocone present in the M^1 of the water shrew.

Order Chiroptera
Family Vespertilionidae
Pipistrellus hesperus (Allen, 1864)

Material: LM^2 (LACM 129768). AP = 1.26, TR = 1.75.

This very small tooth is distinctly wide (transversely), thus appearing narrow antero-posteriorly. It has strong styles, a separate paraconule, a well developed anterior cingulum and a single hypocone with a large lingual cingulum. The small size distinguishes this from many larger bats (both resident and migratory) found in the area today. Species in only three genera of small bats found in the general area today have the wide and narrow M^2: Lasiurus, Lasionycteris and Pipistrellus. Lasiurus lacks the anterior cingulum and has a less distinct paraconule. Lasionycteris has a peculiarly split hypocone. Pipistrellus hesperus is the only species of pipistrel in western North America, and no comparisons have been made with the eastern species. Myotis, a common small bat of this area, lacks the wide and narrow M^2.

Order Lagomorpha
Family Leporidae
Sylvilagus, cf. S. audubonii (Baird, 1858)

Material: RP_4 or M_1 (LACM 129771), LdP^4 (LACM 129772), right calcaneum (LACM 129770) and other, uncatalogued postcranial fragments.

The isolated teeth are not particularly diagnostic. The length of the calcaneum (16.3 mm) is shorter than average specimens of S. audubonii, thus much smaller than the other leporids in western North America except the tiny S. idahoensis (Merriam, 1891). The fossil calcaneum is larger than average specimens of S. idahoensis.

Order Rodentia
Family Sciuridae
Tamias minimus (Bachman, 1839)

Material: RM^2 (LACM 129819), LM^3 (LACM 129820). M^2: AP = 1.18, TR = 1.56; M^3: AP = 1.14, TR = 1.36.

The small size and triangular outline of the molars, constriction of the metaloph at the

connection to protocone and absence of a protoconule distinguish these specimens as a species of Tamias, rather than Ammospermophilus. There are only two species of Tamias in western North America as small as these specimens, T. minimus and T. alpinus (Merriam, 1893). The teeth are well within the size range of T. minimus, but slightly larger than the smaller T. alpinus.

Ammospermophilus, cf. A. leucurus
(Merriam, 1889)

Material: LM_2 (LACM 129822). AP = 1.83, TR = 1.84.

This single specimen is slightly larger than the Tamias minimus teeth described above, and it has lower, more rounded cusps, subdued conules and lacks a mesoconid generally present in Tamias lower teeth. The specimen is considerably smaller than all other western "ground squirrels" (Marmota, Spermophilus), some of which also have low, subdued cusps.

Family Geomyidae
Thomomys monticola J. A. Allen, 1893

Material: LP^4 (LACM 129784), RM^1 (LACM 129778), LM^1 (LACM 129783), LM^2 (LACM 129779), RM^3 (LACM 129780), RP_4 (LACM 129785), RM_1 or $_2$ (LACM 129781) and LM_3 (LACM 129782).

Species of gophers are difficult to distinguish on the basis of isolated teeth. A few characters present in the available sample support the referral of these specimens to the mountain gopher, T. monticola, rather than to the common gopher T. bottae (Eydonx and Gervais, 1836). All the teeth are hypsodont and bear particularly narrow dental tracks and relatively thin enamel. The P_4 is the most diagnostic tooth for differentiating this material. It has an anteriorly expanded protoloph which is due, in part, to a wear pattern produced by this tooth being set in an alveolus that is tilted anteriorly in the jaw. This condition, and the apparent expansion of the protoloph, was observed in nine specimens of T. monticola and was not found similarly expressed in any other species.

Thomomys ? townsendii (Bachman, 1839)

Material: RM^3 (LACM 129777), LM$_1$ (LACM 129776). M^3 AP = 1.74, TR = 1.75.

Although gopher teeth are quite variable, this single M^3 is considerably larger (AP = 1.46, TR = 1.61) than the M^3 referred to *T. monticola*. It suggests the presence of a larger gopher in the size range of *T. townsendii*, or very large specimens of *T. bottae*.

Family Heteromyidae

Isolated teeth of perognathines are the most common elements in the fossil assemblage. Two morphological groupings are present, characterized by size and crown height. Other differences are more subtle; position of the first connection between lophs in cheek teeth and relative width of molars versus premolars.

Perognathus longimembris (Coues, 1875)

Material: LP^4 (LACM 129802), LM^1 (LACM 129804, LACM 129805, LACM 129806), LM^2 (LACM 129807, LACM 129808), LM^3, (LACM 129800), LM$_1$ (LACM 129803), LM$_2$ (LACM 129799, LACM 129810), and RM$_2$ (LACM 129801, LACM 129809).

Perognathus is represented by smaller, lower-crowned molars than *Chaetodipus*. In addition, the metaloph on M^1 is narrower than on the P^4, there is a strong hypostyle/protostyle connection in M$^{1-2}$, and a tendency for central connection of the protoconid with the metalophid in P$_4$. The small size of the fossil material compares well with *P. longimembris*, the smallest species in the general area today. The teeth are smaller than those of either *P. formosus* Merriam, 1889, or *P. parvus* (Peale, 1848), the other two species found in the Mojave Desert and Great Basin.

Chaetodipus penicillatus (Woodhouse, 1852)

Material: RP^4 (LACM 129812, LACM 129813), LM^2 (LACM 129814), RP$_4$ (LACM 129817), RM$_1$ (LACM 129815, LACM 129816, LACM 129818), RM$_3$ (LACM 129811).

Chaetodipus is represented by the larger, more hypsodont teeth with a wider metaloph on

the P$_4$ than on the M$_1$, a weak anterior connection between the hypostyle and protostyle in M$_{1-2}$ and P$_4$ with a labial connection between protoconid and metalophid.

Dipodomys, cf. *D. merriami* Mearns, 1890

Material: RP$_4$ (LACM 129773). AP = 1.01, TR = 1.17.

There are two P$_4$'s in the fossil assemblage that, based on size, represent two different species. The smaller is well within the size range and crown height of the common desert kangaroo rat, *D. merriami*.

Dipodomys, cf. *D. panamintinus*
(Merriam, 1894)

Material: RP$_4$ (LACM 129774). AP = 1.27, TR = 1.50.

This specimen is larger and much higher crowned than the specimen referred to *D. merriami* (both specimens in early wear). It is in the size range of both *D. panamintinus* and *D. agilius* Gambel, 1848, but it is tentatively referred to the more common, high desert species, *D. panamintinus*. More precise determination of both species of Dipodomys will require additional material.

Family Cricetidae
Peromyscus maniculatus (Wagner, 1845)
or
Peromyscus crinitus (Merriam, 1891)

Material: RM$^{1-2}$ (LACM 129790), R maxilla with M$^{2-3}$ (LACM 129792), RM^1 (LACM 129798), LM^1 (LACM 129794), LM^2 (LACM 129795), LM^3 (LACM 129791, LACM 129797), LM$_1$ (LACM 129793), RM$_2$ (LACM 129786, LACM 129787, LACM 129796), LM$_2$ (LACM 129788 - 129789).

Isolated teeth of *Peromyscus* are the second most common element in the fossil assemblage. The M^1 and M$_1$ lack the split anterocone(id), and all teeth lack the mesoloph(id), mesostyle(id) and other accessory cusps characteristic of *P. truei* (Schufeldt, 1885) and *P. boylii* (Baird, 1855). It is difficult to differentiate *P. maniculatus* and *P. crinitus* (Merriami, 1891)

on the basis of isolated teeth, but the specimens are clearly smaller than average specimens of *P. californicus* (Gambel, 1848).

Reithrodontomys, cf. *R. megalotis* (Baird, 1858)
Material: right maxillary fragment with M^{1-2} (LACM 129821).

Very small size distinguishes this specimen from *Peromyscus*. It is referred to the only common species of *Reithodontomys* found in western North America, although no direct comparisons were made with the plains harvest mouse, *R. montanus* (Baird, 1885).

Neotoma fucipes Baird, 1855
or
Neotoma cinerea (Ord, 1815)

Material: associated LM^1 and M^2 (LACM 129775). $M^1 AP$ = 2.44, TR = 1.77; $M^2 AP$ = 2.01, TR = 1.51.

It is difficult to distinguish species of *Neotoma* on isolated teeth, but the size of this specimen is more consistent with *N. fucipes/cinerea* than the smaller, desert species, *N. lepida* Thomas, 1893.

Microtus californicus (Peale, 1848)

Material: RM^1 (LACM 130202), LM^1 (LACM 130210, LACM 130203), RM^2 (LACM 130204), LM^2 (LACM 130205), RM^3 (LACM 130207) LM^3 (LACM 130206, LACM 130208), RM_1 (LACM 130209, LACM 130210, LACM 130211), LM_2 (LACM 130212, LACM 130213), RM_3 (LACM 130214, LACM 130215) LM_3 (LACM 130216 - 130219)

The following description was provided by J. D. Stewart. "All the microtine molars from this site are evergrowing, contain cementum in the reentrant angles, and the enamel of the occlusal surfaces is differentiated with thicker enamel on most leading edge of most triangles, and thinner on the trailing edge. All these are characteristic of the genus *Microtus* (see Zakrzewski, 1985). The lower first molars exhibit the characters of the *Microtus* group of species in that five or six closed triangles precede the posterior loop of the occlusal surface of the M_1. Zakrzewski (1985) showed that the M^2 of many *Microtus californicus* have the labial reentrant angle 2 (LRA2) directed posteriorly so that it appears a fourth triangle would become isolated if the LRA2 lengthened. Except for *M. pennsylvanicus* (Ord, 1815), *M. mexicanus* (Saussure, 1861), and *M. richardsonii* (DeKay, 1842), all other North American *Microtus* species have a four-element M^2 that has a posterior loop that projects directly posteriorly. In *M. californicus*, *M. mexicanus*, and *M. richardsonii*, many of the upper second molars have the LRA2 directed posteriorly, so that it appears that an additional triangle would become isolated if the LRA2 lengthened. This condition results in a posterior loop that is directed somewhat lingually. Such is the case in most of the fossil upper second molars from the Dove Spring lignites (eg. LACM 130204, LACM 130206). In *M. pennsylvanicus*, the M^2 always has the additional closed triangle, resulting in a 5-element M^2. In *M. richardsonii*, the first and second triangles of the M_3 are closed, producing a four-element M_3, but they are confluent in other species (Hall and Cockrum, 1953). The Dove Spring fossil lower third molars show the typical three-element condition."

DISCUSSION AND CONCLUSIONS

Although fossils have been recovered from three different levels separated by 3 m stratigraphically (Figures 2, 6), they are treated here as a single assemblage. There are some differences in the relative abundances of species recovered from within individual beds, but sample sizes are small, thus precluding significant conclusions about different biostratigraphic distributions. For example, all but two of the *Peromyscus* teeth (total 13), but no gopher teeth (total 10), have been recovered from locality LACM 5772. LACM 5772 has also produced all but three of the herpetological specimens; in contrast, the fairly common *Perognathus* and *Chaetodipus* are evenly distributed in all the lignitic beds sampled.

Taken as a whole, the Dove Spring Lignites Local Fauna contains a mix of generalists, xeric-adapted species typical of desert environments, and more mesic-adapted species that presently inhabit either montane habitats that border the desert or cooler, more equable habitats that are today hundreds of kilometers farther north. The combined assemblage has no modern ecologic equivalent. However, the fossil assemblage is generally similar in composition to other Late

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Pleistocene assemblages from the Mojave Desert and southern Great Basin (Jefferson, 1989; Reynolds, 1989). Several of the species in the Dove Spring Lignites Local Fauna represent the most mesic, cold-water adapted species yet recovered from the Mojave Desert, thus amplifying the already documented xeric/mesic incompatibility in Late Pleistocene fossil assemblages.

All of the invertebrates are extralocals in geographic ranges. The aquatic molluscs live only in areas of permanent water and the terrestrial mollusks require cooler, moister habitats than are present in the high desert. The extralocal vertebrates are: the anuran, *Sceloporus occidentalis* (common fence lizard), *Gerrhonotus* (alligator lizard), *Sorex palustris* (water shrew), *Tamias minimus* (least chipmunk), *Thomomys monticola* (mountain pocket gopher), *T. ? townsendii* (Townsend pocket gopher), *Neotoma fuscipes* (dusky-footed packrat) or *N. cinerea* (bushytailed packrat), and *Microtus californicus* (common California vole). *S. palustris* and *T. monticola* are particularly moist-adapted species that live in areas of permanent, cold running water. *Gerrhonotus* species commonly live near water throughout their ranges. One species (*G. kingi*) is found along desert streams in southeastern California and Arizona, and another species (*G. panamintinus*) near permanent springs in the high mountains of eastern California and western Nevada, but neither are truly desert forms. *Sceloporus occidentalis* and *N. fuscipes* are generalists and can be found in fairly xeric habitats, but they are not present in high desert today, where instead are found the similar, more typically desert species, (*S. speciosus* and *N. lepida*). *Tamias minimus* is found in semi-arid pinyon juniper habitats, but the only ground squirrels in the desert today are *A. leucurus* (antelope ground squirrel), and *Spermophilus mohavensis* (the rare Mojave ground squirrel). Within the desert, *T. bottae*, the common western pocket gopher, and *M. californicus* are limited to stretches of the upper drainage of the Mojave River where permanent water persists.

The remaining taxa in the Dove Spring Lignites Local Fauna are either generalists in habitat preference or are nearly exclusively arid-adapted or desert species. The generalists are *Pituophis catenifer* (common gopher snake), *Lampropeltis getulus* (common king snake), *Pipistrellus hesperus* (a common bat of arid and semi-arid habitats), *Sylvilagus audubonii* (cottontail rabbit), and *Peromyscus maniculatus* and *Reithrodontomys megalotis* (cricetid mice found in many diverse habitats). The desert species are *Ammospermophilus*, cf. *A. leucurus* (antelope ground squirrel), and all four of the heteromyid rodent species: *P. longimembris, C. penicillatus, D. merriami* and *D. panamintinus*.

A coexistence of xeric-adapted and mesic-adapted species that are found in the Dove Spring Lignites Local Fauna has no modern analog, but such associations were common in Late Pleistocene continental areas, inland from coastal influences (Grayson, 1987; Jefferson, 1989). The generally accepted interpretation for this seemingly incompatible mix of species is that continental environments were more equable, with cooler summers, less severe winters, and greater precipitation spread more evenly throughout the year than today.

The Dove Spring Lignites Local Fauna is the most diverse, Late Pleistocene vertebrate assemblage recovered from fluviatile deposits in the Mojave Desert outside of the Mojave River basin (see Jefferson, 1989, for a discussion of fluviatile, lacustrine and cave assemblages). The Late Pleistocene assemblages along the lower Mojave River Valley near Yermo (Reynolds and Reynolds, 1985), at an elevation of 610 m, contain a greater diversity of fossil reptiles than in the Dove Spring Lignites Local Fauna, including more species typical of desert conditions. The Dove Spring Lignites Local Fauna, at an elevation of 920 m, contains eight small vertebrate species (reptiles and mammals) not recognized from the Mojave River Valley assemblages: *Sceloporus occidentalis, Sorex palustris, Tamias minimus, Thomomys monticola, Neotoma fuscipes, Lampropeltis getulus, Pipistrellus hesperus* and *Reithrodontomys megalotis*. The first five listed above are more mesic-adapted species than similar taxa in the lower Mojave River Valley assemblages. This indicates that some ecologic stratification of vertebrate species, a condition that is pronounced today, was already developing by Late Pleistocene time.

Although the Dove Spring Lignites Local Fauna contains more mesic-adapted extralocal taxa than the lower Mojave River Valley assemblages, it does not exhibit the greater diversity of small mammals found in the Late Pleistocene montane habitats in the eastern

Mojave Desert (eg. Kokoweef Cave, elevation 1770 m, Goodwin and Reynolds, 1989) and southern Great Basin (eg. Mormon Mountain Cave, 1372 m, Jefferson, 1982; Smith Creek Canyon, 1860 - 2060 m, Mead, et al., 1982).

The Dove Spring Lignites Local Fauna is the first good sampling of the Late Pleistocene small species diversity found in habitats intermediate between the low (< 625 m) desert basins of the central and eastern Mojave Desert and more montane locations (>1700 m) surrounding the desert. The Dove Spring Lignites Local Fauna contains a greater percentage of mesic and/or cooler adapted species than the central Mojave Desert assemblages, with two species (*Sorex palustris, Thomomys monticola*) that suggest particularly cool, wet local habitats, even wetter than the montane fossil assemblages. This may be due to the proximity of the Dove Spring Lignites Local Fauna to the continuous, high mountain ranges of the Sierra Nevada, an area that supported mountain glaciers in the Late Pleistocene.

ACKNOWLEDGMENTS

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PALEOMAGNETISM AND TEPHROCHRONOLOGY AS AIDS IN STRATIGRAPHIC STUDIES

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Ideally, the widespread ash beds in the western United States can serve as convenient time markers in stratigraphic sections where they can be positively identified and correlated with tephras of known age and provenance. However, applications of tephrochronology to stratigraphic studies are currently limited to correlations which can be based on an arbitrary confidence level of chemical similarities among the volcanic glasses of various ash layers. Another limitation is the lack of definite ages for many named ash beds.

Magnetostratigraphic information is meager in the published investigations on tephrochronology. Since the recorded dates for ash beds encompass two major polarity chron boundaries and 14 polarity-reversal horizons between 3.5 Ma and 0.6 Ma, investigations of the magnetostratigraphy of the depositional sequences containing ash beds can aid in further refining the tephrochronology of Plio-Pleistocene ash beds.

Recent paleomagnetic studies of a section of lake beds in the Confidence Hills of southern Death Valley have placed age constraints on a number of previously-unidentified ash beds in the 1.6 to 2.0 Ma range.

A RANCHOLABREAN MAMMALIAN FAUNA FROM CATHEDRAL CAVE, WHITE PINE COUNTY, NEVADA

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Recent excavations in Cathedral Cave (Smith Creek Canyon, White Pine County, Nevada) have yielded fossil remains of a diverse Quaternary mammalian fauna. Recovered taxa include *Antrozous* (pallid bat), *Ochotona* (pika), *Phenacomys* (heather vole), *Synaptomys* sp. (bog lemming), *Mustela nigripes* (black-footed ferret), *Camelops* (extinct camel), and *Equus* (extinct horse). Uranium/thorium dates of a flowstone and a fragment of an ungulate leg bone will provide chronologic control. Further taxonomic identifications and taphonomic studies are in progress.

LATE QUATERNARY GEOMORPHIC EVOLUTION OF THE CRONESE BASINS, CALIFORNIA: IMPLICATIONS FOR SYNCHRONOUS GEOMORPHIC RESPONSES IN DESERT BASINS OF SOUTHERN CALIFORNIA AND NEVADA

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East and West Cronese Lake basins are currently at the terminus of the Mojave River drainage basin in southern California. Under the present arid regime, large-scale precipitation events in the San Bernardino Mountains are able to discharge floodwaters downstream of Afton Canyon to a broad fan-delta region, where flow can either go north to the Cronese playas or east to Soda and Silver Lake playas. Prior to overflow of Lake Manix (~22 ka. B.P.) and subsequent buildup of the Mojave fan-delta, the Cronese basins were isolated from the Mojave River. Mojave inflow enters the Cronese basins via a sediment-mantled bedrock channel in the southern margin of East Cronese Lake (which also acts as the lake outflow when lake waters have backfilled to this elevation).

Detailed mapping of shoreline-geomorphic features, excavation of several shallow trenches, and drilling of a short core (3.7 m deep) in East Cronese Lake indicate a complex and well-preserved late Quaternary geomorphic history. At least six different alluvial fan units and five separate eolian units are present in the Cronese basins. Depositional characteristics, shoreline relationships, and relative degree of soil development suggest these units are temporally correlative with similar deposits in the Silver/Soda basins and the Salt Springs Hills area.

Nineteen separate shorelines were mapped in East Cronese Lake. The two highest shorelines (339.5 and 336.0 msl) are preserved as wavecut benches cut into bedrock and were formed at elevations corresponding to the inflow-outflow spillway. Shoreline-geomorphic relationships indicate the A-shoreline was occupied sometime between ~22 ka. and 12 ka. B.P. and the B-shoreline between 12 ka. and 9 ka. B.P. Shorelines C through S were formed during the Holocene. Drilling logs from the east lake indicate deposition of brown-to-green fine-grained clays continued during much of the Holocene, implying the Cronese basins were substantially wetter during this period than nearby Silver Lake. Lake sediments from East Cronese Lake at 5.2 m depth were dated at 3500+/-180 years B.P. (Drover, 1979). Three distinct lacustrine intervals are preserved in the upper 86 cm. of playa sediments and are tentatively correlated to periods of human activity which were investigated by Drover (1979) that center around dates of 570, 390, and <150 years B.P.

The lake stands at 390 and 3500 years B.P. correspond to similar events which have been recorded in desert basins throughout southern California and Nevada, including Silver Lake, Ash Meadows, Death Valley, Searles Lake, and Mono Lake. These renewed pluvial periods coincide with Holocene glacial expansions during the "Little Ice Age" and "Neoglacial."

THE LATE QUATERNARY HISTORY OF LAKE MOJAVE AND THE EVOLUTION OF THE LOWER MOJAVE RIVER DRAINAGE BASIN, SOUTHERN CALIFORNIA

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A complex history of lake-level fluctuations is recorded in subsurface cored lake deposits and shoreline features of Silver Lake and Soda Lake playas, location of former pluvial Lake Mojave and present terminus of the Mojave River. Dated lake sediments from Silver Lake indicate that periodic flooding of the basin began as early as 22,000 years B.P., probably from an already established lake in the deeper Soda Lake basin. Two high and persistent lake stands occurred in the Silver Lake basin: Lake Mojave I (~18 to 16 ka. B.P.) and Lake Mojave II (13.7 to 11.4 ka. B.P.). These lake stands were the result of seasonal discharge of the Mojave River and increased frequency of large-scale floods sourced in the upper Mojave River drainage basin. Periods of intermittent lake conditions separated these lake phases during which Silver Lake experienced several desiccation events, including an extensive drying period at ~15 ka. B.P. Numerous ^{14}C dates on *Anodonta* shells and tufa, and AMS radiocarbon dating of lake sediments indicate that Lake Mojave II produced the majority of the prominent A- and B-shoreline features surrounding the playas. Recent biostratigraphic correlations and age dating of shells (16,270+/-310 years B.P.) in northern Silver Lake indicate that Lake Mojave I also reached the elevation of the overflow spillway (287 msl).

From its beginning to approximately 14 ka. B.P., Lake Mojave was the second of two large desert lakes sustained by the Mojave River. An abandoned spillway (Baxter Wash), south of present day Afton Canyon, probably provided Lake Mojave with Lake Manix overflow during this period. The beginning of Lake Mojave II appears to coincide with the incision of Afton Canyon and the draining of Lake Manix, an event that significantly reduced total lake volume and evaporative surface area (~505 km^2 to ~290 km^2) sustained by the Mojave River. This drastic change in terminal basin morphometry, combined with a progressive loss in Lake Mojave basin storage capacity due to basin sedimentation and spillway downcutting, resulted in substantially greater Lake Mojave overflow. Correlative high stands in downstream Dumont Lake and Lake Manly are due in part to increased Lake Mojave discharge.

A transition to a drier climatic regime eventually resulted in the total drying of Lake Mojave by ~8.7 ka. B.P. Dry playa conditions characterized Silver Lake and Soda Lake basins following this event; however, at least four short-lived lakes (10^1 to 10^2 years in length) occurred during this period. The youngest two lakes (390+/-90 and 3620+/-70 years B.P.) formed during the cooler, wetter periods of the "Little Ice Age" and "Neoglacial" and correlate with similar lake stands recorded in desert basins along the Amargosa and Owens River drainages. The older two lakes are inferred to represent neoglacial conditions in the mid- to early-Holocene.

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VERIFICATION OF PREHISTORIC CAMPFIRES BY THE ARGON-40/ARGON-39 METHOD

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^{40}Ar-^{39}Ar analysis of potassium-bearing minerals from suspected hearth rocks may be used to verify whether or not the rocks were in fact heated above ~500°C for ~30 minutes or more. This new appproach may significantly augment existing techniques such as thermoluminescence and paleomagnetic analysis.

If heating was intense or of long duration, it may be possible to date the heating episode from an "age spectrum" derived from a stepwise heating method. Fires as young as 50,000 years could be dated by analysis of microcline heated to incandescence (>650°C) for ~1 h or more. Younger events are difficult to date because of the minute amounts of ^{40}Ar created in such short intervals. Dating campfires of ancient man is thus feasible if they are late Pleistocene or older.

^{40}Ar-^{39}Ar analysis is promising because it can be used to date events beyond the reach of ^{14}C analysis (~40,000 years), because it can be used even if no organic matter is available, and because it provides an independent check on dates in the age range where both techniques are applicable. It is worth noting that ^{40}Ar-^{39}Ar analysis is fundamentally dependent on the decay rate of ^{40}K, which is known and constant. In contrast, ^{14}C is produced in proportion to the flux of cosmic rays, which may be variable and is poorly known for the Pleistocene.

SOILS AND EROSION ON THE GRANITE COVE PEDIMENT, SAN BERNARDINO COUNTY, CALIFORNIA

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Soils on the Granite Cove Pediment in the east Mojave Desert were studied to determine their morphology and distribution over a representative portion of the pediment. The pediment surface is smooth with a nearly constant 5-6% slope to the southeast. Erosion was an important process which stripped away argillic horizons and exposed petrocalcic horizons (calcrete) at the pediment surface. The presence of petrocalcic horizons had an important effect on the evolution of the pediment surface. Erosion experiments consisted of the placement of a known quantity of painted gravels along transects at three different locations on the pediment. Movement of gravels away from one of the transects was quantified by counting gravels in a grid of dm^2 quadrats following a combined total of 28 mm of precipitation. Raindrop impact, overland flow, and streamflow were the important processes which scattered gravels as far as 85 cm to 85 m downslope from original transects.

LATE HOLOCENE LAKE IN SILVER LAKE PLAYA, EASTERN MOJAVE DESERT: CAUSES AND HYDROCLIMATIC CONDITIONS DURING THE "LITTLE ICE AGE" IN SOUTHERN CALIFORNIA

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Dated lake deposits and the degree of soil development in shoreline features indicate the existence of a shallow perennial lake about 400 years BP in Silver Lake, the terminal playa basin of the Mojave River. Because this lake is so recent, we analyzed modern hydrological and climatological data to demonstrate a present-day physical link between anomalous storm patterns and eight floods in the Mojave River that produced ephemeral lakes in the Silver Lake playa. We then used this physical link as a tool for reconstructing hydroclimatic conditions needed for the establishment of the "Little Ice Age" lake. Flood-frequency analyses of the systematic and historical annual peak discharge of the Mojave River revealed recurrence interval (RI)>8 years for the modern lake-building floods. Simple flood routings from the Mojave River headwaters in the San Bernardino Mountains to the terminal playa and water budget calculations for the resulting lakes indicate a large decrease in floods RI (more frequent floods) during the "Little Ice Age". To produce a perennial lake would require a RI between 0.25 and 2 years for the two largest floods in the systematic record (occurred in 1938 and 1969). These two floods presently have RI>20 years. The water budget calculations were performed with reduced amounts of modern winter and/or summer evaporation and indicate that the above increase in flood frequency is needed even with 50% of modern evaporation. The eight modern lake-building floods are the results of a large-scale anomalous North Pacific atmospheric circulation pattern. The main component of this pattern is a deep low pressure system centered off-shore of central California, often accompanied by a blocking high pressure system in the eastern Aleutians and the Gulf of Alaska. This pattern produces strong westerly/southwesterly winds laden with subtropical moisture into southern California, incuding high-intensity orographic precipitation in the San Bernardino Mountains. These are the only precipitation events which produce sufficiently large floods to overcome discharge losses along the Mojave River and reach the terminal playa 200 kilometers downstream to produce a lake. We suggest that the "Little Ice Age" lake and perhaps older prehistorical lakes in the Mojave River's terminus were formed as a result of these atmospheric circulation patterns. Furthermore, the present-day anomalous pattern had to occur almost annually during the late Holocene to produce the large floods needed to build the lake.

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FRAGILE SOILS OF THE CALIFORNIA DESERT: FACT OR FICTION?

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Numerous investigators have alleged the soils of the California Desert are "fragile". Fragile is normally defined as easily broken or damaged, frail or delicate. Classical organic soil profiles containing A, B, C, and D horizons could be considered as such, particularly when protective vegetative cover is removed and they are subjected to direct impact of precipitation and run-off. This is very evident after such soils are exposed to wildland fire and hydrophobic soil conditions that prevent moisture from infiltrating.

The California Desert, prior to the Holocene modification in greenhouse conditions, was much wetter than today, with average annual rainfall commonly exceeding 20 to 40 inches or more on higher ranges. Precipitation exceeded evaporation. Rainfall now commonly ranges below 6 inches per year over much of the California Desert. Sometimes it comes all at once, several years apart.

During the late Pleistocene, desert valleys supported grasslands and lakes with vast herds of antelope and other animals. Desert mountain ranges supported forests, the desert generally had a protective vegetative cover and classic organic soils with A, B, C, and D horizons covering the landscape. The arid cycle which began about 11,000 years ago must have been accompanied by countless wildland fires. Over a few centuries, the fragile organic soils disappeared down slope into the now dry lakes or playas in internally draining basins, or perhaps down the Colorado River into the delta at the head of the Gulf of California.

About 70% of the California Desert surface is soft, erodible, colluvial or alluvial "soil: or "regolith". Detailed studies of desert surface exposures frequently document poorly-developed "A" or "B" horizons. A detailed study of ten heavily-impacted desert race sites in different terrains and microclimates from Inyo to Imperial counties determined that in nine out of ten cases, the long term impact was apparently negligible. How can this have been?

The desert alluvial, or water-deposited, soils are subject to constant reworking and burial from desert thunderstorms and wind erosion, particularly because of the lack of protective vegetative cover. Calling the desert surface "soil" might be a misnomer; the surface materials might better be described as fluvian or eolian deposits. The material generally has a high percentage of sand, gravel, or stones, low moisture-holding capacity, little organic matter, and often a high alkaline content.

Most of General Patton's more than 38,000 armored vehicles were on continuous maneuvers in the eastern Mojave Desert for 3.5 years during World War II. On isolated older surfaces, tracks remain. However, flash floods, blown sand, and revegetation on dynamic alluvial fans have destroyed most of the original disturbance. All across the California Desert, millions of bomb and shell impact craters were stripped of scrap metal shortly after World War II. Each impact made a hole in the desert; the wind deposited sand and seeds in these depressions which filled with water during the first cloudburst. Each impact became a "flowerpot". Bulldozed playa sediments used as bomb targets and impact craters on playa surfaces were eroded during storm seasons which shallow water continually moving back and forth; eventually, reworking and healing even the largest target or crater, much as giant desiccation fissures heal after a thunderstorm. On many alluvial surfaces, the wind deposited sand around the new clump of sagebrush...ultimately replacing the original depression with a small mount of sage and sand.

A STUDY OF THE WINTER POPULATION OF BALD EAGLES AT SILVERWOOD LAKE AND THE BIG BEAR--BALDWIN LAKE AREA

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Baldwin Lake, a shallow natural body of water east of Big Bear Lake, has probably been the winter habitat of bald eagles for as long as a food supply (fish and water fowl) has been available.

The damming of Bear Valley in 1885 created a much larger food supply and the wintering population of bald eagles increased. A formal count of the population has been conducted since 1979.

With the completion of the Cedar Springs Dam and formation of Silverwood Lake in 1973, more suitable habitat became available, and there is now a constant wintering population of bald eagles at this location. Counts of this population have been conducted for the past three years.

This paper will deal with these statistics and the ecological and environmental implications noted in studying and observing the bald eagle population in these areas.

LATE PLEISTOCENE *NEOTOMA* BIOGEOGRAPHY OF THE GRAND CANYON OF THE COLORADO PLATEAU

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Five species of woodrats (*Neotoma albigula*, *N. lepida*, *N. stephensi*, *N. mexicana*, and *N. cinerea*) currently occur on the Colorado Plateau. This is the largest number of species occurring and potentially interrelating in any region of North America. Woodrats comprise a large percentage of the late Quaternary microfauna of any given site on the Colorado Plateau including the Grand Canyon. Because of the lack of a suitable dental key for the various species of woodrats, most researchers lump these remains under the category *Neotoma* sp. I am developing a dental key to separate the five local species of *Neotoma*.

Dental characteristics of thirty specimens of each species were used to quantitatively and qualitatively differentiate the five species of woodrats. This key will then be used on the remains from a number of Grand Canyon caves containing late Pleistocene deposits. In turn, I hope to reconstruct the late Pleistocene biogeography of *Neotoma* species in the Grand Canyon.

Although this analysis was directed toward *Neotoma* species of the Colorado Plateau, it is applicable to fossil woodrat remains of the Mojave Desert, because several of the same woodrat species (*N. lepida*, *N. albigula*, and *N. cinera*) that occur on the Colorado plateau are also found in the Mojave Desert and adjacent regions.

STRUCTURAL RELATIONS AT THE TWENTYNINE PALMS MARINE CORPS BASE, TWENTYNINE PALMS, CALIFORNIA

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Structural relations at the Twentynine Palms Marine Corps Air Ground Combat Center (MCAGCC) document a mid-Pleistocene change in stress. Extensional block faulting ended 50,000 to 100,000 years before present and has been replaced by compression, causing right-slip shearing in mid-basin and reidel-type associated left shear tearing and ground cracking. Gravity, magnetic, and seismic modelling based on extensive geophysical field work was tested with subsurface work including trenching, remote sensing, and surface mapping.

The West Bullion Mountain Fault Zone was originally mapped by Dibblee (1968) as a concealed fault near the west edge of the mountains behind the main camp area of the MCAGCC. Significant linear basement offsets were identified by geophysical modelling during later studies by Biehler Associates (1983) and Wahler Associates (1983). These lineaments were trenched at several locations and faulting was observed in one area within 30 centimeters of the surface. Pleistocene soil development as old as 100,000 years was identified in the trench (Shlemon, pers. com., 1984), while surface deposits with desert varnish estimated as 35-50,000 years B.P. (Shlemon, pers. com., 1984) were uncut by faulting. The fault is therefore conservatively estimated to have become inactive between 50,000 and 100,000 years B.P. The gentle sinuosity of the mountain front also supports fault inactivity. As mapped, the fault is about 10 miles long and is interpreted to dip steeply to the southwest with a basement offset of about 75 meters down to the west.

Mesquite Lake Fault and various north-trending ground cracks are wrench faults which result from active compression and shearing. These structures disrupt the most recent basinal sediments. Radiocarbon dates of a carbonaceous silt in a trench south of the base yielded an age of 730 AD +/- 100 years cut by the fault within one foot of the surface (Wahler, 1983). The faults are the results of strain accumulated from north to south compression. Reidel shear faulting identified by Fife, 1976, strikes due north through Mesquite Lake sediments at an angle of 25° from the Mesquite Lake Fault. Occasional severe desert floods on the playa have exposed one major fissure.

The north-south Mesquite Lake Fault is up to 25 meters wide and extends from the area of Deadman Lake to its intersection with the Pinto Mountain Fault and southward to the Pinto Mountains. Extreme warping of the basement has occurred in the wedge where these faults meet. Basement at Mesquite Lake is estimated to be 1.5 to 2 km deep whereas, just north of the Pinto Mountain Fault in Twentynine Palms, basement is exposed at the surface. These relations are the result of Pleistocene and earlier downdropping, followed by Pleistocene and later strike-slip faulting. Campbell Hill, east of Twentynine Palms, is composed of Plio-Pleistocene sediments and has resulted from strike-slip compression on the convex side of the fault.

Subsequent studies will concentrate of the Quaternary geology along Mesquite Lake Fault and aspects of the fissuring and playa development.

SPACTIAL SOIL VARIABILITY IN THE CAJON PASS CHRONOSEQUENCE: IMPLICATIONS FOR THE USE OF SOILS AS A GEOCHRONOLOGICAL TOOL

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Spactial variation of soil properties on a single geomorphic surface can have a significant influence on correlations between and age determinations of surfaces based on soil properties. We described 35 soils on four terrace surfaces which constitute part of a well-dated previously described soil chronosequence in Cajon Pass in southern California. Soils were described on both bar and swale sites, removed from the influence of deposition from adjacent sideslopes. Variation in soil properties between these two groups of soils is attributed to different geomorphic processes. Soils from bar sites were less variable and generally less strongly developed than soils from swale sites from the same surface. The degree of variation of soil properties from the same landscape position on a given surface is sufficiently great to raise questions concerning the utility of many conventional chronofunctions for determining the rate of pedologic processes or for providing numerical-age determinations for otherwise undated soils and associated deposits.

AN EVALUATION OF A NON-LINEAR DIFFUSION EQUATION AS A MODEL FOR DETERMINING THE RATE OF SCARP DEGRADATION IN CAJON PASS, SOUTHERN CALIFORNIA

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Many empirical models have been proposed to evaluate the rate of slope degradation; determination of the rate of slope processes will allow for estimating ages of landforms. For tectonic settings involving vertical separation, the degree of degradation of scarps may be one of the more useful tools for determining the most recent faulting event. Measurements made on a terrace riser and associated lower terrace tread in Cajon Pass allow us to evaluate one model of scarp degradation. Radiocarbon dates constrain the time of abandonment to approximately 8,350 years. We measured fourteen scarp profiles along this terrace riser and, using the non-linear diffusion equation of Hanks and Andrews (1988), estimated scarp age. These predicted ages range from 4,830 to 10,920 years. On three of these scarp profiles we described catenas of soils. This allowed us to compare the rate of colluvial accumulation for different parts of the slope as determined from soil profiles with what is predicted by the model. We were also able to compare the variability of soil development with the variability of predicted scarp ages. Previous studies in this area have shown that the most important factor affecting soil development is the influx of eolian dust, so that the profile mass of silt+clay is an adequate measure of degree of soil development. A parallel study of the soils on the terrace tread allows us to compare both the degree of soil development and the variability of the tread soils with the soils on the catenas. Soils below the inflection point were at least as strongly developed as those soils on the terrace tread, and the maximum soil development occurred at the base of the scarp. Most surprising is that the variation of soils on the terrace tread is greater than the variation of catena soils on the same geomorphic position. The variation of predicted ages based on the diffusion model was not reflected in variation of soil development. This would suggest imprecision in the model itself, rather than variation in slope processes.

PIKA (*OCHOTONA*) AND PALEOECOLOGICAL RECONSTRUCTIONS OF THE INTERMOUNTAIN REGION

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Pika (*Ochotona*) are recovered from 36 extralocal sites in the Intermountain Region. Remains include skeletal and dung specimens recovered from cave and packrat (*Neotoma*) midden deposits. Radiocarbon dates (direct and associated) range from 8,030 to greater than 44,600 yr B.P. for extralocal situations. Skeletal remains recovered from deposits may be local or long-distant transports. Packrat middens record the local plant and animal communities. Dung recovered from middens represent local habitation. Pika dung pellets are distinct from those produced by rodents, pygmy rabbits (*Brachylagus*), and cottontails (*Sylvilagus* spp.). Identifications are based on size differences and the biochemical signature produced by nuclear magnetic resonance. Dung may be processed for microhistology, which provides a quantitative list of ingested plant remains. Living pika eat between 58 and 24% graze species; during the late Pleistocene they consumed 0 to 28% graze taxa. Local plant community reconstructions were built using the macrobotanical remains from packrat middens and from the microhistological remains from pika dung, both from the same deposits. Packrats collect a greater number of plant species than do pika; however, the pika provides a more detailed examination of the local grasses. Plant community reconstructions based on packrat middens tend toward a woodland, shrub-open woodland, browse species bias. Pika dung analyses indicate that grasslands were nearby or that the woodlands were possibly more open, containing more grass species.

THE ROLE OF TECTONISM ON THE MOJAVE RIVER STRATIGRAPHIC RECORD

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The Quaternary record of lakes in the Mojave River drainage reflects both climatic shifts and major tectonic changes, especially in the headwater San Bernardino Mountains. Rapid Pleistocene uplift of the San Bernardino Mountains has led to a progressive rain shadow throughout the Mojave Desert, thereby reducing the importance of moisture contributions from the desert region and increasing potential evapotranspiration. At the same time, the percentage and volume of water contributed by the San Bernardino Mountains has increased.

Because of rapid lateral displacements along the San Andreas and adjacent faults, an entire mountain mass has been added to, and then removed from, the Mojave River headwaters during the Quaternary. With the beheading of the Victorville Fan, probably during the middle Pleistocene, the Mojave River drainage became more xeric. Only with the continued rise of the San Bernardino Mountains during the late Pleistocene have hydrologic conditions returned to early Pleistocene moisture levels equivalent to the glacial intervals.

Tectonism has also played a major role in the extension of the Mojave River drainage network. Extensive early and middle Pleistocene ponding in the Hinkley-Harper Lake Basin was probably forced by a low ridge in the Barstow vicinity. Surplus moisture during the late middle-Pleistocene appears to have led to the breaching of the basin, and the extension of the drainage network into the Manix Basin. Due to tectonic activity, the Manix Basin has developed rapidly in the Quaternary, and in turn, may have been breached by an earthquake on the Manix Fault.

TAPHONOMY OF DINOSAUR CAVE, A NATURAL TRAP LAVA TUBE IN THE SNAKE RIVER PLAIN OF SOUTHWEST IDAHO

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Dinosaur Cave was formed in basalts of the Snake River Plain, laid down during the mid to late Pleistocene. Faunal studies of the cave sediment indicate that the present cave entrance opened during the Holocene and has been gradually widening via spalling of the roof. The size of the entrance hole and the dead-fall distance to the roof-spall cone have combined to make Dinosaur Cave a carnivore trap.

Surface material consists of bones and mummies of large microfauna (*Felis rufus, Canis latrans, Taxidea*, and leporids). Most of these taxa are absent from the sub-surface sediment. The majority of the buried fossils are represented by *Spermophilus, Eutamias, Mustela*, and *Peromyscus*. Extra-local species, such as *Phenacomys* and *Ochotona*, have been brought into the cave by owls and possibly in the stomachs of wide-ranging carnivores.

A LATE PLEISTOCENE PECCARY (*PLATYGONUS COMPRESSUS*) AND A PYGMY RABBIT (*BRACHYLAGUS IDAHOENSIS*) FROM THE COLORADO PLATEAU

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A mandible of *Platygonus compressus* was discovered in a borrow pit near Show Low, Navajo County, Arizona. Isolated teeth of *Brachylagus, Microtus*, and *Thomomys* were found in matrix immediately near the peccary jaw. The matrix sediment appears to be non-stratified stream-bank slump. No datable material was associated with the fossils.

Platygonus has been reported from only one other site on the Colorado Plateau (Anita, Coconino County, Arizona). Originally identified as *Mylohyus*, this *Platygonus* is probably not *P. compressus* since the Anita site is Blancan/Irvingtonian in age and *P. compressus* is only found in late Rancholabrean faunas. Only four other sites in Arizona have yielded *P. compressus*.

A literature search has uncovered no reference to *Brachylagus* anywhere in Arizona or on the Colorado Plateau.

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[1] speaker

THE RELATIONSHIP OF THE MANIX FORMATION TO THE UNDERLYING "MOJAVE RIVER FORMATION"

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Jefferson (1985, and earlier) described three interfingering units (B, C, D) of the informally-defined Manix Formation exposed in Manix Wash and in nearby locations along the Mojave River Wash. These fossiliferous units record the history of ancient Lake Manix from well before 350,000 years BP to about 20,000 years ago when the natural dam, in what is now Afton Canyon, was broken by movement of the Manix Fault. Jefferson also designated Unit A, a coarse, unfossiliferous fanglomerate emanating from the Cady Mountains to the south. Unit A disconformably to unconformably underlies fluvial Unit B on the north side of the Mojave River in the Big Bend section. On the south side, Unit A is conformably overlain by a thin section of lacustrine Unit C and deltaic Unit D.

Just east of the intersection of Manix Wash and the Mojave River, an older sequence of gypsiferous silts and clays containing a number of ash layers is exposed in cliffs along the south side of the Manix Fault. Pluhar, Kirshvink, and Adams (1988; also at this symposium) describe an important sequence of paleomagnetic reversals in these playa deposits. Similar reversals occur in analagous strata southward across the Mojave River Wash. That section also displays coarsening upward.

In this presentation we informally denote these pre-Manix deposits as the "Mojave River Formation," and we focus on the stratigraphic relationship between the "Mojave River Formation" and the overlying Manix Formation.

Jefferson (1985) briefly mentions these gypsiferous deposits and infers that they reflect deposition in a closed, internally-drained basin. He infers that this basin existed before the present eastward runoff from the San Gabriel and San Bernardino Mountains developed. He cites stratigraphic and paleomagnetic evidence in Cajon Pass, relevant to the development of easterly runoff, to argue that the gypsiferous and other beds we denote here as the "Mojave River Formation" are probably more than two million years old. If that interpretation is correct, a million or more years, and probably substantial regional tilting, separate the Manix and "Mojave River" formations.

However, east of Manix Wash, we find field evidence for conformable contact between the "Mojave River Formation" and Manix Unit B. Directly south of that area, across the Mojave River Wash, we find that the contact between the highest portion of the "Mojave River Formation" and overlying Manix Unit A is not only conformable but appparently transitional as well. Thus, preliminary field interpretation suggests to us that little if any time interval separates at least the upper portion of the "Mojave River Formation" from the overlying Manix Unit A. In our presentation, this stratigraphic interpretation is compared with the current paleomagnetic evidence of Pluhar, Kirshvink, and Adams. Regional implications are considered.

EVOLUTIONARY ECOLOGY OF MOJAVE DESERT DRAGONFLIES

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My previous work has focused on the behavioral and physiological mechanisms allowing desert insects, dragonflies in particular, to tolerate the extreme thermal environment. Mojave Desert populations of a number of dragonfly species exhibit vigorous flight activity during the hot summer days, enduring extreme head loads gained passively by solar absorption and generated directly as a metabolic byproduct of flight. Since insects lack elaborate heat-dumping mechanisms (such as controlled evaporative heat loss), they have adapted to the thermal environment via tolerance of elevated body temperatures, often as high as 43-46 C for extended periods. Furthermore, these temperatures seem to be not only an outcome of diurnal flight, but are also a prerequisite to flight, as this high range of temperatures is maintained even at much lower air temperatures. Current research is being conducted at the molecular level to elucidate the mechanistic bases of temperature tolerance, as well as the evolutionary history and population structure with respect to these molecular adaptations. Since the species present in the Mojave Desert are also present in many other, much cooler, habitats, and the desertification process is very recent relative to the divergence of these dragonfly species, comparative studies at the molecular level should shed light on the evolutionary and physiological ecology of these insects.

A NEW, LATE BLANCAN FAUNAL ASSEMBLAGE FROM MURRIETA, RIVERSIDE COUNTY, CALIFORNIA

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Composite faunas from the Nutmeg and Crowell-David sites near Murrieta (Table 1) include *Paraneotoma fossilis* and *Mimomys (Ophiomys) parvus* (Repenning, pers. comm. to R.E. Reynolds, 1990) which indicate a late Blancan Land Mammal Age, 3.0 m.y. to 2.0 m.y. *Microtus californicus, Clethrionomys* sp., and *Mammuthus* sp. are absent from these faunas, but are present at the late Irvingtonian (<0.85 Ma) California Oaks Road faunas, one mile to the southeast.

The geographic and structural relationships, and the absence of early Irvingtonian taxa, suggests that separate sections of the Unnamed Sandstone containing the faunas have been juxtaposed along a fault.

Table 1
Faunal Assemblage, Nutmeg Faunas, Unnamed Sandstone

Amphibia
  Ranidae
    Rana sp. (frog)
  Hyliidae
    Hyla sp. (tree frog)
  Bufonidae
    Bufo sp. (toad)
  Plethodontidae
    Plethidontinae (salamander)
Reptilia
  Testudinidae
    Geochelone sp. (giant tortoise)
    Clemmys? sp. (pond turtle)
  Colubridae
    Masticopis sp. (whipsnake)
    Pituophis melanoleucus (gopher snake)
  Viperidae
    Crotalus sp. (rattlesnake)
Mammalia
  Talpidae
    cf. *Scapanus* (mole)

Leporidae
  Leporinae (rabbits)
Geomyidae
  Thomomys bottae (pocket gopher)
Heteromyidae
  ?Dipodomys (kangaroo rat)
  Perognathus sp. (pocket mouse)
Cricetidae
  Peromyscus sp. (deer mouse)
  Paraneotoma fossilis (ancestral wood rat)
  Sigmodon sp. a (cotton rat)
  Sigmodon sp. b (cotton rat)
Arvicolidae
  Mimomys (Ophiomys) parvus (vole)
Canidae
  Canis latrans (coyote)
Equidae
  Equus sp. (large horse)
Antilocapridae
  Antilocapra sp. (pronghorn)

CALIFORNIA OAKS ROAD:
AN EARLY-LATE IRVINGTONIAN LAND MAMMAL AGE FAUNA FROM MURRIETA, RIVERSIDE COUNTY, CALIFORNIA

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The Unnamed Sandstone unconformably underlies the Pauba Formation in the Elsinore fault zone at Murrieta, between Elsinore and Temecula in western Riverside County, California. Collections since 1985 have produced the preliminary faunal assemblage given in Table I.

The presence of *Mammuthus* sp. and *Microtus californicus* places the assemblage in the Pleistocene. *Megalonyx wheatleyi*, *Platygonus bicalcaratus*, *Hypolagus* sp. nr. *H. browni*, *Prodipodomys idahoensis*, and *Sigmodon medius* suggest that the assemblage represents the Irvingtonian Land Mammal Age. The presence of *Clethrionomys* sp. in the Unnamed Sandstone indicates that the lower portion of the sedimentary section is less than 850,000 years BP. The Bishop Ash, 700,000 years BP, occurs approximately in the middle of the section at California Oaks. The 75 m (240 ft) thick section may span 200,000 years between approximately 850,000 and approximately 650,000 years BP.

Table 1
California Oaks Road Composite Fauna, Unnamed Sandstone

Pelecypoda
  Pisidium sp. (fresh water clam)
Gastropoda
  Gyraulus sp. (fresh water snail
  Amnicola sp. (fresh water snail)
  Physa sp. (fresh water snail)
  Vertigo sp. (land snail)
  Pupilla sp. (land snail)
  Succinea sp. (land snail)
  Vallonia sp. (land snail)
Osteichthyes
  Gasterosteidae
    Gasterosteus aculeatus (stickleback)
Amphibia
  Ranidae
    Rana sp. (frog)
  Hyliidae
    Hyla sp. (tree frog)
  Bufonidae
    Bufo sp. (toad)
Reptilia
  Testudinidae
    Geochelone sp. (tortoise)
  Emydidae
    ?*Clemmys* (pond turtle)
  Lacertilia
  Gekkonidae
    Coleonyx variegatus (banded gecko)
  Scincidae
    Eumeces sp. (skink)
  Teiidae
    Cnemidophorus sp. (whiptail lizard)

Anniellidae
    Anniella pulchra (legless lizard)
  Iguanidae
    Phrynosoma sp. (horned lizard)
    Sceloporus sp. (spiny lizard)
    Uta stansburiana (side-blotched lizard)
  Anguidae
    Gerrhonotus sp. (alligator lizard)
Serpentes
  Colubridae
    Masticopis and/or *Coluber* (whipsnake/racer)
    Salvadora ? (patch-nosed snake)
    Diadophis punctatus (ringneck snake)
    Thamnophis ? (gopher snake)
    Lampropeltinae (kingsnakes and ratsnakes)
  Viperidae
    Crotalus sp. (rattlesnake)
Mammalia
  Vespertilionidae
  Talpidae
    cf. *Scapanus* (mole)
  Soricidae
    Sorex sp. (shrew)
  Leporidae
    Lepus sp. (jackrabbit)
    Sylvilagus sp. (cottontail rabbit)
    Hypolagus nr. *browni* (extinct rabbit)
  Sciuridae
    Spermophilus sp. (squirrel)
    Ammospermophilus sp. (ground squirrel)
    cf. *Eutamias* (chipmunk)
  Geomyidae
    Thomomys bottae (pocket gopher)

Heteromyidae
  Prodipodomys idahoensis (ancestral kangaroo rat)
  Dipodomys sp. (kangaroo rat)
  Perognathinae (pocket mice)
Cricetidae
  Peromyscus sp. (deer mouse)
  Reithrodontomys? (harvest mouse)
  Onychomys torridus (southern grasshopper mouse)
  Sigmodon minor medius (cotton rat)
  S. sp. (lg) (large cotton rat)
  Clethrionomys sp. (red-backed vole)
  Neotoma prefuscipes (ancestral wood rat)
  Microtus californicus (vole)
Erethizontidae
  Coendu cascoensis (porcupine)
Mustelidae
  cf. *Mephitis* (skunk)
  Mustela sp. cf. *M. frenata* (long-tailed weasel)

Canidae
  Vulpes sp. cf. *V. macrotis* (kit fox)
  Canis sp. cf. *C. latrans* (coyote)
Equidae
  Equus sp. (large horse)
  Equus sp. (small horse)
Camelidae
  Camelops sp. (camel)
Tayassuidae
  Platygonus bicalcaratus (peccary)
Cervidae
  Odocoileus sp. (deer)
Antilocapridae
  Antilocapra sp. (pronghorn)
Elephantidae
  Mammut sp. (mastodon)
  Mammuthus? (mammoth)
Megalonychidae
  Megalonyx wheatleyi (ground sloth)

IRVINGTONIAN? FAUNAS FROM THE PAUBA FORMATION, TEMECULA, RIVERSIDE COUNTY, CALIFORNIA

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The Pauba Formation unconformably overlies the Unnamed Sandstone in the Elsinore fault zone between Lake Elsinore and Temecula. Recent excavation between Murrieta and Temecula has produced the fossil assemblage listed in Table I.

The presence of *Microtus californicus* indicates a Pleistocene age for the assemblage, and *Mammuthus* sp. cf. *M. imperator* suggests the late Irvingtonian and early Rancholabrean land mammal ages. The fauna from the Pauba Formation contrasts with the early-late Irvingtonian fauna from California Oaks in the Unnamed Sandstone because the Pauba Formation assemblage does not include *Geochelone*, *Hypolagus*, *Prodipodomys*, *Clethrionomys*, or *Sigmodon*.

Table 1
Faunal Assemblage, Pauba Formation

Gastropoda
  Succinea sp. (land snail)
Osteichthyes
  Cyprinidae
    Gila ? *orcutti* (chub fish)
Amphibia
  Bufonidae
    Bufo sp. (toad)
Reptilia
  Emydidae
    Clemmys sp. (pond turtle)
  Viperidae
    Crotalus sp. (rattlesnake)
  Colubridae
    Lampropeltis (kingsnake)
Mammalia
  Soricidae
    Sorex sp. (shrew)
  Leporidae
    Lepus sp. (jack rabbit)
    Sylvilagus sp. (cottontail)
  Sciuridae
    Ammospermophilus sp. (ground squirrel)

Geomyidae
  Thomomys bottae (pocket gopher)
Heteromyidae
  Dipodomys sp. (kangaroo rat)
Cricetidae
  Neotoma sp. (wood rat)
  Peromyscus sp. (deer mouse)
  Microtus californicus (vole)
Equidae
  Equus sp. (large horse)
  Equus sp. (small horse)
Camelidae
  Camelops sp. (camel)
  Hemiauchenia sp. (llama)
Cervidae
  Odocoileus sp. (deer)
Antilocapridae
  Antilocapra? sp. (pronghorn)
Elephantidae
  Mammut sp. (mastodon)
  Mammuthus sp. cf. *M. imperator* (imperial mammoth)

THE BISHOP ASH IN THE COACHELLA VALLEY: STRATIGRAPHIC AND TECTONIC IMPLICATIONS

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Geologic mapping of Pliocene and Pleistocene deposits (including the 0.73 Ma Bishop ash) in the Coachella Valley reveals new evidence on the location and timing of depositional environments and on the evolution of geologic structures developed within the San Andreas fault zone. The Bishop ash is exposed in, from northwest to southeast, the Indio, Mecca, and Durmid Hills, and is tentatively identified in a well at the southeast end of the Salton Sea. In the Indio Hills and western end of the Mecca Hills, the Bishop ash is near the top of the upper part of the Palm Spring Formation. In the northwestern part of the Mecca Hills, the ash is exposed about 5 m above the base of the Ocotillo Formation, which stratigraphically overlies the upper Palm Spring Formation. In both the Durmid Hill area and the well, the Bishop is in the Borrego Formation. The environments displayed in these exposures range from high-energy fluvial to lacustrine--for example, from proximal alluvial fan, to distal alluvial fan, to ponded parts of streams, to shallow and deep lacustrine environments. The exposures of the Bishop ash in the Coachella Valley present a "snapshot" of the geography and depositional environments at 0.73 Ma. The picture revealed is a tectonic valley similar to the present Coachella Valley, except that much of what is now hills was in low relief. Environments revealed in the snapshot are likewise similar to the present settings, with proximal and distal lobes of alluvial fans depositing most of the sediment along the northeast side of the valley. An exception to the similarity is the large lake that was present when the Bishop ash was deposited. The extent of this paleolake is poorly constrained, but we can infer from the thickness of lacustrine deposits that the lake existed for a long time.

A structural implication revealed by the presence of the Bishop ash in the Coachella Valley is that the maximum compressive stress appears to have rotated since the deposition of the ash. New geologic mapping in the western end of the Mecca Hills, for example, shows fold development parallel to the San Andreas Fault, whereas folds developed in slightly older Pliocene and Pleistocene strata are oriented at an angle of about 15 to 30° to the fault. The fault-parallel folds are locally present in the Indio and Mecca Hills, but have not yet been found in the Durmid Hill area. Fault-normal compression thus may be only local and not a regional feature, but needs to be taken into account when describing the structural setting of this part of the Salton Trough.

LATE BLANCAN VERTEBRATES AND MAGNETOSTRATIGRAPHY FROM THE UPPER GLENNS FERRY FORMATION, SOUTHWESTERN IDAHO

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Collections of vertebrate fossils from two new localities in the upper Glenns Ferry Formation near Murphy, southwestern Idaho, failed to yield fossil mammals of an early Irvingtonian Land Mammal Age (beginning approximately 1.9 m.y.). The possibility of Irvingtonian faunas to the northwest of localities of the Grand View Local Fauna (late Blancan) was suspected because the Glenns Ferry Formation decreases in age northwestward. First appearance of the microtine immigrants, *Allophaiomys* sp. or *Phenacomys* sp., was used to recognize the early Irvingtonian. Paleomagnetic analyses of samples from three stratigraphic sections totaling 605 feet, in addition to previous K-Ar analysis of basalts, correlate well to the lower Matuyama Magnetic Chron.

The first locality (Idaho Museum of Natural History, IMNH 145) occurs from 2,800 to 2,900 feet elevation, is composed of fine sands, and has yielded isolated and often worn bones of *Glossotherium harlani*, *Satherium piscinarium*, Canidae, *Thomomys* sp., *Mimomys (Ophiomys) parvus*, *Ondatra idahoensis*, *Mictomys (Synaptomys) vetus*, Leporidae, *Equus* sp., and Proboscidea. The second locality (IMHN 659) occurs at 3,040 feet elevation, contains a fossiliferous silt bed within medium to coarse sands, and has yielded snails, amphibians, reptiles, *G. harlani* (partially complete), *M. parvus*, *Ondatra idahoensis*, *M. vetus*, *Thomomys* sp., and Leporidae.

The new localities near Murphy are probably late Blancan because no Irvingtonian microtines were found, typical late Blancan microtines were found, and the sediments were deposited during the lower Matuyama Chron.

ANALYSIS OF PLANT MACROFOSSIL REMAINS FROM *NEOTOMA* (PACKRAT) MIDDENS IN SOUTHEASTERN UTAH

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The contents of packrat (*Neotoma*) middens in an alcove site in Arches National Park, southeastern Utah, have provided a local floral record for the late Wisconsin glacial period. Late Pleistocene radiocarbon dates ranging from 16,460 to 12,420 B.P., and one Holocene date, 1,930 B.P., were obtained on individual midden samples.

The Pleistocene middens include flora from the existing montane Douglas Fir/White Fir Zone (3050-2400 m), and plants presently growing at 2285 to 1645 m in elevation. No local modern analog is represented by this Pleistocene assemblage of Limber pine (*Pinus flexilis*), Douglas fir (*Pseudotsuga menziesii*), and prickly pear cactus (*Opuntia* sp.). The modern vegetation, a pinyon-juniper woodland, was established within the Holocene period.

RUNOFF CHANGES IN THE SOUTHWESTERN BASIN-AND-RANGE PROVINCE AND THE MOJAVE DESERT: 150,000 YEARS AGO TO THE PRESENT

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Estimates of evaporation rates and closed-basin-lake areas during the past 150,000 years (150 k.y.) allow reconstructions of the volumes of runoff required to sustain the several lakes that formed a chain in the Pleistocene Owens River system. That system at times included large and overflowing lakes in the basins that now contain Owens, China, Searles, and Panamint (dry) Lakes, and it probably contributed water to the lake in Death Valley. The number of lakes in the chain and the size of the terminal lake were functions of the volume of water flowing into them and the volume lost by evaporation from their collective surfaces. If the present climatic regime is considered to be "dry" and the wettest conditions known from the geologic record to be "wet," then the Owens River drainage was characeized by an "intermediate" regime for about 130 of the past 150 k.y. During such "intermediate" regimes, Searles Lake was the terminal lake of the Owens River system. Reconstruction of the sequence of lakes that occupied Searles Lake's basin during these "intermediate" regimes, therefore, allows reconstruction of the magnitudes of, and variations in, runoff from the Owens River drainage. The Mojave Desert, which lies immediately south of this drainage system, had to be affected by a similar sequence of climate changes during this period.

The wetter intervals may have been cooler intervals as well, but it is unlikely that cooling reduced evaporation by more than half. Changes in relative humidity, insolation, and wind velocities are also unlikely to have reduced evaporation rates greatly. By contrast, runoff rates during the wettest intervals appear to have increased by factors of at least 4.5 and perhaps as much as 10 times present rates. Estimates of modern runoff volumes from areas like those in the Owens River drainage--primarily the east side of the southern half of the Sierra Nevada--range from about 30 percent of total precipitation (at low elevations) to 70 or 80 percent (at high elevations). Thus, increases in average runoff percentages could at most double the amount of water reaching the basins downstream. Past increases in runoff from mountains that rarely produce runoff in today's "dry" regime are difficult to estimate, but no combination of reasonable assumptions produces the volume of water required to maintain the series of downstream lakes unless one also proposes a substantial increase in regional precipitation.

Although most of the Mojave Desert is not rimmed by mountains as high as the Sierra Nevada, and precipitation on them would not have been as great, it seems likely that runoff from them during this 150 k.y. period varied by some fraction of the changes documented for the Sierras. Cores of sediments beneath the surfaces of 27 presently-dry lakes in and near the Mojave Desert most probably represent about 1 m.y. of deposition. They show that perennial lakes existed during one or more periods in all 14 of the basins that receive water from drainages extending in part above 2,000 m (6,560 ft). Cores from 10 of the remaining 13 basins that drain lower regions, which would have received even less precipitation, also indicate brief periods of perennial-lake deposition. Clearly, one or more very wet periods occurred in the Mojave Desert when runoff was more than adequate to offset evaporation from areas at least as large as the present playas. As modern evaporation rates in the area average about 2 m per year, Pleistocene runoff volumes must have increased by factors great enough to contribute this much--or more--water to these areas on a perennial basis.

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