Targeting early man sites in the western United States: An assessment of the Manix type section, central Mojave Desert, California

Fred Emil Budinger

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TARGETING EARLY MAN SITES IN THE WESTERN UNITED STATES:
AN ASSESSMENT OF THE MANIX TYPE SECTION,
CENTRAL MOJAVE DESERT, CALIFORNIA

A Thesis
Presented to the
Faculty of
California State University,
San Bernardino

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts
in
Special Major

by
Fred Emil Budinger, Jr.
June 1992
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6/1/92

2 June 92

6/2/92
FRONTISPICE LOW-LEVEL AERIAL OBLIQUE PHOTO OF BASSETT POINT. VIEW TO SOUTHEAST.
ABSTRACT

Adequate testing of the hypothesis that the New World may have been occupied by hunters and gatherers prior to Clovis times (ca. 12,000 B.P.) will require the use of systematic site search strategies. Such strategies should be based on the geoarchaeological potentials of various types of microdepositional environments to yield artifacts in proper stratigraphic context. Consideration of ten basic types of site contexts suggests that coastal marine terraces and lake basins have significant potential to yield evidence relevant to the early man hypothesis.

The geology, geomorphology, stratigraphy, and paleontology, of the Pleistocene Lake Manix basin of the central Mojave Desert suggest it has significant geoarchaeological research potential. The interdigitating lacustrine, fluvi- al, and alluvial sediments of the Manix Formation sediments of appropriate ages for research pertaining to early New World archaeology. The beds have yielded a rich vertebrate and invertebrate Rancholabrean fauna, elements of which are datable by radiocarbon and uranium series techniques. A layer of tephra provides a laterally extensive time marker. Paleoenvironmental studies suggest that lake edge habitats would have been attractive to early human populations.

Careful examination of the Manix sediments resulted in the discovery of a possible lithic artifact. The chalcedony
specimen has a prominent bulb of force, force rays, and compression rings on its ventral surface. Its dorsal surface exhibits evidence of a hinge flake removal, a step termination, and localized unifacial edge flaking. The artifact was discovered in situ in a thin layer of alluvium 5.0 m below a layer of volcanic ash which has been chemically correlated with the Long Canyon ash of the southern Sierra Nevada dated at 185,000 ± 15,000 b.p.

KEY WORDS: Geoarchaeology, Mojave Desert, pre-Clovis archaeology, site search strategies.
ABSTRACT

Adequate testing of the hypothesis that the New World may have been occupied by hunters and gatherers prior to Clovis times (ca. 12,000 B.P.) will require the use of systematic site search strategies. Such strategies should be based on the geoarchaeological potentials of various types of microdepositional environments to yield artifacts in proper stratigraphic context. Consideration of ten basic types of site contexts suggests that coastal marine terraces and lake basins have significant potential to yield evidence relevant to the early man hypothesis.

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Hansen for technical assistance.

Finally, I wish to thank my families. My parents, Fred and Barbara Budinger, and my sister, Pat Budinger, have provided a lifetime of love and encouragement. To my wife, Diane, and my son, Scott, sincere heartfelt thanks.
DEDICATION

This thesis is respectfully dedicated to my families: to my parents and sister: Fred, Barbara, and Pat Budinger, and to my wife, son, and daughter: Diane, Scott, and Angela. This work would never have been finished without their love, understanding, and support.
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CHAPTER I. INTRODUCTION

A persistent question in New World archaeology concerns the hemisphere's initial peopling from Asia. One hypothesis maintains that the continent was uninhabited until circa 12,000 B.P. (years before the present) when people practicing the Clovis adaptive strategy first appeared south of the late Pleistocene continental ice sheets. The other hypothesis maintains that the hemisphere was occupied earlier than Clovis times by generalized hunters and gatherers.

Adequate testing of the pre-Clovis hypothesis will require the use of systematic site search strategies. It is suggested here that such strategies be based on the geoarchaeological potentials of various types of microdepositional environments to yield artifacts or features in proper stratigraphic context.

Geoarchaeological potential is defined here as the potential of a microdepositional environment to yield relatively unambiguous archaeological and paleoenvironmental data. The term is meant to include consideration of environmental factors known to be strong predictors of hunter-gatherer site locations. Such factors include horizontal and vertical distance to water, slope, aspect, rugosity, and overview. Careful consideration should also be given to the depositional and post-depositional factors which affect the
completeness and fidelity of archaeological and paleoenviron-
mental records. Accessibility for study is also a major
factor in any assessment of geoarchaeological potential.

This thesis has two major goals. The first is to
assess, in very general terms, the potential of various
microdepositional environments to yield acceptable archaeo-
logical evidence. The second goal is to access the geoarch-
aeological potential of the upper members of the Manix For-
mation of San Bernardino County, California. This formation
is a complex late Quaternary sedimentary sequence of inter-
digitated lacustrine, fluvial, and alluvial sediments which
has been exposed by incision of the Mojave River in the
Manix basin (Lower Mojave Valley).

This study was undertaken within the context of geoar-
chaeology, a major branch of contextual archaeology (Butzer
1982). Butzer (1982:211) has defined the goal of contextual
archaeology as "...the study of the archaeological record as
part of a human ecosystem within which communities once
interacted spatially, economically, and socially with the
environmental matrix into which they were adaptively net-
worked." Geoarchaeology is a multidisciplinary science in
which the methods and theories of the earth sciences are
applied to problems in archaeology. With its emphasis on
contextual analysis, geoarchaeology integrates geomorphol-
ogy, geology, stratigraphy, sedimentology, soils analysis,
palynology, and paleontology with archaeology (Butzer 1982).
The basic goal in geoarchaeological research is not simply to provide general descriptions of past environmental settings, but rather, to facilitate the holistic understanding of cultural systems in dynamic environmental contexts. Geoarchaeological perspectives and techniques should be useful in developing and implementing systematic search strategies for evidence of early New World populations.

The principal conditions affecting archaeological site formation include sedimentation, erosion, and geomorphic stability. Sedimentation can generate stratigraphic sequences which may seal cultural evidence. Erosional processes can expose, transport, and redeposit cultural evidence. If a geomorphic surface is stable for extended periods, a mixed component record can be generated in which early artifacts are mixed with later ones. Mixed component archaeological records can also be generated by complex cycles of sedimentation and erosion.

In order to predict the location of buried sites in an area it is necessary to develop an understanding of its geomorphic and paleoenvironmental history. Because an area's geomorphology is sensitive to changing patterns of climate and vegetation, it is necessary to understand paleoclimatology and its influence on vegetation and geomorphic responses.

Through the use of geoarchaeological perspectives and techniques it should be possible to develop site locational
models for various microdepositional environments which identify the loci of sedimentation during particular time intervals. Equally important, it should also be possible to delineate areas where sites may have been already removed by erosion or where sites would not be expected to occur because of sediment age or mode of deposition.

The goal of assessing the geoarchaeological potential of the Manix area is attained by completing various tasks. One task is to integrate previous Manix basin studies into a middle and late Pleistocene paleoenvironmental reconstruction of the Manix basin. A second task is to analyze the depositional character of the upper Manix Formation through the preparation of a fine-scale stratigraphic profile. The completion of these two tasks should provide insights into the paleoenvironment of the Manix basin. This study is meant to provide a baseline for future interdisciplinary Quaternary studies which integrate the methods and perspectives of the earth sciences with those of archaeology.

The thesis contents are presented within the framework of four broad divisions: background contexts, literature overviews, stratigraphic analysis, and geoarchaeological evaluation (discussion and conclusions). Chapter II introduces the issue of the initial peopling of the hemisphere as a persistent theme in New World archaeology. The major hypotheses are discussed and the principal scholars on each side of the debate are identified. Chapter III presents a
brief overview of 29 early man sites recorded in the hemisphere thus far.

Chapter IV considers the matter of targeting possible evidence of early man in the western United States. A preliminary search strategy is developed through a consideration of microdepositional environments, archaeological visibility, hunter/gatherer responses to marginal environments, and paleohabitat persistence. Pluvial lake basins are judged to be likely candidate regions in the search for early man and the focus is narrowed to the Great Basin. In this context, paleoclimatology and the dynamics of pluvial lake fluctuations are considered.

Chapter V introduces the Manix basin and the Bassett Point Study area. Climate, biotic communities, and both regional and local geology are discussed. Chapter VI presents the culture history of the southwestern Great Basin.

Chapters VII through IX focus consideration on the Manix basin and its stratigraphic, paleontological, and possible archaeological records. The Mojave River and its drainage basin are discussed in Chapter VII. Chapter VIII describes the stratigraphy of the Pleistocene Manix Formation. The results of field investigations are presented in the microstratigraphic analysis of the upper members of the formation. Chapter
IX presents an overview of Manix basin depositional history. While conducting stratigraphic studies, a unifacially flaked artifact was discovered. This specimen is described and discussed in Chapter X.

The evaluation of paleontological evidence is basic to the reconstruction of any past environment. Chapter XI discusses Manix basin paleontology.

The overriding goal of the thesis is the evaluation of the geoarchaeological potential of the Bassett Point area to yield evidence of early man. This is discussed in Chapter XII.
CHAPTER II. THE EARLY MAN QUESTION IN NEW WORLD ARCHAEOLOGY


The question of when human populations first arrived in the Western Hemisphere is fundamentally an archaeological question. As such it must be answered by archaeological field investigations and analyses (Bryan 1986b; Meltzer 1989). Although data from
other disciplines can contribute to understanding the phenomenon, they cannot constrain, a priori, the timing of the first arrival of people from Asia. Nonetheless, the strategy of placing temporal limits based on estimates derived from other disciplines such as linguistics, physical anthropology and geology has been popular, especially in the last decade.

Greenberg et al. (1986), for example, have suggested that the native languages of North America can be divided into three basic groups: Amerind, Na-Dene, and Eskimo-Aleut. These three language groups are thought to be the result of no more than three migratory pulses from Asia. Based on the relative internal differentiation of each language group, Greenberg and his colleagues postulated that the Amerind migration occurred sometime prior to 11,000 B.P., the Na-Dene at about 10,000 B.P., and the Eskimo-Aleut at about 4,500 B.P. (Greenberg 1987; Greenberg et al. 1986). This formulation contends that the Clovis archaeological record is tangible evidence of the early Amerind migration (Greenberg et al. 1986).

Turner (1983, 1985, 1986, 1987) has asserted that evidence derived from late Pleistocene and Holocene Asian and American teeth supports Greenberg's model of three migrations. He based his conclusions on shared trait patterns, the age of certain dental specimens, and
assumptions about the rates of dental microevolution. According to Turner (1987), the dental evidence suggests a common ancestor of all Native American populations in northern China about 20,000 years ago and the divergence of the Amerind group about 14,000 years ago.

Scholars have looked to Pleistocene geology for evidence which might constrain the time of first arrival in the Western Hemisphere (e.g., Antevs 1935; Wendorf 1966). Beringia, the large landmass exposed during the Pleistocene when the level of the Bering Sea dropped at least 46 m (151 ft) (relative to its current stand), existed for the last time between approximately 35,000 and 14,400 years ago (Hopkins 1982). It was evidently still traversable in winter until at least 10,000 years ago (Bloom 1983; McManus and Creager 1984). Once across the land bridge, movement south into the heart of the continent may have been constrained by the absence of an ice-free corridor between the Cordilleran and Laurentide ice sheets (Haynes 1969). It is thought that such an ice-free corridor was open prior to the last glacial maximum at about 18,000 B.P., and again after the meltback of the ice sheets about 14,000 to 12,000 B.P. (MacDonald 1987; White et al. 1985). Such Pleistocene "windows of opportunity" have suggested to many scholars that entry into the New World would have been possible between 35,000 and 19,000 B.P. and again between 14,000 and 12,000 B.P. Given the linguistic and dental models, these scholars
favor the 14,000 to 12,000 year period as the time of first entry, and view the Clovis culture as its manifestation.

As Meltzer (1989) has pointed out, however, there is no particular a priori reason to believe this or any other time-of-entry scenario. The precise timing of earlier exposures of the Bering Land Bridge is not well understood (Hopkins 1982). It is probable, however, that Beringia was dry land during many of the Pleistocene glacial maxima. It may have been possible for hundreds, or even thousands, of small populations to have moved out of Asia (and perhaps back into Asia from North America) over tens of thousands of years (Meltzer 1989). Furthermore, entry into the heart of North America was not necessarily constrained by the timing of an ice-free corridor. Fladmark (1979, 1986) has suggested that early entry may have been along the Pacific coast.

It is important to keep separate the question of when human populations first arrived in the Western Hemisphere from questions about early subsistence and settlement patterns (Schweger et al. 1982; Morlan 1987). The generally accepted model is that early Western Hemisphere populations were highly specialized big-game hunters who used technologically sophisticated projectile points. This model is based largely on the repeated discovery of Clovis and Folsom projectile points in direct association with very late Pleistocene megafauna on the High Plains. It would not be appropriate to
uncritically project such a pattern of adaptation to other ecosystems and other times (Meltzer 1989). Yet, many archaeologists are doing just that. They believe that a big-game hunting adaptation was necessary for a successful crossing of Beringia (see, for example, Diamond 1987; Haynes 1982). Our understanding of Clovis and Folsom adaptive strategies is based primarily on evidence recovered from a paleoenvironmental record which was monotypic and characterized by low biological diversity (Meltzer 1989). There is no necessary reason to believe that adaptive strategies were similar in high-diversity, high-productivity environments.

A variety of subtle assumptions may be acting to constrain the way in which the issue of the early peopling of the hemisphere is being approached and manner in which potential evidence is being evaluated (Meltzer 1989). Most discussions, for example, assume that only a few discrete periods of migrations occurred and that each involved small, demographically-coherent founding populations. Ruhlen (1987:10), for example, stated that "...at most we can conclude that there were no more than three migrations." Martin (1973:970) envisioned that the early migration from Asia was a one-time event involving 100 people.

There is no reason to believe that early migrations were few and discretely episodic, involving only very small founding populations. The Bering Land Bridge was apparently a dryland corridor between the continents many times during the
Pleistocene. It is known that Beringia was not glaciated during the late Pleistocene. Given clothing and fire, its climate was not beyond human endurance. The faunal paleontological records suggest that there were no major barriers to movement (Grayson 1988). Beringian conditions during earlier glacial maxima, while not yet well understood, may have been similar. People probably could have crossed from Asia to North America during numerous glacial episodes, each of which lasted tens of thousands of years. Windows of opportunity were numerous and not restricted to just the very late Pleistocene. Conceivably, small bands could have entered the New World hundreds or thousands of times during the Pleistocene. However, they may have been here in such small numbers that simply they were not demographically viable over the long run. They may have left archaeological records and still not have produced detectable genetic traces. To find and understand such archaeological records will require well-structured search strategies. Chapter IV considers the goals, site criteria, and data requirements of such strategies.
CHAPTER III. NEW WORLD EARLY MAN SITES

More than 70 archaeological sites predating 12,000 B.P. have been discovered in North and South America. These sites are generally regarded as problematic by the majority of American archaeologists. Skepticism usually concerns the anthropogenic origin of purported artifacts and/or the depositional character and age of host deposits.

This chapter presents an overview of some of the important pre-Clovis sites in the Western Hemisphere (Figure 1). The order of presentation is based on age (i.e., whether 12,000 to 40,000 years old or greater than 40,000 years old) and latitude (generally from north to south through the hemisphere). More complete listings and descriptions of pre-Clovis sites can be found in Bryan (1978, 1986a), Reeves (1985), and Payen (1982b). The synopsis presented here is meant to be an introduction to the artifactual and depositional character of some of the important pre-Clovis sites. By considering the known archaeological record it should be possible to identify factors to be considered when structuring site search strategies.
FIGURE 1
MAP SHOWING THE LOCATIONS OF SIGNIFICANT PRE-12,000 B.P. ARCHAEOLOGICAL SITES IN THE WESTERN HEMISPHERE
North American Sites 12,000 to 40,000 Years Old

Old Crow Basin, Canada

The Old Crow Basin of the northern Yukon Territory of Canada has long been studied because of its rich paleontological record (Irving and Harington 1973). The discovery in 1966 of a mineral-stained caribou tibia flesher tool prompted intensive investigations after it was radiocarbon dated to 27,000 ± 3000 B.P. (GX-1640) (Irving and Harington 1973). The initial radiocarbon estimation was conducted on a sample characterized as "bone mineral apatite." However, as Taylor (1987:53) has pointed out, a more appropriate designation would have been "total carbonate fraction." Such an inorganic fraction is composed both of bone apatite and diagenetic or secondary carbonates. "The $^{14}$C activity of the secondary carbonate fraction generally reflects the degree of isotopic exchange with groundwater carbonates rather than the actual age of the bone" (Taylor 1987:54-55). Subsequent accelerator radiocarbon dating of the tibia flesher yielded an age of only 1,350 ± 150 B.P. (Nelson et al. 1986).

The artifactual discoveries in the Old Crow basin are all bone or antler. Despite the re-evaluation of the tibia flesher, most are still judged to be more than 30,000 years old (Irving 1978; Irving and Harington 1973; Bonnichsen 1978; Morlan 1978). Among the collagen radiocarbon dates derived
from butchered mammal bones are the following: 29,300 ± 1,200 B.P. (laboratory sample number I-11050) on a mammal long bone (Harington 1980:818), 22,600 ± 600 B.P. (I-3573) on a mammoth femur (Bonnichsen 1979:67), 33,800 ± 200 B.P. (I-4227) on a bison humerus (Bonnichsen 1979:67), 25,750 +1,800/- 1,500 (GY-1568) (Irving and Harington 1973), and 29,100 +3,000/-2,000 B.P. (GY-1567) (Irving and Harington 1973). Morlan (1983:54) has reported a uranium-thorium date of 81,068 ± 7,500 b.p. on a butchered mammoth bone recovered from an alluvial deposit.

Fluvial processes have exposed and concentrated some of the fossils on river point bars and in floodplain sediments. Most of the specimens do not appear battered or extensively smoothed and rounded, suggesting that they were not transported great distances. Hundreds of the specimens exhibit cultural modification. Artifactual forms include flaked bone cores and flakes, bones exhibiting spiral fractures thought to have been broken for the removal of marrow, and implements fashioned while bones were green by cutting, fracturing, flaking, and polishing (Bonnichsen 1978, 1979; Morlan 1978). It should be noted, however, that each of these types of alteration can be caused by natural processes. For example, river icing and spring breakup can cause fracturing, flaking, polishing, and striations. Nonetheless, the principal investigators of the Old Crow record believe it is possible to unambiguously distinguish cultural from natural modifications (see, for example, Morlan 1986; Irving 1978, 1982, 1985;
Jopling et al. 1981; Irving et al. 1986). No lithic artifacts have been reported from the Old Crow Basin.

At Old Crow Locality 12, flaked, polished, and cut bones of mammoths and other large mammals have been recovered from pre-Sangamon age deposits. Irving (1985; Irving et al. 1986) has suggested that the specimens, which exhibit little evidence of transport, were systematically modified by man while still fresh. According to Irving, experiments have demonstrated that no agency other than man (using heavy hammerstones) is capable of fracturing probosidian bones in regular and systematic patterns (see also Bonnichsen 1979). Irving reasoned that if natural processes were responsible for the fracturing, modified specimens should have been present in all of the bone assemblages examined. They were not. Irving tentatively dated the Locality 12 specimens to approximately 150,000 B.P. based on the fission-track age of an overlying volcanic ash layer, site stratigraphy, and faunal associations.

The Old Crow discoveries are generally regarded as problematic. Denkin (1973) has stressed that the purported artifacts are in secondary contexts and that no other cultural associations have been recorded. Haynes (1971) has questioned whether the bone specimens were modified while still green. He suggested that in subarctic environments bones can remain durable and suitable for modification for long periods.
Blue Fish Caves, Canada

The Blue Fish Caves site (Morlan and Cinq-Mars 1982) is located in the limestone foothills of the Keele Mountains in the northeast Yukon Territory of Canada. Although there are three caves, only two have been excavated. Thousands of animal bones have been recovered from the two small caves, including a mammoth scapula with cut marks on its surface. A group of selected skeletal elements suggestive of human collecting has also been found. In the upper strata a variety of artifacts of exotic lithologies have been found in association with a horse bone radiocarbon dated to 12,900 ± 100 B.P. (GX-2881) (Morlan and Cinq-Mars 1982:368). Notable in the small lithic assemblage were a burin fashioned on a retouched chert flake and a possible microblade fragment (Morlan and Cinq-Mars 1982). Radiocarbon dates on the butchered mammoth remains range from 15,500 ± 130 B.P. (GSC-3053) (Morlan and Cinq-Mars 1982:368) to 22,000 B.P. (Morlan 1984). Several mammal bones exhibited evidence of human modification. These include two tibiae which each had one end polished. Skepticism regarding the Blue Fish Caves site has focused on the absence of tools in the lower levels and the general absence of features such as hearths.
Sheguiandah, Canada

The Sheguiandah site is a lithic quarry, workshop, and habitation site located on Manitoulin Island in Lake Huron, Ontario, Canada. Five successive and distinctive assemblages of stone tools and flakes have been recorded. The lower two include quartzite scrapers, thin bifaces, flakes, blades and polyhedral cores in glacio-fluvial deposits (Lee 1954, 1955). These artifacts are stratigraphically below late Wisconsinan (Valders) glacial till and are believed to date to the Cary-Tazewell interstadial or earlier. Griffin (1965) questioned the age of the artifacts suggesting that the glacial till was redeposited during an early phase of a Holocene occupation.

Meadowcroft Rockshelter, Pennsylvania

The Meadowcroft Rockshelter is a deeply-stratified, multicomponent site located near Pittsburgh, in southwestern Pennsylvania (Adovasio et al. 1982a, 1982b). Eleven important strata have been described, within which fire pits, ash, and charcoal lenses have been identified. Other cultural evidence includes lithic artifacts, animal bones, fruits of many plant species, and two human bones. In all, 52 stratigraphically concordant radiocarbon dates have been obtained on charcoal and a single burned basket fragment.
Eight of the dates establish a Pleistocene age for the human occupation. Seven of the dates were derived from fire pit charcoal: 12,800 ± 870 B.P. (SI-2489), 13,240 ± 1,010 B.P. (SI-2065), 13,270 ± 340 B.P. (SI-2488), 14,925 ± 620 B.P. (SI-1872), 15,120 ± 165 B.P. (SI-1686), and 19,100 ± 810 B.P. (SI-2062) (Adovasio et al. 1983:Table 1). A date of 19,600 ± 2,400 B.P. (SI-2060) was obtained on the specimen of carbonized basketry (Adovasio et al. 1983:Table 1). The two human bones were found in association with charcoal dating from 14,000 to 12,000 B.P. More than 400 cultural items were recovered including unifacial flake implements and microblade-like cores.

Some workers have suggested that the small assemblage of lithic artifacts recovered at Meadowcroft fit within the general Clovis Complex. Haynes (1980) questioned whether contamination by coal dust in the groundwater may have produced erroneous radiocarbon dates. This idea has been strongly opposed by Adovasio and his colleagues (Adovasio et al. 1982b). Haynes has called attention to the fact that only Holocene floral and faunal remains were recovered. If paleoenvironmental reconstructions are correct, 19,000 years ago continental ice would have been very close to Meadowcroft and the flora and fauna should have been different (Mead 1980).
Timlin, New York

The Timlin Site, located in New York's Catskill Mountains, has been the focus of two major studies. The first group of investigators (Timlin and Raemsch 1971; Raemsch 1977a, 1977b; Raemsch and Vernon 1977) reported the discovery of two Paleolithic assemblages in glacial till deposits. Artifacts recovered from the buried surface of the early Wisconsin Olean till (local New York terminology) included unifacial projectile points, ovate bifaces, and a variety of other core and flake tools (Timlin and Raemsch 1971). One ovate biface was discovered lodged in a bovid radius (Raemsch 1977a:5). A bovid metacarpal with notches may have been culturally modified. Below the till, chopping tools, scrapers, and "coriform" points were found, which probably pre-date 70,000 B.P.

Both the age and artifactual character of the Timlin artifacts have been questioned (Cole and Godfrey 1977a, 1977b; Funk 1977a, 1977b, 1977c). Reinvestigation of the site by Bryan et al. (1980) disproved Raemsh's contentions, but did result in the discovery of unifacial tools and flakes in association with charcoal which dated to 16,040 ± 170 B.P. (SI-412B).
Fort Rock Cave, Oregon

Fort Rock Cave in south-central Oregon has yielded two projectile points, several scrapers and gravers, a crescent, side-struck flakes, and a mano fragment (Bedwell 1973). One of the projectile points was fluted and had a concave base while the other was described as being similar to Lake Mojave points. Charcoal from a hearth was radiocarbon dated to 13,200 ± 720 B.P. (Gak-1738) (Bedwell 1970, 1973:35). The association of the dated charcoal with the artifacts (Irwin 1971) and the identification of the fluted projectile point (Fagan 1975) have been questioned.

Wilson Butte Cave, Idaho

Wilson Butte Cave is located on the Snake River Plain of south-central Idaho. Its lowest level yielded a biface, a blade, and a burinated flake, in association with numerous small animal bones. One bone element appears to be engraved (Gruhn 1961, 1965). The artifactual character of the lithic specimens is unambiguous (Crabtree 1969). Radiocarbon dates of 14,550 ± 500 B.P. (M-1409) and 15,000 ± 800 B.P. (M-1410) were obtained from bone samples (Gruhn 1965:57). Haynes (1967) suggested that humic acid contamination may have affected the radiocarbon dating and questioned the association of the artifacts with the bones (Haynes 1969b:353-354).
China Lake, presently a desert playa, is located in Inyo County, California. During the late Pleistocene (and probably earlier), China Lake was one of a series of pluvial lakes fed by Owens River, which drains a major portion of the eastern Sierra Nevada. Davis (1975, 1976, 1978a, 1978b) has recorded surface assemblages of lithic artifacts around the margin of the extinct lake. She identified at least six cultural traditions, four of which were judged to pre-date Clovis and possibly as old as mid-Wisconsinan. Davis distinguished cultural traditions on the basis of artifact weathering, associations with Rancholabrean fauna, and soils-geomorphic considerations. The Wisconsinan age artifacts were termed by Davis the Early and Late Core-Tool Traditions. They were estimated to date between 25,000 and 45,000 years ago. Among the artifact types recognized in these traditions are choppers, spokeshave-like tools, beaks, and miscellaneous flake tools. The artifacts are primarily of chert and various igneous rocks; they were fashioned by simple hard-hammer percussion flaking.

Davis et al. (1980) reported the discovery of two flakes directly beneath a mammoth tooth plate. The fossil was dated to 42,500 b.p. by the uranium-thorium technique (Note: analytical dates derived by methods other than radiocarbon analysis are designated by the lowercase abbreviation b.p.).
Lake Manix Lithic Industry Sites, California

Surface sites of the Lake Manix Lithic Industry have been recorded in the northern half of the Manix basin in the Mojave Desert of southern California (Simpson 1958, 1960, 1976). Artifacts include large oval bifaces, scrapers of several forms (end, straight, concave, pointed, convex, pointed, and plano-convex), cutting tools, choppers, chopping tools, large stout picks, rotational tools, gravers, cutting tools, rotational tools, and flakes, as well as cores, anvils and hammerstones. The artifacts were fashioned primarily of chalcedony, chert, and jasper. They are often found embedded in desert pavements. Simpson has estimated the age of the Lake Manix Lithic Industry to be 15,000 to 20,000 years, based on the observation that most sites occur above an elevation of 543 m (1780 ft), which marks the last stand of Pleistocene Lake Manix. Recent studies by Meek (1990) suggest that Lake Manix did not drain until sometime between 13,600 and 13,800 years ago.

The Lake Manix Lithic Industry artifacts usually exhibit rock varnish on both their buried and exposed surfaces. Cation-ratio dating (Dorn and Oberlander 1982; Dorn 1983) of the dark, manganese-rich varnishes has been conducted by Dorn and others (Dorn, personal communication, 1988; Dorn et al. 1986, Bamforth and Dorn 1988). Of the 21 artifacts analyzed, 12 specimens yielded ages greater than...
10,000 B.P., and nine dated to between 11,500 B.P. and 32,000 B.P. The older artifacts had a mean estimated age of 30,600 to 32,000 B.P. Three of the 21 specimens dated younger than 1,000 years and nine dated between 2,500 and 9,500 B.P.

Pendejo Cave, New Mexico

Pendejo Cave is located near Oro Grande in New Mexico’s Chihuahua Desert. The site is currently (1992) being investigated by R.S. MacNeish. The following account is based on Turnmire (1990) and a personal conversation with Dr. MacNeish on March 26, 1991.

The upper levels (Zones B to F) of Pendejo Cave have yielded Ceramic and Archaic period artifacts including Pendejo projectile points, split-stitch baskets, twilled sandals, knotted nets, and corn kernels. A charcoal sample from Zone B was radiocarbon dated to 1,150 ± 100 B.P. (UCR-2506). Zone G yielded snub-nosed end scrapers, a graver, and a prismatic blade in association with remains of extinct horses (both large and medium-sized) and large llama. Zone H has yielded gravers and blades in association with charcoal which has been dated to 16,410 ± 260 B.P. (UCR-2505).

A human fingerprint and a human palm print were identified on clay samples in Zone I, directly beneath a firepit in Zone H (Allison 1991). The prints were estimated to be
about 28,000 years old based on the radiocarbon dating of associated charcoal samples. Samples from Zone H, immediately above and adjacent to the prints, were dated to 27,860 ± 260 B.P. and 30,300 B.P. respectively (Allison 1991). A sample from Zone I yielded a date of 27,960 ± 970 (Allison 1991).

Zone K, lower in the sequence, has yielded a bifacial core tool, spokeshave-like tools, utilized flakes, and a knife fashioned from a rib bone. Associated faunal remains included tapir, weasel, turtle, salamander and toad and suggest a mesic forest environment. Charcoal from this zone has been radiocarbon dated to 25,420 ± 560 B.P. (UCR-2499A).

Zones L, M, and N have yielded unifacial points, bifacially-flaked choppers, and possible bone artifacts in association with fossils of small and medium horse, small camel, antelope, goat, and turtle. Zone L has been dated to >32,000 B.P. (UCR-2498). A charcoal sample from Zone M has been radiocarbon dated to >29,200 B.P. (UCR-2495). Zone O has yielded several quartz and chert artifacts including split-pebble tools, bifacial choppers, and an awl fashioned from a horse scapula.

Sierra Pinacate, Mexico

The Sierra Pinacate volcanic region, located near the head of the Gulf of California in northwestern Sonora,
Mexico, has been studied extensively by Hayden (1965, 1967, 1976). Weathered and varnished artifacts identified as Malpais have been found embedded in desert pavement. Hayden (1976:280) defined Malpais as "...an early and indistinct basal stage of the San Dieguito Complex...." The lithic assemblage, described as a chopper-scraper industry, is characterized by unifacially flaked basalt artifacts. Among the tool forms reported are choppers (including a few disc choppers), scrapers, spokeshave-like tools, knives, as well as beaked and notched implements. The assemblage does not include projectile points. Flaked shell implements have been recorded, including scrapers, gouges, and small knives fashioned from heavy bivalve shells. The overall artifact assemblage was characterized by Hayden as "especially adapted to woodworking." Based largely on considerations of rock varnish, desert pavement, and caliche development, Hayden estimated that the Sierra Pinacate artifacts date to a late Wisconsinan pluvial period, perhaps 20,000 to 40,000 years ago.

Chapala Basin, Mexico

The Laguna Seca Chapala Basin is located approximately 480 km south of the U.S.-Mexico border in central Baja California. Geomorphic evidence indicates that the basin held pluvial lakes at least three times during the late
Pleistocene. Neotectonic movements have uplifted the eastern portion of the basin preventing the formation of any future deep lakes (Arnold 1957, 1975).

Arnold (1957, 1975) described three distinct lithic traditions in the Chapala basin. These he termed flake-core-chopper, scraper-plane, and elongate-biface. Relative age assessments were made on the basis of artifact weathering and geomorphic considerations. Artifacts in the elongate-biface tradition (the oldest of the three) are found only above the highest shoreline. They are highly weathered and are found embedded in the desert pavement.

Arnold (1957:251; 1975:62) identified the heavy bifaces as hand-axe-like implements rather than quarry blanks. He suggested that they were similar to tools of the Lake Manix Lithic Industry in San Bernardino County, California (Arnold 1975:62). Ritter (1976) reexamined the Chapala basin sites. He found no direct age correlation of the artifacts with high shorelines and argued that the bifaces were quarry blanks rather than formed tools.

Tlapacoya, Mexico

The Tlapacoya site, located near Mexico City, has yielded an obsidian projectile point, obsidian flakes, deliberately arranged piles of mammal bones, and two hearth features (Limbrey 1976; Mirambell 1978). Wood from a hearth was radiocarbon
 dated to 24,000 ± 4000 B.P. (A-794B); and samples from another hearth were dated to 21,700 ± 500 B.P. (I-4449) (Mirambell 1978:224).

El Cedral, Mexico

El Cedral is located at a fossil spring near San Luis Potosi, Mexico. It has yielded simple lithic flakes in association with butchered, cut, and worked mammal bones, many of extinct species. Radiocarbon dating of some of the bones has yielded dates of >15,000 B.P., 21,960 ± 540 B.P., 31,850 B.P., and 33,300 B.P. A bone projectile point fashioned from a horse tibia and a discoidal scraper were recovered from the 33,300 B.P. level (Lorenzo and Mirambell 1986).

El Bosque, Nicaragua

El Bosque, located in the district of Esteli in northwestern Nicaragua, has yielded unifacially flaked jasper and possible bone artifacts in association with numerous bones of horse, giant ground sloth, tortoise, and turtle (Gruhn 1978). Geomorphic, stratigraphic, and radiocarbon data suggest that the site dates in excess of 30,000 years (Gruhn 1978:257).
North American Sites Older Than 40,000 Years

Black’s Fork, Wyoming

In the 1930s, crude artifacts were discovered on high river terraces above the Black’s Fork of the Green River in southwestern Wyoming (Renaud 1936, 1938, 1939, 1940, 1955, 1957). Because of their geomorphic setting, the artifacts are thought by some scholars to date to Illinoian times. Many of the artifacts exhibit bifacial flaking; others have steep-edged unifacial flaking. Well-abraded from stream tumbling, most of the artifacts were subsequently covered with dense layers of dark manganese-rich rock varnish.

Santa Rosa Island, California

Numerous fire pits, some containing burned pygmy mammoth (*Elephas exilis*) bones and stone tools, have been found on Santa Rosa Island, one of the Channel Islands off the coast of southern California (Orr 1956a, 1956b, 1964, 1968). Two types of hearths have been identified. One is approximately 60 cm in both diameter and depth. The second type is 3.5-5 m in diameter and approximately 60 cm deep. Associated mammoth bone specimens have been radiocarbon dated to 11,800 ± 800 B.P. (UCLA-106) (Fergusson and Libby 1964: 110) and >37,000 B.P. (UCLA-749) (Berger and Libby 1966:468-469).
The Woolley Site, excavated in the 1970s, has yielded mammoth bones, stone tools, and charcoal radiocarbon dated to >40,000 B.P. (UCLA radiocarbon dates 2100A, 2100B, 2100C, and 2100D) (Berger 1980:75).

Reservations have been expressed about the Santa Rosa Island sites. Riddell (1969) and Griffin (1977) suggested that the fire features may have resulted from natural processes. Griffin (1977) also questioned the artifactual character of the lithic specimens. Cushing et al. (1986) proposed a groundwater hypothesis for the origin of the "fire areas." They suggested that the "charcoal" identified in earlier studies may have been vegetal material carbonized by groundwater chemicals and recommended that the radiocarbon dating be reevaluated.

Calico, California

The Calico site, located in the central Mojave Desert of Southern California, is a lithic workshop (Leakey et al. 1968, 1970; Schuiling 1972, 1979; Simpson 1978, 1982; Budinger 1983; Budinger and Simpson 1958; Simpson et al. 1986. It has yielded 856 technically significant stone tools and diagnostic percussion flakes (R.D. Simpson, personal communication, 1991). Tool types include scrapers of many forms, cutting tools, denticulates, gravers, burin-like tools, rotational tools, core and flake choppers, stout pointed
picks, a few bifacial tools as well as hammerstones and anvils. These artifacts have been recovered from an alluvial deposit presumed to be middle Pleistocene. Calcium carbonate rinds on artifacts recovered from the basal meter of the alluvial deposit dated to 193,000 ± 80,000/-40,000 b.p. (SF-1), 260,000 ± 80,000/-40,000 b.p. (SF-2), and 203,000 +27,000 or -20,000 b.p. by uranium-thorium dating (Bischoff et al. 1981). Independent soils-geomorphic studies corroborated an age estimate of 200,000 ± 20,000 b.p. (Bischoff et al. 1981).

The Calico artifacts are fashioned principally of chalcedony, chert, and jasper. Approximately 300 unifacial tools have been recovered. Bifacial tools are few, and limited to chopping tools, picks, cutting tools, and reamers. More than 400 prismatic flakes have been recovered. Use-wear patterns have been detected on approximately one to two percent of the tools and flakes. More than 3,000 of the flakes recovered exhibit force bulbs. Other technically significant attributes include eraillure scars (bulb scars), undulating compression rings, striking platform angles of less than 90°, evidence of striking platform preparation by edge grinding or multi-faceting, and partial or complete crushing of striking platforms.

A quasi-circular arrangement of cobbles was uncovered at a depth of 8.5 m in the site’s Master Pit II. Similarity of clast size among the large cobbles, a radiating pattern
of dip to the center, and an alternating pattern of three large and two small cobbles suggested the arrangement might be the result of human activity. A paleomagnetic study of one of the cobbles indicated a significantly higher degree of magnetism on the proximal end. This was interpreted to mean that at some time in the past the cobble had been heated to about 360° C (Berger 1972). A reassessment of the feature (Bischoff et al. 1984; Budinger et al. 1986) using thermoluminescence, electron spin resonance, cryogenic paleomagnetic analysis, and 40-39 argon techniques indicated that rocks in the arrangement had not been heated since their formation during the Miocene.

Texas Street, California

The Texas Street site, located on the south side of Mission Valley in San Diego, California, has yielded core and prismatic blade artifacts, fire-broken rocks, and both large and small hearths with distinct concentrations of charcoal (Carter 1952, 1954, 1957, 1978, 1980). The artifacts are fashioned of quartzite and porphyry. Charcoal from a hearth situated near the base of the section has been radiocarbon dated to >35,000 B.P. (L-2990) (Broecker and Kulp 1957:1328). Among the artifact forms identified are concave scrapers, end scrapers, sinuous-edged cleaver-like tools with thick backs, and large triangular blades. Large
flakes with force bulbs and eraillures (bulb scars) and polyhedral cores with multiple parallel flake scars and both prepared and natural striking platforms are also present in the assemblage. The cultural evidence has been exposed in alluvial deposits geomorphically dated to the Sangamon Interglacial (85,000 to 130,000 B.P.) (Carter 1980).

Several workers have suggested that the lithic specimens might be geofacts (Haury 1959; Heizer 1964; Graham and Heizer 1967; Griffin 1977). Witthoft (1955) and Patterson (1977) supported Carter’s view that the specimens are artifacts.

Buchanan Canyon, California

The Buchanan Canyon site, located in San Diego, California, has yielded quartzite artifacts, including thick, sinuous-edged chopping tools described as being similar to Siberian skreblos, heavy triangular picks, beaked tools, spokeshaves with deep notches, blades, cores, and longitudinally split cobbles (Minshall 1973, 1974, 1976, 1989; Carter 1978).

Mission Ridge, California

The Mission Ridge site is located in Mission Valley in San Diego, California. The site has yielded quartzite
artifacts, including unifacial cobble and core tools, percussion flakes, and bipolar cores (Reeves et al. 1986).
Unlike specimens recovered from the nearby Texas Street site, the Mission Ridge artifacts do not exhibit evidence of having been transported by natural processes. No associated bipolar spalls have been recovered which might suggest natural fracture by differential weathering or brush fires. Reeves (Reeves et al. 1986:79) agreed with Carter (1952, 1954, 1957) that the quartzite cobble core and unifacial flake tradition of people living along the Pacific coast dates to the middle and late Pleistocene.

Yuha Desert, California

The Yuha Desert, located in southwestern Imperial County, California, has been investigated by Childers (1974, 1977, 1983; Childers and Minshall 1980). He has described a lithic tradition characterized by large, unifacially flaked implements with pronounced dorsal ridges. In addition to such "ridge-backs," Childers recorded bipolar cores, large concave flakes suggestive of spokeshaves, and large blade flakes, triangular in cross section, with some with small flake removals near the point producing a sharp curved tip. The artifacts are found above the high stand of an extinct Pleistocene lake. Tufa from that level has been radiocarbon dated to 37,400 ± 2,000 B.P. (LJ-959) (Hubbs et al. 1965;
Childers and Minshall 1980:301). Shell samples were dated to 37,100 ±2,000 B.P. (LJ-504) and >50,000 B.P. (LJ-954) (Hubbs et al. 1963:262-263).

Hueyatlaco, Mexico

Hueyatlaco (Steen-McIntyre et al. 1981), located on the shore of Valsequillo Reservoir near Puebla, Mexico, yielded small scrapers and cutting tools in association with a camel pelvis with a Th-230 date of 245,000 ± 40,000 b.p. and a Pa-231 date of >180,000 b.p. A triangular bifacially flaked artifact projecting through a mastodon jaw was also found. The cultural evidence occurred stratigraphically beneath two tephra layers dated to 370,000 ± 200,000 b.p. (2σ) and 600,000 ± 340,000 b.p. (2σ) (Steen-McIntyre et al. 1981).

South American Sites 12,000 to 40,000 Years Old

Monte Verde, Chile

The Monte Verde site in south-central Chile is a camp-site sealed by a layer of waterlogged peat (Dillehay 1989; Dillehay et al. 1982). The site has yielded well-preserved evidence of log-framed huts that were evidently roofed with hides, wooden mortars, wooden tools (including composite tools of fortuitously fractured stone and wood), butchered
mastodon bones, uneaten mastodon meat, and plant remains, including 27 plants used as herbal medicines by traditional healers in the Andes today. Approximately 100 simple lithic artifacts have been recovered. These include a core, a split cobble, two fairly large bifacially worked implements of exotic lithology, two deliberately shaped and grooved bola stones and three edge-battered rocks. A footprint from a child or small adult has also been discovered. Eighteen radiocarbon dates derived from wood and bone firmly place the time of principal occupation at about 13,000 B.P. (Dillehay 1986, 1988; Collins and Dillehay 1986). Bone recovered from a cultural layer was dated to 12,350 ± 200 (Tx-3760). Among the features recorded at Monte Verde are a cluster of 26 stones and three clay-lined charcoal pits which were radiocarbon dated to approximately 33,000 B.P. (Dillehay 1984, 1986).

A chopper, a chopping tool, and flakes were found in association with the butchered remains of six mastodons of various ages (Dillehay et al. 1982; Collins 1981). Naturally wedge-shaped and round rocks apparently used for bashing, scraping and planing were also recovered.

Monte Verde is a prime contender for a bona fide pre-12,000 B.P. site. Skeptics, pointing out that the site is bisected by a stream channel, have suggested that the associations apparent at the site may be fortuitous.
Taima-Taima is a waterhole site located in north coastal Venezuela (Bryan 1973; Bryan et al. 1978; Gruhn and Bryan 1984). The midsection of an El Jobo projectile point was found embedded in the pelvic cavity of a semi-articulated juvenile mastodon dated to 13,000 ± 200 B.P. (Birm-802) (Bryan et al. 1978, Gruhn and Bryan 1984). Eighteen radiocarbon dates now confirm the age of the elephant at approximately 13,000 B.P. Among these dates are the following: 12,730 ± 120 B.P. (IVIC-664), 12,770 ± 120 IVIC-669), 12,990 ± 260 (IVIC-670), 13,010 ± 280 B.P. (IVIC-191-1), 13,130 ± 130 B.P. (IVIC-663), 13,180 ± 130 B.P. (IVIC-671), 13,390 ± 130 B.P. (IVIC-668), 14,010 ± 140 B.P. (IVIC-670), and 14,440 ± 435 B.P. (IVIC-191-2) (Bryan 1973:244). Sheared and masticated twigs, thought to have been part of the elephant’s stomach contents, were dated to 12,980 ± 85 B.P. (SI-3316), 13,000 ± 200 B.P. (Birm-802), 13,860 ± 120 B.P. (USGS 247), and 14,200 ± 300 (UCLA-2133) (Bryan et al. 1978:1277). The El Jobo Complex is characterized by long, lanceolate points with thick, cylindrical cross-sections. Skeptics have suggested that the artifacts were mixed with the mastodon remains by rising water levels or by animal wallowing.
Los Toldos, Argentina

The 14 Los Toldos caves, located in Argentine Patagonia, have been episodically investigated since the 1950s (Cardich 1978). Cave 3, a well-stratified cavern, has been excavated. Charcoal from a critical layer has been radiocarbon dated to 12,600 ± 600 B.P. (FRA-98) (Cardich 1978). Associated artifacts include side scrapers, large end scrapers, unifacially retouched knives, large, thick flakes, and a simple unifacial, subtriangular "Mousteroid" projectile point (Cardich 1978). Osteological food remains included guanaco, horse, camel, and rodent bones.

Cave 3 was again occupied approximately 11,000 B.P. (Cardich 1978). Artifacts from this more recent occupation included side and end scrapers, bifacially retouched knives, fragments of bifacially worked core tools, a discoidal tool, and fragments of "fishtail" projectile points. Associated osteological evidence included bones of camels, horses, and birds.

While the radiocarbon dates available for Los Toldos Cave 3 have not been questioned, skeptics believe that too few artifacts have been recovered to make an unambiguous interpretation.
Toca de Boqueirão de Pedra Fruada, Brazil

Toca de Boqueirão de Pedra Fruada, a large rockshelter in the state of Piauí in northeastern Brazil, has yielded large circular hearths as well as quartz and quartzite flakes from undisturbed occupational floors. Charcoal radiocarbon dates suggest the rockshelter was occupied from 32,000 to 6,000 B.P.

A slab of rock spalled from the rockshelter, and bearing spots of red ochre, was found in direct association with charcoal radiocarbon dated at 17,000 ± 400. Lower in the sequence, one layer has yielded small flaked pebble tools and flakes in association with charcoal radiocarbon dated to 26,000 ± 600 B.P., 26,400 ± 500 B.P., 31,500 ± 950 B.P., and 32,160 ± 1,000 B.P. (Gf-6653) (Guidon 1984, 1986; Guidon and Delibrais 1986; Delibrais and Guidon 1986). Recently, dates as old as 45,000 B.P. have been reported. At Toca do Sítio do Meio, another nearby rockshelter, a chopper, hammerstones, and retouched flakes were found in association with charcoal radiocarbon dated to 12,000 ± 600 B.P. and 13,900 ± 300 B.P.

Pikimachay Cave, Peru

Pikimachay Cave is located near Ayacucho in the central highlands of Peru (MacNeish 1981; MacNeish et al. 1970, 1979). Thirteen zones containing four definable occupational phases
have been identified. These date from 23,000 B.P. to the time of Spanish contact. The Pacaicaisa Phase level, radiocarbon dated between 14,100 ± 1,400 B.P. (UCLA-1653C) and 20,250 ± 1,050 B.P. (I-5851) (MacNeish 1981:201), has yielded an assemblage of unifacially worked implements including choppers, scrapers, spokeshaves, and retouched flakes fashioned of volcanic tuff (MacNeish et al. 1970, 1979).

South American Site Older than 40,000 Years

Toca da Esperança, Brazil

Toca da Esperança is a cave located on the northern slope of la Serra da Pedra Calaria, north of the city of Central, in the state of Bahia, Brazil (de Lumley et al. 1987, 1988). The lowest of four layers of Quaternary deposits in the cave has yielded quartzite and quartz artifacts in association with three mammal bones (de Lumley et al. 1988). The nearest outcrops of these lithologies are at least 10 km from the cave. Uranium-thorium dating of the bone specimens has placed their age between 204,000 and 295,000 b.p. The small lithic assemblage includes "...a chopper, a pebble exhibiting two bifacial removals and a pebble fragment with three undulating fracture planes" (de Lumley et al. 1988:241). Toca de Esperança is the presently the oldest archaeological site in the Western Hemisphere.
CHAPTER IV. TARGETING EARLY MAN SITES

A Search Strategy for Evidence of Early Man in the Western United States

Goals, Site Criteria, and Data Requirements

A persistent question in New World archaeology concerns the hemisphere's initial peopling from Asia. One hypothesis maintains that the continent was uninhabited until approximately 12,000 B.P. when people practicing the Clovis adaptive strategy first appeared south of the late Pleistocene continental ice sheets. The other hypothesis maintains that the hemisphere was occupied earlier than Clovis times by generalized hunters and gatherers. Table 1 lists the principal proponents of the Clovis and early man models.

Adequate testing of the pre-Clovis hypothesis will require the use of systematic site search strategies. Such strategies should be based on assessments of the potential of various microdepositional environments to yield datable artifacts in sound stratigraphic contexts. Environmental factors known to be strong predictors of evidence of hunting-gathering sites should be considered. Such factors include horizontal and vertical distance to water, slope, aspect, rugosity, and view. It will also be important to
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<th>Principal proponents of the Clovis model:</th>
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<td>Dincauze, Dena (1984)</td>
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<td>Heizer, Robert (1964)</td>
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<td>Jennings, Jesse D. (1968)</td>
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<td>Waters, Michael R. (1985)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Principal proponents of the pre-Clovis model:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alsoszatai-Pethoe, John (1975, 1984)</td>
</tr>
<tr>
<td>Bonnichsen, Bryan (1979; Bonnichsen and Dorn, 1986)</td>
</tr>
<tr>
<td>Bonnichsen, Robson (1979; Bonnichsen and Bonnichsen, 1984; Bonnichsen et al. 1987)</td>
</tr>
<tr>
<td>Childers, Morin (1977, 1983; Childers and Minshall 1980)</td>
</tr>
<tr>
<td>Cinq-Mars, Jacques (1979; Cinq-Mars and Jocque, 1982)</td>
</tr>
<tr>
<td>Collins, Michael B. (1981, Collins and Dillehay 1986)</td>
</tr>
<tr>
<td>Dinev, Dane (1984)</td>
</tr>
</tbody>
</table>

INITIAL POPULATING OF THE NEW WORLD
AND EARLY MAN HYPOTHESES REGARDING THE
PRINCIPAL PROPONENTS OF THE CLOVIS
TABLE 1.
Principal proponents of the pre-Clovis model (continued):

Guidon, Niede (1984, 1986; Guidon and Delibrais 1986)
Krieger, Alex (1962, 1964, 1979)
d’Lumley, Henri (d’Lumley et al. 1987, 1988)
Mirambell, Lorena (1978)
Orr, Phillip (1956a, 1956b, 1964, 1968)
Reeves, Brian O.K. (1983, 1985; Reeves et al. 1986)
consider both depositional and post-depositional factors which have affected both the archaeological and paleoenvironmental records. Modern accessibility for study is also an important consideration in any search strategy.

To be widely accepted, any site must yield either human fossil evidence or indisputable artifacts and/or manmade features, such as hearths. Site stratigraphic context should be unambiguous and datable by at least one, and preferably several, chronometric techniques.

Pre-Clovis sites, especially open-air sites, will not be easy to find in the Western Hemisphere. Sediments of an appropriate age and depositional character must be located either in outcrops or in the subsurface by remote sensing or drilling. Each candidate location must be carefully evaluated with regard to geoarchaeological potential. Among the questions which should be asked are: (1) Is the sedimentary column datable by one or more analytical techniques? (2) Was it deposited under high or low energy conditions and could it yield an unambiguous archaeological record if one is present? (3) Does the sedimentary sequence indicate that paleoenvironmental conditions were attractive for human occupation? and, (4) Does the sedimentary context have the potential to yield osteological evidence as well as evidence of material culture?
Microdepositional Environments

Perhaps the best way to approach the matter of targeting sediments with significant geoarchaeological potential is by considering basic landscape types and their depositional microenvironments. The type and rate of deposition which can occur at a particular site are influenced primarily by local topography, effective geomorphic processes, the size and character of the available sediment supply, and the type and amount of local ground cover. Sediments can be deposited (means from the air) over large areas (e.g., tephra layers, lacustrine deposits, and aeolian dune fields), linearly (e.g., coastal and river terraces), or at point locations (e.g., at springs and in caves) (Butzer 1982). Butzer (1982) has characterized ten basic types of microdepositional environments: spring, karst, cave, seacoast, floodplain, fluvial delta, aeolian, slope, volcanic, and lakeshore/marsh. By assessing the depositional processes and sedimentary products of each, it should be possible to assess relative geoarchaeological potentials.

Springs often provide attractive habitats for human subsistence and settlement. Their deposits can effectively seal and preserve archaeological evidence, including bones. The point location character of springs, however, can make targeting their location on Pleistocene landscapes difficult.
Karst topography often contains cavities which may serve as natural traps for bone and artifacts. Rarely, however, are such locations conducive to habitation. Like springs, the entrances to karst cavities are idiosyncratic in their location, and therefore, difficult to target on Pleistocene landscapes.

Caves and rock shelters are sometimes suitable for human habitation. Many caves, however, are relatively young. Old caves, more likely than not, have been flushed and early sediments partially or completely removed, sometimes more than once (Butzer 1988). Stratigraphic relationships in caves are often complex and difficult to interpret. Like other point location depositional contexts, previously unrecorded caves which would have been attractive during Pleistocene times will be difficult to target.

Due to their spatial extent, the potential of finding unambiguous evidence of early man increases dramatically in linear and areal depositional environments. Coastal landforms, especially marine terraces, afford excellent environments for human subsistence and settlement. Wave processes and eustatic marine transgressions, can, in some cases, cause significant reworking of sediments and artifacts. Nonetheless, coastal terraces can be considered to have excellent potential to yield acceptable evidence of pre-Clovis sites. Because they occur over long stretches of the present coastline and are readily accessible, marine terraces are
probably the largest of the potential landscape target types. Unfortunately, in California, many marine terraces have been extensively developed and are unavailable for detailed inspection.

River terraces may have been suitable for settlement and subsistence activities only on a seasonal basis. Geomorphically, river terraces are often unstable; periodic pulses of erosion have the potential to scour out much of a pre-existing archaeological record. Nonetheless, sealed evidence may be recovered in fine-grained overbank deposits. Point bar deposits of stream meanders also have very high potentials to yield undisturbed cultural evidence. Overall, river terraces can be considered as having moderate to good potential for finding pre-Clovis sites.

Human settlements on deltaic deposits are often discrete and localized to shorelines and the banks of distributary channels. Deltas are geomorphically active; targeting past habitation foci may be difficult.

Aeolian dune fields may have attractive subsistence foci in places where groundwater conditions promote the development of biologically diverse habitats. Deflationary aeolian processes, however, tend to coalesce cultural evidence, producing ambiguous archaeological records. Because of targeting difficulties and stratigraphic complexities, aeolian contexts are assessed as having a low to moderate potential for yielding acceptable evidence of pre-Clovis populations.
Depositional processes on hill and mountain slopes can, in some cases, preserve portions of archaeological sites. However, serious stratigraphic problems can occur when upslope sites are redeposited onto lower footslopes. Post-depositional disturbances can result from selective winnowing, transport, and coalescing of assemblages. In cold environments, cryoturbative processes on hillslopes can significantly distort stratigraphic relationships.

A variety of different archaeological contexts can be generated by volcanic activity. Sites in the immediate vicinity of an explosive volcanic crater are usually destroyed and nearby hillslope sites are rapidly buried by lava and airborne pyroclastics. Pyroclastic tephra ejected by an eruption can travel great distances and become incorporated into the sedimentary profiles of river terraces, deltas, and lakes. In such contexts, tephra can effectively bury and preserve archaeological records. Because tephra blankets are produced by singular geologic events, they may serve as laterally extensive time-stratigraphic horizons. With regard to the search for early man in the Western Hemisphere, pyroclastic deposits are regarded as having moderate potential.

Pleistocene lakeshore and marsh depositional environments probably have the most significant to yield unambiguous evidence of pre-Clovis man and ancillary paleoenvironmental evidence. Lacustrine settings provide some of the
most biologically diverse and productive environments available. They were undoubtedly very attractive for early human subsistence and settlement. Rapid sedimentation in such contexts can often provide good preservation of archaeological materials.

Archaeological Visibility

If people were in the Western Hemisphere prior to 12,000 years ago, they were undoubtedly here in very small numbers. The archaeological visibility of their presence will undoubtedly be low due to small initial populations, discontinuous settlement, and low settlement densities.

It is generally recognized that archaeological site frequency deceases exponentially as one goes back through time in the Quaternary. Two large-scale inventories, one in South Africa and one in Spain, document this pattern very well. In 1985, Sampson reported on almost 15,000 surface sites spanning the last 600,000+ years in South Africa. The areas studied in this exhaustive survey were predominantly erosional contexts. Sampson found 7,200 sites dating within the last 1,500 years, 4,900 sites between 1,500 B.P. and 8,000 B.P., 1,250 sites dating to an interval of about 4,000 years at the time of the Pleistocene-Holocene transition, 968 sites for the last 100,000 years of the Pleistocene, and only 517 sites for the previous 500,000+ years. If these
figures are converted to number of sites-per-century, the
exponential pattern of the dropoff is even more dramatic: 1-500
B.P.: 480.0 sites/century; 1,500-8,000 B.P.: 75.3
sites/century; 8,000-12,000 B.P.: 31.25 sites/century; 12,000-
110,000 b.p.: 0.968 sites/century; 110,000-500,000 b.p.: 0.103
sites/century.

Butzer (1988) reported a similar exponential decline
pattern for identified surface and buried sites in Cantabrian
Spain. For thousand year intervals, 25.7 sites were recorded at
about 8,000 B.P., 9.5 at 13,500 B.P., 8.8 at 19,500 B.P., 1.4 at
28,000 B.P. and only 0.2 at 75,000 b.p. Such ratios suggest
that very early archaeological sites in the Western Hemisphere
will be rarely encountered. Moreover, Butzer (1988) has
suggested that compared to the Paleoindian record already
documented, archaeologists could probably expect to find less
than a dozen pre-12,000 B.P. sites in North America.

Dramatic population growth during the late Pleistocene is
the principal reason for the substantial increases in site
visibility during the latter part of the archaeological record.
Such growth was facilitated by improved extractive efficiencies
supported by technologies which included micro-blades and
pressure-flaked projectile points. In contrast, earlier
populations were probably small and in steady-state equilibrium
with their local environments.

Butzer (1988) has pointed out that, to some degree,
success or failure in the search for early sites will depend on
the expectations archaeologists have about the character of such a record. Artifacts which pre-date the Clovis Culture will probably be simple and generalized. Technologies based on the modification of bone, antler, ivory, and wood may have been important in early subsistence strategies. Because most subsistence functions can be accomplished with simple flakes, either modified or unmodified (Toth 1987), early lithic assemblages will probably have very low visibility on the landscape. For this reason, the most convincing field evidence of early human populations will probably be hearths.

If the New World was populated significantly earlier than 12,000 years ago, it is probable that early migrants brought with them relatively simple technologies derived from Asian traditions. Much of the Asian Paleolithic record has low archaeological visibility (Aigner 1981; Aikens and Higuchi 1982; White and O'Connell 1982; Wu and Olson 1985; Chung and Pei 1986; Larichev et al. 1987). Lithic assemblages tend to be small with few formal tools and limited diversity. Tool types are generalized and usually include simple choppers, chopping tools, crude bifaces, trihedral picks, and poorly standardized utilized flakes. Asian lower and middle Paleolithic assemblages were apparently used more for processing than for procurement; early American assemblages
may be similar. Prepared core techniques and blade technologies did not appear in Asia until about 21,000 years ago (Aikens and Higuchi 1982). Pressure flaking appeared about 14,000 years ago and microblades appeared shortly thereafter.

Marginal Environments

Given the probable constraints of pre-blade technologies, it is likely that human populations in the Western Hemisphere would have responded to marginal environments in much the same way as lower and middle Paleolithic populations did in the Old World (Butzer 1988). Relatively moist environments with high resource predictability and reliability were probably favored, while arid and semi-arid environments with low resource predictability and reliability were probably avoided. Because climate patterns are cyclic, human settlement and subsistence patterns probably responded in kind. Large regions of North America were probably not conducive to human habitation for lengthy periods of time during warm, dry cycles. Regions which afforded high resource predictability and reliability during cool, moist times and deteriorated only moderately during warm, dry times, were probably utilized more than other areas. It is in such regions that archaeologists have the best chance of detecting evidence of early man.
Effective site search strategies must consider the carrying capacities of Pleistocene environments, especially with regard to biomass size, predictability, and reliability (Butzer 1988). Pleistocene environments which exhibited some degree of topographic constraint, low seasonality, high predictability of floral and faunal resources, and minimal environmental hazards were probably attractive to early populations (Butzer 1988).

Patterns recognized in the spatial and temporal distribution of middle and late Pleistocene archaeological sites in South Africa may be relevant to the search for pre-Clovis man in the Western Hemisphere. Butzer (1988) has noted that almost all South African open-air sites dating from approximately 300,000 to 13,000 years ago are associated with former lakes, springs, or floodplains. He further noted that the settlement patterns were discontinuous both in space and time. There were repeated intervals of tens of thousands of years during which the interior of South Africa was essentially uninhabited except for sporadic hunting forays in peripheral areas. In interior areas, evidence of subsistence and settlement was limited to moist climatic periods when water and biotic resources were dependable and predictable. Not all moist periods, however, were accompanied by human settlement in those areas.

Warm, dry periods diminish plant productivity and this, in turn, severely impacts herd-grazing herbivores. Stores
of body fat are significantly reduced in game animals during severe drought, potentially rendering them unsuitable as food sources (Speth 1987). When fat-starved humans eat such super lean meat they crave more and soon begin consuming protein in excess of their actual needs. Such a pattern can have the effect of increasing the metabolic rate and causing diarrhea, dehydration, and death in only a week or two (Speth 1987). For these reasons, the actual resource capacities of drought-prone environments are actually less than species inventories might suggest.

In order to cope with unpredictable, low-yield resources, unspecialized hunter-gatherers sometimes respond with increased mobility over larger areas (Dyson-Hudson and Smith 1978). Yellen (1976) has documented the response of Kalahari Bushman to poor environmental conditions. In a highly productive environment, the radius of their hunting/foraging territory is about 15 km and has an area of about 700 square kilometers. In a poor environment the radius increases to about 75 km and the area to about 17,500 square kilometers. This type of response is potentially maladaptive insofar as bands become spread so thinly across the landscape they cannot effectively monitor the floral, faunal, and hydrological resources of their operational areas. Nor can they adequately maintain information exchange networks with other bands (Yellen 1976). Peripheral bands have the additional difficulty of maintaining mate exchange networks necessary to maintain biological viability (Butzer 1988).
Paleohabitat Persistence

The archeological visibility of early New World populations is probably a function of paleohabitat persistence. It is important, therefore, to target Pleistocene environments which afforded persistent potable water, and food resources, fuel, shelter, and strategic overviews. Such considerations suggest that pluvial lake basins would have been particularly attractive to early populations. Lake-shore/marsh resources, including edible plants, fish, water birds, bird eggs, shellfish, insects, and small animals could be readily exploited with relatively simple technologies. Large mammals, drawn to lakes for water, could be driven into boggy areas to be mired down and killed.

Pluvial Lake Basins as Candidate Regions in the Search for Early Man

In the southwestern portion of North America, at least 110 of the closed basins in the Great Basin held lakes during Pleistocene times (Cf. Snyder et al. 1964) (Figure 2). Probably not all of these lakes were equally attractive to early human populations. In arid and semi-arid environments, lakes fed by allogenic (exotic) streams which carried water from high mountains would have offered the best potentials for persistent fresh water conditions,
FIGURE 2 DISTRIBUTION OF PLEISTOCENE LAKES WITHIN THE GREAT BASIN
especially if these lakes had effective hydrologic export of salts through groundwater movement and/or leaching (Smith 1985). The lakes with persistent marsh conditions may have remained attractive for long enough periods that archaeologically visible records might have been generated. With such considerations in mind, it is possible to cut the list of candidate basins in the Great Basin in half by dropping from consideration those in which water potability was not maintained by overflow. The target list can be further constrained by considering the accessibility of Pleistocene sedimentary records. In most of the basins, alluviation which occurred during the climatic shift from the late Pleistocene to the Holocene has effectively covered the early sediments. The Manix basin in San Bernardino County, California, is one of the very few basins where significant exposures of middle and late Pleistocene deposits are readily available for study.

The remaining chapters of this thesis will examine the geology, geomorphology, stratigraphy, paleontology, and paleoecology of the Manix basin in order to assess its significance for geoarchaeological research. The present chapter concludes with a general discussion of pluvial lake dynamics.
Paleoclimatology and Late Pleistocene Lake-Levels

Fundamental to any paleoenvironmental reconstruction is the study of paleoclimatology. Such study is based on an analysis of proxy data which have incorporated into their structure climate-dependent signatures (Bradley 1985).

Among the principal geological sources of proxy data are lacustrine deposits and associated geomorphic features. Studies of lake-levels in closed basins, for example, can provide climatic inferences regarding effective moisture (Benson 1981; Thompson and Mead 1982; Thompson et al. 1986; Benson and Thompson 1987a, 1987b; Benson and Pallet 1989; Currey 1990, Street-Perrott and Harrison 1985). Stratigraphy, sedimentology, and micropaleontology (especially the study of pollen, fungi spores, ostracodes, and insects) can provide significant data regarding precipitation patterns, hydrology, temperature patterns, soil moisture, and air mass conditions (Bradley 1985).

Times of high lake-levels in the Great Basin are generally termed pluvials. These were periods of greater effective moisture. There is still considerable debate, however, regarding the relative significance of increased rainfall compared to other climatic factors such as temperature, humidity, evaporation, wind, and cloud cover (Brackenridge 1978).

The amount of precipitation which falls within a drainage basin is the most significant factor in the water supply of a
lake. Factors such as the seasonal distribution and intensity of the precipitation, the relative proportions of rain and snow, mean annual and seasonal temperatures, topographic relief, slope angle, and type and amount of vegetative cover can all affect the amount of water that reaches a lake (Smith and Street-Perrott 1983). Smith and Street-Perrott (1983) have estimated that in order to support the pluvial lakes at their maximum late Pleistocene sizes, runoff was two to ten times higher than it is today.

In basins with internal drainage, changes in the overall hydrologic balance resulting from climatic fluctuations can have dramatic effects on lake levels. During periods of positive water budget, lakes may form and expand, and will recede and possibly dry during negative water budget times. In this sense, the study of lake level variations can provide proxy data for paleoclimatic conditions, especially in arid and semiarid regions (Bradley 1985:241). Periods of positive water budget can be identified by lacustrine sediments and diagnostic geomorphic features such as wave cut shorelines, gravel bars, and deltaic and beach deposits (see Morrison 1965; Meek 1990). Negative water budget periods can be identified from recessional shorelines and buried paleosols which formed subaerially on exposed sediments. Stratigraphy, paleontology (particularly micropaleontology), and geochemistry are powerful tools for interpreting lake histories.
In a closed basin, lake level fluctuations are a function of water volume, which, in turn, is a function of water supply and loss. The major parameters which affect lake volume changes include precipitation, basin runoff, evaporation rate, and subsurface inflow and outflow rates (Bradley 1985:243-244). Among the factors which affect runoff and evaporation are precipitation type (whether rain or snow), frequency, duration, event magnitude, and seasonality, ground temperature, degree of ground cover and vegetation type, soil infiltration capacity, slope gradients, and stream size and number (Bradley 1985:244). The principal factors affecting lake water evaporation are temperature (both daily means and seasonal range), solar radiation input as mediated by cloudiness, windiness, humidity, lake volume and surface area, duration of lake ice cover, and water salinity (Bradley 1985:244). A positive water budget results when there is insufficient energy available to evaporate the precipitation which falls in the basin.

Small lakes and shallow lakes with large surface areas respond more rapidly to climatically-driven hydrologic fluctuations than large, deep lakes. Consequently, smaller lakes record high frequency climatic signals much more accurately than larger lakes.

Evaporation plays a major role in influencing the size of a lake. The rate of evaporation depends on the amount of available net radiation (a function of the duration and
intensity of solar radiation), the vapor pressure gradient between the water and the air, and mass transfer (wind/turbulence). The vapor pressure gradient is a function of water temperature, air temperature, and absolute humidity. Smith and Street-Perrott (1983) have suggested that, with regard to evaporation, environmental factors other than temperature may have been essentially off-setting during cool pluvial periods. Pleistocene evaporation rates may have increased as a result of decreased salinities and increased wind velocities, but at the same time, decreased as a result of higher humidity, cloudiness, and precipitation on enlarged lake surfaces.

Non-climatic events can affect lake levels in closed basins. Tectonic events can influence the size and elevation of catchment areas and outlet sills. Erosion of outlet barriers and stream capture brought about by the headward erosion of tributary streams can directly influence the amount of water flowing into a lake. Volcanic eruptions and landslides, in some cases, can dam fluvial channels.

Pluvial lakes can leave both geomorphic and stratigraphic evidence in the geologic record (Smith and Street-Perrott 1983). Geomorphic evidence can include features such as erosional shorelines, gravel bars, and beach deposits. Unlike the geomorphic evidence, however, the stratigraphic evidence in a basin is often difficult to interpret. Exposed basin-edge sedimentary records are often fragmentary;
periods of erosion and non-deposition can produce complex sequences. Cores can be difficult to interpret unless they contain laterally extensive marker horizons such as volcanic ash or salt layers. Soils which developed on exposed lacustrine sediments during low stands can also be used for correlation purposes. Often, stratigraphic evidence from several settings is compared and correlated in order to assemble a more complete record.

Lake-level histories have been reconstructed for 31 of the closed basins of the American west (Smith and Street-Perrott 1983). Table 2 presents a listing of the pluvial lakes in the Great Basin with radiocarbon-dated chronologies. Comparative studies suggest that rapid, large-amplitude fluctuations occurred during the late Pleistocene. In general, one or more high lake stands occurred between 25,000 and 15,000 years B.P. and one or more very brief periods of lake expansion about 12,000 years B.P. (Smith and Street-Perrott 1983). Significant lake size fluctuations have occurred in the last 10,000 years. Smith and Street-Perrott (1983) have postulated that it is feasible to extend the general patterns beyond the areas studied given certain critical assumptions and operational definitions. They defined three arbitrary lake levels: high (70-100 percent
### TABLE 2

**PLUVIAL LAKES IN THE GREAT BASIN WITH RADIOCARBON-DATED CHRONOLOGIES**

<table>
<thead>
<tr>
<th>State</th>
<th>Pluvial lake (and name of modern lake, playa, basin, or valley, if different)</th>
<th>Maximum area (sq. km)</th>
<th>Maximum increase in depth relative to present (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona</td>
<td>Chochise (Willcox)</td>
<td>310</td>
<td>26</td>
</tr>
<tr>
<td>California</td>
<td>Adobe (Black Lake)</td>
<td>52</td>
<td>24</td>
</tr>
<tr>
<td>California</td>
<td>Deep Springs</td>
<td>ca. 44</td>
<td>unknown</td>
</tr>
<tr>
<td>California</td>
<td>Manix (Coyote &amp; Troy)</td>
<td>236</td>
<td>150</td>
</tr>
<tr>
<td>California</td>
<td>Manly (Death Valley)</td>
<td>1600</td>
<td>183</td>
</tr>
<tr>
<td>California</td>
<td>Mojave (Soda &amp; Silver)</td>
<td>ca. 200</td>
<td>ca. 12</td>
</tr>
<tr>
<td>California</td>
<td>Panamint</td>
<td>722</td>
<td>283</td>
</tr>
<tr>
<td>California</td>
<td>Russell (Mono Lake)</td>
<td>692</td>
<td>238</td>
</tr>
<tr>
<td>California</td>
<td>Searles (China Lake, Searles Lake)</td>
<td>994</td>
<td>196</td>
</tr>
<tr>
<td>Nevada</td>
<td>Dixie (Humboldt &amp; Salt)</td>
<td>1088</td>
<td>72</td>
</tr>
<tr>
<td>Nevada</td>
<td>Lahontan (Pyramid, Walker &amp; Honey Lakes; Carson Sink; Winnemuca, Smoke Creek, Black Rock, Desert Valley &amp; Buena Vista Basins)</td>
<td>22,440</td>
<td>160</td>
</tr>
<tr>
<td>Nevada</td>
<td>Las Vegas</td>
<td>unknown</td>
<td>unknown</td>
</tr>
<tr>
<td>Nevada</td>
<td>Teel (Teels Marsh)</td>
<td>unknown</td>
<td>unknown</td>
</tr>
<tr>
<td>Oregon</td>
<td>Chewaucan (Abert &amp; Summer Lakes)</td>
<td>1240</td>
<td>115</td>
</tr>
<tr>
<td>Oregon</td>
<td>Fort Rock (Silver, Christmas &amp; Fossil Lakes)</td>
<td>3885</td>
<td>49</td>
</tr>
<tr>
<td>Utah</td>
<td>Bonneville (Great Salt, Utah &amp; Sevier Lakes; Great Salt Lake and Escalante Deserts; Cache, Sevier, White &amp; Rush Valleys)</td>
<td>51,640</td>
<td>ca. 335</td>
</tr>
</tbody>
</table>

*Note: Modified from Smith and Street-Perrott 1983, Table 10-2.*
of maximum lake level), intermediate (15-percent of maximum, and low (0-15 percent of maximum). Between 24,000 and 14,000 years B.P., all of the lakes in the study were either high or intermediate in water level. High levels were most widespread between 24,000 and 21,000 years B.P. Lake Bonneville, however, remained at an intermediate level. Between 24,000 and 14,000 years B.P., about 70 percent of the lakes had record high levels. Lakes in the northwestern part of the Great Basin, particularly those near the Sierra Nevada, had intermediate levels at this time. Large-amplitude lake level fluctuations occurred between 14,000 and 10,000 years B.P. These were apparently not synchronous across the Great Basin. The pattern of fluctuations between 10,000 years B.P. and 5,000 B.P. is particularly complex. Lakes near the Sierra Nevada (Searles, Mono, and Tulare) reached maximum expansion between 13,500 and 11,000 years B.P. The first of the two major expansions of Lakes Bonneville and Lahontan occurred during this same period. Between 10,000 and 5,000 years B.P., many areas experienced drought which culminated between 6,000 and 5,000 years B.P., when not a single lake is known to have had a high water level. Between 5,000 years ago and the present there have been significant reexpansions of some of the lakes, notably those on the western margins of the Great Basin in California.

Lake-level fluctuation records can provide relatively good quantitative estimates of paleoprecipitation. They are
especially useful for paleoclimatic reconstruction in desert areas where pollen data are often sparse. Difficulties in estimating paleoevaporation rates and run-off percentages, however, are major limitations. Evaporation was probably enhanced during pluvial periods by higher wind velocities. Decreased evaporation was probably promoted by higher relative humidities and lower insolation values. Most pluvial groundwater tables probably rose more than 10 meters (Smith and Street-Perrott 1983).
CHAPTER V. MANIX BASIN AND THE BASSETT POINT STUDY AREA

Location and Mapping

This study is fundamentally concerned with the assessment of the geoarchaeological potential of a locality informally known as Bassett Point. The location and general vicinity of Bassett Point are shown in Figure 3. The study area is located in the Manix basin (also known as the Lower Mojave Valley) of the central Mojave Desert, southern California. This basin is bounded by north latitudes $34^\circ 45'$ and $35^\circ 8'$ and west latitudes $116^\circ 20'$ and $116^\circ 50'$. The topography of the Manix basin is depicted at a scale of 1:62,500 on the following U.S. Geological Survey 15' topographic maps: Daggett, Alvord Mountain, Cave Mountain, Cady Mountains, and Newberry (See also Figure 4). It is depicted at a scale of 1:250,000 on the San Bernardino sheet of the USGS California Atlas.

Bassett Point is at an elevation of 1,680 ft (512 m) in the SW1/4, SE1/4, NE1/4, SW1/4 of Section 10, T.10 N, R.4 E, San Bernardino Baseline and Meridian (SBBM) (Figure 5). The UTM (Universal Transverse Mercator) coordinates for Bassett Point are: zone 11/540250 Easting/3869350 Northing. Bassett Point is so-named because it was often used as a campsite by geologist Alan M. Bassett when he was mapping in the area.
FIGURE 3
MAP SHOWING THE LOCATION AND VICINITY
OF THE BASSETT POINT STUDY AREA
FIGURE 5  NORTHEAST PORTION OF THE U.S.G.S. 7.5' MANIX QUADRANGLE
The topography of the area has been mapped by the U.S. Geological Survey on the 15 minute Newberry Quadrangle map (1956) and the 7.5 minute Manix Quadrangle (1982, provisional, edition), on the west side of the Mojave River approximately 2,250 meters north of a large incised meander. The topography of the study area is depicted in Figure 6.

Relative to selected California cities and towns, Bassett Point is located approximately 188 km (117 mi) northeast of Los Angeles, 122 km (76 mi) northeast of San Bernardino, 43 km (27 mi) east-northeast of Barstow, and 25.7 km (16 mi) east-northeast of Yermo.

Access to Bassett Point is gained by travelling eastward from Barstow on Interstate Highway 15 and exiting the freeway at the Harvard Road offramp. Proceed south on Harvard Road only about 60 m (200 ft) and turn east onto Highway 91. Proceed east on Highway 91 to the Union Pacific Railroad siding known as Manix (located directly south of the southern terminus of Alvord Road). Turn south and cross two sets of railroad tracks. Once across the tracks, proceed approximately 900 m (about 2,950 ft) eastward along the middle road of the three roads available at that junction and then turn southeast and proceed for a total of 3.7 km (2.3 mi) until reaching a junction of two dirt roads. Because the location of this junction is critical to gaining access to Bassett Point it should be noted that its location is in the NW1/4, SW1/4, SE1/4, SE1/4 of Section 9, T.10N.
FIGURE 6
TOPOGRAPHIC MAP OF THE BASSETT POINT LOCALITY
△ PERMANENT DATUM
- - DRAINAGE
CONTOURS IN FEET (5 FT INTERVALS)
R.4E., SBBM. One can field check this road junction from the following compass bearings: the aircraft vortac facility is at a magnetically adjusted azimuth of 250° and the ridge over Interstate 15 at Alvord Road is at an azimuth of 298°. Once it has been established that the road junction is indeed the correct one, turn southeast and proceed approximately 2000 feet to the Bassett Point parking/camping area. This is a bluff overlooking the eroded badlands of the Manix Formation (Jefferson 1968, 1985b).

Modern Environmental Conditions

An understanding of the modern climatic and ecological setting provides a useful baseline against which to assess paleoenvironmental conditions in the Manix basin. For this reason, information about the modern climate, flora, and fauna are set forth in the following sections.

Climate

The climate of the Mojave Desert is characterized by high temperatures, evaporation rates which far exceed precipitation, and extreme variability in the amount, intensity, and spatial distribution of precipitation. Arid conditions and sparse vegetation serve to enhance wind as a major factor in local climates. Humidity is generally very low, usually 15 to 30 percent.
Summers are typically hot and dry; winters are cool and dry. Compared to the Sonoran Desert to the south, summers in the Mojave Desert are cooler and winters are moister. The Mojave Desert is drier, however, than most Sonoran desert areas in Arizona, especially those that receive summer monsoonal or thunderstorm activity. Evapotranspiration exceeds precipitation most of the year and only falls below the precipitation curve for a few months during the winter, allowing for soil storage of water (Major 1977).

The climate of the Mojave Desert is fundamentally influenced by descending dry air of the semi-permanent subtropical high pressure cell situated along the Pacific coast. Early in winter, the high pressure cell is disrupted and displaced southward. This allows some storms generated over the Gulf of Alaska to reach southern California. Orographic uplift of moist polar Pacific air across the Coast Ranges and the Sierra Nevada produces periods of low-intensity precipitation between November and March. Freezing temperatures may occur and some winter precipitation falls as snow (especially in the eastern Mojave Desert), although lower elevations usually only experience snow flurries.

When the high pressure system is reestablished in the spring, it deflects storm tracks to the north. The region is generally dry between April and June. Summer precipitation is convective and results primarily from the influx
of moist, unstable air from the Gulf of California and the Gulf of Mexico. Summer conditions feature high temper-ature, large daily temperature fluctuations, and low humidity.

The climate of the Manix basin is typical of the Mojave desert: warm and dry. As measured at the Barstow/Daggett Airport, the average annual temperature in the Manix basin is 19.6°C (67.3°F). Minimal cloud cover permits high solar insolation during the day and strong infrared cooling during the night. January temperatures average 9.1°C (48.4°F), and July temperatures average 31.4°C (88.5°F) (Felton 1965). The average diurnal temperature range is 16.0°C (60.8°F).

Most of the basin receives less than 96.8 mm of precipitation per year (California Department of Water Resources 1967:plate 1). The precipitation pattern is biannual. During the 1951-1974 period, the annual precipitation averaged 9.17 cm (3.62 in) (Ruffner 1980:74). Typically, over 50 percent of this precipitation occurs from October to April. February is usually the wettest month; May and June the driest. Thunderstorms produce highly localized, intense rainfall during the summer months of July, August, and September. Thunderstorm activity is more frequent in the afternoon and evening hours. The annual relative humidity ranges from 30 to 40 percent, but during summer daylight hours, the humidity is often less than 10 percent (Hagar 1966).
Winds in the Manix basin generally blow from the west, northwest, or southwest. The average wind speed as measured 6.1 m (20 ft) above the ground elevation surface at the Barstow-Daggett Airport is 17.9 km/hr (11.1 mi/hr) (California Department of Water Resources 1985:11).

Flora

The Mojave Desert is the smallest of the North American deserts and, in a strict sense, one of the continent’s few "true" deserts in that it receive less than 150 mm of annual precipitation and has less than 10 percent perennial plant cover (Spaulding et al. 1983). The only other true deserts on the continent are the Chihuahuan Desert and areas along the Lower Colorado River and the upper Gulf of California. In both arid and semi-arid regions, available soil moisture is the prime limiting ecological factor (Odum 1971). Both biomass and amount of vegetative cover are proportional to water availability (Greig-Smith and Chadwick 1965).

According to Spauling et al. (1983), North American deserts can be classified as either cool or warm. In North America, cool deserts occur north of 37° N latitude in the Great Basin where basin floors are usually above 1400 m (4,593 ft) elevation, and where the annual precipitation is usually less than 460 mm (18.1 in). Characteristically, such deserts have steppe-like vegetation. Shrub communities
are dominated by various species of sagebrush (Artemisia spp.). Other important shrubs include saltbush (Atriplex spp.), rabbitbrush (Chrysothamnus spp.), horsebush (Tetradymia spp.), winterfat (Ceratoides lanata), greasewood (Sarcobatus vermiculatus), and hopsage (Grayia spinosa) (Spaulding et al. 1983:259-260). At higher elevations pinyon-juniper (Pinus monophylla and Juniperus osteosperma) woodlands occur. The woodlands are open canopy communities dominated by small trees.

In contrast, warm deserts are characterized by greater plant diversity with regard to perennial species, growth forms, and climatic regimes (Spaulding et al. 1983). The principal floristic adaptation to arid conditions is not the limitation of evapotranspiration by individual plants, but rather, at the level of the community such that there is a "reduction of transpiring plant surfaces per unit of land area" (Walter and Stadelman 1974).

A dominant shrub in all North American warm deserts is the creosote bush (Larrea divaricata tridentata), a robust exotic which arrived from South America during the very late Pleistocene or early Holocene (Spaulding et al. 1983:285). Creosote bush communities predominate on valley floors, alluvial fans, and low mountain slopes. Plant density increases directly with annual precipitation. As individual bushes increase in size and require greater amounts of water, the amount of bare ground
surrounding each shrub also increases (Buffington and Herbel 1965), giving the community an appearance of openness.

The Mojave Desert is the least floristically defined of the North American warm deserts. In addition to creosote bushes, lowlands and valley flanks support a variety of other shrubs including saltbush, hopsage, white bur-sage (Ambrosia dumosa), wolfberry (Lycium pallidum), pepperwood (Lepidium fremontii), and Mormon-tea (Ephedra californica) (Spaulding et al. 1983:263). Blackbush (Coleogyne ramos-sima) scrub covers large areas between elevations from 1300 m to 1850 m (4265 ft to 6070 ft). Joshua tree (Yucca brevi-folia) and Mojave yucca (Yucca scidigera) often predominate. Mojave upland vegetation is similar to that of the Great Basin, with pinyon-juniper woodlands on mesic slopes and stands of mountain mahogany (Cercocarpus ledifolius) chaparral on xeric slopes. The floral communities of the Mojave Desert have been described by Munz and Keck (1949), Munz (1968), and Latting (1976).

In the Manix basin the dominant modern plant community is creosote scrub (Munz and Keck 1949; Munz 1968). It prevails on well-drained slopes, alluvial fans, and on the valley floor. Xerophytic shrubs include creosote bush, sagebrush, and burro bush (Franseria dumosa). Thick stands of phreatophytic trees and shrubs grow locally along the Mojave River and in areas of high groundwater, such as Coyote Springs and on the west side of the Calico fault.
The most common phreatophytes include mesquite (*Prosopsis julifora*), salt cedar (*Tamarix gallica*), saltbush (*Atriplex lentiformis*), saltgrass (*Distichlis stricta*), and pickleweed (*Allenrolfea occidentalis*) (Munz and Keck 1949; Munz 1968). Also present in the Manix basin are Mormon-tea, white bur-sage, desert holly (*Atriplex hymenelytra*), buckwheat (*Eriogonium* sp.), inkweed (*Suaeda torreyana var. ramosisima*), brittlebush (*Encelia farinosa*), Anderson thornbush (*Lycium andersonii*), catclaw acacia (*Acacia greggii*), screwbean (*Prosopis pubescens*), desert fir (*Peucephyllum schottii*), beavertail cactus (*Opuntia basilaris*), and barrel cactus (*Ferocactus acanthodes*). Annual plants in the basin include turkshead (*Echinocactus polycephalus*), desert trumpet (*Eriogonum inflatum*), desert alyssum (*Lapidium fremontii*), and pencil cactus (*Opuntia ramosissima*). Stands of slender willow (*Salix exiqua*) and common reed (*Phragmites australis*) are found in Afton Canyon and the Camp Cady area. Dead stands of these plants suggest that large freshwater marshes probably existed around these springs in the recent past.

Fauna

Although relatively abundant, many vertebrate species are seldom observed owing to their nocturnal habits. Notable species include the coyote (*Canis latrans*), kit fox (*Vulpes macrotis*), bobcat (*Lynx rufus*), spotted skunk...
(Spilogale putorius), black-tailed jackrabbit (Lepus californicus), and desert cottontail (Sylvilagus audubonii). Reptiles include the desert tortoise (Gopherus agassizii), chuckwalla (Sauromalus obesus), western collared lizard (Crotaphytus collaris baileyi), and several species of rattlesnakes (Crotalus spp.) (Jaeger 1957, 1961).

Regional and Local Geology

The Manix basin is located in the central part of the Mojave Desert of southern California, an elevated, wedge-shaped region between the San Andreas and Garlock fault zones (Hewett 1954; Dibblee and Bassett 1966; Rogers 1969; Dibblee 1970; 1980a, 1980b; and Tarman 1988). Figure 7 presents a generalized geologic map of the Mojave Desert; Figure 8 depicts the region's faults.

The topography of the Mojave block is dominated by conjugate sets of right- and left-lateral faults; roughly linear, uplifted and folded mountain blocks which are fault-bounded; and broad, alluvial-filled basins, most of which lack external drainage (Buwalda and Richter 1948; Dibblee 1961; 1980a, 1980b; McCulloh 1965; Dibblee and Bassett 1966; Garfunkel 1974; Jennings 1975; Keaton and Keaton 1977; Hamilton 1982; Dokka 1983, 1987; and Tarman and Thompson 1988).
FIGURE 7 GENERALIZED GEOLOGIC MAP OF THE MOJAVE DESERT

Modified After State of California 1966

Legend:
- CENOZOIC ALLUVIUM
- CENOZOIC MARINE SEDIMENTARY ROCKS
- CENOZOIC VOLCANIC ROCKS
- MESOZOIC SEDIMENTARY AND VOLCANIC ROCKS
- PALEOZOIC SEDIMENTARY AND VOLCANIC ROCKS
- PRECAMBRIAN ROCKS
- PRE-CENOZOIC METAMORPHIC ROCKS
- GRANITIC ROCKS

Scale: 80 km (50 mi)
FIGURE 8 MAP SHOWING THE PRINCIPAL FAULTS OF THE MOJAVE DESERT
The Mojave Desert widens eastward, with topographic relief increasing toward the lower Colorado and Sonoran deserts of southeastern California, southern Arizona, and northwestern Sonora, Mexico. On the north and northwest it is bounded by the Garlock fault zone, the Tehachapi Mountains, and north-trending, block-faulted mountains of the Basin and Range Province; on the south and southwest it is bounded by the San Andreas fault zone and east-trending mountains of the Transverse Ranges. On the east it is defined by the southern extension of the Death Valley Fault Zone.

The Mojave block has experienced divergent, convergent, and transform crustal plate interactions (Burchfiel and Davis 1981) and extensional and rotational displacements (Ross et al. 1989). A basement complex of pre-Cenozoic granitic and metamorphic rocks is overlain by Cenozoic volcanic flows, volcanic ash, and sedimentary formations. A major period of erosion during Mesozoic and early Cenozoic time separates the basement complex from overlying volcanic and sedimentary rocks. Mesozoic mountain belts were reduced to an elevated open plateau of little relief by early Miocene time, when volcanic activity began in several large east-west elongated structural troughs (Dibblee 1980a, 1980b). Many thousands of meters of lava flows and ash deposits, together with alluvial, fluvial, and lacustrine sediments, accumulated in these troughs as they formed.
Cenozoic sedimentary and volcanic rocks are folded along east-west axes, and the crust has been broken into many blocks between the east-west trending left-lateral faults and northwest trending right-lateral faults. This deformation has been accompanied by local extrusion of late Pliocene and Pleistocene basalt along and near the zones of faulting (Hewett 1954; Rogers 1969; Jennings 1975).

Until the late Pliocene the elevated Mojave Desert region drained to the Pacific Coast through broad valleys in the low ancestral Transverse Ranges (Woodburne and Golz 1972; Woodburne 1975; Ponti 1985; Meisling and Weldon 1989). Subsequent uplift of the San Gabriel and San Bernardino Mountains shifted drainages into the closed structural basins of the Mojave Desert (Hewett 1954; Dibblee 1980a; 1980b; Woodburne and Golz 1972; Woodburne 1975; Meisling and Weldon 1989).

Pleistocene age sediments of the Mojave Desert often reflect fluctuations in climate. Studies throughout the southwestern United States indicate that episodes of high rainfall, run-off, and erosion have marked the rapid transitions from cold, glaciopluvial periods to warm interglacials (Ponti et al. 1980; Ponti 1985). In the Mojave Desert, intervals of alluvial deposition were climatically controlled, occurring rapidly and nearly synchronously across the region during the glacial/pluvial
to interglacial/interpluvial transitions of the middle and late Pleistocene and early Holocene (Ponti et al. 1980; Ponti 1985).

Alluvial fan deposits may be correlated by relative age diagnostic criteria. Most important in this regard are soil profile development, degree of primary surface dissection, desert pavement and rock varnish development, morphostratigraphic relationships and evidence of in situ shear-wave velocities (Christenson and Purcell 1985; Ponti 1985).

Christenson and Purcell (1985) recognized three non-mutually exclusive age classes of alluvial fans: (1) young (less than 15,000 years old); (2) intermediate (15,000 to 700,000 years old); and (3) old (greater than 500,000 years old). Young fans exhibit distributary drainage patterns with bar and swale topography, stream incisions of less than one meter, and undeveloped to weak soil profiles. Intermediate fans exhibit dendritic to parallel drainage patterns, major stream incisions of one to ten meters with undissected interfluves, and weak to strong soil development. Old fans retain little of their original surface morphology. Stream incision is usually greater than ten meters. Such fans are typically cut off from their original source areas by modern drainages, and strongly developed soils are found only on remnant drainage divides.

The Manix basin is circumscribed by the Calico, Paradise, Alvord, Cronese, Cave, Cady, Dunn, and Newberry
Mountains (Figure 7) composed primarily of Precambrian (?), Paleozoic, and Mesozoic igneous and metamorphic basement rocks, Cenozoic and non-marine sedimentary rocks, and Cenozoic shallow intrusive bodies (Hagar 1966; Dibblee and Bassett 1966; Dibblee 1970, 1980a). The Calico Mountains (maximum elevation 1385 m [4543 ft]) on the northwest side of the basin are composed of Paleozoic rocks, Mesozoic plutonic and metamorphic rocks, and Miocene continental sediments overlain by volcanic rocks (McCulloh 1952; Dibblee 1970, 1980a). The Paradise Range (maximum elevation 1104 m [3621 ft]) consist largely of Paleozoic metamorphic rocks and Mesozoic plutonic rocks (Dibblee 1980a). The Alvord Mountains (maximum elevation 1053 m [3456 ft], on the north side of the basin, are composed of Paleozoic metamorphic rocks, Mesozoic plutonic and metamorphic rocks, and Miocene continental sediments (Byers 1960). The Cronese Mountains (maximum elevation 573 m [1880 ft]) and Cave Mountain (1093 m [3585 ft]) on the northeast and east side of the basin are composed of pre-Tertiary igneous and metamorphic rocks (Dibblee 1980a). On the southeast and south side of the valley are the Cady Mountains (maximum elevation 1410 m [4627 ft]) composed predominately of Cenozoic volcanic rocks, continental sediments, and some Mesozoic plutonic and metavolcanic rocks (Dibblee and Bassett 1966). The Newberry Mountains (maximum elevation 1556 m [5105 ft]), composed of possible Precambrian and Paleozoic metamorphic rocks,
Mesozoic plutonic and metamorphic rocks, and Miocene lavas and continental sediments, lie to the south (Dibblee 1970, 1980a). Figure 9 is a generalized geologic map of a portion of the central Manix basin; Figure 10 depicts the surficial geology in the Manix area.

The Manix basin lies in a region of active neotectonism (Shlemon and Budinger 1990). Several faults provide geomorphic expression of Quaternary displacement while others have displayed historical seismicity and, therefore, are clearly active (Buwalda and Richter 1948; Hewett 1954; Byers 1960; Dibblee 1961, 1980a, 1980b; Dibblee and Bassett 1966; Rogers 1969; Garfunkel 1974; and Cummings 1980). Noting numerous offsets of middle and late Pleistocene strata in the vicinity of Agate Hill and the north and southwest edges of the Coyote sub-basin, Meek (1990) has suggested that Quaternary tectonism may be responsible for most of the present topographic relief of the central Mojave Desert.

Two major faults cross the basin, the northwest striking right-lateral Calico fault and the east-west striking-left-lateral Manix fault (Hewett 1954; Dibblee 1961, 1970; Dibblee and Bassett 1966; Rogers 1969). The last major earthquake in the Manix basin was on April 10, 1947. This earthquake, centered near the Manix fault, registered 6.4 on the Richter Scale (Richter 1958) and produced 5 cm (2 in) of left-lateral displacement which was apparent as surface
FIGURE 9  GENERALIZED GEOLOGIC MAP OF A PORTION OF THE CENTRAL MANIX BASIN

Modified After Vanderpool and Danehy 1959.
FIGURE 10 GENERALIZED GEOLOGIC MAP OF THE MANIX AREA

EXPLANATION

- Qal: Surficial deposits, undiff.
- Qns: Mojave River sand
- Qt: Sand
- Qks: Undiff. sand & gravel
- Qlg: Upper gravel facies
- Qf: Lake Manix beach deposits
- Qcl: Lake Manix clay facies
- Qls: Lower gravel facies
- Qox: Quaternary old fan deposits (Yermo formation?)
- Qkr: Tertiary igneous & some metamorphic rocks

Base: U.S. Geological Survey 7.5 minute topographic map of the Manix Quad
Geology after the Southern Pacific Mineral Survey geologic map of T10N R6E4E.
Cartography by F.E. Bottger Jr.
breakage over a distance of 3.2 km. The epicenter was between Manix Wash and Afton Canyon (Buwalda and Richter 1948; Richter 1958; Richter and Nordquist 1951; Keaton and Keaton 1977). Aftershocks continued for three years. They were not aligned in the general east-west trend of the Manix fault, but rather, oblique to the fault in a northwest-southeast trend. This suggests that the earthquake may have occurred along a deeply buried fault.

Faulting and folding associated with the Calico, Manix, and other unnamed faults (Byers 1960; Cummings 1980; Dibblee 1961, 1980b; Garfunkel 1974; McGill et al. 1988) may have lead to greater erosional dissection of geomorphic surfaces in the central Mojave than is typically observed in the tectonically quiescent eastern Mojave Desert (Shlemon 1978; Shlemon and Budinger 1990). Meek (1990) has stressed that the breeching of basins in the central Mojave Desert has also contributed significantly to regional dissection.

Sometime during the middle Pleistocene (perhaps 400,000 to 500,000 years ago), uplift of the Transverse Ranges, along with changes in drainage patterns, precipitation, mountain snow pack, cloud cover, and evaporation increased the discharge of the Mojave River. As a consequence, freshwater Lake Manix formed in the Lower Mojave Valley (Buwalda 1914; Blackwelder and Ellsworth 1936; Blackwelder 1954; Blanc and Cleveland 1961a; 1961b; Snyder et al. 1964; and Jefferson 1968, 1985b).
A very early phase of fluctuating lakes in the Manix basin is indicated by the presence of shoreline facies in the Afton Basin, characterized by distinctive evaporate and faunal evidence (Ellsworth 1932; Jefferson 1985b; Nagy and Murray 1991; see also Chapter IX for a discussion of the depositional history of the Manix basin). Following this early lacustrine period, there was a lengthy period of aridity, the beginning of which was characterized by alluviation around the basin's margin. Playa conditions occurred in the center of the basin. As climatic, and perhaps tectonic conditions changed during the late Pleistocene, another perennial lake began to form as the Mojave River emptied directly into the Afton and Troy sub-basins. This process buried much of the earlier lacustrine evidence. The primary fluvial input maintained the Afton-Troy portion of the lake, and occasionally the delta shifted into Coyote basin, also producing high lakes there. The primary lake in the Afton and Troy basins remained stable at the elevation of the Coyote basin sill (i.e., 543 m, 1780 ft.) for long periods of time resulting in the shorelines at that elevation (Meek 1989, 1990). Lateral edges of interfingered lacustrine, fluvial and alluvial deposits indicate that the lake fluctuated several times, probably due to climatic changes (Jefferson 1968, 1985b). As the water input increased, Coyote basin was finally filled and the level of the entire lake rose to an elevation of the overflow sill in the Afton Canyon area.
Lake Manix had a drainage basin of about 9,363 km\(^2\) (3,615 mi\(^2\)). The maximum late Pleistocene lake had an area of approximately 382 km\(^2\) (91 mi\(^2\)) (Meek 1990:81). Maximum water depth is thought to have been approximately 150 m (492 ft) (Meek 1990:81). The Afton sub-basin of Lake Manix drained between 13,300 and 13,800 B.P. (Meek 1990).

**Manix Area Geomorphology**

In the Manix area, late Pleistocene lacustrine and fluvial sediments are geomorphically expressed as barren and often intricately dissected badlands (Figure 11). At Bassett Point the topography is characterized by pinnate ridges, drained and separated by major gullies (Figures 12, 13, and 14). Microrelief is complex, and interfluves are often expressed as knife ridges. Slopes are significantly steeper along the upstream limb of the incised meander (in SW1/4 Section 16, T.10N., R.4E.) than in the Bassett area. The sediments have not been widely gullied into pinnate ridges washes. The linearity of the upper break in slope of badlands in that area suggests that the local area has been tilted, at least slightly, to the north. Significant nick-points have not been allowed to develop and migrate headward. In the northern half of Section 10, T.10N., R4E. SBBM (north and northeast of Bassett Point) the badlands
FIGURE 11 AERIAL VIEW (1:20,000) OF THE MANIX AREA SHOWING BASSETT POINT, MANIX WASH, AND BUWALDA RIDGE
FIGURE 12   LOW-LEVEL OBLIQUE AERIAL PHOTO OF BASSETT POINT
FIGURE 13  NEAR VERTICAL LOW-LEVEL AERIAL VIEW OF THE BASSETT POINT AREA SHOWING UPPER MEMBERS OF THE PLEISTOCENE MANIX FORMATION
FIGURE 14  LOW-LEVEL AERIAL PHOTO OF BASSETT POINT.  
VIEW TO THE NORTHEAST
topography is significantly subdued. There are no deep rills or gullies and the local drainage is much more random. A geomorphic break in expression appears to occur along a roughly linear wash in the NW1/4 of section 10, T.10N, R.4E. The three types of topographic relief in the Manix area suggest that tectonic processes may be affecting local erosion. It appears that the Pleistocene beds have been tilted to the northwest.

Badlands geomorphology has been reviewed by Bryan and Yair (1982). In general, badlands develop where soft, relatively impermeable rocks are exposed to rapid fluvial erosion (Campbell 1989:159). Studies in New Mexico (Wells 1983), and Alberta, Canada (Bryan et al. 1987) have shown that badlands formed in the Holocene are the result of rapid erosion subsequent to significant base-level changes. The possibly catastrophic drainage of Afton basin between 13,300 and 13,800 years ago (Meek 1990) lowered the local base-level of the Mojave River more than 120 m at Afton Canyon. It is probable that incision subsequent to this event and very late Pleistocene pluvial precipitation initiated the creation of the Manix badlands.

Many, but certainly not all, badlands are associated with arid or semi-arid environments. While climate is significant in the creation of badlands (especially prolonged drought punctuated by locally intense rainstorms), primary control resides in the differential erodibility of
sediments. Clay minerals and various cementing agents can also play a significant role.

Micro-climatic factors relating to aspect and exposure are known to influence the geomorphic expression of badlands (Yair et al 1980; Churchill 1981). Studies in South Dakota have shown that south-facing slopes are significantly shorter and steeper than north-facing counterparts (Churchill 1981). The densely rilled north-facing slopes evidently experienced more intense fluvial erosion than those facing south. Studies conducted in Israel by Yair and others (1980) indicated that infiltration differences were aspect-related. North-facing slopes were found to have developed deeper regoliths than south-facing counterparts.

The most prominent geomorphic feature in the study area is the incised hairpin meander of the Mojave River located in the SW1/4 Section 15 and the NW1/4 Section 22, T.10N, R.4E (Figures 15 and 16). Some have speculated that it may be the result of local tectonic control, others that it may be the result of entrenchment of the river around an ancient strandline deposit (Meek 1990).

Manix Wash, a wide drainage channel in Sections 3, 4, 5, and 10, T.10N, R.4E, is located directly east of Bassett point. Meek (1990:115) has suggested that this drainage developed in a natural trough created by the edge of the prograding Mojave River braid delta during the late Pleistocene. The absence of armoring fluvial gavels would have
FIGURE 15  AERIAL VIEW (1:20,000) OF THE MANIX AREA SHOWING THE INCISED MEANDER OF THE MOJAVE RIVER AND BASSETT POINT
FIGURE 16  AERIAL OBLIQUE VIEW, LOOKING SOUTH, OF THE INCISED MEANDER ON THE MOJAVE RIVER
allowed the drainage to develop atop easily erodible lake clays. Murray (personal communication, 1986) has speculated that the unusual width of Manix Wash may be the result of an ancestral meander of the Mojave River. Figure 17 shows some of the ancestral meanders located in Sections 8, 9, 17, and 18 T.10.N, R.4.E, west of the study area. It does not appear that current drainage patterns could account for a channel the size of Manix Wash. Whether Manix Wash is a relict portion of an old meander system remains to be determined.
FIGURE 17: AERIAL VIEW (1:20,000) OF THE MANIX AREA SHOWING ANCESTRAL MEANDERS OF THE MOJAVE RIVER.
CHAPTER VI. CULTURE HISTORY OF THE SOUTHWESTERN GREAT BASIN

The Mojave Desert region has experienced large-scale environmental changes during the Pleistocene and Holocene. Human adaptations to these changing conditions are reflected in the archaeological and ethnographic records. These records provide evidence of changing subsistence and settlement strategies in response to a general pattern of increasing aridity. Understanding such strategies may provide insights useful in the development of methodologies for targeting pre-Clovis sites.

The basic cultural sequence of the Mojave Desert has been fairly well established. The discussion below follows the chronology outlined by Warren (1980, 1984, 1986; Warren and Crabtree 1986). The distribution of major archaeological sites in the southeastern Great Basin is depicted in Figure 18. Figure 19 presents form outlines of major southern California projectile point types.
FIGURE 18 ARCHAEOLOGICAL SITES IN THE SOUTHWESTERN GREAT BASIN
FIGURE 19 FORM OUTLINES OF MAJOR SOUTHERN CALIFORNIA PROJECTILE POINT TYPES
The pre-12,000 B.P. archaeological record of the Mojave Desert remains controversial. The Calico Site, near Yermo, is a lithic workshop which dates to approximately 200,000 ± 20,000 years ago (Leakey et al. 1968, 1970; Schuiling 1972, 1979; Simpson 1978, 1982; Bischoff et al. 1981; Budinger 1983; Budinger and Simpson 1985; Simpson et al. 1986). It has yielded 856 technically significant stone tools and diagnostic percussion flakes (Ruth Dee Simpson, written communication, 1991) and approximately 60,000 pieces of debitage. Tool types include scrapers of many forms, cutting tools, denticulates, gravers, burin-like tools, rotational tools, core and flake choppers, stout-pointed picks, a few bifacial tools as well as hammerstones and anvils (Singer 1979; Budinger and Simpson 1985; Simpson et al. 1986).

Late Pleistocene sites of the Lake Manix Lithic Industry have been recorded in the northern half of the Manix basin in the central Mojave Desert (Simpson 1958, 1960, 1976). Artifacts include large oval bifaces, scrapers, tools, choppers, chopping tools, stout picks, rotational tools, gravers, cutting tools, rotational tools, gravers, cutting tools, rotational tools, and flakes, as well as cores, anvils, and hammerstones. Most of the artifacts are made of chalcedony, chert, and jasper.
Simpson (Budinger and Simpson 1985) estimated the age of the Lake Manix Lithic Industry to be 15,000 to 20,000 years, based on the observation that most sites occur above an elevation of 543 m (1780 ft), which marks the last stand of Pleistocene Lake Manix. Recent studies by Meek (1990), however, suggest that Lake Manix did not drain until sometime between 13,600 and 13,800 year ago. Cation-ratio dating of manganese-rich rock varnishes of artifacts of the Lake Manix Lithic Industry has been conducted by Dorn (Dorn et al. 1986; Bamforth and Dorn 1988). Of 12 samples analyzed, nine dated between 11,500 and 32,000 B.P. The oldest samples had mean estimated ages of 30,600 to 32,000 B.P. It should be noted, however, that three of the twenty-one samples dated younger than 1,000 years and nine had dates between 2,500 and 9,500 B.P.

Lake Mojave Period (12,000 to 7,000 B.P.)

The Lake Mojave Period in the southwestern portion of the Great Basin was a regional manifestation of the general Paleoindian period. In general, the Paleoindian period is defined principally on the bases of distinctive chipped stone projectile points and the association of diagnostic artifacts with fossil megafauna. The traditional view is that Paleoindians had rather narrow-spectrum economies which focused on the hunting of large animals such as mammoths.
during Clovis time, and bison during Folsom time. The Lake Mojave archaeological record, however, suggests a more generalized hunting and gathering adaptation to the moist conditions of the very late Pleistocene and early Holocene. Stone projectile points used to tip atlatl darts and spears varied in form and size. They include Clovis-like forms, leaf-shaped forms, long-stemmed points with relatively narrow sloping shoulders (Lake Mojave, Cougar Mountain, and Lind Coulee points), and short-bladed stemmed points with pronounced shoulders (Silver Lake points) (Warren 1980; Warren and Crabtree 1986). Also present in Lake Mojave assemblages are scrapers, leaf-shaped knives, drills, spiked gravers, crescents, and heavy core choppers (Campbell et al. 1937).

The Lake Mojave evidence has been variously interpreted as suggesting a specialized adaptation to lacustrine resources (Bedwell 1970, 1973; Hester 1973) or a generalized hunting and gathering pattern (e.g., Wallace 1958; Warren 1967; Davis 1969, 1978a).

**Pinto Basin Complex (7,000 to 4,000 B.P.)**

In general, the Archaic period is recognized by plant processing tools and projectile points which were cruder and more varied than earlier Paleoindian points. Such assemblage changes suggest greater plant utilization and the
hunting of smaller animals. In the California deserts, the Archaic adaptation is represented by the Pinto Basin and Gypsum traditions. These adaptive strategies appear to have evolved in response to the increasingly xeric conditions of the Holocene as people apparently withdrew to desert margins and oases. Interior areas were evidently reoccupied only during more mesic times. The California desert Archaic adaptation persisted until relatively late in prehistory, about 1,500 B.P.

The Pinto Basin Complex (7,000 to 4,000 B.P.), an early Archaic adaptive pattern, is characterized by Pinto points with straight stems and concave bases, heavy-keeled scrapers, and rather small, flat milling stones and manos (Warren 1984:412-414). Rogers (1939), suggested that the "milling stones" may have served as pulping platforms, rather than true milling surfaces, for the processing of hard seeds.

Most Pinto Basin sites have surface lithic scatters and lack midden deposits. They are suggestive of temporary occupations by small hunting-gathering groups exploiting resources during seasonal procurement rounds. The exception is the Stahl site near Little Lake in the southern Owens Valley (Harrington 1957). This site appears to have been a seasonal residential base occupied over a long period of time. Post holes suggestive of house structures were found in a 137-cm-deep (54 in) midden. Artifacts included both Lake Mojave and Silver Lake projectile points, narrow
concave scrapers, and small beaked gravers. Manos and circular basin milling stones were found to be common.

Pinto sites in the eastern Mojave include Pinto Basin (Campbell and Campbell 1935), Salt Springs (Rogers 1939), and Death Valley (Hunt 1960, Wallace 1977). These sites lack milling equipment and the adaptation there appears to have been one of generalized hunting and gathering. Subsistence and settlement patterns appear to have changed in response to climatic fluctuations. During xeric conditions, settlement appears to have been restricted to desert margins and oases. Interior valleys were apparently reoccupied during more mesic times about 6,500 B.P. and again abandoned during xeric conditions starting about 5,500 B.P. Much of the desert region was apparently uninhabited until the end of the Pinto Period, about 4,000 B.P. This pattern may indicate that use of the eastern Mojave Desert was part of a larger adaptive strategy.

There is still controversy regarding the dating of the Pinto Basin Complex in California. No Pinto sites have been dated directly and it is not clear how they relate to dated sites with Pinto-like points farther north in the Great Basin.

**Gypsum Period (4,000 to 1,500 B.P.)**

The Gypsum Period (4,000 to 1,500 B.P.) was a California desert manifestation of the late Archaic. It began with the so-called Little Pluvial, a thousand year-long moist period between
approximately 4,000 B.P. and 3,000 B.P. The Gypsum Period was a time when people broadened their desert adaptations (Warren 1984:414-420). This is seen in the increased usage of manos and metates, and the introduction of both the mortar and pestle and the bow and arrow. Increased trade also played a role in this desert adaptation as did participation in widespread magico-religious hunting rituals.

Diagnostic projectile points of the Gypsum Period include the Humboldt Concave Base, Gypsum Cave, Elko Eared, and Elko Corner-notched (Amargosa I) types (Warren 1984:414-415, 1986:188). Other artifacts include leaf-shaped projectile points, knives with rectangular bases, drills, scrapers, large scraper planes, choppers, shaft smoothers, incised sandstone and slate pendants and tablets, drilled slate tubes which may have served as pipes, and hammerstones. Manos and metates became much more common during this period, suggesting a greater reliance on hard seeds. The mortar and pestle were first introduced into the Mojave Desert during the Gypsum Period, possibly for mesquite processing. Shell beads of Haliotis and Olivella indicate limited trade with coastal populations. Diagnostic Amargosa type projectile points provide the first evidence of cultural influence from the Southwest at about 2250 B.P.

Perishable artifacts were found, apparently in association with Gypsum Cave and Elko projectile points, in
Newberry Cave (Smith et al. 1957; Davis and Smith 1981). Among the items recovered were an atlatl hook, atlatl dart main and foreshafts, sandals, cordage, a sheep dung pendant fashioned of droppings wrapped in sinew, tortoise shell bowls, and split-twig figurines thought to have served as magico-religious objects in hunting rituals. Each figurine was fashioned of a single willow branch which had been split, folded, and woven so as to create a small representation of an animal. Similar figurines have been found at least at 16 sites in California, Arizona, Nevada, and Utah. Radiocarbon dates on figurines range from 4,145 B.P. at the Grand Canyon to 1,405 B.P. at Cowboy Cave in Utah. Those from Newberry Cave dated to 3,020 B.P.

Newberry Cave contained other items suggestive of ritual activity such as a plume, black, white, red, and green pigment samples, two quartz crystals painted green, painted rocks, and pictographs depicting mountain sheep and rabbits.

Gypsum Period sites have been excavated at Gypsum Cave (Harrington 1933), Newberry Cave (Davis 1981; Smith et al. 1957), Stuart Rock Shelter (Shutler et al. 1960), Willow Beach (Schroeder 1961), Rose Springs (Lanning 1963; Clewlow et al. 1970), Ray, Baird, and Chapman Caves (Hillebrand 1972, 1974; Panlaqui 1974), O'Mallery Shelter and Conway Cave (Fowler et al. 1973), Etna Cave (Wheeler 1973), and the Indian Hills Rockshelter (Wallace 1962). It is sometimes
difficult to distinguish Gypsum Period components from those of the Pinto Basin Complex because the same sites were often used, and because the projectile point forms are so similar (Warren 1984; Warren and Crabtree 1986).

**Saratoga Springs Period (1,500 B.P. to 800 B.P.)**

The Saratoga Springs Period was a time of significant regional cultural differentiation in the eastern, northwestern, and southern Mojave Desert. In the Southwest this period was the time of the major Basketmaker III-Pueblo development (Cordell 1984). Southwest pottery appeared in the eastern Mojave Desert between 1,500 and 800 B.P. (Warren 1986:189).

Warren (1986) defines the eastern Mojave Desert as that part of the desert which is north of the New York and Providence Mountains, south of the Lathrop Wells and upper Muddy River area, and east of the Mojave-Amargosa trough. Artifact assemblages include Eastgate and Rose Springs projectile points, manos and metates, and incised slate pendants.

This region had a scattered but permanent Puebloan population between approximately 1,200 and 900 B.P. as evidenced by the presence of Anasazi Gray Ware pottery at sites such as Halloran Springs (Rogers 1929; Leonard and Drover 1980:251-252), China Ranch (McKinney et al. 1971), and Ash Meadows (Hunt and Hunt 1964). At Halloran Springs,
hundreds of small mines were dug for turquoise, some of which has been chemically identified in the Gila Butte phase (A.D. 500-A.D. 700) at Snaketown (Sigleo 1975). Rogers (1929) reported a few turquoise chips as far west in the Mojave Desert as Crucero and the Cronese basin.

The northwest Mojave Desert, as defined by Warren (1986; Warren and Crabtree 1986), is that part of the desert west of the Mojave-Amargosa trough and a line as yet undetermined running east-west, north of the Mojave River. Important Saratoga Springs sites in this region include Rose Springs (Lanning 1963) and Chapman Cave (Hillebrand 1972). Assemblages at those sites show a strong general continuity with the preceding Gypsum Period. The predominance of the small Eastgate and Rose Springs projectile points over the earlier Elko and Humboldt series dart points, however, suggests the first local use of the bow and arrow.

The southern Mojave Desert (Warren 1986; Warren and Crabtree 1986) includes that portion of the Mojave River drainage which is upstream of the Cronese basin, and the remaining area west of the New York and Providence Mountains. During the drainage Springs Period this region was influenced by cultures along the Lower Colorado River. Small, crude, "Rose Springs-like" projectile points also date to this phase.

The Oro Grande site near Victorville contains evidence of a non-ceramic Yuman-like occupation (Rector et al. 1983). A
midden deposit was bracketed by radiocarbon dates of A.D. 500 and A.D. 1500. The artifacts recovered included Cottonwood series projectile points, manos and metates, mortars and pestles, incised slate pendants, shell ornaments, and lithic knives, drills, and perforators.

**Protohistoric Period (800 B.P. to Historic Contact)**

The defining characteristics of the Protohistoric Period in the Mojave Desert are Desert Side-notched projectile points and various types of brown ware pottery, including Owens Valley Brown (Warren 1986). Important sites and components which date to this period are the Cottonwood Creek site in Owens Valley; the Cottonwood phase at Rose Springs; Colville Rockshelter and several sites in the Indian Ranch area of Panamint Valley; Chapman II phase components of sites in the Coso Range, Death Valley IV sites, China Ranch, and Shoshone and Rustler's Rockshelters.

In the northwestern Mojave Desert, Side-notched and Cottonwood Triangular projectile points appear in the archaeological record, as do small steatite beads and Owens Valley Brown pottery. Evidence indicates that such artifacts were used by the historic Paiute Indians.

Protohistoric assemblages in the eastern Mojave Desert contain both Desert Side-notched points and brown pottery, and, in general, are very similar to assemblages in the
northwestern Mojave Desert. According to Warren (1986), this suggests that the Paiute were migrating into the region by about 900 B.P.

The protohistoric pattern is somewhat different in the southern Mojave Desert. The Mojave River valley became increasingly important during this period as a trade route across the desert. As a consequence, sites firmly identified as relating to the Shoshonean-speaking Serrano of historic times show attributes of Yuman-speaking cultures to the east. For example, brown and buff pottery which first appeared in the Lower Colorado River region about A.D. 800 also appeared in the southern Mojave Desert during this period. Desert Side-notched projectile points also appeared and were spread through the region.

The Vanyume

During the ethnographic period, the central Mojave Desert was inhabited by the Vanyume, a desert division of the Serrano (Kroeber 1925:614, Plate 1; Bean and Smith 1978:570, Figure 1). It is also possible that the Kawaiisu may have travelled through the region, and that during recent times, the Chemehuevi occupied parts of the central Mojave (Sutton and Parr 1991).

Relatively little is known about the Vanyume (Coues 1900; Kroeber 1925; Strong 1929; Bean and Smith 1978; Harrington 1986; Schneider 1989; Sutton 1991). Kroeber (1925:614) referred
to the Vanyume as the "Serrano of the Mojave River." Both the Vanyume and Serrano were Takic speakers of the Shoshonian linguistic stock within the larger Uto-Aztekan linguistic family (Bean and Smith 1978). Kroeber (1925:614) considered the Vanyume dialect more closely related to that of the Kitanemuk to the west than the Serrano to the south. The primary difference between the Vanyume and the Serrano may have been their political affinities. The Vanyume aligned with the Mojave and Chemehuevi, people who were both hostile toward the Serrano proper (Kroeber 1925:614).

The Vanyume apparently were never a very large group and died out before 1900 and the time of systematic ethnographic studies. While it is known that the Vanyume were hunter-gatherers, very few details of their subsistence and settlement strategies have been recorded. They are generally regarded to have been a poor people (Kroeber 1925:615; Bean and Smith 1978:571). Bean and Smith (1978:571) have suggested that the general subsistence strategy was similar to that of the Serrano. Mesquite was evidently important in the Vanyume diet, however, Kroeber (1925:615) described one group as having "...nothing but tule roots to eat." Major ethnographic accounts of the Serrano include Gifford (1918), Kroeber (1925), Strong (1929), Benedict (1924, 1926), and Drucker (1937).
Pre-Pleistocene Drainage Patterns

During most of the Pliocene, much of the area which is today the Mojave Desert was a west-sloping upland. Drainage was to the Pacific and deposition was primarily in basins aligned approximately east-west (Woodburne and Golz 1972; Woodburne 1975; Ponti 1985; Meisling and Weldon 1989). As a result of continued uplift of the Transverse Ranges, drainage shifted to the interior early in the Pleistocene (Woodburne 1975; Ponti 1985; Meisling and Weldon 1989). In this sense, tectonic events created the ancestral Mojave River drainage basin.

Early Pleistocene Drainage

Tectonic displacements along the San Andreas fault zone produced successive gains and losses in mountain mass in the headwaters region of the ancestral Mojave River drainage during early and middle Pleistocene times (Meisling and Weldon 1989). Corresponding fluctuations in drainage basin size are reflected broadly in downstream sedimentary records, including those of the Manix basin (Meek 1990).

Only small portions of the Transverse Ranges were glaciated during the late Pleistocene (Sharp et al. 1959). The
glacial history of earlier Quaternary times has not yet been documented. It would appear that glacial meltwaters provided only a relatively small part of the Mojave River’s discharge. It is thought that runoff influx into the Manix basin, and later into the Soda Lake/Silver Lake basin, were directly related to fluctuations in the rainfall, snowmelt, and runoff in the San Bernardino Mountains headwaters region as well as changes in regimal temperature and evaporation rates.

The Mojave River did not flow as far as the Manix basin during the early and early middle Pleistocene (Meek 1990). Rather, deposition of both lacustine and deltaic sediments occurred in the area of the modern Harper Lake playa. Reynolds (1989) has described an Irvingtonian fauna in that area. A high stand of Lake Harper is thought to have overflowed into the Manix basin through the Barstow corridor (Meek 1990). Extension of the drainage into the Manix basin probably occurred during the latter part of the middle Pleistocene (Jefferson 1985b).

The Modern Mojave River Drainage Basin

The Mojave River drainage is a closed hydrologic system. The overall drainage basin has an area of approximately 9,500 km² (3,668 mi²). Approximately 95 percent of its area lies within the Mojave Desert, where it is one of the
largest watersheds (Figure 20). It extends from the northwestern San Bernardino Mountains northeastward into the central portion of San Bernardino County. More specifically, it is located between latitudes 34° north and 35° 30' north and longitudes 115° 30' and 119° west. The Mojave River is the only major stream in the drainage basin and the main source of aquifer recharge. The headwaters region is an area of approximately 560 km² (216 mi²) in the eastern Transverse Ranges. At present, the Mojave River terminates at the playas of Soda Lake and Silver Lake over 200 km away from its headwaters region in the San Bernardino Mountains.

Hydrologic studies have, for convenience, divided the overall drainage basin into a headwaters region, the Upper, Middle, and Lower Mojave Valleys, and Harper Lake (see, for example, Thompson 1929; Kunkel 1962; California Department of Water Resources 1967; Hardt 1971). Except for its headwaters region, the drainage basin is an alluvial plain which slopes gently to the northeast within the Mojave Desert.

The distribution of annual precipitation within the Mojave River drainage basin is highly variable. In the San Bernardino Mountains headwaters region, mean annual precipitation exceeds 1,000 mm (40 in) per year. In the remaining 95 percent of the drainage basin, mean annual precipitation is less than 125 mm (4.92 in) (California Department of Water Resources 1980). Under modern conditions, the seasonality of precipitation changes from the headwaters to the
FIGURE 20  THE MOJAVE DESERT PORTION OF THE MOJAVE RIVER DRAINAGE BASIN
terminal basins. In the Victorville area, precipitation occurs primarily in the winter, whereas in the Barstow area precipitation occurs in two seasons. Most of the precipitation in the Barstow area results from large storms during the winter, primarily in February. Smaller amounts of precipitation occur during the summer, primarily in August.

Evaporation exceeds precipitation in most of the Mojave River drainage basin. In the Upper Mojave Valley, potential evapotranspiration is 200 to 250 cm annually (California Department of Water Resources 1967). Conditions are similar in the Middle and Lower Mojave Valleys. Therefore, most precipitation falling directly in these valleys, is lost, and does not contribute to streamflow and aquifer recharge.

**The Headwaters Region**

The Mojave River is an allogenic (exotic) stream, that is to say, it is primarily an arid area stream with a non-arid source (Cooke and Warren 1973:22). It originates high in the western San Bernardino Mountains, where its flow is perennial, and joins Deep Creek at the base of the mountains at an elevation of approximately 915 m (3,002 ft). The junction of the two streams is called The Forks. The headwaters region includes those portions of the San Bernardino Mountains that are tributary to Deep Creek (also sometimes known as the East Fork of the Mojave River),
the West Fork of the Mojave River, as well as areas in both
the San Bernardino and San Gabriel Mountains drained by
minor streams which reach the river below the Forks. App-
proximately 92 percent of the basin’s recharge comes from
the San Bernardino Mountains. Runoff from the nearby San
Gabriel Mountains provides five percent of the total
discharge, and the remaining three percent is added as
groundwater flow (Hardt 1971). About 80 percent of the
recharge by the Mojave River occurs between the months of
November and March. Because the San Bernardino Mountains
are composed of relatively impermeable rocks, most snow melt
rain and is carried directly into streams. Some precipi-
tation, however, is retained by soil and vegetation, and
this serves to more evenly distribute the river’s flow
through the year. Water which drains to alluvial deposits
along the West Fork and in Horsethief Canyon is absorbed,
and flows underground into the water table of the Upper
Mojave Valley.

The Deep Creek basin accounts for approximately two-
thirds of the total headwaters region. It is approximately
610-915 m (2,000-3,000 ft) higher than the West Fork basin.
Despite these factors, precipitation is greater in the West
Fork basin possibly due to an orographic barrier southwest
of Deep Creek. Most of the precipitation occurs between
November and March. Most winter precipitation is frontally
induced as moist air is brought in from the Pacific.
Mountain precipitation at Squirrel Inn near Crestline (elevation 1,585 m [5,200]) is approximately 102 cm (40.2 in) per year. In contrast, the average annual precipitation at Victorville (elevation 853 m) is about 12.62 cm (5 in) (1939-1968 record), and at Barstow, is 10.56 cm (4.2) (1938-1969 record) (Hardt 1971).

Precipitation exceeds evapotranspiration only during December, January, and February (Hardt 1971). The average annual evaporation from the Mojave River in Victorville is approximately 1.5 m (4.9 ft).

The Upper Mojave Valley

After it debouches from the mountains north of The Forks, the Mojave River emerges onto the desert plain of the Upper Mojave Valley where most of its water infiltrates into coarse alluvial deposits. This portion of the Mojave River basin includes Victor Valley, Apple Valley, Sunrise Valley, and Fairview Valley. There is perennial streamflow for approximately 24 km (15 mi) of the channel in the Victorville area. At the Upper and Lower Narrows the drainage is superimposed on impermeable bedrock, and this forces groundwater flow to the surface. Below the Lower Narrows, the river channel again crosses alluvial deposits and much of the water infiltrates. Today, surface water of the Mojave River generally disappears in the vicinity of Oro Grande.
The Middle Mojave Valley

The Middle Mojave Valley is a lowland between Hodge (formerly called Hicks) and Barstow. The Harper Valley is usually also considered to be part of this portion of the drainage basin. During the early and middle Pleistocene the ancestral Mojave River fed a pluvial lake in the Harper basin. Geomorphic expression of this lake, however, is not readily apparent. Thompson (1929:426) reported that shells were recovered at a depth of 61 m (200 ft) in a well drilled in Harper Dry Lake. Reynolds (1989) has reported an extensive Irvingtonian Land Mammal Age fauna in the area. There is evidence near Barstow that the Mojave River has entrenched its valley by 7.5 to 15.2 m (25 to 50 ft). Similar evidence occurs at intervals all the way back up to the San Bernardino Mountains, and in some places indicates entrenchment to a depth of 61 m (200 ft) or more.

The Mojave River channel is highly permeable and capable of recharge. For this reason, minor river flows do not normally reach as far as Barstow. Aquifer recharge in the Barstow area and farther downstream occurs primarily during flood events. During the period 1931 to 1968, for example, only about 27 percent of the water passing The Forks reached Barstow, and most of this was as the result of flooding (Hardt 1971).
The Lower Mojave Valley

The Lower Mojave Valley is bordered by the Calico Mountains, low hills north of the Coyote playa, Alvord Mountain, and the Cronese, Cave, Cady, and Newberry Mountains (Figure 4). It has an area of approximately 3,108 km² (1,200 mi²).

During the middle and late Pleistocene the Lower Mojave Valley was the terminal basin for the Mojave River. Lacustrine, fluvial, and alluvial deposits exposed in bluffs along the Mojave River were first described by Buwalda (1914). Buwalda recovered fossil remains of terrestrial vertebrates including horses, camels, mammoth, antelope, and birds and proposed that the fossiliferous deposits be called the "Manix Beds" for the name of the nearby station on the San Pedro, Los Angeles and Salt Lake Railroad.

The Pleistocene age of the lacustrine sediments was established by Ellsworth (1932, 1933) who described evidence of at least three major lakes and a late Pleistocene cutting of Afton Canyon at the east end of the basin. The location of Pleistocene Lake Manix relative to other pluvial lakes in the southwestern Great Basin is shown in Figure 21.

The lacustrine sediments and coeval interdigitating fluvial and alluvial deposits were described in significant detail by Jefferson (1968). He informally named the stratigraphic sequence the Manix formation (Jefferson 1968,
FIGURE 21 PLEISTOCENE LAKES OF THE SOUTHWESTERN GREAT BASIN

MODIFIED AFTER SNYDER ET AL. 1964
1985b) and divided it into four members based on lithologically distinctive facies.

Today, the Lower Mojave Valley, which includes the Manix basin, consists of two sub-basins which are still topographically intact (the Coyote sub-basin to the north and the Troy sub-basin to the south), and the Afton sub-basin, which was breached during the possibly catastrophic drainage of Lake Manix approximately 13,300 to 13,800 years ago (Meek 1990). Since the incision of Afton Canyon, the Afton sub-basin has held the through-flowing channel of the Mojave River. During positive water-budget times, the river flows farther east into the Soda Lake/Silver Lake basins in the Baker vicinity. Lakes can form today in these terminal basins when the sub-tropical jet stream brings warm humid air in from the central Pacific Ocean. Wells et al. (1989) have suggested that Holocene lake stands in the terminal basins were the result of increases in the frequency of large magnitude storm events over the Transverse Ranges which occurred in response to large-scale oceanic-atmospheric phenomena.

The incision of Afton Canyon lowered the local base-level more than 120 m (>366 ft) (Meek 1989, 1990). Subsequent erosional dissection has exposed the thick Manix Formation sequence.
CHAPTER VIII. MANIX FORMATION STRATIGRAPHY

Stratigraphy, the backbone of the geological and archaeological sciences, is the study of depositional layers and the correlation of layers in time and space. In archaeology, stratigraphic studies are especially useful in the reconstruction of past microenvironments (Butzer 1982).

Methods

The principal field activity undertaken for this thesis involved the sampling, description, and preliminary analysis of the fine-scale stratigraphy of the upper 15 m (49 ft) of the Manix Formation type section at Bassett Point within the Manix area.

The type section of the Manix Formation has been described by Jefferson (1968, 1985b). His reports present a composite stratigraphic column based on data derived from numerous profiles. The microstratigraphic section presented here is meant to supplement Jefferson's analysis.

The stratigraphic analysis reported here was undertaken as part of an assessment of the Manix area's potential to yield data pertaining to archaeological
research. A major goal was to determine if the sedimentary record could be used to characterize Pleistocene depositional environments, and in so doing, characterize past biological habitats.

In most cases a stratigraphic section is measured upward from its base. In this study, however, the strata were examined from top to bottom, more in keeping with the traditional procedures of archaeology. All measurements and descriptions were made from fresh vertical exposures. Indurated strata were exposed using a pick mattock; softer strata were exposed with a square-nosed shovel and a trowel. Every visible stratigraphic layer in the cross-section, however thin, was measured and described with regard to structure, texture, Wentworth grain size, degree of sorting, and Munsell color (Munsell Color Division, Kollmorgen Corporation 1971). All depth measurements were made relative to the upper surface of Manix Formation member D at permanent datum MANIX 1 (Figure 6). Both dry and moist Munsell color values were recorded for all sediment samples. Only the moist values are reported here. Munsell values were determined while examining samples under open shade conditions. A 250 to 350 g sediment sample was taken from each layer described. The total sample collection has been archived by the author for possible future analyses. Figure 22 depicts a portion of the Upper Manix Formation deposits at Bassett Point.
FIGURE 22  UPPER MANIX FORMATION DEPOSITS AT BASSETT POINT
Once described, related sequences of sedimentary layers were grouped into depositional units. Within the 15 m (49 ft) section that was examined, four types of depositional units were recognized: shallow lake deposits, deep lake deposits, deltaic deposits, and alluvial deposits. Shallow-lake deposits consist of silts and clays with a few sandy layers. The clays are often platy and blocky. Sandy zones are sometimes reddened due to the oxidation of ferrous minerals. Deep-lake deposits typically consist of indurated silts and clays. Claystones are typically blocky and massive, and sometimes mottled as a result of differential oxidation. Soft, platy, clay layers are locally interbedded with indurated, fissile layers. The few layers of fine sand which occur are sometimes oxidized. Deltaic deposits consist of coarsening-upward sequences of fine to coarse sands. Alluvial deposits consist of fine to coarse sands, as well as pea gravels, pebbles, and cobbles.

Once described and classified, depositional units were related to the basic stratigraphic framework described by Jefferson (1968, 1985b). Using Jefferson's terminology, the microstratigraphy presented here describes Member D, Upper Member C, Upper Member B, Middle Member C, and the upper 125 cm of Lower Member B (Table 3). Figure 23 is a generalized stratigraphic profile of the Bassett Point locality.
**TABLE 3**

MICROSTRATIGRAPHY OF THE UPPER MEMBERS OF THE MANIX FORMATION, BASSETT POINT, SAN BERNARDINO COUNTY, CALIFORNIA

EXPLANATORY NOTE: Layer designations include member designation (Jefferson 1968, 1985b), unit number, and layer number. For example, D1.1 indicates Manix Formation Member D, unit 1, layer 1. Depth measurements are relative to the exposed upper surface as measured at the base of fixed datum MANIX 1. MANIX 1 is one of two permanent datum points established in the study area (Figure 6).

<table>
<thead>
<tr>
<th>LAYER</th>
<th>DEPTH (cm)</th>
<th>GRAIN SIZES</th>
<th>COLOR (moist)</th>
<th>THICKNESS (cm)</th>
<th>DEPOSIT TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1.1</td>
<td>0.0</td>
<td>fine and medium sand and pea gravel</td>
<td>10 YR 5/3</td>
<td>8.9</td>
<td>delta</td>
</tr>
<tr>
<td>D1.2</td>
<td>8.9</td>
<td>fine, medium, and coarse sand and pea gravel (shells at 10.2 cm and 20.3 cm)</td>
<td>10YR 5/3</td>
<td>20.3</td>
<td>delta</td>
</tr>
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<td>D1.3</td>
<td>29.2</td>
<td>primarily coarse sand with small amounts of fine and medium sand</td>
<td>10 YR 5/3</td>
<td>10.2</td>
<td>delta</td>
</tr>
<tr>
<td>D1.4</td>
<td>39.4</td>
<td>primarily coarse sand with small amounts of fine sand (shells at 40.6 cm)</td>
<td>10YR 5/3</td>
<td>10.2</td>
<td>delta</td>
</tr>
<tr>
<td>D2.1</td>
<td>49.6</td>
<td>silt with small amounts of fine and medium sand</td>
<td>10YR 5/3</td>
<td>15.2</td>
<td>shallow lake</td>
</tr>
<tr>
<td>D2.2</td>
<td>64.8</td>
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<td>12.7</td>
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<td>77.5</td>
<td>silt</td>
<td>10YR 5/3</td>
<td>8.3</td>
<td>shallow lake</td>
</tr>
<tr>
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<td>DEPTH (cm)</td>
<td>GRAIN SIZE</td>
<td>COLOR (moist)</td>
<td>THICKNESS (cm)</td>
<td>DEPOSIT TYPE</td>
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<td>delta</td>
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<td>12.7</td>
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<td>10YR 3/2</td>
<td>2.5</td>
<td>shallow lake</td>
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<td>7.5YR 5/4</td>
<td>12.7</td>
<td>delta</td>
</tr>
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<td>45.7</td>
<td>delta</td>
</tr>
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</tr>
<tr>
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<td>291.5</td>
<td>fine sand and small amounts of coarse sand</td>
<td>10YR 5/3</td>
<td>1.6</td>
<td>shallow lake</td>
</tr>
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<td>silt and very small amounts of very fine and fine sand</td>
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<td>GRAIN SIZES</td>
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FIGURE 23
STRATIGRAPHIC PROFILE OF THE BASSETT POINT LOCALITY


Member D

The uppermost member of the Manix Formation is Member D (Jefferson 1985b). It consists of deltaic deposits of pink to orange arkosic sands with a few conglomerate lenses. The member thins from west to east and from north to south. In the vicinity of Buwalda Ridge the lithology changes to a cobble conglomerate with very well-sorted coarse sand (McGill et al. 1988), probably indicative of a beach environment.

Member D is composed of seven depositional units. The uppermost Unit 1, is 39.4 cm (15.5 in) thick, and consists of fine to coarse sands and pea gravels suggestive of deltaic deposition. The surface of Member D is a lag deposit which has been winnowed by aeolian processes. A soil (Munsell color 10YR 5/3) with some secondary carbonates is present. Fresh water mussel shells (Anodonta californiensis) are found at depths of 10.2 cm, 20.3 cm, and 40.6 cm (4, 8, and 16 in respectively). Prior to this study it was believed that Member D had only two shell layers. The study reported here documents the presence of seven distinct shell layers. In addition to the three mentioned above, shell layers were encountered at 58.4 cm, 88.9 cm, and 154.3 cm (23 in, 35 in, and 61 in, respectively). Jefferson (1985b) reported that an upper shell layer (depth not reported) was radiocarbon dated to 19,100 ± 250 years B.P.
Recent studies of radiocarbon uptake by *Anodonta californiensis* suggest that a -450 year correction factor may be needed to account for reservoir effects in the Mojave River basin (Meek 1990). Incorporating this correction factor, the age of the upper shell layer becomes 18,600 ± 250 years B.P. The lowest of the shell layers was recorded at 248.9 cm (98 in). Shells from this layer have been dated to 74,000 years b.p. by the uranium-thorium method (Bischoff, written communication, 1988). Earlier attempts to date shells from this layer by the conventional radiocarbon method indicated that they were older than 35,000 years B.P. (Bassett and Jefferson 1971), and older than 45,000 years B.P. (Jefferson 1985b), and thus radiocarbon "dead."

Uranium-thorium dating of three fossil bone elements recovered at depths between 2 and 3.8 m (6.6 ft to 12.4 ft) below the measured top of Member D have provided additional chronometric control. Th-230 decay series dates of 47,000 ± 2,000 b.p., 51,000 ± 2,500 b.p., and 60,300 ± 2,000 b.p. were determined for a mammoth (*Mammuthus* sp.) femur, a llama (*Hemiauchenia* sp.) femur, and an unidentified mammal bone element respectively (Bischoff, written communication, 1988). The concordant Pa-231 decay series dates for these specimens were 51,600 ± 5,500 b.p., 55,000 ± 8,000, and 55,600 ± 5,000 b.p. (Bischoff, written communication, 1987). These dates suggested to Jefferson (1986b) that the lower
portion of Manix Formation Member D was deposited during Marine Oxygen-Isotope Stage 4 (see Shackleton and Opdyke 1973; Shackleton 1976).

Unit 2 of Member D is 36.2-cm (14.25 in) thick and consists of silt layers, some of which have small amounts of fine sand. This unit is interpreted as indicative of a shallow lake. An Anodonta shell layer occurs at a depth of 58.4 cm (23 in), in the uppermost silt layer.

Unit 3 is a 59.7-cm (23.5 in) thick deposit of well-indurated, fine to medium sand, with small amounts of silt. Anodonta shells occur at a depth of 88.9 cm (35 in), near the top of the unit. The sands of this unit generally coarsen upward, suggesting deltaic deposition.

Unit 4 is 38.1-cm (15 in) thick. It consists of silt layer and a basal layer of silty clay. A layer of Anodonta shells is found at a depth of 154.3 cm (61 in), in the top layer.

Unit 5 is mostly a coarsening-upward sequence of fine to coarse sands, and measures 109.5 cm (43 in) in thickness. The coarsening upward pattern suggests this unit was deposited under deltaic conditions. The lowest of the seven identified Anodonta shell layers is found near the middle of this unit at a depth of 248.9 cm (98 in).

Unit 6 is a 49.5-cm (19 in) thick deposit of silts, suggestive of shallow lake deposition. The uppermost layer has a very small amount of very fine and fine sand.
Unit 7 is at the base of Member D. It is a 44.5-cm (17.5 in) thick, coarsening upward sequence of very fine to coarse sands, indicative of deposition under deltaic conditions. A 5.7 cm (2.24 in) layer of very fine sand is noticeably oxidized (10 YR 5/3) and may indicate sub-aerial exposure.

Upper Member C

Member C is composed primarily of lacustrine silts and clays (Jefferson 1968, 1985b). Jefferson (1985b) has divided this member into upper, middle, and lower units.

Upper Member C is believed by Jefferson (1985b) to be temporally correlative with Marine Oxygen-Isotope Stages 4 though 6, covering the timespan from 58,000 to 188,000 years ago. He characterizes it as being approximately 9.5 m (31 ft) thick and composed of light green and gray silty sands, with fine sands which coarsen from south to north. In places, Member C progrades over Members A and B. In such contexts, clasts encrusted with lithoid tufa are found at the very top of Member A or Upper Member B. Such tufa layers are covered in turn by layers of oxidized (reddish orange) arkosic sand.

Reddish orange arkosic layers are present at three other levels in Upper Member C and are believed by Jefferson (1985b) to represent Marine Oxygen-Isotope Stage 5b.
At 28.6 cm (11.25 in) above the base of Upper Member C (and at a depth of 891.1 cm [350.8 in]) is a 7.6 cm (3 in) thick layer of air-fall tephra. The chemical composition of the ash in Upper Member C is nearly identical to the glass of the rhyolitic glass of Long Canyon in the Kern Plateau of the southern Sierra Nevada (Bacon and Duffield 1981; Izett 1981; Sarna-Wojcicki et al. 1984). According to Izett (1981), the sanidine of the Long Canyon rhyolite was dated to 185,000 ± 15,000 years b.p. by the potassium-argon method.

Very explosive volcanic eruptions can lay down blankets of tephra over large areas. Such tephra layers form regionally isochronous stratigraphic markers which can be dated either directly using the potassium-argon, argon-argon, or fission track methods, or indirectly by closely-bracketing chronometric dates from above and below the tephra layer. Petrographic and chemical analyses can be used to determine unique tephra signatures.

Two camel fossils recovered from Upper Member C have been dated by Bischoff using the uranium-thorium method. A camel (Camelops sp.) humerus yielded a Th-230 date of 68,000 ± 4,000 b.p. and a Pa-231 date of 87,200 ± 17,000 b.p. (Bischoff, written communication, 1988). The concordance of the two dates implies a high level of accuracy. The second specimen, a camel scapula, was recovered 1.5 m (5 ft) above the 185,000 ± 15,000 b.p. volcanic ash (Jefferson 1985b). It was dated to 183,000 ± 12,000 b.p. by the Th-230 method.
and >140,000 years by the Pa-231 technique (Bischoff, written communication, 1987). Even though the dates are not concordant, there is no reason to reject them.

Microstratigraphic analysis of Upper Member C indicates that it is 542.7 cm (214 in) thick and composed of clays and silty clays with stringers of very fine sand. Such particle sizes suggest deposition occurred in a shallow lake. Four reddish-orange oxidized sand layers were recorded at depths of 426.4 cm (168 in), 604.9 cm (238 in), 712.0 cm (280.3 in), and 863.8 cm (340 in) (Table 3).

**Upper Member B**

According to Jefferson (1968, 1985b), Manix Formation Member B sediments are alluvial deposits derived from the northwest (Jefferson 1968, 1985b). The member is sub-divided into upper and lower units. Upper Member B is described by Jefferson (1985b) as being up to 18 m (59 ft) thick and composed of moderately to poorly-sorted tan, medium to coarse arkosic sand, with lenses of gravel conglomerate. Flow direction is indicated by cross bedding and the relative abundance of granodioritic clasts in the coarser sediments which were probably derived from outcrops on the west side of Alvord Mountain (Byers 1960; Jefferson 1968, 1985b).

Microstratigraphic analysis of Upper Member B suggests that it is a deltaic deposit, not an alluvial one. It is 18.8
cm (7.4 in) thick and consists of silts and very fine to coarse sands. The basal sand layer was oxidized (7.5 YR 5/2), presumably due to subaerial exposure.

Middle Member C

Middle Member C underlies Upper Member B. It consists of siltstones and claystones (Jefferson 1968, 1985b). Some of the clays are oxidized, but no carbonates or soil horizons indicative of long-term weathering have been reported (Jefferson 1985b). Where Middle Member C interdigitates with Member A or overlies Lower Member B, there is a 50 to 100 cm thick layer of moderately-to-well sorted oxidized arkosic sand. These sands often rest directly atop layers of lithoid tufa-encrusted clasts. Based on an assumption that high-latitude glacials correlate with mid-latitude pluvials, Jefferson (1985b) believes Middle Member C to be correlative with Oxygen-Isotope Stage 8, covering the time-span from 244,000 to 279,000 years ago.

Microstratigraphic study indicated that Middle Member C consists of 455.9 cm (179.5 in) of deep lake sediments. These include silts, silty clays, and clays with stringers of very fine sand.
Lower Member B

According to Jefferson (1968, 1985b), Lower Member B consists of arkosic sands and interbedded conglomerates ranging from gravel to cobble-size, thinly bedded silty sands, and micaceous claystones. Moderately-to-well sorted, coarse, arkosic sands found near the top of Lower Member B contain cobbles covered with tufa (Jefferson 1985b). This tufa has not yet been dated, but Jefferson (1985b) has correlated that layer with Marine Oxygen-Isotope Stage 12. The lowest portion of Member B, a stratum of thinly bedded silty sands, was found to have a normal magnetic polarity (Jefferson 1985b). This suggests that the sands are younger than the Brunhes-Matuyama magnetic reversal event 730,000 years ago.

The microstratigraphic analysis of the upper Manix Formation examined only the upper 125 cm (49.2 in) of Lower Member B. The portion of this member that was examined was found to consist primarily of fine to coarse sands (with several coarsening-upward sequences), suggestive of fluctuating playa margin conditions and deltaic deposition. At the top of Lower Member B is unit 1, a thin (2.5 cm [1 in]) layer of fine to very coarse sand, pea gravel, and pebbles which were probably laid down under alluvial conditions. This unit contains chalcedony and jasper clasts. One unifacially flaked chalcedony specimen was identified as an
artifact of early man (see Chapter X). It was found in situ at a depth of 13.7 m (45 ft) (5.0 m [16.4 ft] below the 185,000 ± 15,000 b.p. Long Canyon ash).

Below the alluvial unit is unit 2, a 69.9 cm (27.5 in) thick sequence of mostly upward-coarsening very fine to very coarse sands. A 9.5 cm (3.7 in) thick layer of oxidized, medium to very coarse sands is located at the very top of this unit.

It has a 2.5YR 6/4 color. Unit 3 is only 4.5 cm (1.8 in) thick and consists exclusively of clay, suggestive of deep lake deposition.

Only a 52.1 cm (20.5 in) portion of unit 4 was examined. Three coarsening-upward sequences of fine to coarse sand and pea gravel were identified.

Jefferson (1985b) believes that the basal portion of Lower Member B correlates with Marine Oxygen-Isotope Stage 14 (475,000 to 505,000 years ago). A horse (Equus sp.) ulna recovered 9 m (29.5 ft) above the base of Lower Member B proved to be too old to be dated by the uranium-thorium technique (i.e., >350,000 b.p.) (Bischoff, personal communication, 1988). The upper portion of Lower Member B is believed by Jefferson (1985b) to be correlative with Marine Oxygen-Isotope Stage 9 (334,000 to 347,000 b.p.).
**Member A**

Member A is a brown conglomerate of cobble- to boulder-size andesitic igneous and metamorphic clasts (derived from the Cady Mountains on the south side of the basin) and interbedded sandstones (Jefferson 1968, 1985b). It both dips and thins to the north-northwest. The conglomerate is poorly sorted and clast implication indicates paleoflow from the southeast. The uppermost portion of Member A locally interdigitates with Members B and C.
CHAPTER IX. DEPOSITIONAL HISTORY OF THE MANIX BASIN

The Plio-Pleistocene Mojave River Formation

The oldest sedimentary sequence yet identified in the central Manix basin is the Plio-Pleistocene Mojave River Formation (Nagy and Murray 1991). This formation is more than 80 m (262 ft) thick and is a generally coarsening-upward fine-grained deposit that accumulated in a closed basin as playa/sabkha sediments. Bedded gypsum deposits decrease up-section, whereas caliche layers and desiccation features increase.

The type section of the Mojave River Formation is located north of the Mojave River, adjacent to the Manix fault and Manix Wash, along what is known informally as Buwalda Ridge (sometimes designated cartographically as Field Ridge). Nagy and Murray (1991) claim that the uppermost sediments of the Mojave River Formation are in transitional contact with Member A of the Manix Formation (Jefferson 1985b) on the south side of the River. Jefferson (George Jefferson, personal communication, 1991) has questioned this assertion, claimed that all exposed contacts are unconformable, not transitional.

Sediments of the Mojave River Formation vary from well-indurated claystones to friable sandstones (Nagy and Murray 1991). Beds are folded into a series of northwest and northeast
trending synclines and anticlines. As a whole, the Manix River Formation is a broad anticline. Stratigraphy, magnetostratigraphy, and tephrochronology suggest the formation has an age of 920,000 to 2,480,000 years (Nagy and Murray 1991; Pluhar et al. 1991). The Mojave River Formation presumably includes the Plio-Pleistocene lacustrine sediments described by Jefferson (1985b) as ephemeral saline lakes and playas. The Manix River Formation contains three traceable volcanic tuff layers: a gray ash layer overlain by two different white ashes. All three ashes were deposited under sub-aqueous conditions. The lowermost gray ash has been correlated by Sarna-Wojcicki et al. (1984) with the Huckleberry Ridge ash (formerly the Pearlette B ash) of Meade County, Kansas. The Huckleberry Ridge ash, in turn, is correlative with a family of ashes from the Yellowstone caldera of Wyoming, dated by Izett (1981) to approximately 2,100,000 years using the potassium-argon (K/Ar) method. Neither of the white ashes has been correlated directly with any dated tuff. It has been noted, however, that their chemistries are similar to that of tephra from the Long-Valley/Glass Mountain caldera near Bishop, California (Sarna-Wojcicki et al. 1984; Izett 1981; Izett et al. 1988). The middle white ash of the Mojave River Formation has been correlated with the 2,300,000 Waucoba Road bed W3A (Taylor Canyon) of Owens Valley, California (Izett 1981). An upper white ash has also been described. The preservation of the
three ash layers has been interpreted by Nagy and Murray (1991)

as indicating that the sediments of the Mojave River Formation

were deposited under playa conditions.

There is no evidence in the Mojave River Formation that

the Afton sub-basin received any eastward flow of the ancestral

Mojave River prior to 730,000 B.P. (Nagy and Murray 1991).

The Pleistocene Manix Formation

Jefferson (1985b) has suggested that a perennial Pleistocene Lake Manix formed about 500,000 years ago, fed by the ancestral Mojave River and stabilized by a spillway in the Afton Canyon area. Fossil freshwater ostracodes (Jefferson and Steinmetz 1986; Steinmetz 1988a, 1988b; Steinmetz and Jefferson 1988), gastropods, and bivalves provide unambiguous evidence of the lacustrine conditions. Fossil evidence of Tui chub (Gila bicolor mojavensis) has also been recovered from fine-grained sediments (Jefferson 1968, 1985b). A rich Rancholabrean fauna, termed by Jefferson (1968, 1985b) the Camp Cady local fauna, has been documented (See Chapter XI).

The lowest member of the Manix Formation (Member A) is a wedge-shaped conglomerate of volcanic and metavolcanic rocks and sand shed from the Cady Mountains on the southeast side of the basin (Jefferson 1985b). The structural and textural characteristics of Member A suggest that alluviation occurred rapidly, probably under torrential conditions.
Fluvial sands and conglomerates of Member B are rich in
granodioritic clasts which were shed from the north, presum-
mably from old alluvial deposits southeast of Alvord Moun-
tain (Byers 1960; Jefferson 1985b). These alluvial deposits
coalesce with those of Member A on the east side of the
Manix basin (Jefferson 1968, 1985b).

Under positive water budget conditions, the Afton sub-
basin impounded the flow of the ancestral Mojave River,
forming Lake Manix. As the water level rose, lacustrine
sediments of lower Member C interdigitated with and pro-
graded over the alluvial deposits of Members A and B (Jeff-
erson 1985b). Jefferson (1985b) suggested that the earliest
lacustrine sediments were deposited during Marine Oxygen-
Isotope stage 8 (279,000 to 244,000 years ago). During the
early, shallow-water phase of this lake stand, lithoid tufa
was deposited on the uppermost rocks of Members A and B.
This suggests that nearshore waters were warm and wave-
agitated. Well-sorted sands were deposited and subsequently
oxidized atop the tufa-encrusted clasts. This suggests
beach conditions.

Subsequent xeric conditions during Marine Oxygen-Iso-
tope Stage 7 caused this early stand of Lake Manix to con-
tact. There is no evidence that the lake became saline or
was reduced to an ephemeral playa/sabkha. Some of the
lacustrine clay layers became slightly oxidized, presumably
due to sub-aerial exposure. The lacustrine deposits of
lower Member C were subsequently overlain by the fluvial sands and gravels of upper Member B. Cross-bedding suggests these latter deposits were transported into the basin from the north.

A second major episode of lacustrine transgressions began approximately 190,000 years ago (Jefferson 1985b). Again, lithoid tufa and beach sands provide evidence of an early, shallow-ater interval. Jefferson (1985b) has suggested that the thick lacustrine sequence deposited by this major transgression dates to Marine Oxygen-Isotope Stages 6 through 4 (from approximately 188,000 to 58,000 years ago). Three oxidized sand layers in the upper portion of the lake sediments are thought by Jefferson (1985b) to represent times of sub-aerial exposure during the sub-stages of Marine Oxygen-Isotope Stage 5 (128,000 to 72,000 years ago).

Late in the Pleistocene, deposition of deltaic sediments by the Mojave River (Member D of the Manix Formation) served to constrain the lake to the central and eastern portion of the Manix basin (Hagar 1966; Groat 1967). During this period, the lake had three stands (Meek 1990). These were between 31,000 and 29,000 years B.P., 21,000 and 17,500 years B.P., and 14,700 and 13,700 years B.P. (Meek 1990). The lake drained, perhaps catastrophically, sometime between 13,800 and 13,300 years ago (Meek 1990) as a result of the down-cutting of Afton Canyon. Water from the draining lake filled the Lake Mojave basin approximately 32 km (20 mi) to the east-northeast.
The cutting of Afton Canyon lowered the local base-level by approximately 120 m (394 ft) (Meek 1990). This entrenched the Mojave River close to its present course and initiated the erosional dissection of the Manix Formation beds in the vicinity of an entrenched meander (informally known as the "Big Bend"). It was this dissection which exposed the Manix beds in the Bassett Point area.
A unifacially-flaked chalcedony specimen was discovered in situ in Lower Member B of the Manix Formation (Figure 24). The specimen was found at a depth of 13.7 m from the top of the Manix section as measured from the datum designated MANIX 1 (Figure 6). The possible artifact weighs 31.1 g (1.5 oz) and measures 44.86 mm x 33.66 mm x 23.05 mm (1.8 in x 1.3 in x 0.9 in). It has a prominent bulb of force and distinct compression rings. Both of these attributes are diagnostic of human craftsmanship (Phagan 1976; Patterson 1983). Force lines radiating from the point of percussion are evident. The dorsal surface of the specimen exhibits evidence of a hinge flake removal and a step termination. Hinge flaking and step flaking are also indications of human manufacture (Patterson 1983). The dorsal surface of the specimen exhibits irregular-edge flaking.

The putative artifact was discovered in situ in a 2.5 cm-thick layer of alluvium. It was the largest siliceous clast observed in the layer. Six specimens of very problematic origin were also recovered from the same alluvial sediments. Four of these were chalcedony and two were yellow jasper. Given the problematic nature of their attributes, these specimens are not identified here as artifacts. A possible
FIGURE 24  UNIFACIALLY FLAKED CHALCEDONY ARTIFACT RECOVERED FROM LOWER MEMBER B OF THE MANIX FORMATION
source area for the chalcedony and yellow jasper would be the eastern Calico Mountains (Figure 4) and outcrops in the vicinity of the Calico Site, 16 km (10 mi) to the west.

In the Mojave Desert, intervals of alluvial deposition during the middle and late Pleistocene and early Holocene were climatically controlled, occurring rapidly and nearly synchronously across the region during the glacial/pluvial to interglacial/interpluvial transitions (Ponti et al. 1980; Ponti 1985). Given this, and the fact that the artifact was found 5 m (16.5 ft) below the Long Canyon ash (Bacon and Duffield 1981; Izett 1981; Sarna-Wojcicki et al. 1984; see also Chapter VIII) which has been dated to 185,000 ± 15,000 b.p., it is suggested here that the putative artifact was deposited approximately 230,000 to 240,000 years ago (during the climatic transition from Marine Oxygen-Isotope Stage 7 to Oxygen-Isotope Stage 6).
CHAPTER XI. MANIX BASIN PALEONTOLOGY

The lacustrine and fluvial sediments of the type Manix Formation have yielded a rich Rancholabrean fauna (Kurten and Anderson 1980) ranging in age from 19,000 B.P. to more than 350,000 years b.p. (Buwalda 1914; Compton 1934; Howard 1955; Winters 1954; and Jefferson, 1968, 1985b, 1987, 1988, 1989, 1991). Jefferson (1968, 1985b, 1988) named the diverse assemblage of invertebrate and vertebrate fossils the Camp Cady local fauna. The name reflects the fact that the fossiliferous fluviatile and lacustrine deposits are located 1-5 km east of Camp Cady, a small, abandoned Union Army post.

The Camp Cady local fauna includes both extinct species and species which are still extant but do not currently live in the region (Table 4). The taxa suggest that both the climate and biogeography of the Manix basin were significantly different during the middle and late Pleistocene than today.
### TABLE 4

**Taxonomic List of Organisms in the Camp Cady Local Fauna**

<table>
<thead>
<tr>
<th>Class CRUSTACEA</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Limnocythere bradburyi</td>
<td>ostracode</td>
</tr>
<tr>
<td>L. cerirotuberosa</td>
<td>ostracode</td>
</tr>
<tr>
<td>L. platyforma</td>
<td>ostracode</td>
</tr>
<tr>
<td>L. robusta</td>
<td>ostracode</td>
</tr>
<tr>
<td>Heterocypris sp.</td>
<td>ostracode</td>
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<table>
<thead>
<tr>
<th>Class PELECYPODA</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Anodonta californiensis</td>
<td>freshwater clam</td>
</tr>
<tr>
<td>Pisidium compressum</td>
<td>freshwater clam</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class GASTROPODA</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Valvata humeralis</td>
<td>freshwater snail</td>
</tr>
<tr>
<td>Fossarina modicella</td>
<td>freshwater snail</td>
</tr>
<tr>
<td>Planorbilla ammon</td>
<td>freshwater snail</td>
</tr>
<tr>
<td>P. subcrenata</td>
<td>freshwater snail</td>
</tr>
<tr>
<td>P. tenuis?</td>
<td>freshwater snail</td>
</tr>
<tr>
<td>Carinifex newberryi</td>
<td>freshwater snail</td>
</tr>
<tr>
<td>Gyraulus vermicularis</td>
<td>freshwater snail</td>
</tr>
<tr>
<td>Physa sp.</td>
<td>freshwater snail</td>
</tr>
<tr>
<td>Vorticifex effusa</td>
<td>freshwater snail</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class OSTEICHTHYES</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Gila bicolor mojavensis</td>
<td>Tui (Mojave) chub</td>
</tr>
<tr>
<td>Gasterosteus aculeatus</td>
<td>three-spined stickleback</td>
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<table>
<thead>
<tr>
<th>Class REPTILIA</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Clemmys marmorata</td>
<td>western pond turtle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class AVES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gavia sp. cf. G. arctica</td>
<td>Arctic loon</td>
</tr>
<tr>
<td>Podiceps sp. cf. P. nigricollis</td>
<td>eared grebe</td>
</tr>
<tr>
<td>Aechmophorus occidentalis</td>
<td>western grebe</td>
</tr>
<tr>
<td>Palecanus aff. P. erythrorhynchos</td>
<td>American white pelican</td>
</tr>
<tr>
<td>Phalacrocorax auritus</td>
<td>double-crested cormorant</td>
</tr>
<tr>
<td>P. macropus</td>
<td>extinct cormorant</td>
</tr>
<tr>
<td>Ciconia maltha</td>
<td>extinct stork</td>
</tr>
<tr>
<td>Phoenicopterus minutus</td>
<td>extinct small flamingo</td>
</tr>
<tr>
<td>P. copei</td>
<td>extinct flamingo</td>
</tr>
<tr>
<td>Cygnus sp. cf. C. Columbianus</td>
<td>tundra swan</td>
</tr>
</tbody>
</table>
Table 4, continued

Class AVES, continued

<table>
<thead>
<tr>
<th>Bird</th>
<th>Common Name</th>
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<tbody>
<tr>
<td>Branta canadensis</td>
<td>Canada goose</td>
</tr>
<tr>
<td>Anas sp. cf. A. crecca</td>
<td>green-winged teal</td>
</tr>
<tr>
<td>A. sp. cf. A. platyrhynchos</td>
<td>mallard</td>
</tr>
<tr>
<td>Aythya sp.</td>
<td>greater scaup or canvasback</td>
</tr>
<tr>
<td>Mergus sp. cf. M. merganser</td>
<td>common merganser</td>
</tr>
<tr>
<td>Oxyura jamaicensis</td>
<td>common merganser</td>
</tr>
<tr>
<td>Haliaeetus leucophalus</td>
<td>ruddy duck</td>
</tr>
<tr>
<td>Aquila chrysaetos</td>
<td>golden eagle</td>
</tr>
<tr>
<td>Fulica americana cf. minor</td>
<td>small American coot</td>
</tr>
<tr>
<td>Grus sp. cf. Actitis sp.</td>
<td>crane</td>
</tr>
<tr>
<td>Phalaropodinae</td>
<td>sandpiper</td>
</tr>
<tr>
<td>Larus sp. cf. L. oregonus</td>
<td>phalarope subfamily</td>
</tr>
<tr>
<td>L. sp.</td>
<td>extinct gull</td>
</tr>
<tr>
<td>Bubo virginianus</td>
<td>large gull</td>
</tr>
<tr>
<td></td>
<td>great horned owl</td>
</tr>
</tbody>
</table>

Class MAMMALIA

<table>
<thead>
<tr>
<th>Mammal</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Megalonyx sp.</td>
<td>medium-sized ground sloth</td>
</tr>
<tr>
<td>Northrotheriops sp. cf. N. shastense</td>
<td>small ground sloth</td>
</tr>
<tr>
<td>Glossothrium sp.</td>
<td>large ground sloth</td>
</tr>
<tr>
<td>Mammutthus sp.</td>
<td>mammoth</td>
</tr>
<tr>
<td>Lepus sp.</td>
<td>jack rabbit</td>
</tr>
<tr>
<td>Cricetidae</td>
<td>mouse</td>
</tr>
<tr>
<td>Canis sp. cf. C. dirus</td>
<td>dire wolf</td>
</tr>
<tr>
<td>C. latrans</td>
<td>coyote</td>
</tr>
<tr>
<td>Arctodus sp. cf. Ursus sp.</td>
<td>short-faced bear</td>
</tr>
<tr>
<td>Felis (Puma) sp.</td>
<td>bear</td>
</tr>
<tr>
<td>Homotherium sp.</td>
<td>mountain lion</td>
</tr>
<tr>
<td>Equus sp. cf. E. conversidens</td>
<td>extinct small horse</td>
</tr>
<tr>
<td>Equus sp.</td>
<td>extinct large horse</td>
</tr>
<tr>
<td>Camelops sp. cf. E. hesternus</td>
<td>extinct camel</td>
</tr>
<tr>
<td>Camelops aff. C. minidokae</td>
<td>extinct camel</td>
</tr>
<tr>
<td>Hemiauchenia macrocephala</td>
<td>extinct llama</td>
</tr>
<tr>
<td>Lamina sp. nov.</td>
<td>extinct large llama</td>
</tr>
<tr>
<td>Antilocapra sp.</td>
<td>antelope</td>
</tr>
<tr>
<td>Ovis canadensis</td>
<td>mountain sheep</td>
</tr>
<tr>
<td>Bison sp. cf. B. antiquus</td>
<td>extinct bison</td>
</tr>
</tbody>
</table>

Source: Jefferson 1987
Invertebrate Taxa

Ostracodes

Lakes are very complex physical and chemical systems in which water temperature and chemistry are often coupled to the local climate (Lerman 1978). Proxy evidence which incorporates signatures of such parameters can provide continuous detailed records of climatic change. Aquatic organisms are especially sensitive to hydro-environmental conditions. Few, however, are preserved in large enough numbers to be statistically useful for paleoenvironmental reconstructions. Ostracodes, diatoms, charophytes, chrysomod cysts, the camoebans, and occasionally mollusks may be common in lacustrine microfossil records (Forester 1987). Of these, ostracodes and diatoms have been found to accurately record physical and chemical properties of the water column (Dolorme 1969; Forester 1983, 1984, 1986, 1987). Ostracode valves, composed of low-magnesium sulfate, are readily preserved in all alkaline, and some acidic, depositional environments (Forester 1987). Diatom valves, composed of opaline silica, are preserved in all acidic and most alkaline sediments (Forester 1987).

Ostracodes can be used to study water Mg/Ca and Sr/Ca ratios, and the stable isotopes of carbon, oxygen, and strontium. They can also be used for radiocarbon and
uranium-series dating (Forester 1987). Data derived from such studies can provide information regarding water temperature and salinity, as well as sedimentary age. Ostracode species living in water which is thermally coupled to the atmosphere can provide information about seasonal air temperature variability. Most ostracode species have upper and lower survival temperatures, life cycle temperatures, and egg hatching temperatures (Forester 1987). Many species have optimal temperature ranges within which productivity is maximized. Data on abundance can be used to map the expansion and contraction of biogeographic ranges and correlative climatic signals.

Ostracodes are highly sensitive to both the salinity and solute composition of water (Forester 1987). Of the two, solute composition is a more limiting factor. Freshwater ostracodes are restricted to waters dominated by calcium and magnesium ions, and low in carbonates. Saline water ostracodes are restricted to, or prefer, waters enriched with calcium ions or carbonates. Because lakes are often coupled to climate through evaporation, ostracodes can provide information about past precipitation/evaporation ratios (Forester 1987).

Manix Formation ostracode assemblages have been studied by Steinmetz and Jefferson (Jefferson and Steinmetz 1986; Steinmetz 1988a, 1988b; Steinmetz and Jefferson 1988). Two major biostratigraphic zones were identified on the basis of
dominant taxa within a 24 m (79 ft) thick sedimentary sequence. Sediments dating to approximately 400,000 years in the basal 3 m (10 ft) were dominated by *Limnocythere platyforma*, a species whose modern representatives live in cold water ponds and lakes in Alaska and Canada. *Limnocythere robusta*, now extinct, was found to be moderately abundant at intervals in the basal 3 m (10 ft) zone. *Limnocythere ceriotuberosa* was abundant in the other 21 m (69 ft) of the sedimentary sequence. Steinmetz (1988a, 1988b) postulated that the ecological replacement of *L. platyforma* by *L. ceriotuberosa* records a climatic and depositional change during the transition from Marine Oxygen-Isotope Stage 8 to Stage 7.

*Limnocythere platyforma* and *L. robusta* were found to be abundant in two discrete sedimentary intervals, suggesting deep lake conditions during pluvial maxima (Steinmetz and Jefferson 1988). A subsequent decrease, in each case, of *L. platyforma* suggested the return to warmer conditions.

In the upper portion of the sedimentary sequence, *L. platyforma* was replaced by *L. ceriotuberosa*. This was interpreted by Steinmetz as indicating a change from cool, fresh water to warmer, slightly alkaline water. Sparse populations of *L. ceriotuberosa* high in the sequence (19.3 m [63 ft] above the base) were interpreted as indicative of ephemeral lake conditions (Steinmetz and Jefferson 1988). A subsequent increase in this taxon in the uppermost 4 m
(13 ft) of the sequence suggests the return of perennial lake conditions with two high water stands. Steinmetz and Jefferson (1988) noted that the ostracode population changes appeared to be periodic. They suggested a possible relationship to the 23,000 year Milankovitch orbital cycle as documented by the marine oxygen-isotope record.

Mussels and Snails

Freshwater mussels and snails have been found in Member D of the Manix Formation. Jefferson (1985b, 1987) suggested their occurrence together may be indicative of deposition under flood conditions. The mussels are Anodonta californiensis, a species which today prefers the shallow waters (less than 2 m [6.6 ft] deep) of larger rivers and lakes (Ingram 1948; Schneider 1989). Large specimens with heavy shells are found in dense concentrations in rivers which have substantial currents. The preferred habitat of Anodonta californiensis is stable gravel, or gravel and sand in places where rooted vegetation is absent and where the water is slightly alkaline and well-oxygenated (Schneider 1989). The larval stage of this mussel is an obligate ectoparasite on fish fins (Purchon 1977).

Nine species of freshwater snails have been recovered from the Manix deposits (see Table 4). Under modern conditions Fossaria modicella and Planorobella spp. prefer moving
water and bottom vegetation such as cat-tails or lilies (Jefferson 1987). *Planobeela subcrenata* and *Carinifex newberryi* prefer cool water. *Valvata humeralis* is today restricted to lakes in the region of the Mojave River headwaters; *Planorobella tenuis* is found in perennial stretches of the Mojave River such as in the Victorville area.

**Vertebrate Taxa**

**Fish**

Only one species of fish has been found in the type locality of the Manix Formation. This has been identified as the small Tui chub (*Gila bicolor mojavensis*). The common name Mojave chub is also applied to this species. Abundant scales and bones of this fish have been found in the lacustrine deposits at the base of middle Member C (Jefferson 1987). Reynolds and Reynolds (1985) recovered fossil evidence of threespine stickleback (*Gasterosteus aculeatus*) from the lacustrine sediments of the Coyote sub-basin to the north.

The Tui chub is the only fish known to be native to the Mojave River today (California Academy of Sciences, Catalog Number 26353). Its biology has been described by Snyder (1918), Kimsey (1954), and Bailer and Uyeno (1964).
Archaeological and historic evidence indicates that chub were used as a food source by both Indians and Euro-Americans in the Great Basin (Kimsey 1954). Chub can easily be captured either by net or by hand.

**Turtles**

Western pond turtle (*Clemmys marmorata*) plastron scutes and carapace fragments have been recovered from both lacustrine and fluvial sediments of Members C and D of the Manix Formation (Jefferson 1987). Living representatives of this species subsist on aquatic plants and insects and prefer the muddy bottoms of streams, ponds, lakes, and marshes.

**Birds**

Twenty-five extinct and extant species of avifauna have been recovered from the Manix deposits (Jefferson 1968, 1985a, 1985b). Most extant species range throughout southern California and seasonally visit inland lakes, such as the Salton Sea. Others frequent coastal waters or inland areas from the San Joaquin Valley northward. The extant migratory species are presently absent from southern California during summers. During Pleistocene times the Pacific flyway probably included the pluvial lakes of the western Great Basin.
Approximately two-thirds of the extant species prefer or subsist exclusively on small fish. These include the Arctic loon (Gavia arctica), eared grebe (Podiceps nigricollis), western grebe (Aechmophorus occidentalis), American white pelican (Pelecanus aff. P. erythrorhynchos), double-crested cormorant (Phalacrocorax auritus), common merganser (Mergus merganser), golden eagle (Aquila chrysaetos), bald eagle (Haliaeetus leucocephalus), and gulls (Larus spp.) (Jefferson 1985a, 1987). The Tui chub would have provided an abundant food source for these birds.

The great horned owl (Bubo virginianus) is the only bird species in the Camp Cady fauna which feeds exclusively on small mammals. The bald and golden eagles will hunt small mammals occasionally.

The rest of the avifauna feed on aquatic plants and freshwater invertebrates. These include the tundra swan (Cygnus sp. cf. C. columbianus), Canada goose (Branta canadensis), green-winged teal (Anas cf. A. crecca), mallard (Anas cf. A. platyrhychos), ruddy duck (Oxyura jamaicensis), and sandpipers (Actitis sp.) (Jefferson 1985a, 1987).

Extinct species represented in the Manix fossil record include a cormorant (Phalacrocorax macropus), a stork (Ciconia maltha), a flamingo (Phoenicopterus copei), a small flamingo (Phoenicoptetus minutus), and a gull (Larus sp. cf. L. oregonus) (Jefferson 1985a, 1987).
The habitat requirements, food preferences, procurement strategies, and nesting habits of the Manix avifauna suggest that the waters of Lake Manix were fresh or only moderately saline and that lake margin habitats included sandy beach flats and reedy marshes (Jefferson 1985b, 1987).

Mammals

The mammals of the Camp Cady local fauna include herbivores, omnivores, and carnivores (Jefferson 1964, 1987). Herbivores far outnumber carnivores at a ratio of 61:1 (Jefferson 1987). This ratio is based on numbers of identified specimens (NISP) not minimum numbers of individuals (MNI). The actual counts as of 1987 were 673 identified herbivore specimens and only 11 identified carnivore specimens (Jefferson 1987).

Carnivores account for only 2.4 percent of the total mammalian assemblage (Jefferson 1987). Taxa represented include the coyote (Canis latrans), dire wolf (Canis dirus), mountain lion (Felis [Puma] sp.), and scimitar cat (Homotheregium sp.). Omnivorous feeders include the black bear (Ursus sp.) and the short-faced bear (Arctodus sp.).

Herbivores account for 97.6 percent of all the mammal fossils recovered. They include ground sloths, horses, mammoths, camels, antelopes, bison, sheep, and small mammals (Jefferson 1987).
Three taxa of ground sloths are present: a small ground sloth (*Nothrotheriops* sp. cf. *N. shastense*), a medium-sized ground sloth (*Magalonyx* sp.), and a large ground sloth (*Glossotherium* sp.) (Jefferson 1987). Jefferson has suggested that these animals were mixed feeders that browsed on leaves, twigs, and bark, and also grazed on grasses.

Extinct large and small horses are well represented. The extinct small horse has been identified as *Equus* sp. cf. *E. conversidens*; the larger horse was simply classified as *Equus* sp. (large). Jefferson has suggested that the larger horse may have browsed as much as it grazed. Its presence in the fossil record suggests that the valley floor may have been primarily patchy grasslands (Jefferson 1985b, 1987).

Fragmentary fossils of mammoths (*Mammuthus* sp.) have been recovered. Three late Pleistocene species (*Mammuthus columbi*, *Mammuthus imperator*, or *Mammuthus jeffersoni*) appear to be present. However, most of the elephant fossils are fragmentary and not specifically identifiable (Jefferson 1987). Mammoths are thought to have ranged widely in small herds browsing on leaves and twigs and/or grazing on grasses.

Two extinct camels and two extinct llamas have been identified in the fossil assemblage. The two camel species have been identified as *Camelops* sp. cf. *C. hesternus* and *Camelops* aff. *C. minidokae*. Jefferson has suggested that these animals were probably browsers which ranged in small
The two extinct llama species were identified as *Hemiauchenia macrocephala* and *Lamini sp. nov.* These animals were probably opportunistic browsers and grazers which took advantage of seasonally available plants (Jefferson 1987).

One fossil specimen of pronghorn (*Antilocarpa sp.*) has been identified. Jefferson (1987) suggested that it may represent the extant taxon *Antilocarpa americana*. Modern pronghorn are primarily browsers which prefer sagebrush.

Bison remains are rare in the Camp Cady local fauna. They have been identified as *Bison bison antiquus*. It is thought that these bison were primarily grazers, and only occasionally, browsers.

The mountain sheep (*Ovis canadensis*) is well represented in the herbivore assemblage. Living representatives of this species are opportunistic browsers and grazers that live in family groups in rugged terrain where there is usually little vegetation.
CHAPTER XII. THE GEOARCHAEOLOGICAL POTENTIAL OF THE BASSETT POINT LOCALITY: DISCUSSION AND CONCLUSIONS

The Manix Formation is a complex sequence of middle and late Pleistocene lacustrine, fluvial, and alluvial deposits in the central Manix basin (Lower Mojave Valley) of San Bernardino County, California. This formation has been exposed by the Mojave River in the vicinity a large incised meander near Camp Cady. A reconnaissance survey of the upper members of the Manix Formation has been undertaken at the type locality, a place informally known as Bassett Point. This was done to assess the area's geoarchaeological potential to yield data relevant to the hypothesis that the New World was occupied prior to 12,000 B.P. Field efforts included the preparation of a fine-scale stratigraphic profile for the upper 15 m (49 ft) of the Manix Formation. The strata were also carefully examined for artifactual evidence. One unifacially flaked specimen of chalcedony was discovered in situ of 13.7 m (45 ft) below the top of the stratigraphic column.

Numerous studies of the Manix Formation have been conducted since it was first described in 1914 by John Buwalda. A major objective of this thesis has been to integrate the earlier studies into geological, hydrological, and paleontological contexts which could serve to provide a
framework for the paleoenvironmental reconstruction of the Manix basin during the late Quaternary.

The concept of geoarchaeological potential has been explored in this thesis. Geoarchaeological potential may be defined as the potential of a depositional microenvironment to yield unambiguous archaeological and paleoenvironmental data. It is suggested that this concept may be useful in structuring search strategies for potential archaeological evidence of early New World populations.

Open-air early man sites will not be easy to find in the New World. Archaeological assemblages will probably have low archaeological visibility due to small initial populations, discontinuous settlement, and low settlement densities. Artifacts which pre-date the Clovis culture will probably be simple and generalized. Technologies based on the modification of bone, antler, ivory, and wood may have been important in early subsistence strategies. Because most subsistence functions can be accomplished with simple modified, or unmodified flakes (Toth 1985), early lithic assemblages may have very low archaeological visibility. Probably the best field evidence of early human populations will be hearths or human fossil evidence.

New World lithic assemblages older than 12,000 B.P. may be technologically similar to middle and upper Paleolithic assemblages in east Asia. While upper Paleolithic Asian assemblages exhibit significant diversity, middle
Paleolithic assemblages are typically small and exhibit limited diversity. Artifact types include simple choppers, chopping tools, trihedral picks, rough bifaces, and poorly standardized retouched flakes. Asian middle Paleolithic assemblages were apparently used more for processing than for procurement; early American assemblages may be similar.

Effective site search strategies must consider the carrying capacities of Pleistocene environments especially with regard to paleobiomass size, predictability, and reliability (Butzer 1987, 1988, 1991). Pleistocene environments which had some degree of topographic constraint, low seasonality, high predictability of floral and faunal resources, and minimal environmental hazards were probably attractive to early populations (Butzer 1988, 1991).

The archeological visibility of early New World populations will probably be a function of paleohabitat persistence. In this regard, it will be important to target Pleistocene environments which afforded persistent potable water, and food resources, fuel, shelter, and strategic viewpoints. Pluvial lake basins would have been particularly attractive in this regard.

Lakeshore.marsh environments have significant potential for containing locatable evidence of early human populations in the Western Hemisphere. Marsh resources, including edible plants, fish, water birds, bird eggs, shellfish, insects, and small animals could be readily exploited with
relatively simple technologies. Large mammals, drawn to lakes for water, could be driven into boggy areas to be mired down and killed.

In the southwestern portion of North America it is known that at least 110 of the closed basins in the Great Basin held lakes during Pleistocene times (Snyder et al. 1964). Probably not all of these lakes were equally attractive to early human populations. In arid and semi-arid environments, lakes fed by allogenic (exotic) streams carrying water from high mountains would have offered the best potentials for persistent fresh water conditions, especially if they had effective hydrologic export of salts through groundwater movement and/or leaching (Smith 1985). Freshwater lakes with persistent marsh conditions would have afforded relatively stable and reliable habitats which remained attractive long enough so that an archaeologically visible record might be generated.

With these factors in mind, it is possible to cut the list of candidate basins in the Great Basin in half by dropping from consideration those in which water potability was not maintained by overflow. It is possible to narrow the search even further by considering the accessibility of Pleistocene sedimentary records. In most of the basins, alluviation which occurred during the climatic shift from the late Pleistocene to the Holocene has effectively covered the early sediments. The Manix basin is one of fewer than six
basins where significant exposures of middle and late Pleistocene lacustrine deposits are readily available for study.

The geology, geomorphology, stratigraphy, paleontology, and paleoecology of the Manix basin suggest it has significant geoarchaeological research potential. The Manix Formation sediments are of an appropriate age for research pertaining to early New World archaeology. The beds have yielded a rich vertebrate and invertebrate Rancholabreani fauna, elements of which are datable by radiocarbon and uranium-series techniques. A layer of tephra provides a laterally extensive time marker. Paleoenvironmental studies suggest that lake edge habitats would have been attractive to early human populations.

Stratigraphic studies suggest that climatic changes, moderated by basin run-off characteristics, caused lake water levels to change through time. Lake levels rose during times of increased precipitation and subdued evaporation. They fell during periods of decreased precipitation and increased evaporation. As a consequence, areas suitable for human subsistence and settlement would have expanded during cool, moist periods, and contracted during the warm, dry periods.

The geomorphic processes attendant to cyclic lake fluctuation could have produced highly complex, deeply-stratified sites. The search for, and analysis of, an archaeological record in such a context can only proceed
after a thorough understanding of lakeshore geomorphology and stratigraphy (Larsen 1985). A rise in lake level, for example, would also have raised the local base level for tributary streams. This would have caused aggradation along floodplains near stream mouths. Higher lake levels would have also raised local groundwater tables and facilitated the establishment of marsh habitats in low-lying lake edge margins.

During periods of falling lake levels, tributary streams would have responded to lowered base levels and would have eroded previously deposited deltaic deposits. Lake-edge marshes would have shifted downslope as they desiccated because of falling groundwater levels. During subsequent periods of rising lake levels, streams would have aggraded and marsh habitats would have been reestablished. Human subsistence and settlement patterns associated with marsh edges and stream mouths would have shifted from place to place as a function of the geomorphic processes which accompanied climatically-driven lake-level fluctuations (Larsen 1985). Cultural evidence which may have been deposited in such contexts could be reworked and buried in subsequent cycles.

Stratigraphic studies indicate that the landscape surrounding Lake Manix was repeatedly exposed and submerged by lacustrine recessions and transgressions. During transgressions, sediments would have been eroded from exposed
shorelines, transported by longshore currents, and deposited in sheltered areas. If cultural evidence was present near such shorelines it may have been similarly redepotised. Lacustrine regressions would have made available new surfaces for habitation. Such processes probably also modified the geological and archaeological stratigraphy of near-shore sediments. As the lake receded, former lake bottom sediments would have been newly exposed to wave erosion. Such wave action and the deposition of near and foreshore sediments could have reworked and reburied cultural evidence which may have been present on former lake edge surfaces.

It may be concluded from this study that the Manix basin has significant geoarchaeological potential to yield unambiguous data which may be used to test the hypothesis that the Western Hemisphere was populated prior to 12,000 B.P.
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