UNIVERSITY OF CALIFORNIA
RIVERSIDE

LATE HOLOCENE HUNTER-GATHERERS AND VOLCANISM IN THE LONG VALLEY-MONO BASIN REGION: PREHISTORIC CULTURE CHANGE IN THE EASTERN SIERRA NEVADA

A Dissertation submitted in partial satisfaction
of the requirements for the degree of

Doctor of Philosophy

in

Anthropology

by

Matthew Clyde Hall

July, 1983

Dissertation Committee:

Professor R. Ervin Taylor, Chairperson

Professor Eugene N. Anderson

Professor Sylvia M. Broadbent

Professor Philip J. Wilke

research in the future.

ABSTRACT OF THE DISSERTATION

Late Holocene Hunter-Gatherers and Volcanism in the Long Valley-Mono Basin Region: Prehistoric Culture Change in the Eastern Sierra Nevada

by

Matthew Clyde Hall

Doctor of Philosophy, Graduate Program in Anthropology
University of California, Riverside, July 1983
Professor R. Ervin Taylor, Chairperson

Prehistoric culture-environment relationships are a major interest of archaeologists in the Great Basin and throughout western North America. Previous studies have emphasized regional climatic shifts as a principal, if not the causal, variable underlying prehistoric culture change. As research progresses, however, the diachronic complexity of human adaptations and natural phenomena in addition to climate becomes more and more evident. Geologic findings indicate numerous Holocene volcanic eruptions in the Long Valley-Mono Basin region of the eastern Sierra Nevada. To date, there has been little consideration of the impact on prehistoric cultures of volcanism in the eastern Sierra. Two primary objectives of this study are to simply document and integrate temporal patterns suggestive of Holocene "change" as measured separately with archaeological, volcanic, and climatic data. Another primary objective is to demonstrate the utility of obsidian hydration dating in the eastern Sierra.

Obsidian hydration dating of prehistoric sites in the general vicinity of the Long Valley-Mono Basin volcanoes suggest that obsidian stoneworking, and perhaps land-use activities on the whole, increased substantially in the region after ca. 3500 radiocarbon years b.p., declined abruptly ca. 1750-1250 b.p., and continued thereafter on a much reduced, intermittent basis. Relatively frequent or intense stoneworking after ca. 3500 b.p. appears to coincide with (1) an apparent period of minimal volcanic activity in the eastern Sierra; (2) a predominantly cool, moist climatic regime that may correlate with an overall increase in cultural activity in the Sierra Nevada, and in the western and southwestern Great Basin; and (3) the growth of an extensive trans-Sierra obsidian exchange system during the Middle Horizon in central California. The decline in stoneworking ca. 1750-1250 b.p. appears to have begun at the outset of a late Holocene episode of multiple volcanic eruptions in the Long Valley-Mono Basin region. Between ca. 1900 and 500 b.p., more than fifteen volcanoes erupted in the region. It is suggested that recurrent late Holocene volcanism in the eastern Sierra may have significantly affected regional and inter-regional economic and demographic patterns among indigenous hunter-gatherer populations.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Table | Page

Chapter I

PREHISTORY IN THE EASTERN SIERRA

Holocene environmental change continues to be a major concern of prehistoric archaeologists in the Great Basin and throughout western North America. This stems in part from the fact that several other disciplines, such as geology, palynology, hydrology, dendroclimatology, and biogeography, pursue prehistoric research in areas where there is also an active archaeological interest. As a result, past environments and natural phenomena can be assessed for their cultural significance on a specific geographic basis. An interdisciplinary orientation in the analysis and evaluation of archaeological data reflects as well a common, but often unstated, assumption that environmental change does affect cultural behavior in one way or another. Though arguably deterministic, this assumption attempts no more than recognition of inherently systemic relationships between human societies and the environments they occupy. *A major premise of the research described herein is that cultural explanation on a diachronic basis requires comprehensive contextual data.* The problem in prehistoric archaeology is to integrate disparate findings from many fields and arrive at a balanced understanding of the roles of cultural and environmental processes in shaping human development. Questions of causality and culture change in prehistory cannot, after all, be resolved without benefit of the best possible accounting of the behavior of potentially critical variables over time regardless of whether or not their origins and significance are in the abstract purely "cultural" or "environmental." Thus, in the Great Basin, a historical emphasis on culture-environment studies will prevail until Holocene natural history has been reconstructed in sufficient detail to permit easy differentiation among phenomena according to their immediate and long-term consequences for human adaptive strategies.

Archaeological research in the Great Basin suggests that Holocene environmental change was in certain instances a crucial factor in local and perhaps regional economic and demographic trends among indigenous hunter-gatherers. Initial efforts to relate Great Basin archaeological records to Holocene environmental history were severely constrained by information about the latter that was restricted in time and space. Culture-environment reconstructions were necessarily quite generalized and poorly documented on a local level (Bryan and Gruhn 1964). There was also (and continues to be) a distinct preoccupation with regional climatic history as a principal, if not the causal, variable behind most culture change. As paleoenvironmental and archaeological data multiply, however, the complexity over time of human ecological patterns and natural processes and events in addition to climatic change becomes more and more evident. This has forced a reappraisal of traditional concepts about climatic history and cultural development, and a "retreat" from "less encompassing models and explanations" (Mehringer 1977:114). The theoretical goal in the present research is to examine the archaeological record in a particular region where (1) climatic and non-climatic environmental history is well-studied and locally specific; and where (2) a real opportunity may exist to a attempt a precise chronological analysis of cultural and natural change.

In the last decade or so, geologic research and natural events have

encouraged a growing awareness of the significance of volcanism in Holocene environmental history in the Long Valley-Mono Basin region of eastern California (Fig. 1). Situated on the eastern border of the Sierra Nevada physiographic province and the west-southwestern border of the Basin and Range physiographic province (Fenneman 1939), the Long Valley-Mono Basin region lies along the eastern base of the central Sierra Nevada Mountains. Long Valley consists mainly of a 17 x 32-km elliptical caldera created by subsidence following the cataclysmic ash flow eruption of 600 km^3 of Bishop Tuff approximately 700,000 (0.7 m.y.) years ago (Gilbert 1938; Dalrymple, Cox, and Doell 1965; Gilbert et al. 1968; Bailey, Dalrymple, and Lanphere 1976). Mono Basin is a similarly large depression in the eastern Sierra roughly 30-35 km north-northwest of Long Valley that appears to have a structural rather than volcanic origin (Gilbert et al. 1968; cf. Pakiser, Press, and Kane 1960; Pakiser, Kane, and Jackson 1964). Extending some 35-40 km from southwestern Long Valley to southern and western Mono Basin stretches a chain of late Quaternary, primarily composite, volcanoes featuring obsidian domes, extensive local tephra deposits and pyroclastic ash flows, cinder cones, and phreatic explosion pits. Three volcanic complexes comprise the chain: the Inyo Craters and Domes, Mono Craters, and the volcanoes and volcanic islands of western Mono Basin. All three complexes have been active in the last 10,000 years and to a large extent these volcanoes are Holocene geologic phenomena (Rinehart and Huber 1965; Huber and Rinehart 1967; Lajoie 1968; Gilbert et al. 1968; Chesterman 1971; Wood 1975, 1977a, 1977b, 1977c; Wood and Brooks 1979; Kilbourne, Chesterman, and Wood 1980; Kilbourne and Anderson 1981).

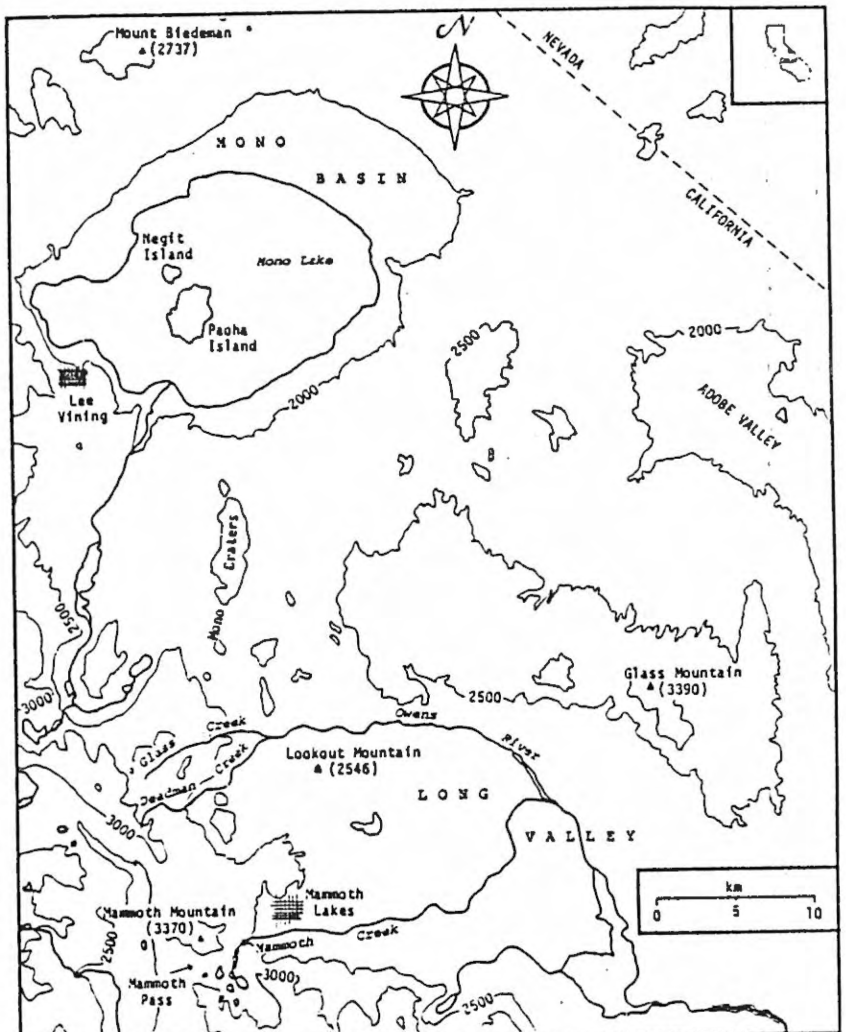


Fig. 1. The Long Valley-Mono Basin region, Mono County, California. Adapted from USGS 60 x 120' series maps: Mariposa, California-Nevada, and Walker Lake, Nevada-California. Contour interval 500 m, scale: 1:250,000.

Apart from the time-stratigraphic value of tephra deposits that can accompany volcanic events (Mehringer 1977:125-126), Holocene volcanism in the Long Valley-Mono Basin region is of interest for its potential role in influencing land-use strategies, demographic patterns, and trans-Sierra economic interaction. Although he did not elaborate on cultural implications of volcanism in the eastern Sierra, Mehringer (1977:126) was the first to call for an appreciation of the environmental significance of volcanic eruptions in Great Basin prehistory:

> The immediate and long-term effects of a single major eruption and ash fall could be locally far more important to man than regional climatic change.

This avenue of research has been pursued in the northern Great Basin and Pacific Northwest with reference to the violent eruption of Mount Mazama (Crater Lake) in south-central Oregon 7000 years ago (Grayson 1979; Blinman, Mehringer, and Sheppard 1979). To date, however, there has been little consideration of the impact of Holocene volcanism on prehistoric cultures in the eastern Sierra and adjacent regions of the Great Basin and central California. This can be partially attributed to a current lack of known archaeological deposits showing an immediate volcanic impact on people (e.g., tephra-sealed cultural horizons, victims). It is also an indication of how recent the appearance has been of time-sensitive Holocene volcanic data for the eastern Sierra. These data, as described in Chapter II, clearly suggest that volcanism in the Long Valley-Mono Basin region has been a recurrent phenomenon during the Holocene, and that multiple eruptions have occurred within relatively short time-spans. Thus, evaluation of the cultural significance of volcanism in the eastern Sierra must take into account the immediate, direct and indirect impacts on plants, animals, and human ecology, and the cumulative effects of recurrent volcanic activity on long-term patterns of cultural adaptation.

Notwithstanding the broad chronological and processual ramifications of Holocene volcanism for prehistoric research in the eastern Sierra, the general region has another characteristic that makes it especially attractive for diachronic culture-environment studies. A variety of paleoclimatic indicators have been investigated in the eastern Sierra and nearby regions of the southwestern Great Basin (e.g., neoglacial morainal deposits, bristlecone pine [*Pinus longaeva*] tree-ring variability and treeline fluctuations, pollen profiles, and lacustrine stratigraphic sequences). Consequently it is possible (see Chapter II) to construct a regional Holocene climatic history that can be contrasted spatially and chronologically with the Holocene record of a non-climatic, perhaps critical mechanism of environmental change such as volcanism. In this manner, specific environmental phenomena can be differentiated over time and space and then assessed for their cultural significance.

Two additional, but cultural features of the prehistoric eastern Sierra assure an expansion of archaeological effort in the region. First, the abundant use of obsidian in prehistoric tool production in the eastern Sierra offers an opportunity to use obsidian hydration dating to build a regional cultural chronology of great precision. Hydration analysis is most effective, it appears, when the sample data are controlled for source geochemistry and temperature provenience (see Chapter IV). Source determination has the added value of supplying information about the movement of obsidian from its point of acquisition to its location

in an archaeological deposit. Second, available archaeological evidence indicates quite clearly a tremendous volume of prehistoric cultural debris in the eastern Sierra and surrounding areas of the southwestern Great Basin. Thousands of prehistoric sites have already been recorded and thousands more await inventory within large tracts of unsurveyed lands. Obsidian, it appears, was only one of several prehistoric resources exploited on a continuous basis, but at apparently varying intensities since humans first settled the eastern Sierra. The problem is not finding the archaeological materials to resolve research issues, it is successfully manipulating ever more abundant and exact information in order to formulate regional research strategies that efficiently incorporate these data, minimize excessive duplication of effort, and take full advantage of the chronological potential to conduct "diachronic anthropology" (Plog 1973) on a cost-effective basis.

PRIMARY RESEARCH OBJECTIVES

A cursory appraisal of the archaeological, volcanic, and climatic records for the Holocene in the eastern Sierra creates the distinct impression of a complex regional prehistory punctuated by sometimes dramatic cultural and environmental changes. Chronological ordering of these records would seem, therefore, to be a necessary first step if processes of prehistoric culture change and its causal relationships are to be delineated and explained. Thus, to establish a time-space framework of prehistoric cultures in the eastern Sierra, two primary objectives of this research are to simply document and integrate temporal patterns suggestive of Holocene "change" as measured separately with archaeological, volcanic, and climatic data. Essentially inductive undertakings, these objectives derive from the question of whether or not volcanic eruptions in the eastern Sierra might have more directly affected regional human prehistory than did apparent shifts in climatic patterns (cf. Mehringer 1977:126). (Because of the uncertainties in calibrating secular variations in radiocarbon production over time, and in the methods of using a given calibration scheme [R.E. Taylor, personal communication 1983], ^{14}C dates presented in the discussion below are given in conventional radiocarbon years b.p. [Stuiver and Polach 1977]. Chronological determinations that represent calendar years are described in terms of years B.P. [cf. Curry 1969:3].)

A third primary objective of this research is to consider some possible implications of recurrent Holocene volcanism in the eastern Sierra for prehistoric economic exchange systems, demographic patterns, and land-use strategies. Of concern here are current interpretations about prehistoric culture change in the eastern Sierra and adjacent regions of the Great Basin and central California and its association with postulated demographic, economic, technological, or climatic developments (Bettinger 1977a, 1979a, 1982a; Ericson 1977, 1982; Singer and Ericson 1977; Moratto, King, and Woolfenden 1978; McGuire and Garfinkel 1980; Bettinger and Baumhoff 1982).

The final primary objective of this research is to demonstrate the utility of source-specific obsidian hydration dating in the eastern Sierra as a method by which to empirically measure the frequency of a particular material activity — obsidian tool-use — over time on a site-specific, local, and regional basis. Presumably, variations in a

given frequency curve of hydration sample dates (see Chapter V) can be used to gain an idea of relative occupational intensities. There are, of course, some analytical considerations to take into account, namely sample size (total number of hydration readings [dates]), sample composition (specimen types), and stratigraphic provenience. For example, occupational patterns that were not characterized by extensive obsidian tool production may be difficult to temporally evaluate with hydration samples composed of manufacturing debitage. Nonetheless, this should not be a major problem since there are certain tool categories (e.g., projectile points) that were probably relatively standard features of most of the tool-kits of prehistoric hunter-gatherers in the eastern Sierra.

SECONDARY RESEARCH OBJECTIVES

Secondary objectives of the research and analysis presented in the following chapters are to describe and evaluate the results of an archaeological excavation at CA-MNO-561 in southwestern Long Valley. The study was conducted during the summer of 1982 by the Archaeological Research Unit (ARU), Department of Anthropology, University of California, Riverside, under the field direction of this author. CA-MNO-561 is located on upper Mammoth Creek approximately 6 km east-northeast and 1000 m below the summit (3370 m) of Mammoth Mountain, a huge late Pleistocene rhyodacite volcano in the east-central Sierra Nevada. In gross figures, the fieldwork involved the excavation and screening of 35.7 m^3 of earth, rock, and cultural fill, and the collection of over 150,000 prehistoric items. Limited test excavations (ca. 3.5 m^3) had previously been undertaken at the site by the United States Forest Service (USFS). These investigations minimally reveal that CA-MNO-561 was occupied at various times within the last 4500 radiocarbon years. Assuming an accurate chronological analysis, CA-MNO-561 may therefore offer an occupational record that can be integrated with dated volcanic and climatic events in the immediate and general vicinity.

In light of the findings at CA-MNO-561, two other secondary objectives of this research are to (1) assess the archaeological value of proposed hydration rates for obsidian sources in the eastern Sierra (e.g., Michels 1965, 1982; Friedman 1968; Ericson 1975, 1977; Wood 1977b; Wood and Brooks 1979; Garfinkel 1980a; Basgall 1982); and (2) examine evidence suggesting that intra-assemblage variation in exploited obsidian sources could reflect residential movements, tool-specific or group-specific source preferences, or, over time, changes in conditions affecting the use of and access to diferent sources (Jack 1976:195; Bettinger 1981:48-55, 1982b).

Chapter II

RECENT CLIMATES AND VOLCANISM

The Sierra Nevada are an enormous westward-tilted fault-block with a sheer eastern face. Frontal faults at its eastern base structurally depress a narrow zone that separates the Sierran block from eastward-tilted fault-block ranges (such as the White Mountains) in the adjacent Basin and Range province (Alfors 1980:1). Regional downwarping and faulting in the last three to four million years have produced great topographic relief and reflect the latest pulse of periodic Cenozoic and late Mesozoic orogeny (Wahrhaftig and Birman 1965:330; Gilbert et al. 1968:310). Pleistocene crustal deformation uplifted the eastern wall of the Sierra as much as 1220 m in places (Christensen 1966) and created a modern landscape of towering mountains flanked be deep valleys filled with thick accumulations of Quaternary sediments. Coupled with massive Pleistocene glaciation and volcanism, these forces shaped a magnificently rugged land surface that continues to undergo rapid modification by tectonism, volcanism, and neoglacial surges. The results of recent research in several disciplines suggest that Holocene climatic and geologic change may have at times affected the course of prehistoric cultural development in the eastern Sierra.

HOLOCENE CLIMATES

Modern climate in the eastern Sierra is markedly seasonal; warm, mostly dry summers precede cool, usually wet winters at the higher elevations. Spring temperatures are relatively mild, and brief winter-like storms mar an otherwise warm early fall at lower elevations in the region.

From October to May, orographic lifting of easterly migrating cyclonic storms originating over the Pacific causes heavy snowfall along the crest of the Sierra (Šercelj and Adam 1975:737). This accounts for the bulk of annual precipitation in the region and imposes a pronounced rainshadow effect over a wide area east of the Sierra. These storms are deflected northwards during the summer by a subtropical high pressure system that invades the general region (LaMarche 1974:1046). Unstable masses of moist subtropical air can generate localized, but often intense, summer convectional downpours.

Climatic records for the years 1931-1960 in the eastern Sierra (Curry 1969:Pl. 1) describe, respectively, mean maximum, annual, and minimum temperatures in upland areas (above 2500 m) of ca. 10°, 3°, and -4°C, and about 60 cm in annual precipitation. Correspondingly higher mean temperatures (ca. 24°, 13°, and 3°C) and reduced annual precipitation (15 cm) were recorded for the same years at a lower elevation near the eastern base of the mountains (Curry 1969:Pl. 1). Although these values provide some idea of long-term Holocene climatic parameters and their extremes, it should be noted that they apply to a period of time (A.D. 1930-1960) of what appears to have been unusually mild climate (warm and dry) in North America (Bryson and Hare 1974). Climate today in the Long Valley-Mono Basin region is substantially different from what it must have been during periods of major Pleistocene glaciation when Lake Russell overflowed Mono Basin into the Owens drainage system and extensive lakes formed in many now-dry or near-dry interior basins of western North America (Morrison 1965:Fig. 1). Soon after its creation the Long Valley caldera was filled with a deep body of water — Pleistocene Long Valley Lake (Mayo 1934) — that at its high stand may have reached an elevation slightly over 100 m below that of the town of Mammoth Lakes (Bailey, Dalrymple, and Lanphere 1976:736). Despite the evident contrast in moisture levels between modern and glacial climates, most researchers discount the climatic significance of a Pleistocene-Holocene temporal boundary and consider climatic patterns over the last 10,000 years or so as interglacial and not truly postglacial (LaMarche 1978:335). Moreover, available evidence may suggest that the northern hemisphere is still in the midst of the latest, perhaps coldest episode of periodic Holocene neoglaciation (Denton and Karlén 1973:196-198).

The study of Holocene climates and their fluctuations has led to an abundance of labels for (1) a widely recognized middle Holocene trend toward warm, dry climate with few, brief, cool/moist reversals; and (2) more recent intervals of less mild climatic conditions (Cooper 1958; Porter and Denton 1967; Wright 1976). Archaeologists have been especially fond of the tripartite Holocene (Neothermal) sequence reconstructed by Antevs (1948, 1953; cf. Aschmann 1958). The sequence consists of the Anathermal, ca. 10,000-7500 B.P., characterized by relatively cool, moist climate; the Altithermal, ca. 7500-4000 B.P., a period of maximum Holocene aridity and temperature; and the Medithermal, a period of essentially modern climate over the last 4000 years. Other researchers, in many related fields, find the Antevs system unworkable for various reasons and use other models, in particular: Hypsithermal and Neoglaciation (Deevey and Flint 1957; Porter and Denton 1967; Wright 1976). The Hypsithermal, ca. 10,000-3000 B.P., is perceived as a period of maximum long-term glacial shrinkage and minimal short-term glacier expansions. As defined, Neoglaciation encompasses the last three millennia and has been a period of intermittent glacial advance.

Varying levels in solar activity may be a principal factor underlying Holocene climatic change (Denton and Karlén 1973:198). Correlations between known short-term variations in natural radiocarbon activity and climatic change over the last thousand years (Suess 1968) support the view that significant intervals of high radiocarbon production accompanied alpine glacial surges during the Holocene (Denton and Karlén 1973:200). Presumably, periods of low solar activity (hence less radiant energy) bring about cooler global temperatures and a weakening of the earth's magnetic field that, in turn, increases radiocarbon production by permitting more frequent penetration of the upper atmosphere by cosmic-rays; a process reversed during periods of relatively high solar activity and low radiocarbon production.

HOLOCENE CLIMATIC HISTORY

Pollen cores from an alpine meadow just south of Lake Tahoe indicate a cool but dry late Pleistocene in the central Sierra (Adam 1967). Soon thereafter, in contrast, the initial post-Pleistocene climate seems to have been somewhat cooler and much more moist. The Hilgard glacial advance has an estimated age of ca. 10,500-9000 b.p. (Curry 1971:Table 1), and corresponds to the earliest of three periods of significant Holocene glacier growth in the Sierra recognized by Birman (1964). Recess Peak and Matthes are the more recent neoglacial episodes that Birman (1964) identified. Rahm (1964) described a similar morainal sequence in the Sierra west of Bishop (Wonder Lakes, Basin Mountain, Gilbert advances).

Paleoclimatic data from other regions in the Fare West also indicate a predominantly cool, moist climate during the early Holocene, although short-term intervals of more arid, presumably warmer conditions probably occurred (e.g., Mehringer 1967; Benedict 1968; Ore and Warren 1971; Butler 1972; Harper and Alder 1972; Mack et al. 1978). Black Lake in Adobe Valley (Fig. 1) may have reached its post-Pleistocene high stand ca. 9000-8500 b.p., and then receded to a nearly dry level that underwent little change for the next several thousand years (Batchelder 1970a, 1970b). By 8000 b.p., a macroclimatic mid-Holocene warming trend (i.e., Hypsithermal or Altithermal) was apparently affecting climatic patterns and, by 7000 b.p., most of the once-large interior basin lakes had disappeared. Conditions may have been the most xeric at Black Lake ca. 7000-6000 b.p. (Batchelder 1970a), and consistently high summer temperatures are indicated for the period ca. 7350-3950 B.P. by an advance of the upper bristlecone pine (*Pinus longaeva*) treeline in the White Mountains (LaMarche 1973:655; LaMarche and Mooney 1967).

Despite dating discrepancies, a brief interval of increased effective moisture seems to have occurred ca. 6000 B.P. Mehringer (1977:149) noted the widespread evidence of such an increase ca. 6500-5500 b.p. in the Great Basin, and there was a slight rise in the level of Black Lake ca. 6000-5000 b.p. (Batchelder 1970a). Of the four post-Hilgard neoglacial advances in the Sierra identified by Curry (1969:Fig. 10), the earliest (pre-Recess Peak) was dated ca. 7000-6000 B.P. using morinal lichenometric dates based on *Rhizocarpon* and *Acarospora*. This temporal assignment, however, appears to be slightly too old given alternate paleoclimatic data and diverse continental evidence of a neoglacial episode ca. 5800-4900 B.P. (Denton and Karlén 1973:159). Neoglaciation ca. 6000 B.P. does not appear to have been as extensive as later glacial surges. Following this brief period of relatively cool, moist climate, the dominant mild macroclimatic system (cf. Johnson 1977) seems to have persisted until about 3400 B.P. Bristlecone pine tree-ring data reflect relative warmth at the upper treeline in the White Mountains ca. 5420-3250 B.P. (LaMarche 1974:Fig. 5), and advanced treeline elevations indicate significantly high summer temperatures ca. 4950-3950 B.P. (LaMarche 1973:655). At Little Lake, just south of Owens Valley, a saltgrass meadow and marsh (no lake) appears to have developed ca. 5000-3000 b.p. (Mehringer and Sheppard 1978:153). Short-term intervals of less mild climate probably occurred between ca. 5300 and 3400 B.P., but these are difficult to document because the overall magnitudes involved were probably not great and, in the case of neoglacial records, subsequent glacial activity may have obliterated depositional sequences (cf. Denton and Karlén 1973:196). A short interval of somewhat cooler, more moist conditions may have prevailed in the White Mountains and locally ca. 4500-4100 B.P. (LaMarche 1978:Fig. 4). Black Lake was deeper than at present about 4500 radiocarbon years ago (Batchelder 1970a).

A broad spectrum of paleoclimatic indicators shows a pronounced increase in effective moisture levels after ca. 3400 B.P. The onset of cooler summer temperatures ca. 3450-2950 B.P. forced a retreat of the upper bristlecone pine treeline in the White Mountains (LaMarche 1973: 655) and marks the beginning of a major period of Holocene neoglaciation (Denton and Karlén 1973:159). Relatively more moist conditions are apparent ca. 3600-2100 b.p. at Black Lake (Batchelder 1970a) and in the

central Sierra after ca. 2900 b.p. (Adam 1967). A shallow lake apparently took the place of the saltgrass meadow and marsh at Little Lake ca. 3000 b.p. (Mehringer and Sheppard 1978:153). Although the geochronology is not precise, it is apparent that shallow lakes formed not too long before or after 3000 B.P. in interior basins such as Searles Valley (Smith 1967, 1968) and Death Valley (Hunt and Mabey 1966). Russell (1889:326) was among the first to correlate neoglacial surges with the rebirth of "desert" basin lakes. Abundant evidence of a Hypsithermal/Neoglaciation or Altithermal/Neothermal transition can also be found in many other nearby regions (e.g., Sears and Roosma 1961; Bright 1966; Davis and Elston 1972; Harper and Alder 1972; Kautz and Thomas 1972; Madsen 1972; Elston 1976).

Neoglacial activity culminated in North America ca. 2800-2600 B.P. (Porter and Denton 1967:202; Denton and Karlén 1973:197). In the Sierra, the Recess Peak advance was dated by Curry (1969:Fig. 10) ca. 2600-2000 B.P., again on the basis of lichenometry. These dates slightly postdate the peak in neoglacial expansion elsewhere and suggest, perhaps, the use of lichen growth curves that are not yet precisely calculated (Šercelj and Adam 1975:744). However, the lichenometric dates agree well with (1) bristlecone pine data indicating cool, moist climate ca. 2700-2200 B.P. in the White Mountains (LaMarche 1978:Fig. 4); (2) a marked pollen change toward less xeric conditions ca. 2430 b.p. in the central Sierra (Adam 1967; Šercelj and Adam 1975); and (3) the emplacement of wet meadow deposits ca. 2500 B.P. in the upper San Joaquin drainage areas west of Mammoth Lakes (Wood 1975). Aside from intrinsic dating errors, the differences between regional and hemispheric dating of neoglacial maxima are probably a function of the time-transgressive nature of macroclimatic change (Wright 1976). In this regard, it may be notable that neoglacial deposits stratigraphically comparable to Recess Peak units in the Sierra appear to date slightly earlier at higher latitude alpine sites in the Rocky Mountains (Benedict 1973; Mehringer 1977).

Climatic forces behind neoglacial activity apparently began to wane after ca. 2200 B.P., Black Lake may have been nearly dry after 2100 b.p. (Batchelder 1970a) and a saltgrass meadow and marsh seems to have returned to Little Lake (Mehringer and Sheppard 1978). Cool-moist conditions in the White Mountains gave way to initially warm-moist then warm-dry climate that advanced the upper bristlecone pine treeline and retarded annual tree-ring growth (LaMarche 1974, 1978). Predominant summer cooling after 1700 B.P. (LaMarche 1974:Fig. 5, 1978:Fig. 4) preceded relatively intense cold and high annual snowfall ca. 1100-950 B.P. that may have accompanied an unnamed neoglacial advance in the Sierra (Curry 1969:Fig. 10) and elsewhere (Porter and Denton 1967:200; Denton and Karlén 1973:196). The elevation of Black Lake may have risen slightly around this time (Batchelder 1970a), and a new series of wet meadow deposits was emplaced west of Mammoth Mountain in the upper San Joaquin drainage (Wood 1975).

Based on bristlecone pine data from the White Mountains, LaMarche (1974:1048) considered the period ca. 950-750 B.P. as the warmest in temperate latitudes in the last 1000 years and associated it with severe drought conditions. Abruptly thereafter, an extended cool period began with the apparent death of many trees and a sharp, 750 m retreat of the bristlecone treeline (LaMarche 1973:655, 1974:1046). An increase

in moisture apparently accompanied the cooling trend, producing cool, relatively moist conditions in the White Mountains that may have prevailed for about 500 years (LaMarche 1978:Fig. 4). Rapid treeline retreat coincided with a surge in neoglacial activity (Denton and Karlén 1973:196-198). In the Sierra, this is the Matthes glacial advance that Curry (1969:Fig. 10) dated ca. 650-190 B.P. The depositional record of Matthes glaciation is not as extensive as that for Recess Peak, and may reflect lower overall precipitation during the more recent advance despite unusual coolness (LaMarche 1973:656-657). Neoglacial maxima in North America were attained ca. 350-200 B.P. (Denton and Karlén 1973:196).

Dendroclimatic data on several species in the Far West indicate an extensive drought between 190 and 130 B.P. (Fritts and Gordon 1980:38). From A.D. 1760 to 1820 an estimated 87% of the annual precipitation totals from 52 locations within 965 km of the California-Nevada border were less than 50 cm, in contrast to the period A.D. 1901-1960 when only 28% of these totals were less than 50 cm (Fritts and Gordon 1980:38-39). Neoglacial activity in the Sierra resumed significantly after about A.D. 1850 or 1860 (Curry 1969:Fig. 10), though mild climate from 1930 to 1960 (Bryson and Hare 1974) has left but a few cirque glaciers (Wahrhaftig and Birman 1965:305).

In summary, then, a variety of paleoclimatic indicators from the eastern Sierra and elsewhere suggest: (1) a cool, dry late Pleistocene; (2) a relatively cool, moist early Holocene (Hilgard glacial advance) with probable short-term warm intervals (perhaps 10,500-8500 b.p.); (3) the onset of a mild mid-Holocene macroclimatic system (Hypsithermal/

Altithermal) ca. 8300-6000 b.p.; (4) a brief, cool-moist interval ca. 6000-5300 B.P.; (5) resumption of a generally warm, dry climatic regime ca. 5300-3400 B.P.; (6) a significant shift (Neoglaciation/Medithermal) toward cool, moist climate ca 3400-2200 B.P. (Recess Peak glacial advance); (7) warm-moist then warm-dry climatic conditions after 2200 B.P., with a cooling trend more-or-less dominant after 1700 B.P.; (8) a brief period of cool, moist climate ca. 1100-950 B.P. (unnamed glacial advance between Recess Peak and Matthes); (9) a possibly severe drought ca. 950-750 B.P.; (10) unusually cold temperatures after 750 B.P., although mean annual precipitation may have been lower than during the Recess Peak advance; (11) another possibly severe drought ca. 200-130 B.P.; and (12) generally cool, relatively moist climatic patterns over the last century or so with a short period of mild climate ca. A.D. 1930-1960.

Paleoclimatic data also appear to show that during the Holocene short-term periods of relatively high year-to-year climatic variability correlate with periods of above-average mean annual precipitation while, conversely, long-term periods of low variability correlate with periods of average or below-average mean annual precipitation (Curry 1969:42). The cycle may be evident, for example, in a predominantly cool, moist climate in recent centuries that has been interrupted by apparently severe, brief droughts; and in earlier, long-term periods of climate (e.g., ca. 5300-3400 B.P.) when conditions were relatively arid and warm, but not necessarily drought-like, and there were few, minor reversals toward less mild climate. Further, neoglaciation peaks at ca. 5300, 2800, and 350-200 B.P. were identified by Denton and Karlén (1973:196-202)

who noted that each surge lasted 600-900 years and occurred about 2500 years after the previous neoglacial episode. Evidence exists to suggest that this generalized model of relatively long, warm, usually dry intervals and short, cold, usually moist intervals may also apply to early Holocene and late Pleistocene climatic patterns (Denton and Karlén 1973: 196, 202).

GEOLOGIC HISTORY

Much of the Far West was under the sea in late Precambrian and Paleozoic times and more than 3000 m of accumulated seafloor sediments are exposed as distinctive metamorphic strata in the nearly straight, fault-scarp western face of the White Mountains (Bateman 1965). In the eastern Sierra, folding, faulting, cataclasis, and regional metamorphism characterized several periods of Paleozoic and Mesozoic deformation (Nokleberg and Kistler 1980). Mesozoic deformation downwarped the general region into a complexly faulted synclinorium that was filled with contemporaneous sedimentary and, mostly, volcanic rocks (Alfors 1980:1). Late Mesozoic orogeny raised the Sierra well above sea level and intruded the synclinorium with enormous batholithic masses that form the modern basement of granodiorite, quartz monzonite, and granitic rocks (Wahrhaftig and Birman 1965:Fig. 4). Five principal intrusions or "intrusive epochs" took place between about 210 and 79 m.y. ago (Evernden and Kistler 1970).

The oldest Cenozoic rocks in the Long Valley-Mono Basin region are late Oligocene and Miocene (30-12 m.y.) andesites, dacites, rhyolites, and rhyolitic welded tuff (ignimbrite) units generally north and east of

Mono Basin (Dalrymple 1964a; Slemmons 1966; Gilbert et al. 1968; Silverman et al. 1972). Although these primarily Miocene volcanic rocks are located close to Mono Basin, the latter is an unrelated, late Tertiary-Quaternary structural depression while the former occur along the southern margin of an apparent major Miocene volcanic province north of Long Valley and east of Mono Basin (Gilbert et al. 1968:283). Tertiary volcanism continued during the Pliocene with the eruptions in this province of latite ignimbrites dated by the potassium-argon (K-Ar) method at ca. 12-7.5 m.y. (Gilbert et al. 1968:Fig. 5). Pliocene volcanism was relatively minimal in the Long Valley-Mono Basin region 7.5-4.0 m.y. ago. K-Ar dates suggest various basalt and andesite extrusions primarily northeast and east of Mono Basin ca. 6.2-4.2 m.y. ago (Gilbert et al. 1968:Table 1).

Widespread volcanism resumed in the late Pliocene and early Pleistocene and contributed to the formation of an extensive volcanic plateau. Lava flows comprising the plateau rest on a nonmodern surface of moderate relief (Sheridan 1971:9). Northeast of Mono Basin, basalt and andesite flows K-Ar dated at ca. 3.9-3.5 m.y. were followed by similar flows (3.5-2.3 m.y.) accompanied by latite flows and rhyolitic pumice deposits ca. 3.5-3.2 m.y. ago (Gilbert et al. 1968:Table 1). Slightly later, Plio-Pleistocene basalts and andesites were emplaced in the Long Valley area ca. 3.2-2.9 m.y. ago (Dalrymple 1963, 1964a; Bailey, Dalrymple, and Lanphere 1976). Quartz latite was erupted from Two Teats 12.5 km northwest of Mammoth Lakes ca. 3.0-2.7 m.y. ago (Dalrymple 1964a; Curry 1966). (Bailey, Dalrymple, and Lanphere [1976:739] refer to quartz latite as rhyodacite.)

An apparently more recent basalt extrusion on McGee Mountain above southeastern Long Valley, K-Ar dated at ca. 2.6 m.y. (Dalrymple 1963), underlies glacial till that Blackwelder (1931:902) assigned to the McGee (Nebraskan) stage of Sierra Nevada glaciation. At Deadman Pass between Long Valley and Mono Basin, glacial deposits are interbedded with the 3.0-2.7 m.y. quartz latite flows noted above. Though possibly correlative with McGee till, the Deadman Pass till may represent an earlier glaciation(s) not widely recognized in the Sierra (Curry 1966).

Remnant McGee moraines lie at elevations today that reflect well over 1000 m of displacement of the eastern Sierran escarpment by subsequent dip-slip faulting and downwarping during the Pleistocene (Wahrhaftig and Birman 1965:310). Pleistocene volcanism occurred throughout much of the Long Valley-Mono Basin region (Gilbert et al. 1968:Table 1). Glass Mountain, Glass Mountain Ridge, and Bald Mountain on the northern rim of Long Valley are large, composite rhyolite volcanoes built between ca. 1.9 and 0.9 m.y. ago (Gilbert et al. 1968:Table 1; Bailey, Dalrymple, and Lanphere 1976:Table 1). These rhyolites probably represent early leakage along an incipient caldera ring fracture from the magma chamber beneath precaldera Long Valley (Bailey, Dalrymple, and Lanphere 1976:730). Obsidian flows and deposits on Glass Mountain constitute the Mono Glass Mountain obsidian source identified by Ericson, Hagan, and Chesterman 1976:225, Fig. 12.1). A separate, more mafic magma source may have been tapped during an andesite extrusion K-Ar dated at ca. 0.94 m.y. in the Devils Postpile area southwest of Mammoth Lakes (Dalrymple 1964b).

The cataclysmic eruption of Bishop Tuff ca. 0.7 m.y. ago spread a voluminous sheet of rhyolite ash flows east and north out of Long Valley

(Sheridan 1971:Fig. 11; Bailey, Dalrymple, and Lanphere 1976:Fig. 1). Most of the tuff was deposited east and southeast of Long Valley as a thick ignimbrite that forms the well-eroded Volcanic Tablelands north of Owens Valley. Perhaps 40 km^3 flowed north into Mono Basin and southwestern Adobe Valley (Gilbert et al. 1968:297). Bishop Tuff at the south end of the Mono Craters is over 150 m thick (Putnam 1949), but it is buried east of the craters by a deep overburden of Holocene pyroclastic debris. A small lobe of ash flowed west into the Reds Meadow area where it is overlain by andesite K-Ar dated at ca. 0.63 m.y. (Huber and Rinehart 1967). Between here and Long Valley, Bishop Tuff is located at some depth considerably eroded (perhaps to nonexistence) and deeply buried by subsequent glacial deposits and the massive late Pleistocene rhyodacite extrusions that built Mammoth Mountain. Elsewhere, Bishop Tuff is underlain by glacial till attributed to the Sherwin (Kansan) glaciation in the Sierra ca. 0.75 m.y. ago (Blackwelder 1931:918; Sharp 1968:32). The withdrawal of 600 km^3 of magma from the Long Valley chamber led to a subsidence on the order of 2000-3000 m, and the resultant caldera quickly filled with runoff from Sierra (Sherwin) glaciers (Bailey, Dalrymple, and Lanphere 1976:730-735). Pleistocene Long Valley Lake probably rose to a low point on the caldera rim (ca. 2380 m near the present outlet) and then overflowed to the southeast rapidly eroding a channel through the upper 60 m of nonwelded or partly welded Bishop Tuff (Bailey, Dalrymple, and Lanphere 1976:736). When more densely welded tuff was exposed in the channel, the lake level stabilized for a time at 2320 m which is roughly the elevation of the highest beach terraces on the caldera wall. Regional warping and faulting gradually lowered the outlet

(and lake levels) until the lake was completely drained ca. 0.10 m.y. ago (Bailey, Dalrymple, and Lanphere 1976:736-741).

Intracaldera volcanism resumed within 40,000 years after subsidence. Silica-rich, unusually fluid rhyolite tuffs and flows were emplaced in the west-central area of the caldera ca. 0.71-0.63 m.y. ago (Bailey, Dalrymple, and Lanphere 1976:732). Lookout Mountain, 9 km north-northeast of Mammoth Lakes and an early postcaldera rhyolite extrusion, forms part of a complex intracaldera "resurgent dome" that at the close of resurgence ca. 0.60 m.y. ago had risen 500 m above the caldera floor (Smith and Bailey 1968:646; Bailey, Dalrymple, and Lanphere 1976:735). The dome was no doubt an island during early, high stands of Pleistocene Long Valley Lake and icebergs probably rafted glacial erratics to its windward sides (Bailey, Dalrymple, and Lanphere 1976:735). Obsidian flows and inclusions in the dome represent the Casa Diablo obsidian source identified by Ericson, Hagan, and Chesterman (1976:226, Fig. 12.1). Coarser, more porphyritic rhyolites were extruded from three vent groups in the "moat" surrounding the resurgent dome ca. 0.51-0.47, 0.35-0.28, and 0.11-0.10 m.y. ago (Doell, Dalrymple, and Cox 1966; Bailey, Dalrymple, and Lanphere 1976). These extrusions delimit the Long Valley ring fracture and may reflect periodic pressure build-ups in the magma chamber that are released every 200,000 years or so where major northwest-trending precaldera faults intersect the fracture (Bailey, Dalrymple, and Lanphere 1976:733, Fig. 2).

Curry (1971:6) identified a distinct Pleistocene glaciation in the Sierra, Casa Diablo, ca. 0.40 m.y. ago but serious discrepancies in K-Ar dates on andesite and basalt flows interbedded with the correlative till remain to be resolved (compare Curry 1971:49 with Bailey, Dalrymple, and Lanphere 1976:734). The lack of rhyodacite clasts in Casa Diablo till means that the latter (at type locality) was emplaced prior to the eruptions of rhyodacite from at least ten vents on Mammoth Mountain with K-Ar ages ranging from ca. 0.18 to 0.05 m.y. ago (Huber and Rinehart 1967:D15; Curry 1971:49; Bailey, Dalrymple, and Lanphere 1976:734). Lipshie (1976:78) suggested that Casa Diablo till may be a composite unit representing more than one glaciation — including perhaps the Mono Basin (Illinoian?) advance (Sharp and Birman 1963) dated ca. 0.13-0.08 m.y. ago (Curry 1971:Table 1; Birkeland, Crandell, and Richmond 1971: Chart B).

Three stages of significant Wisconsin glaciation are known in the Sierra Nevada. Blackwelder (1931:918) recognized and labeled the oldest (Tahoe) and most recent (Tioga) stages, and Sharp and Birman (1963; Birman 1964) defined an intervening glaciation (Tenaya). Crude age estimates for each are: Tahoe, ca. 75,000-50,000 B.P.; Tenaya, ca. 45,000-30,000 B.P.; and Tioga, ca. 22,000-18,000 B.P. (Curry 1971:Table 1; Birkeland, Crandell, and Richmond 1971:Charts A and B). Tenaya till was reported by Curry (1971:37-39) in the Mammoth Lakes embayment in Long Valley, but its presence here is questioned by Lipshie (1976:80). Tahoe and Tioga moraines emplaced within the Long Valley caldera along its Sierra rim have been cut at a number of localities by active Holocene frontal faults (e.g., Hilton Creek) (Alfors 1980:5).

Late Pleistocene volcanism in the Mammoth Lakes-Long Valley area includes the eruptions of Mammoth Mountain and other rhyodacites near Deadman Creek and at the base of Glass Mountain (Bailey, Dalrymple, and

Lanphere 1976:Fig. 3). Basaltic flows and cinder cones dated ca. 0.22-0.06 m.y. ago in the west moat of the Long Valley caldera comprise part of a chain of trachybasaltic, basaltic, and trachyandesitic volcanic rocks that extends from the Mammoth Pass area 45 km north to Mono Basin (Lajoie 1968; Bailey, Dalrymple, and Lanphere 1976). These more mafic lavas may represent a deeper, different magma source in the region (Bailey, Dalrymple, and Lanphere 1976:734). Black Point, on the western shore of Mono Lake, is a basaltic cinder cone in the mafic chain that erupted below the surface of Pleistocene Lake Russell ca. 13,300 b.p. (Lajoie 1968). Late Pleistocene eruptions in the Mono Craters chain between Long Valley and Mono Lake may signal the appearance of magma from a new chamber beneath a circular ring fracture in the June Lake area (Kistler 1966:E48; Bailey, Dalrymple, and Lanphere 1976:735; Wood 1977b: 25). Tufa deposits on the oldest (and only rhyodacite) dome in the Mono Craters indicate that eruptions began prior to the last high stand (Tioga?) of Lake Russell (Lajoie 1968; Wood 1977b, 1977c; Wood and Brooks 1979). Lajoie (1968) identified 17 tephra layers intercalated with late Wisconsin lacustrine sediments in Mono Basin and, based on two radiocarbon dates, extrapolated tephra ages between ca. 30,300 and 13,300 b.p. These tephras may derive from separate magma chambers feeding the Mono Craters and western Mono Basin (including Black Point) volcanoes (cf. Wood 1977b: 1; Kilbourne, Chesterman, and Wood 1980:10-12). Available evidence also suggests more extensive, recent pulses of rhyolitic eruptive activity in the Mono Craters occurring in late Pleistocene/early Holocene and late Holocene times (Wood 1977b:Table 1, Fig. 5; see below). Finally, Bailey (USGS 1976:153-154) has noted that relationships between the June Lake ring fracture and the Mono Craters could represent early stages in the evolution of a caldera much like the one in Long Valley.

HOLOCENE VOLCANISM

In the past several years geologic data have accumulated that rather conclusively document recurrent Holocene volcanism in the Long Valley-Mono Basin region. A sublacustral volcanic explosion at Mono Lake in A.D. 1890 (Kilbourne, Chesterman, and Wood 1980:16), the possible upwelling of a pocket of magma below southwestern Long Valley coincident with four major tectonic earthquakes in May, 1980 (Sherburne 1980; Savage and Clark 1982), and repeated recent episodes of intense microearthquake activity in Long Valley (Boylan 1982; Ryall and Ryall 1983) discourage any contemporary notion of dormant volcanism in the eastern Sierra. A brief discussion of paleoclimatic data earlier in this chapter is supplemented in this section by a cursory review of the broad physical and temporal parameters of Holocene volcanism in the eastern Sierra. Such a framework is crucial to a full appreciation of the environmental factors that may have affected occupational patterns in the Long Valley-Mono Basin region.

The three volcanic complexes of central interest, the Inyo Craters and Domes, Mono Craters, and the volcanic islands and volcanoes of western Mono Basin, collectively form a late Quaternary volcanic chain 35-40 km in length that extends south from Mono Lake to South Inyo Crater Lake, roughly 5 km northwest of Mammoth Lakes (Mayo, Conant, and Chelikowsky 1936; Putnam 1938; Rinehart and Huber 1965; Huber and Rinehart 1967; Lajoie 1968; Wood 1977a, 1977b; Kilbourne, Chesterman, and Wood

1980). The Inyo Craters and Domes are a relatively linear, but discontinuous 11-km-long north-south chain of five chemically and physically heterogeneous rhyolite to rhyodacite domes, several phreatic explosion craters, and locally abundant tephra deposits. Possible mixing of magmas from separate chambers below Long Valley and the Mono Craters may be reflected in the Inyo Domes by the presence of (1) sparsely porphyritic rhyolitic obsidian mineralogically and texturally similar to Mono Craters obsidian, and (2) coarsely porphyritic rhyodacite comparable to the rhyodacites associated with the Long Valley caldera (Jack and Carmichael 1968:22; Lajoie 1968:140; Bailey, Dalrymple, and Lanphere 1976:735). Three phreatic explosion craters are located on the south flank of Deer Mountain, a rhyolite dome ca. 8 km northwest of Mammoth Lakes that was extruded approximately 0.11-0.10 m.y. ago in the west caldera moat (Bailey, Dalrymple, and Lanphere 1976:735). Two other explosion craters occur in the Glass Creek area and there are probably several more buried by recent pyroclastic deposits around the Inyo Domes (Kilbourne, Chesterman, and Wood 1980:13). The Mono Craters comprise a virtually continuous, 17-km-long arcuate chain of overlapping, chemically homogeneous rhyolite domes, flows, and tephra deposits, and a single rhyodacite dome (Jack and Carmichael 1968; Lajoie 1968; Wood 1977b). Black Point and Negit and Paoha islands in Mono Lake are the western Mono Basin volcanoes that may be tapping a magma source separate from the chambers below Long Valley and the Mono Craters (Wood 1977b:1). Negit Island is made up of rhyodacite flows and a single cinder cone; Paoha Island is a more recent rhyolite dome partly overlain by a rhyodacite flow and cinder cones (Kilbourne, Chesterman, and Wood 1980:10-12).

As described by Kilbourne, Chesterman, and Wood (1980:13-14), there are several types of eruptions associated with the volcanoes in the Long Valley-Mono Basin region. In terms of magnitude, magma releases on the order of 0.01 km^3, 0.10 km^3, and 1.00 km^3 are considered, respectively, minor, moderate, and major eruptions (Crandell and Mullineaux 1978). Nonmagmatic phreatic explosions excavate small craters and are caused by either a shallow pocket of magma that flashes groundwater to steam (Bailey, Dalrymple, and Lanphere 1976:735) or by tectonic quakes that release the pressure of confined, superheated groundwater (Kilbourne, Chesterman, and Wood 1980:13). Phreatic explosions are sometimes followed by a second type of eruption involving localized tephra deposits around the vent of gray and white pumice, and fragments of basement rocks (Kilbourne, Chesterman, and Wood 1980:13). A third, massive type of eruption (Plinian) characteristic of eastern Sierra volcanoes can produce extensive local ash flows and mantle the area within several kilometers of a vent with thick deposits of white pumice lapilli. Depending upon wind direction, lobes of pumice lapilli and ash from such an eruption can generate volcanic fallout over 100 km from the vent (Kilbourne, Chesterman, and Wood 1980:13). Extrusion of a steep-sided dome above the vent may mark the close of an eruptive phase, but domes remain subject to later phreatic or magmatic eruptions or collapse as block and ash avalanches (Smith 1973:2686; Kilbourne, Chesterman, and Wood 1980:14).

Chronological data examined for this research and briefly reviewed below suggest eruptive Holocene volcanic episodes ca. 1100-500 b.p. in western Long Valley; prior to ca. 3300 b.p., and ca. 1900-1500 and 1200-600 b.p. along the Mono Craters chain; and ca. 680-100 b.p. in western

Mono Basin.. It must be emphasized that these are at best gross, quite tentative temporal divisions of complex, sometimes inconsistent, chronological data. As volcanic research progresses in the eastern Sierra, however, the quality and quantity of such data will undoubtedly improve and increase. Available radiocarbon age determinations that relate to Holocene tephra stratigraphy in the region are described below and displayed in Fig. 2.

To begin with, a ^{14}C date of 550 ± 150 b.p. is reported for a phreatic explosion 6.7 km west of Mammoth Lakes on the north side of Mammoth Mountain (Koeppen and Rubin in Kilbourne, Chesterman, and Wood 1980:Table 2). This may possibly be the southernmost expression of recent eruptive activity in the Inyo Dome and Crater chain (Kilbourne, Chesterman, and Wood 1980:19) and could also indicate the presence of magma at shallow depth within Mammoth Mountain. Active fumaroles occur high on the mountain (Rinehart and Smith 1982:55) and the summit rhyodacite dome has a potassium-argon age of ca. 50,000 B.P. (Bailey, Dalrymple, and Lanphere 1976:734).

Further north and at about the same time, a phreatic explosion excavated a crater 200 m across and 60 m deep that is presently occupied by South Inyo Crater Lake (Rinehart and Huber 1965:Fig. 2). The nonmagmatic eruption, dated by radiocarbon at 550 ± 60 b.p. (Wood 1977a:92), hurled millions of tons of earth and pre-existing volvanic rock onto the surrounding countryside. These ejecta are underlain by a thick (1.2-1.7 m) layer of predominantly pumice lapilli that blankets much of the Mammoth Lakes area. The lapilli were identified and labeled as tephra 1 by Wood (1977a:91-95) who, based on two remarkably close tephra-bracketing ^{14}C

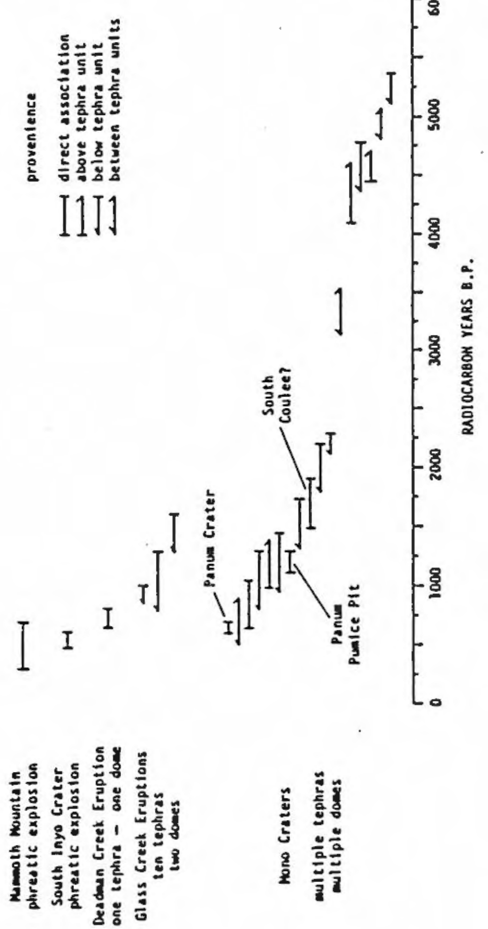


Fig. 2. Radiocarbon age determinations associated with volcanic eruptions in the eastern Sierra Nevada as reported by Rubin and Alexander (1960), Rinehart and Huber (1965), Berger and Libby (1966), Wood (1977a, 1977b), Wood and Brooks (1979), Kilbourne, Chesterman, and Wood (1980), and Kilbourne and Anderson (1981). Each determination expressed horizontally as ^{14}C date ± s. Historic accounts and tephra stratigraphy indicate that the Mono Lake Islands (Paoha and Negit) were active ca. 680-100 b.p. (Kilbourne, Chesterman, and Wood 1980; see text).

dates 63 km apart, dated its eruption at ca. 720 ± 60 b.p. Trace-element analysis of the tephra (Wood 1977a:93-94) indicates that it was erupted from a vent just south of Deadman Creek (roughly 9 km northwest of Mammoth Lakes). A tephra-ringed crater 1 km in diameter encircles the vent. Viscous, silica-rich lava was extruded after the tephra eruption and later congealed as an obsidian dome that overlies portions of the tephra ring (Wood 1977a:93). The fallout zone for tephra 1 lies mainly to the south and southeast, and it occurs in stratigraphic sections up to 190 km south the Deadman Creek vent (Wood 1977a:91, Fig. 3). Locally, tephra 1 mantles all glacial moraines in the Ritter Range above western Long Valley except for those emplaced during the more recent Matthes neoglacial advance (Wood 1977a:91). Roughly 0.1 km^3 of magma was erupted, including a 5.5 km^2 ash flow northeast of the vent (Wood 1977a:94). Hydration measurements on the obsidian dome range from 1.2 to 4.0 μm with an apparent median value of about 2.6 μm (Wood 1977b:Fig. 4b). If a hydration rate of 5μm^2/1000 years, widely used by geologists in the eastern Sierra (Friedman 1968; Wood 1977b; Kilbourne, Chesterman, and Wood 1980), is applied to these values an age range of ca. 3200-300 years is obtained for dome extrusion. A date of 1350 b.p. for a median value of 2.6 μm suggests that this rate may substantially underestimate the actual hydration rate of obsidian in the Deadman Creek dome. For example, since tephra 1 does not occur on the dome (Wood 1977a:94), a much faster rate (more than 9.5μm^2/1000 years) is required to convert the median dome hydration value into an age estimate that is no older than the 720 ± 60 b.p. date for tephra 1 deposition. Also, a relatively warm microenvironment during the first half-century or so of dome cooling may have enhanced hydration and therefore contributed to an empirically derived, but overly rapid rate of hydration (cf. Kilbourne, Chesterman, and Wood 1980: 17; Friedman and Long 1976). But this alone cannot easily account for the wide divergence in dating results produced between assumed and empirical hydration rates. In all likelihood, the actual hydration rate of obsidian in the dome south of Deadman Creek is significantly faster than $5\mu m^2$/1000 years, but perhaps somewhat slower than $9.5\mu m^2$/1000 years.

Underlying tephra 1 in the west moat of the Long Valley caldera are at least ten airfall layers of white pumice lapilli, gray rhyolite pumice, and fragments of andesite and granodiorite (Wood 1977a:93-94). Three radiocarbon dates, 920 ± 80, 1040 ± 250, and 1440 ± 150 b.p. appear to relate to these tephras (Rinehart and Huber 1965; Berger and Libby 1966; Wood 1977a). The oldest date was obtained on charred wood found in alluvium beneath the tephras on Mammoth Mountain, while the other two dates apparently apply to the basal layers of these tephras. Preliminary trace-element analyses of the pumice led Wood (1977a:94) to identify two vents on Glass Creek as the probable eruptive sources. The Glass Creek vents are located ca. 2.0-2.5 km north of the tephra-ringed dome south of Deadman Creek discussed above. Both vents feature post-eruption obsidian domes, the largest (north of the creek) of which is the well-known Obsidian Dome. Recently, a ^{14}C date of 880 ± 25 (A-2325) was obtained for a fallen log on White Wing Mountain above Glass Creek (Richard Weaver, personal communication 1981). Although the stratigraphic relationship of this date to local tephras is unknown (the date is not included in Fig. 2), it certainly would seem likely that the tree died at the outset and perhaps because of the Glass Creek eruptions. Of potential

significance is the fact that the log sampled has been identified as sugar pine (*P. lambertiana*) (Richard Weaver, personal communication 1981), a coniferous forest species rarely if ever encountered today in western Long Valley. This could reflect a shift in vegetation patterns brought about by volcanic devastation or climatic change, or by a combination of both. Though not addressed in this work, the potential ecological consequences for humans of a shift in local biotic associations ca. 900 b.p. are research topics that may merit focused prehistoric study. Stratigraphic sections in the Glass Creek area also suggest that more recent (post-tephra 1) eruptions may have taken place at Glass Creek (Wood 1977b:45).

On the north side of Deadman Creek is another obsidian dome that may have been extruded in late Pleistocene or early Holocene times. The dome is heavily mantled by recent tephras, and Wood (1977b:Fig. 4b) obtained hydration readings on the dome that range from 7.0 to 11.5 μm with a median value of ca. 9.25 μm. Based on an assumed hydration rate of $5\mu m^2$/1000 years, Wood (1977b:46) dated the eruption ca. 27,000-10,000 b.p. Application of a faster rate, as suggested by the obsidian data on the dome south of Deadman Creek, will of course yield a more recent age estimate for the north vent eruption — ca. 13,900-5100 b.p. (median 9000 b.p.) if a rate of $9.5\mu m^2$/1000 years is used.

Two late Holocene tephra layers found in meadow deposits near Devils Postpile and in the upper San Joaquin drainage area (Wood 1975) may derive from one or more vents in the Inyo Domes, or perhaps from Mammoth Mountain. Wood (1977b:44) observed stratigraphic associations that indicate ages for these tephras greater than 1200 but less than 5000 radiocarbon years. Also, Wood (1977b:42-43) reported two tephras in a stratigraphic section near Minaret Summit. The tephras may represent late Pleistocene (early Holocene?) eruptions of Mammoth Mountain (Wood 1977b:42). Obsidians in the two tephras, MM-2 and MM-3, have measured hydration ranges of, respectively, 8.7-12.7 μm (median ca. 10.7 μm) and 7.5-11.0 μm (median ca. 9.25 μm). Wood (1977b:42-43) summarized the measurements as 9-12 μm, and dated the tephras ca. 30,000-16,000 b.p. using an assumed hydration rate of 5μm^2/1000 years. A faster, perhaps more accurate hydration rate would produce early Holocene upper age limits for tephras MM-2 and MM-3.

A number of radiocarbon dates are available that can be associated with eruptions in the Mono Craters over at least the last 5500 radiocarbon years (Fig. 2). The most recent of these, 640 ± 40 b.p., dates the eruption of Panum Crater at the north end of the volcanic chain (Wood and Brooks 1979:543). Panum Crater was previously thought to be the source of a widespread white aphyric pumice that Wood (1977a:91-95) labeled as tephra 2 and which he dated ca. 1190 ± 80 b.p. based on two bracketing ^{14}C determinations obtained in a stratigraphic section of meadow deposits in the upper Kings River drainage are 100 km to the south. A vent adjacent to Panum Crater (Panum Pumice Pit) now appears to have been the eruptive source of tephra 2 (Wood and Brooks 1979:543). The Panum Crater tephra also consists of white aphyric pumice but is less widespread than tephra 2, occurring primarily at the northern end of the Mono Craters and to the east. Neither tephra has a well-defined distribution, although generally east-trending and northeast-trending ashfall lobes may be apparent (Wood 1977a:Fig. 4; Davis 1978:29; Wood and Brooks 1979:543). Tephra 2 derived from a large-size Plinian eruption that ejected a minimum

of 0.2 km^3 of magma (Wood 1977a:94). The Glass Creek tephras in the west moat of the Long Valley caldera are underlain in places by a charcoal-rich soil and tephra 2 (Wood 1977a:94).

Across Mono Lake from Panum Crater, Rubin and Alexander (1960) reported a radiocarbon date of 700 ± 200 b.p. for carbonized wood situated between two ash layers on Bodie Creek. Stratigraphic details of the sample location were not published, but it appears likely that the upper ash layer is Panum Crater tephra in light of the 640 b.p. date for this eruption. It is less clear as to whether or not the lower ash layer at Bodie Creek is tephra 2. White aphyric pumice in a stratigraphic section east of Panum Crater is associated with a ^{14}C date of 840 ± 200 b.p. (Wood 1977b:32), and comparable tephra was found in spring deposits in the Excelsior Mountains northeast of Mono Lake underlain by sediments with a radiocarbon age of 1040 ± 250 b.p. (Bucknam in Wood 1977b:Fig. 6b). Thus it would seem possible that there may have been tephra eruptions in the Mono Craters prior to 700 b.p. but after the 1190 b.p. eruption of tephra 2. Radiocarbon dates of 1170 ± 200 and 1170 ± 250 b.p. were obtained for samples from above and below white aphyric pumice in stratigraphic sections in the Excelsior Mountains and at Sawmill Meadows on the northwest side of Glass Mountain (Wood 1977b:Fig. 6b). The dates suggest a tephra 2 identification of these pumice deposits.

Several tephras, again primarily white aphyric pumice, were located in stratigraphic sections near Wilson Butte (southernmost dome in Mono Craters), at Sawmill Meadows, and on Bodie Creek. Applicable radiocarbon dates from the sections include 1520 ± 200, 1695 ± 200, and 1990 ± 200 b.p. (Wood 1977b:Fig. 6b). Stratigraphic relationships indicate that the tephras probably correlate with two tephras observed above sediments with a ^{14}C date of 2190 ± 90 b.p. in a piston core from Black Lake in Adobe Valley (Batchelder 1970a). The 1695 ± 200 b.p. date was derived for a pine log sample located within a tephra unit in a stratigraphic section 2.7 km north of Wilson Butte on Highway 395. Depositional characteristics suggested to Wood (1977b:Fig. 6b, Appendix II) a local vent for the tephra. A strong candidate for this tephra within the Mono Craters is the South Coulee. According to the volume estimates of Wood (1977b:Table 1), the South Coulee eruption involved ca. 0.10-20 km^3 in distant tephra, ca. 0.20 km^3 in local tephra, a 0.56 km^3 ash flow, and the extrusion of a moderately large obsidian dome.

The upper two of three porphyritic tephras in the Sawmill Meadows section are associated with a radiocarbon date of 3330 ± 200 b.p., while the lower tephra occurs above a peat deposit ^{14}C dated at 4570 ± 200 b.p. (Wood 1977b:Fig. 6b). A similar tephra sequence also occurs in the Black Lake cores, but sediments from above, between, and below the tephras have radiocarbon dates of 4580 ± 130, 4940 ± 120, and 5230 ± 110 b.p. (Batchelder 1970a). The two sets of tephras could be the same, and the radiocarbon dates wrong for one or the other, or the tephras may represent six separate eruptions of the Mono Craters between ca. 5300 and 3300 b.p. (Fig. 2). Finally, a tephra reminiscent of Mono Craters porphyritic pumice was found on the west slope of the Sierra 60 km southwest of Mono Lake in association with material dated by the radiocarbon method at 7705 ± 90 b.p. (Wood 1977b:31).

In an effort to gain additional chronological data on Mono Craters eruptions, Wood (1977b) obtained obsidian hydration measurements for 18

domes in the volcanic chain. These data supplement measurements on six other domes in the Mono Craters previously reported by Friedman (1968). Although the hydration data are not reviewed in detail here, an inspection of the readings for all 24 sampled domes (Wood 1977b:Table 1) suggests overall hydration ranges of 1.2-4.7 μm for 13 domes (including Panum Crater and Wilson Butte), 5.1-7.7 μm for 8 domes, 10.0-11.4 μm for 2 domes, and 12.7-14.2 μm for 1 dome. Wood (1977b:13-23) attempted to empirically derive hydration rates for dome and tephra obsidians based on associated radiocarbon dates (above). The potential rates calculated include 5.3, 5.5, 6.3, 7.6, 9.4, and 9.6μm^2/1000 years. Nonetheless, in calculating ages Wood (1977b:23) assumed a hydration rate of 5μm^2/1000 years that Friedman (1968) had used to date six domes. This rate represents the median value in the 4.5-6.5μm^2/1000 years range of theoretical hydration rates proposed by Friedman and Smith (1960) for northern temperate and continental climates. Application of a rate of 5μm^2/1000 years to the four groups of dome hydration values noted above yields overall age estimates of 4400-300 b.p. (13 domes), 11,850-5200 b.p. (8 domes), 26,000-20,000 b.p. (2 domes), and 40,300-32,300 b.p. (1 dome). However, in light of the empirical rates calculated by Wood (1977b:13-20), the 5μm^2/1000 years rate certainly appears to be too slow. Also, readings of 2.8 ± 0.4 μm on the Panum Crater obsidian dome require a hydration rate of 12.2 ± 3.8μm^2/1000 years to match hydration values with the radiocarbon date of 640 ± 40 b.p. for the eruption (Wood and Brooks 1979). An initially warm microenvironment around the dome following extrusion is probably a factor in such a "fast" rate, but as discussed for the south Deadman Creek hydration data, it seems unlikely that this can entirely account for the differences in dating results between assumed and empirical hydration rates (cf. Wood 1977b:9-10; Kilbourne, Chesterman, and Wood 1980:17). Further, a hydration rate for Mono Craters domes faster than 5µm²/1000 years may be indicated by the lack of any tephra in the Black Lake cores between sediments dated by radiocarbon at 11,350 ± 350 b.p. and 5230 ± 110 b.p. (Batchelder 1970a; cf. Wood 1977b:31). For comparative purposes, it is noted here (see also Fig. 3) that application of a rate of 7.5µm²/1000 years to the dome hydration values yields overall age estimates of 2950-200 b.p. (13 domes), 7900-3450 b.p. (8 domes), 17,300-13,300 b.p. (2 domes), and 26,900-21,500 b.p. (1 dome); for a rate of 9.5µm²/1000 years the estimates are 2350-150 b.p. (13 domes), 6250-2750 b.p. (8 domes), 13,700-10,500 b.p. (2 domes), and 21,000-17,000 b.p. (1 dome); and for a rate of 12.0µm²/1000 years the estimates are 1850-120 b.p. (13 domes), 4950-2150 b.p. (8 domes), 10,850-8300 b.p. (2 domes), and 16,800-13,400 b.p. (1 dome). The effects of faster hydration rates in dating Mono Craters obsidian dome extrusions are straightforward (Fig. 3): aside from dating eruptions more recently, the faster the rate the shorter the intervals between eruptions. At the present time, it would appear that radiometric data are insufficient and measured hydration ranges too broad to determine an optimum hydration rate for Mono Craters obsidian.

Of further interest in examining the eruptive history of the Mono Craters are: (1) increases in the volume of magma erupted over time, and (2) a change in the type of magma reaching the surface. Extrusions of the eight domes with hydration values between 5.1 and 7.7 µm appear to reflect a major increase in eruptive magnitudes (to ca. 0.2km³/1000

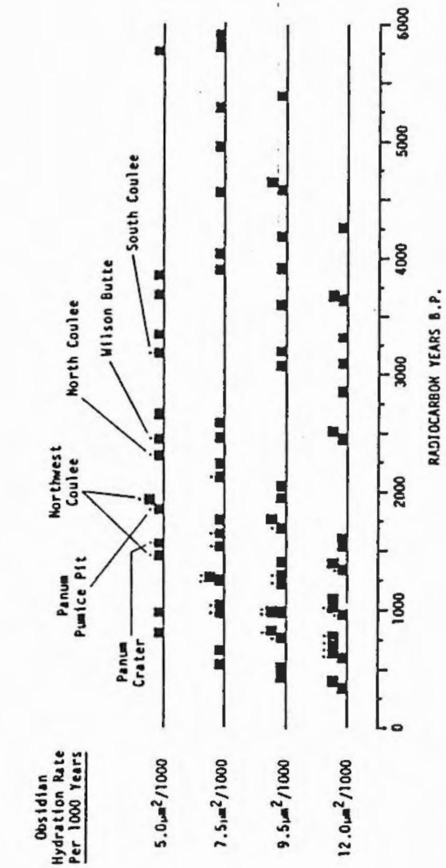


Fig. 3. Approximate hydration dating of Mono Craters obsidian dome extrusions based on data reported by Friedman (1968) and Wood (1977b). Note: the dating of each extrusion was determined by the midpoint in the usually wide range of hydration values obtained for a given dome, hence the chronological ordering of these events depicted above is quite tentative.

years, based on a hydration rate of 5μm^2/1000 years) over previous periods of early Holocene and late Pleistocene volcanic activity (Bailey, Dalrymple, and Lanphere 1976:742; Wood 1977b:32-33). The tephras associated with these eruptions are porphyritic rhyolite. A more pronounced increase in extrusion rates (to ca. 0.8km^3/1000 years, based on the same hydration rate) characterized eruptions of the 13 domes with hydration values between 1.2 and 4.7 μm (Wood 1977b:32-33). These eruptions, in contrast, featured tephras that are sparsely porphyritic to aphyric rhyolite, a petrographic change also apparent in stratigraphic relationships (Wood 1977b:22). The fourfold increase in extrusion rates and the change from porphyritic to aphyric tephra appears to have occurred, based on radiocarbon data, between ca. 3300 and 1900 b.p. (Fig. 2; Wood 1977b: 30). Wood (1977c:528) suggested that the changes in eruptive volumes and tephra composition began with the eruption of the South Coulee. Using a hydration rate of 5μm^2/1000 years, Friedman (1968) dated this eruption at ca. 2500 b.p. Again, though, this rate may be too slow. Faster rates, e.g., 7.5 or 9.5μm^2/1000 years, would place the South Coulee eruption in a time frame more compatible with the earliest radiocarbon dates, ca. 1900-1500 b.p., on aphyric tephras in stratigraphic sections near Wilson Butte, at Sawmill Meadows, and on Bodie Creek.

Overlying the rhyodacite flows on Negit Island in Mono Lake are two surficial tephras, the lower one of which is a rhyodacite-dacite tephra that can be traced to a vent on nearby Paoha Island (Wood 1977b:40). The upper tephra consists of white aphyric rhyolitic pumice ash and lapilli that may have originated with the 640 ± 40 b.p. eruption of Panum Crater. Wood (1977b:40) measured hydration bands of 2.0-2.2 μm on the Paoha obsidian dome that probably indicate an age within the last several centuries. Based on island tephra stratigraphy and observations of Russell (1889) and Lajoie (1968), Kilbourne, Chesterman, and Wood (1980:Table 2) assign an age of ca. 680-100 B.P. to the eruptions of Paoha and Negit islands. Historic evidence exists to suggest eruptive activity in or around Mono Lake just prior to A.D. 1834 (116 B.P.). In 1833, Joseph Walker led the Bonneville expedition to California. On the return leg the following year, the party crossed the southern Sierra at Walker Pass and worked its way northward along the eastern base of the Sierra before turning east in western Nevada. Zenas Leonard, a member of the party, mentioned in his later account of the expedition the occurrence of abundant pumice nearby and floating on one of the lakes passed along the way (Wilke and Lawton 1976:49). Although the exact route taken by Walker through the eastern Sierra is unclear, other observations of Leonard make it likely that Mono Lake was where he saw the floating pumice (see Wilke and Lawton 1976:49). The pumice may have been ejecta from an eruption of Paoha or Negit islands or the Mono Craters, or from a sublacutral eruption, that took place a short time before the Walker party reached Mono Lake. A sublacustral volcanic explosion at Mono Lake in A.D. 1890 is the most recent eruption in the eastern Sierra and it was vividly described in the *Homer Mining Index*, a newspaper then serving the mining town of Lundy high in the Sierra above Mono Lake (Kilbourne, Chesterman, and Wood 1980:16).

ENVIRONMENTAL CONSIDERATIONS

A number of simple considerations emerge from an examination of the

Holocene paleoenvironmental record. Minimally, it seems reasonable to assume that native flora and fauna recognized today are a fairly accurate reflection of what the essential biotic constituents and associations have been since the end of the Pleistocene. In terms of human adaptive significance, therefore, the natural introduction of previously non-existent biotic resources of value to human populations probably did not play a major role in shaping prehistoric cultures (e.g., a new species of large game appeared and became established in the region). Culturally significant environmental change more likely occurred when either (1) important, gradual, but nonetheless minor changes in the behavior of key biotic resources or in their spatial distribution necessitated adjustments in human land-use systems (e.g., reduction in the productivity and availability of riparian resources during relatively arid climatic intervals); or when (2) rapid, adverse change brought about by short-term phenomena forced dramatic adjustments in local subsistence and settlement strategies. The abrupt late prehistoric rise-and-fall cycle of Lake Cahuilla in southeastern California is a good example of the latter (Wilke 1978). In the eastern Sierra, radical change of this sort may have been induced by the violent pyroclastic eruptions of volcanoes in the Long Valley-Mono Basin region. To be sure, low prehistoric population densities in the general region would tend to minimize the number of people faced with an immediate and absolute threat to their survival. Nonetheless, those caught in directly affected areas were confronted with a whole host of miseries, e.g., unrelenting darkness during significant ashfalls, constant irritation of the eyes, skin, and lungs by glassy tephra particles (a problem that would have persisted for a considerable

time after an ashfall), inability to move around easily, and exposure to noxious gases (Workman 1979:343-344). Indeed, one hazard of volcanic eruptions peculiar to high-relief regions like the eastern Sierra is the trapping of heavier-than-air poisonous gases in basins such as Mono Basin that are enclosed by high mountains (Kilbourne and Anderson 1981:167). Relatively low population densities also did not preclude occurrence of potentially severe demographic repercussions accompanying the eruptions. The destruction or inaccessibility of productive traditional resource procurement areas would have required people to go elsewhere for the same or comparable resources — therefore generating, perhaps, adaptive stress for both indigenous and newly arrived groups in less affected, outlying regions.

Paleoecologic studies of the effects of the cataclysmic Mount Mazama eruption ca. 7000 years ago in south-central Oregon suggest that fundamental long-term changes in flora and fauna did not occur as a result despite the violence of the eruption (Grayson 1979:453; Blinman, Mehringer, and Sheppard 1979:422). It is, rather, the short-term impacts on plants, animals, and human ecology that may be of greatest importance in assessing the prehistoric significance of volcanic events. Such impacts might include, for example, devastation of the plant resources upon which animals and people are dependent, concomitant reductions in game populations, contamination of available drinking water, destruction of productive riparian ecosystems, and accelerated erosional processes. The severity of direct volcanic impacts would, of course, vary according to the magnitude and location of an eruption and also, perhaps, according to the time of year involved. Summer eruptions, for example, may have been the most significant for human land-use patterns since ethnographic data (see Chapter III) may show that summer and early fall were the principal seasons of cultural activity in the Long Valley-Mono Basin region. Volcanic chronology in the eastern Sierra indicates, moreover, multiple eruptions within relatively short time-spans. Thus, significant short-term impacts may have been sufficiently recurrent to render some areas largely inhospitable to human occupation for a period of time beyond that to be expected following a single eruption (e.g., western Long Valley, eastern Mono Basin, southwestern Adobe Valley). Evaluation of the volcanic impacts on prehistoric hunter-gatherers in the eastern Sierra must also take into account other, perhaps unrelated, environmental factors affecting human existence during periods of eruptive activity (Blinman, Mehringer, and Sheppard 1979:422). For example, the Glass Creek and south Deadman Creek tephra eruptions in western Long Valley may have coincided with a period (ca. 950-750 B.P.) of severely arid climate in temperate North America (LaMarche 1974:1048).

With regard to the general problem of determining the cultural significance of climatic change it is imperative to distinguish between climatic change, an atmospheric phenomenon, and climatically-induced environmental change that was important to people (Aikens 1977:212). For one thing, there is no innate security in following the usual tendency to simply equate, sometimes unquestioningly, warm-dry climate with conditions less favorable than under a cool-moist pattern for prehistoric cultures (e.g., Baumhoff and Heizer 1965; Kowta 1969; Bettinger 1977a; Moratto, King, and Woolfenden 1978). This assumed relationship remains to be justified in most localities (cf. Bryan and Gruhn 1964; Weide 1976).

It may also be useful to recall an observation made by Curry (1969:42) that periods of generally cool-moist climate are also usually periods of maximum climatic variability, a pattern reversed during periods of relative warmth and aridity. Hence, among the critical factors in apparent associations of culture change with the onset of cool-moist conditions may be the adaptive stresses brought on by and responses to a highly variable climatic pattern and its unpredictable effects on the environment — and not just simply the long-term biotic consequences of gradual overall increases in effective moisture.

Chapter III

ETHNOGRAPHIC CONTEXT

Ethnographic information pertaining to indigenous people in the Long Valley-Mono Basin region is extremely limited. In contrast, recent years have seen an expanding archaeological effort to reconstruct regional prehistory. This chapter briefly reviews what is known or surmised about demographic and linguistic distributions, sociopolitical organization, economic interaction, and subsistence activities in the eastern Sierra just prior to historic contact (ca. A.D. 1850).

INDIGENOUS CULTURES

Although there are conflicting interpretations, available linguistic data indicate two language families and several dialect communites in the general vicinity of Long Valley and Mono Basin (Heizer 1966:Map 5; Heizer and Whipple 1971:Map 1). West of the crest of the Sierra and northwest of Long Valley were Penutian-speaking central and southern Sierra Miwok. Numic-speaking western Sierra Monache inhabited upper western Sierra slopes directly west and south of Long Valley. Lands immediately east of the central Sierra were occupied by at least two distinct Numic-speaking Northern Paiute groups, Mono Lake Paiute and Owens Valley Paiute. Long Valley lies between territories traditionally assigned to these two groups. Comparable subdivisions of Northern Paiute, based on habitat and dialect, are known for adjacent regions (Steward 1933, 1938; Stewart 1939). But it is not clear whether the indigenous inhabitants of Long Valley were members of a locally distinct geographic and linguistic unit, or whether the area was more a locus of

seasonal resource exploitation by different groups, none of which maintained permanent residence. Steward, however, did mention (1938:62-63) two, possibly three, individuals who had lived at or come from a village on Hot Creek or *Paŋwihumadu* (fish creek place). Also, Doyle (1934:204-206) briefly described a well-attended festival ("fandango") at Hot Creek in the 1880's that was held following the local fall pine nut harvest.

Territorial margins among Northern Paiute groups were fluid, with strong intergroup relations underpinned by a network of social and cultural bonds. Stewart (1939:130) saw a "basic unity" among these groups that stemmed from an exact awareness of boundaries dividing Northern Paiute and neighboring tribal territories, and a disinclination toward active control of intergroup borders. There were nevertheless generally recognized natural physiographic boundaries between Northern Paiute groups (Johnson 1975:13-14). Given relatively open borders, therefore, it seems unlikely that plant, animal, and geologic resources in the Long Valley-Mono Basin region were used by any particular group to the complete exclusion of all others. For example, Gifford (1932:19) noted that parties of Northfork Mono (Monache), close linguistic relatives of eastern Sierra Paiute, would sometimes cross over the Sierra to gather pine nuts (pinyon) and remain on the east side of the mountains for one or two years. The trip was an eight- or nine-day affair with several apparently traditional traveling camps. *Dakwanukwe* was one such camp (about mid-trip) located in a "level place" near a creek west of Mammoth Mountain (Reds Meadow-Devils Postpile area?) and another, *Anakwumakwê*, was located near a spring on the slopes of Mammoth Mountain (Gifford 1932:19). Somewhere east of here they camped at *Ebiskonoowê*, a streamside (Mammoth Creek?) site "near Eastern Mono [Northern Paiute] country" (Gifford 1932:19). After reaching its destination, *Saibatkiwe* ("in eastern Mono Country"), the party waited for pine nuts to ripen on nearby mountain slopes. *Saibatkiwe* was located south of *Pazikama*, an Eastern Mono settlement according to Gifford (1932:19). Actual locations of these camps, in particular *Ebiskonoowê* and *Saibatkiwe* and the Paiute settlement of *Pazikama* (Monache name), are presently unknown. Hunting, seed-gathering, and the manufacture of obsidian tools are among some of the other activities that trans-Sierra procurement parties probably pursued, along with considerable social and economic interaction with eastern Sierra Paiute peoples.

Steward (1933:236, Map 2) identified separate dialects of Northern Paiute spoken by Paiute groups residing in northern Owens Valley (Round Valley, Bishop-Laws area), in Mono Basin, and in Bridgeport Valley. Steward (1933, 1938) did not report the presence of a geographically or linguistically independent Paiute population in Long Valley. Linguistic data collected by Merriam, on the other hand, led the latter (Heizer 1966:Map 5) to identify separate Paiute dialects in Mono Basin, in Long Valley, near Benton, and in northern Owens Valley. Merriam (1955:71-76) provides some information on the Mono Lake Paiute, but does not in that work present ethnolinguistic data on Long Valley as some scholars have previously indicated. Kroeber (1959:265) also assumed dialectal differences between Paiute in Long Valley and in northern Owens Valley. Based on his ethnographic research, Merriam apparently considered Long Valley and Mono Lake Paiute as closely related, and similarly grouped Benton Paiute with the Paiute of northern Owens Valley (Grosscup 1977:

130). Both Steward (1933:326) and Merriam (Grosscup 1977:130) were told by some of the Paiute they interviewed that there were slight differences in dialect between Owens Valley Paiute and the Paiute living near Benton. It was also indicated to Steward (1933:236) that the Benton Paiute dialect resembled that of the Mono Lake Paiute. Kroeber (1959:265) referred to the speech of Benton Paiute as a subdialect. In a review of ethnolinguistic data, Grosscup (1977:131) accepted the relationships recognized by Merriam and suggested a boundary between Long Valley-Mono Lake Paiute and the Paiute of Round Valley, Bishop-Laws, and Benton. Perhaps the dialectal differences noted by Merriam reflect, in some fashion, linguistic (and sociocultural) interaction between each of the four dialect groups he identified and adjacent outlying groups; i.e., between Mono Lake Paiute and Bridgeport Valley Paiute (cf. Hall 1980:18-20), Sierra Miwok, and perhaps the Paiute of Smith and Mason valleys further north, between Long Valley Paiute (?) and Northfork Monache, between Benton Paiute and Fish Lake Valley Paiute and perhaps the Paiute of Soda Springs Valley to the north (Hall in preparation), and between northern Owens Valley Paiute and other Paiute groups further south in the valley and to the east (Deep Springs Valley Paiute). Why Steward could not or did not provide information on the problematic Long Valley Paiute are questions that may never be resolved. In all likelihood, there were probably some Northern Paiute who spent the better part of their lives in and around Long Valley but the overall number of such residents was certainly never comparable to Paiute populations in nearby areas. Further, the entire question of whether or not there was a permanent, distinct group in Long Valley may be somewhat moot. Given the relatively high elevation of the valley, there can be little doubt that winters were on occasion so severe as to force people down to lower elevations (e.g., Round Valley, Owens Valley, Benton Valley) for months at a time. It also remains to be shown that there was a sufficient resource base in Long Valley to support a permanent population of any significant size.

Northern Paiute groups spoke dialects and languages of common origin and all are included in the Numic language family of the Northern Utaztekan linguistic stock (Goss 1977). Lexicostatistical dating of the linguistic divergence from prehistoric parent languages suggests that about a thousand years ago people speaking Numic languages ancestral to those known historically spread out like a fan and then across the Great Basin from southeastern California (Lamb 1958; cf. Bettinger and Baumhoff 1982). Kroeber (1959:265) felt that this expansion could have occurred as little as 500 years ago. More recently, Numic ancestors of the Monache apparently emigrated westward across the crest of the Sierra and occupied the Kings River area perhaps 500 B.P., and the San Joaquin River area (Northfork Monache) perhaps 300-200 B.P. (Kroeber 1959:265).

SOCIOPOLITICAL ORGANIZATION AND ECONOMIC INTERACTION

Much of what is known about the early historic and protohistoric Paiute in the eastern Sierra derives from the ethnographic investigations of Julian Steward in the 1920's and 1930's (among other works, Steward 1933, 1934, 1938, 1955, 1970). Additional material is found in a few other sources (e.g., Kroeber 1925; Parcher 1930; Chalfant 1933; Merriam 1955; Davis 1965; Johnson 1975) and in, for example, the accounts of nineteenth-century surveyors (Lawton et al. 1976) and military expeditions

(Wilke and Lawton 1976).

The tabulations of Steward (1933, 1938) indicate a relatively large, indigenous population of about 1000 Paiute in Owens Valley. Wilke and Lawton (1976:46) cite historical sources that suggest a population as high as 2000 before A.D. 1860. Adjacent Paiute and Shoshone (Numic) populations were substantially less dense (Steward 1938:Fig. 6). Owens Valley settlements included large, permanent lowland villages consisting of 100-250 people; seasonal satellite camps occupied by smaller groups of people engaged in a particular subsistence activity, e.g., harvesting of pinyon pine nuts or ricegrass seeds; and temporary, limited activity sites used, for example, during communal rabbit drives, by hunting parties or travelers, or when individual families left the village to expolit specific resources (seeds, roots, greens, small game and fish, raw tool material, etc.) (Bettinger 1979a:37). Most lowland villages in Owens Valley were located along major Sierran tributaries of the Owens River with a few others situated near the river itself or near springs in adjacent desert scrub areas (Steward 1933:Map 2; Bettinger 1975). The basic sociopolitical unit among Owens Valley Paiute was the autonomous district made up of either a single, usually large village, or a group of smaller allied villages (Steward 1933, 1938). Districts represented formal, communal organizations, owning rights to seed-gathering, hunting, and fishing within their territories (Steward 1933:305). The ethnographic data show that the nearest districts to Long Valley and Mono Basin were located near Benton Hot Springs (*Ū́tŪ'ŪtŪ witŪ*) and in Round Valley (*Kwina patŪ*) (Steward 1933:Map 1).

A village-oriented cultural system among the Owens Valley Paiute sharply contrasts with that of Paiute and Shoshone groups to the north, east, and south, where the basic societal unit was apparently the nuclear family (Steward 1938; Bettinger 1979a). Sociopolitical organization among these groups closely corresponded to the family band model (Steward 1955). The household in this case, or "kin clique" (Fowler 1966), consisted of an independent nuclear family accompanied by one or two other persons, usually relatives. Largely independent of more-inclusive social entities, the kin clique or "microband" (Flannery 1968:75) was free to adjust residence according to need or desire (Johnson 1975:13). Each kin clique was isolated for much of the year and determined its own schedule of seasonal activities and movements. As a consequence, the "macroband" (MacNeish 1964:532) at winter villages varied in annual composition (Bettinger 1979a:41). Recurrent fission and fusion wherein household residence decisions are dictated by ecological as well as sociopolitical factors is common to many hunter-gatherer societies (Lee and DeVore 1968; Bicchieri 1972). A regular pattern of microband camps and fluid macroband villages is effective in regions where seasonally available critical resources are more often widely dispersed and limited than clustered and abundant (cf. Binford 1980). Among the Paiute (and Shoshone) groups adjacent to the Owens Valley Paiute, therefore, settlements appear to have cycled between mobile microband camps during spring, summer, and fall, and macroband villages during winter (Bettinger 1979a:41). Winter villages were probably most often located in a lowland setting, or at the base of major mountain canyons. When the pinyon pine nut crop was exceptional, wintering may have taken place in the vicinity of upland nut harvest sites.

Sociopolitical organization beyond the kin clique was informal among Great Basin groups adjacent to Owens Valley Paiute. Common dialectal and economic territory brought together loose associations of these groups for communal drives and festivals. The director of cooperative activities had to show "dependability, skills, and [the] ability to organize and lead" (Johnson 1975:13). It was not necessary that the director be the same person each season or for each activity (Speth 1969:238). District leaders or "head men" (Steward 1933:304) in Owens Valley were charged primarily with the orchestration of communal activities, e.g., irrigation tasks, pine nut trips, rabbit drives, fishing, war parties, and annual festivals. The position of head man was usually inherited through the father and, though influential, head men did not always take the lead in communal activities, sometimes selecting (with group approval) leaders more skilled at a given activity (Steward 1933:304). The political power vested in head men had real social and economic significance. Communal events were ideal times to engage in cooperative planning, trade negotiations, marriage arrangements, and a whole range of social, political, and economic transactions (cf. Bettinger and King 1971).

Throughout the Great Basin, marriage was a virtual economic necessity given the importance of subsistence and maintenance tasks performed by each sex (Steward 1938:242). It was not permitted between individuals sharing a lineal ancestor within, perhaps, three generations (Steward 1938:244). Among Mono Lake Paiute, marriages were somewhat informal and separations were not uncommon (Davis 1965:17-18). In Owens Valley, marriage patterns were based on rules that prohibited marriage within a village (and possibly the district in some cases) or between a village member and someone from that person's father's village (Steward 1933: 294). Newly wed couples resided with the wife's family the first year, the husband's family the second year, and became independent after that. Families of both spouses were visited frequently after this, and permanent residence with the wife's family was common (Steward 1933:295). Marriages also occurred across dialectal borders between Northern Paiute groups, and on occasion between the latter and neighboring Monache, Miwok, and Shoshone groups.

Abundant ethnographic and archaeological evidence exists of significant trans-Sierra trade and commerce between Owens Valley Paiute and Sierra Monache, and between Mono Lake Paiute and Sierra Miwok. Monache and Miwok, in turn, served as intermediaries in trade between eastern Sierra Paiute and Yokuts and Plains (Central Valley) Miwok (Spier 1978: 429; Levy 1978:411). Although it clearly did occur, virtually no data are available on economic interaction between Paiute groups, and between these groups and others to the south, east, and north in the Great Basin. Owens Valley Paiute apparently obtained black pigments from Paiute groups to the north (in Nevada, or perhaps at Mono Lake) and yellow pigments from Shoshone groups to the east (Steward 1933:276-277; Davis 1961:21).

Among the items Owens Valley Paiute are said to have traded to Monache were: salt, pinyon pine nuts, seeds, obsidian, sinew-backed bows, rabbitskin blankets, deerskins, moccasins, mountain sheepskins, foxskin leggings, balls of tobacco, baskets, basketry water bottles waterproofed with pitch, wooden hot rock lifters, and red and white pigments (Steward 1933:257, 1934:431, 437; Gifford 1932:26; Davis 1961:21, 42; Spier 1978:429-430). In exchange, Monache sent east of the Sierra shell money (e.g., clam disc beads, tubular clam beads, and more recently white glass beads), acorns and acorn meal, finely constructed Yokuts baskets, canes for arrows, manzanita berries, squaw berries (or "sow berries" [Steward 1933:257; Sample 1950:17; cf. Davis 1961:21]), and elderberries (Steward 1933:257-258, 1934:438; Gifford 1932:21; Davis 1961:21). Mammoth Pass (2926 m), ca. 6.5 km southwest of Mammoth Lakes, is the lowest pass across the Sierra for a considerable distance both north and south and thus may have served as an important trans-Sierra commerce route (Steward 1933:329; Chalfant 1933; Hindes 1959:Map 1). Northfork Monache probably traversed Mammoth Pass during pine nut (or obsidian) procurement expeditions to the eastern Sierra (see above). Steward (1934:431) was told of one salt-trading trip made by six Owens Valley men who went over the Sierra above Round Valley, perhaps Piute Pass (see Steward 1933:329), and returned "by way of Mammoth." Also, since communal parties from Owens Valley came into the Long Valley-Mono Basin region to gather *piüga* (Pandora moth larvae [*Coloradia pandora*]) in July, it is possible that *piüga* was either traded to or collected as well by Monache, although ethnographic accounts are lacking.

Further north, Mono Lake Paiute are reported to have traded to Sierra Miwok such things as salt, pinyon pine nuts, *piüga*, brine fly larvae (*Hydropyrus hians*, blown ashore at Mono Lake), rabbitskin blankets, baskets, pumice stones, and red and white pigments, receiving in return shell money, acorns, baskets, arrows, a fungus used in paints, manzanita berries, elderberries, and squaw berries (Steward 1933:257; Barrett and Gifford 1933:256; Merriam 1955:112; Davis 1961:17, 21; Levy 1978:403, 411-412). Extensive social interaction between Mono Lake Paiute and Sierra Miwok is documented; the former often wintered in Yosemite Valley when fall pinyon pine nut crops were particularly poor (Steward 1933: 257). Miwok traveled over Mono Pass (not Tioga) to trade and participate in dances (Muir 1917:80-81; Steward 1933:329).

A long prehistory of obsidian procurement and export in the eastern Sierra, including specialized trade-oriented tool production at local quarries and stoneworking camps, is well shown by the presence of obsidian from sources in the region at sites of varying ages throughout central and southern California (Jack 1976; Singer and Ericson 1977; Ericson 1977, 1982). Spier (1978:429) stated that Monache, rather than importing obsidian, sometimes obtained it from a source in the Devils Postpile area ca. 15 km south-southwest of Mammoth Lakes. Such procurement expeditions were probably not infrequent (cf. Basgall 1979), but no specific obsidian source has been located near Devils Postpile (Ericson, Hagan, and Chesterman 1976:Fig. 12.1). Possibly the Monache engaged in exchange activity with eastern Sierra groups at a meeting place in the vicinity of Devils Postpile. Also, it seems reasonable to assume that Northfork Monache and perhaps others, at times came over Mammoth Pass to quarry obsidian at sources in the Long Valley area (e.g., Casa Diablo, Inyo Domes, Mono Craters, Glass Mountain).

SUBSISTENCE ACTIVITIES

Traditional Northern Paiute subsistence activities were keyed to the seasonal distribution, density, and breeding and ripening cycles of plants and animals exploited for food and raw materials. Considerable

effort was made by Owens Valley Paiute to enhance the productivity of food-bearing plants (primarily two wild crops: wild hyacinth corms [*Dichelostemma pulchella*] and yellow nut-grass tubers [*Cyperus esculentus*]) by irrigating large plots on the floor of Owens Valley and on lower alluvial slopes (Steward 1930, 1933; Lawton et al. 1976). Similar agricultural activities may have occurred north of Mono Lake along the Walker River in Smith and Mason valleys and elsewhere in the western Great Basin (Lawton et al. 1976:31; Philip Wilke, personal communication 1982). High elevations and prohibitive edaphic conditions make it improbable that either Long Valley or Mono Basin was the scene of such irrigation projects. Furthermore, barring discovery of a lost local ethnography, it remains for archaeology to determine and evaluate the relationships among multiple indigenous economic activities in the Long Valley-Mono Basin region. The issue derives in large part from an inability to assume a permanent population throughout most of the eastern Sierra and from ethnographic and archaeological evidence that suggests that the effort expended on any particular activity involved decisions between a number of significant, potentially concurrent economic choices available to geographically separate groups of people.

Ethnographic data (Steward 1933, 1934, 1938; Davis 1965; Johnson 1975; see Bettinger 1979a) indicate that by early spring, winter stores of seeds and nuts were starting to dwindle though they still supplied the bulk of sustenance. Small game trapping may have been an important food activity at this time of the year (cf. Janetski 1979:316). During the spring, roots and greens in riparian areas provided some food; fishing was undertaken along parts of the Owens River and related sloughs and tributaries. The species of fish procured at *Paŋwihumadu* (Hot Creek) in Long Valley are unknown but presumably were minnows and suckers, e.g., Owens tui chub (*Gila bicolor snyderi*), speckled dace (*Rhinichthys osculus*), and Owens sucker (*Catostomus fumeiventris*) (Miller 1948, 1973). Davis (1964:264) reported the recovery of *Catostomus* sp. remains at one of the excavated Hot Creek rockshelters. It is also not known if fishing took place on Mammoth Creek (the upper end of Hot Creek) though it would hardly be inconceivable. Trapping of small game continued throughout the spring and probably throughout the year. By late spring and early summer, a wide variety of foods were appearing and ripening. Seeds from rushes along watercourses, and from chia and ricegrass (see below), augmented the contribution of small game and fish. Late spring was also about the time that Owens Valley Paiute could harvest wild-hyacinth (*nahavita*) in considerable quantities from irrigated plots (Lawton et al. 1976:33). A good crop of (non-irrigated) *nahavita* in Long Valley requiring several days to harvest was recalled for Steward (1934:436) by an Owens Valley Paiute.

Summer was a busy season of subsistence activity for a major effort was made to secure winter food supplies. Seeds from several grasses were collected (Bettinger 1979a:Fig. 5). These seeds are available for only a few weeks after ripening before they fall to the ground, and the harvest period for given stands of grasses varies over the summer depending upon species, elevation, soil, and other local conditions. Consequently seed collecting strategies required a good understanding of plant behavior and an efficient system of scheduling procurement tasks (cf. Bettinger 1979a:25). Also, short-term summer camps were established in

July to gather Pandora moth larvae, when available, in infested areas of the Jeffrey pine (*P. jeffreyi*) forest between Long Valley and Mono Basin.

Although some grasses might continue to produce seeds in the late summer and early fall (Bettinger 1979a:Fig. 5), the greater part of the seed-collecting season had passed by this time of the year. Brine fly larvae blown ashore off Mono and Owens lakes were a favorite food and were gathered in large quantities during the middle and late summer (Steward 1933:256; Wilke and Lawton 1976:30). While much of what was gathered was probably stored as winter food, the larvae were also widely traded. Antelope drives were sometimes conducted in the lowlands in the late summer, but massive kills may have severely restricted the size of local herds for many years thereafter (Steward 1938:55).

Fall subsistence efforts in much of the eastern Sierra centered on the gathering of pinyon pine nuts. This was also the season that Owens Valley Paiute intensively harvested yellow nut-grass tubers (Lawton et al. 1976:33-36). Short-term seasonal upland camps were established by single families or groups of related families in the pinyon-juniper woodland during the fall pine nut harvest. Nuts collected for the winter food supply were carried back down to the lowland winter village and stored, or cached in the uplands for later retrieval. If a local crop was especially bountiful and the weather not too inclement, the winter village was sometimes relocated from its usual site in the lowlands to one closer to or in the area of the nut harvest. The irregularity of pinyon cone productivity on a local level, however, meant that people were required to go substantial distances on occasion to obtain the desired nuts when local crops were poor (Steward 1938:27-28; Johnson 1975:

10). This was apparently not a big problem in Owens Valley where bad nut harvests could be offset by adequate stores of yellow nut-grass tubers, seeds, and other foodstuffs such as processed larvae (cf. Bettinger 1979a:37-38). Elsewhere, pine nuts played a pivotal role in the fall-winter subsistence strategy and sometimes required major adjustments in wintering locations.

The yellow nut-grass harvest in Owens Valley usually preceded a fall festival ("fandango") that attracted people from a large area (including Mono Lake Paiute, Monache, Miwok, as well as certain Shoshone groups from the south and east) and lasted for five days to a week (Steward 1933: 320-322). Bettinger and King (1971) postulated that in Owens Valley banking of shell money acquired through trans-Sierra trade and its food-purchasing power alleviated seasonal resource inequities at the local level, thereby promoting residential stability and social interaction (cf. Orans 1975). In this context, nut-grass tubers may have been a principal commodity purchased by festival attendants from outside Owens Valley (Hall 1982a).

Communal jackrabbit drives were also held in the fall, probably before, during, or after the fall crop harvests when people tended to gather together in larger numbers. Major game such as deer and mountain sheep were hunted or ambushed from brush or stone blinds erected along game trails and creeks or near springs. Hunting parties might have employed beaters to drive game toward a concealed hunter (or hunters) or into a brush and stone corral where they could be easily dispatched (Johnson 1975:12).

Food stores accumulated over the summer and fall supplied most of

the meals during winter, a season in which there was much socializing, planning, and probably a good deal of craftwork in anticipation of the needs for the coming year (basketry weaving, hidework, stone tool manufacture, clothing manufacture, etc.).

Chapter IV

ARCHAEOLOGICAL INVESTIGATIONS

Archaeological research in the eastern Sierra and adjacent regions has grown considerably over the last decade. Increasingly frequent field studies since the early 1970's reflect not only a widening variety of research questions, but also the emergence of cultural resource management as an applied process and as a means of funding basic research. The first part of this chapter presents a short overview of (1) previous archaeological research in the eastern Sierra; (2) artifact and site categories common to the region; and (3) conventional archaeological temporal units as defined by diagnostic, time-sensitive projectile point forms. These discussions are followed by a description and an evaluation of the results of archaeological investigations carried out at CA-MNO-561 during the summer of 1982. CA-MNO-561 is located on upper Mammoth Creek in the community of Mammoth Lakes, Mono County, California (Fig. 4). The site lies within the Mammoth embayment at the southwest edge of the Long Valley caldera. Source-specific hydration dating of obsidian artifacts from CA-MNO-561 suggests that the site was probably the scene of recurrent, relatively short-term occupations over several thousand years (ca. 4500-500 b.p.). The hydration data also indicate that the site was occupied primarily between ca. 3000 and 1500 b.p. Stratigraphic analysis of the CA-MNO-561 artifact assemblage suggests that despite evident temporal variation in the frequency of certain activities, the nature of those activities as measured by assemblage diversity appears to have remained remarkably uniform throughout the period of prehistoric

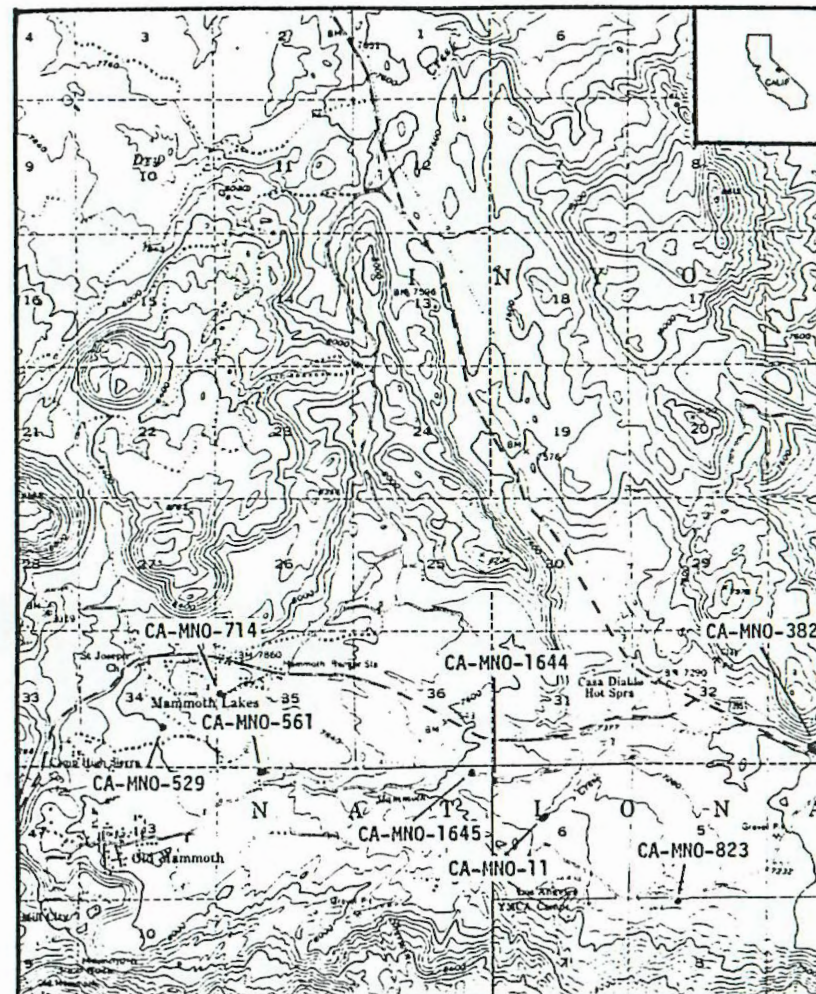


Fig. 4. Location of CA-MNO-561 on upper Mammoth Creek and previously excavated prehistoric sites in the Mammoth Lakes area, Mono County. Adapted from Mt. Morrison, Calif. 15' series USGS Quadrangle, Townships 3 and 4 South, Ranges 27 and 28 East, MDBM.

habitation at CA-MNO-561.

PREVIOUS RESEARCH

Notable early efforts in the eastern Sierra include surveys of five Mono County localities (Meighan 1955) and the general Mono Basin area (Davis 1964), and excavations at the two Hot Creek rockshelters (Davis 1964), the Mammoth Junction site (CA-MNO-382; Michels 1964, 1965; Sterud 1964), and Mammoth Creek Cave (Enfield and Enfield 1964). All four of these excavated sites are located downstream from CA-MNO-561. Mammoth Creek, along with Sherwin Creek and other small streams, drains the Mammoth embayment and flows generally east and northeast through meadows and wooded areas into Long Valley, feeding Hot Creek and, ultimately, the Owens River. More recent excavations have taken place at the Triple R (CA-MNO-714) and Forest Service Forty (CA-MNO-529) sites in the Mammoth Lakes area (Bettinger 1980a; Basgall 1982) and at the Hot Creek Hatchery site (Tadlock and Tadlock 1972). Also, test excavations were conducted in 1982 at an open site (CA-MNO-11) near Mammoth Creek Cave, at two sites (CA-MNO-1644, CA-MNO-1645) north of the creek between the cave and Mammoth Lakes, and at a fourth site (CA-MNO-823) on Laurel Creek (Bouscaren, Hall, and Swenson 1982). The results of excavations supplement survey data generated by a probabilistic sampling of several areas within the Long Valley caldera (Bettinger 1977b) and by subsequent cultural resource inventories of proposed timber-sale compartments in western Long Valley and in the Glass Mountain Range (Richard Weaver and Robert Jackson, personal communications 1982).

Further east, Cowan and Wallof (1974) reported on test excavations

undertaken at eleven sites located along a transmission line corridor in the Benton Range and eastern Long Valley (see also King 1973a, 1973b). Garfinkel and Cook (1979) reported on excavations at the Sherwin Grade site on lower Rock Creek, and Bettinger (1978a) described investigations at the Blue Flag site in McGee Creek Canyon. To the southeast in Owens Valley, Bettinger (1975, 1976, 1977a, 1979b, 1982b) conducted significant studies of prehistoric sites located within a broad transect across the valley near Big Pine. Several small-scale excavations and surveys have also taken place in northern Owens Valley near Bishop and Five Bridges (e.g., Cowan and Wallof 1974; Warren and Hearne 1974; Garfinkel 1980a; Hall 1982a). Major prehistoric and historic villages just south of Owens Valley were excavated at Little Lake (Harrington 1957; Meighan 1981), Rose Spring (Lanning 1963), and on Cottonwood Creek (Riddell 1951; see Wilke 1983).

North of Long Valley, test excavations have been carried out at the Portillo's Drill site on Oh! Ridge above June Lake (Bettinger 1973), near Gull Lake (Hildebrandt 1981), and at CA-MNO-389 just south of the June Lake junction on Highway 395 (Garfinkel 1980b). Excavation of a prehistoric child burial near Mono Lake was described by Davis (1959), and Bettinger (1981) reported on subsurface investigations at the Lee Vining Creek site (CA-MNO-446) below Tioga Pass. North of Mono Basin, Singer and Ericson (1977) conducted a tool production analysis of the Bodie Hills obsidian quarry (CA-MNO-612). Results of a probabilistic sample survey of archaeological resources in the southwestern Bodie Hills above Bridgeport Valley were presented by Hall (1980). Northeast of Long Valley and east of Mono Basin, limited surveys in the vicinity of Truman Meadows and Montgomery Pass in southern Mineral County, Nevada, were described by Davis (1963, 1964) and Hall (1982b) reported on a survey of upper Queen Canyon in the northern White Mountains. High-altitude late prehistoric summer camps in the White Mountains are being studied by Bettinger (1982a). Finally, Hall (in preparation) is completing a study of archaeological resources within a large area of southern Mineral County lying between Truman Meadows on the south (near the California-Nevada border) and Teels Marsh on the north.

PREHISTORIC SITE ASSEMBLAGES

The results of the work noted above and other studies not mentioned reveal an extensive archaeological record in the eastern Sierra and nearby areas. Prehistoric research in the eastern Sierra has been fortunate, in a sense, for most artifacts and sites can apparently be assigned to a relatively small number of functional categories (Bettinger 1979a:59). To some extent, this simplicity in material culture remains attests to the generally gradual rate of technological change among prehistoric and historic hunter-gatherers barring the introduction of industrial products (cf. Yellen 1977). It also reflects archaeological formation processes (Schiffer 1976) that in the eastern Sierra and other regions of the Far West usually preclude preservation of all but the most enduring of cultural materials (e.g., stone tools and debitage, rock structures, ground stone, ceramics, and rock art).

Regional categories of flaked stone tools include projectile points, bifaces, roughouts, cores, drills, and unifaces. Sharp-edged, bifacially flaked projectile points were hafted to the foreshafts or mainshafts of

arrows and atlatl (spearthrower) darts. From all available archaeological evidence, it appears that the bow and arrow was introduced into the eastern Sierra about 1250 radiocarbon years ago (Thomas 1981a; Heizer and Hester 1978; Bettinger and Taylor 1974) and largely replaced use of the atlatl. Because of inherent ballistic differences between the two weapons, projectile points attached to atlatl darts are usually, though not always, larger and heavier than arrow points (Fenenga 1953; Thomas 1978). Thus the prehistoric transition in weaponry ca. 1250 b.p. is marked in the archaeological record by the appearance of significantly smaller and lighter points. Given their sharp edges, projectile points probably also underwent incidental use as fine cutting tools (cf. Ahler 1970). Stone bifaces (bifacially flaked) and unifaces (unifacially flaked) were used in a variety of cutting, scraping, and chopping tasks. It is also evident that obsidian bifaces were specifically manufactured in the eastern Sierra as a trans-Sierra exchange commodity (Singer and Ericson 1977; Ericson 1977, 1982; Bettinger 1980a, 1981). Some bifaces and unifaces may have been hafted to short wooden handles (see Steward 1933:Fig. 3). Roughouts were crude blanks or preforms to be made into projectile points or bifaces (Bettinger 1979a:61). Cores were natural cobbles or chunks of stone struck repeatedly to detach large flakes for use, unmodified, as cutting tools or for fashioning into various specific tool forms. Drills were used to punch or bore holes in skins, wood, bone, horn, or imported shell and steatite. Interestingly, these markedly pointed tools are relatively common at archaeological sites in the general region but none of the Paiute interviewed by Steward (1933: 277) could identify them.

Flaked stone debitage consists of the by-products of core reduction, tool manufacture, and tool repair. It was the primary source for simple flake tools, and is by far the most frequently encountered category of archaeological debris. For this research, debitage is comprised of (1) biface retouch flakes (distinguished by a striking platform that retains part of the bifacially worked edge of the tool from which it was removed [Bettinger 1980a:17]); (2) use-modified flakes; (3) use-modified flakes, cortex present (cortex is defined as the original surface of the unmodified rock); (4) unmodified flakes; and (5) unmodified flakes, cortex present. Widely available obsidian was the most commonly used flaked stone tool material in the general region, although cryptocrystalline materials (cherts, jaspers, chalcedonies), rhyolite, basalt, and fine-grained andesite were also used.

Ground stone tools include millingstones, manos, bedrock millingstones, portable and bedrock mortars, and pestles. Millingstones include block and portable slab metates, with flat or shallow concave work surfaces, used in the processing of seeds and pine nuts. Manos are hand-held stone cobbles employed to grind seeds and pine nuts on block, portable, and bedrock millingstones. The latter are functionally equivalent to millingstones but, of course, cannot be removed for use elsewhere. Portable stone and bedrock mortars, both relatively rare in the eastern Sierra, are usually deep, steep-walled depressions in which vegetal matter, e.g., imported acorns, was pounded or crushed with a stone or wood pestle.

Ceramic vessels were used for cooking and storage. Available evidence suggests that ceramics in the eastern Sierra, classified as Owens

Valley Brown Ware (Steward 1928; Riddell 1951), appear relatively late in the prehistoric record — no earlier than about 650 b.p. and probably closer to 400 or 500 b.p.

Prehistoric structural remains in the eastern Sierra include rock rings, hearths, hunting blinds, stone walls, and non-rock-lined house depressions and storage pits. Rock rings are cleared areas, one to five or more meters across, encircled by a low wall of loose stones. These features probably represent remnants of brush shelters for which the stones acted as supports and weights (e.g., see Stewart 1941:378), although Paiute asked by Steward (1933:334) could not explain them. It is also possible that the smaller rock rings represent seed or nut caches (Davis 1965:9-10). Steward (1933:242) and Davis (1965:12) reported that after the fall pine nut harvest, what was not consumed or transported back to the winter village was stored in caches ringed with rocks, and covered over with pine boughs and needles weighted down by stones. Most nut caches, and probably seed caches as well, were reclaimed before spring, but there are reported instances when a year or more might pass between storage and retrieval (Steward 1934:433). However, the theoretical cut-off in rock ring size that could be used to distinguish between prehistoric shelters and caches has yet to be established (Hall 1980: 34-35). Hearths are accumulations of charcoal, charred soil, and fire-cracked rock that reflect cooking and other domestic activities. Hunting blinds are arc-shaped or circular, loose stone walls located in strategic positions along game trails or near springs and creek sites frequented by game (cf. Brook 1980). Prehistoric stone walls may have been erected to channel the retreat of game during communal hunting efforts.

Prehistoric sites in the eastern Sierra are characterized by varied assemblages of artifacts, features, and, occasionally, organic refuse. The prehistoric site taxonomy adopted for this research is based on the inferred activities associated with different assemblages, given available ethnographic and archaeological data. The particular set of activities ascribed to sites displaying similar assemblages define a settlement "type" (Struever 1968:135) or "category" (Bettinger 1979a:66). Three general prehistoric site types or categories are recognized here: limited activity, camp, and habitation sites. Typically small, limited activity sites (cf. Wood 1978) comprise the vast majority of prehistoric sites in the eastern Sierra. As a rule these sites lack midden development and are generally characterized by assemblages featuring a narrow range of cultural materials. Activities at such sites probably involved few people and were directed primarily toward resource procurement (e.g., hunting station, butchering, plant gathering). Site locations and the likelihood of reoccupation depended to a large extent on the activity and time of year. In the Long Valley-Mono Basin region and adjacent areas, limited activity sites are predominantly represented by assemblages containing flaked stone debitage and usually a few flaked stone tools (Meighan 1955; Davis 1964; Cowan and Wallof 1974; Bettinger 1975, 1977b, 1979a; Hall 1980, in preparation). Also included in this site category are hunting blinds, isolated rock rings (which may represent overnight shelters or possibly seed or nut cache remains [Hall 1980:35]), isolated bedrock millingstones and mortars, most isolated block or slab millingstones, and isolated rock art (petroglyphs, pictographs) panels.

A more diverse set of procurement and domestic activities occurred

at camp and habitation sites (cf. Binford 1980:12). In archaeological terms, such sites are distinguished from limited activity sites by more varied assemblages that in the Long Valley-Mono Basin region also include ground stone implements or structural remains. Both site categories represent multiple activity locations. Although these categories are sometimes difficult to differentiate with only surface data, habitation sites are generally indicated by assemblages of greater density, diversity, and extent. Relative to camp sites, habitation sites usually contain larger quantities of tools and features associated with prolonged occupation — e.g., millingstones, roughouts, cores, unifaces, ceramics, hearths, and so on (cf. Bettinger 1979b). Most camp sites were probably occupied by a small group of people or a few related families all engaged in a particular activity (e.g., pine nut harvesting, gathering of *piüga* [moth] and *kutsavi* [brine fly] larvae, obsidian stoneworking) with other domestic and subsistence activities taking place with a frequency regulated by the number of people in the camp and the length of time spent there. On occasion, the pine nut harvest camp might become the winter village when the crop was extraordinary. Such sites, comparable to the lowland villages of historic times, are better referred to as habitation sites. Habitation sites were semi-permanent to permanent settlements that in some cases may have consisted of several, usually related, families. These sites include the large, well-organized villages of the early historic Owens Valley Paiute.

The three defined site categories, limited activity, camp, and habitation sites, are generalized and certainly not all-inclusive. There are of course varieties within these gross categories (Bettinger 1979a, 1979b; Hall 1980, in preparation). Also, isolated stone flakes and tools are likely to be found anywhere in the general region; usual tools include projectile points, bifaces, and roughouts (Hall 1980, in preparation). The majority of these isolates were probably lost or discarded after breaking. Useful diachronic information, however, can still be gained from the study of certain isolates. For example, isolated, diagnostic projectile points can serve to illuminate local hunting strategies over time.

TEMPORAL UNITS

A number of prehistoric cultural chronologies have been proposed for Great Basin and Sierran regions including Long Valley and Mono Basin (e.g., Bennyhoff 1956; Elsasser 1960; Wallace 1962; Davis 1963, 1964; Elston 1971; Moratto 1972; Hester 1973; Bettinger and Taylor 1974; Aikens 1978). In the eastern Sierra and nearby regions of the Great Basin these historical reconstructions are to a large extent based on apparent temporal distributions among time-sensitive artifact forms (principally projectile points) — and not on the basis of a complex of cultural patterns demonstrably unique to a given span of time. It should be understood, therefore, that the temporal limits of the various proposed periods or phases do not necessarily have any historical significance unto themselves; i.e., these dates do not represent episodes of culture change from one time unit to the next outside of the formal change in projectile point forms associated with each unit. Though not entirely satisfactory (cf. Plog 1974:44-45), this approach employs common, diagnostic artifacts to create a framework of temporal units that can be

used to organize the chronological record and help structure questions about prehistoric culture change. For the last 5000 radiocarbon years, a variety of projectile point forms appear to be sensitive to at least four separate temporal units: ca. 4950-3250 b.p., 3250-1250 b.p., 1250-650 b.p., and 650-100 b.p. Virtually nothing is known about earlier post-Pleistocene occupations in the eastern Sierra. Projectile point forms (spear and atlatl dart tips) reported in the general region, such as Lake Mohave and large fluted points, presumably indicate cultural activity during early Holocene times (Campbell 1949; Davis 1963, 1964; Warren and Ranere 1968; Bettinger 1977b; Hall 1982a, in preparation). But aside from the obvious suggestion of hunting, subsistence and settlement activities prior to 5000 b.p. remain significant mysteries. Also, while the possibility of a Pleistocene occupation (before ca. 10,500 b.p.) in the region can certainly be entertained, the available evidence is so conjectural that another review here of the general problem would serve little purpose (cf. Payen 1982).

Projectile point forms used to identify the earliest of the four temporal units noted above, ca. 4950-3250 b.p., include certain of the so-called "Pinto" projectile points (Amsden 1935; Harrington 1957) that have been more recently referred to as Little Lake series (Lanning 1963; Bettinger and Taylor 1974), Silent Snake series (Layton 1970), Bare Creek Eared (O'Connell 1975), and Gatecliff Split Stem (Thomas 1981) point forms. As noted by Thomas (1981:33) and others (e.g., Layton 1970; Bettinger and Taylor 1974), there appear to be significant morphological (perhaps temporal) differences between some of the "Pinto" points found by Harrington (1957) at the Stahl site near Little Lake and specimens from the type locality, Pinto Basin (Amsden 1935). The appellation Gatecliff Split Stem (Thomas 1981:22) reflects an effort to take these differences into account and to recognize that the large, corner-notched, split-stem points from Little Lake are, as time-sensitive morphological forms, more akin to "Pinto" points from further north and east in the Great Basin than to the original Pinto Basin specimens from southeastern California. However, historical precedent (Lanning's [1963:250-251] "Little Lake series") and common procedures of nomenclature suggest that a more appropriate designation for this particular point form is Little Lake Split-stem.

A projectile point form that may have a temporal range coinciding or partly overlapping Little Lake Split-stem is the Gypsum Cave point (Harrington 1933), also referred to as Elko Contracting-stem (Heizer and Baumhoff 1961). Thomas (1981) considered this point form, which he labeled Gatecliff Contracting Stem, to be coeval with Gatecliff Split Stem points at Gatecliff Shelter in central Nevada and, jointly, the two forms comprise the Gatecliff point series dated ca. 4950-3250 b.p. Again, historical considerations suggest Gypsum Cave Constracting-stem as an appropriate designation for this particular point form. Moreover, it may be that at least the contracting-stem form persists somewhat later than the split-stem form in the Great Basin (see Heizer and Hester 1978:169-170), in instances co-occurring in well-dated deposits with early Elko series point forms (e.g., Davis and Smith 1981:Figs. 6, 35).

Elko Corner-notched and Elko Eared projectile point forms (Heizer and Baumhoff 1961) identify the succeeding temporal unit, ca. 3250-1250 b.p. (O'Connell 1967; Bettinger and Taylor 1974; Heizer and Hester 1978; Thomas 1981). Although this dating of Elko series points is strongly supported by associated radiocarbon data in the central and western Great Basin, evidence has been found of a much earlier appearance of Elko points in the eastern and northern Great Basin (Aikens 1970; Bedwell 1973; Jennings, Schroedl, and Holmer 1980). Rose Spring series (Lanning 1963) and Eastgate series (Heizer and Baumhoff 1961) projectile point forms, widely felt to be the earliest arrow point tips in the Great Basin, characterize the third temporal unit recognized here, ca. 1250-650 b.p. (Clewlow 1967; Bettinger and Taylor 1974; Heizer and Hester 1978; Thomas 1981). Again, as with Elko points, Rose Spring and Eastgate series points appear to show up much earlier than ca. 1250 b.p. in the eastern and northern Great Basin (Aikens 1970; Layton 1970). The final temporal unit, ca. 650-100 b.p., is represented by Desert Side-notched and Cottonwood series projectile point forms (Baumhoff and Byrne 1959; Lanning 1963) and Owens Valley Brown Ware ceramics (Riddell 1951).

CA-MNO-561 EXCAVATION

As stated, a secondary objective of this research is to interpret the findings made at CA-MNO-561 on upper Mammoth Creek (Fig. 4). A data recovery project at the site developed as the result of a land exchange agreement between the Inyo National Forest and the Ridgeview Company. The original federal property, a five-acre parcel located about 80 m north of Mammoth Creek and bordered on the east by Old Mammoth Road, encompasses a large portion of CA-MNO-561. To salvage as much archaeological information as possible about the subsurface cultural deposit within the parcel prior to the commencement of housing construction activities, the Archaeological Research Unit was engaged by the Ridgeview Company to excavate twenty-one 1 x 2-m units. Earlier USFS test excavations suggested the presence of a substantial subsurface cultural assemblage toward the eastern end of the parcel, and a sparse, essentially surficial deposit of prehistoric debris at its western end (Richard Weaver, personal communication 1982). Though slim evidence at best, the USFS excavations also resulted in the recovery of a single projectile point (USFS 1-146) 50-60 cm below the surface with a basal configuration and size that might reflect a cultural deposit of considerable antiquity in light of temporal data on comparable point forms elsewhere in the general region.

PROJECT DESCRIPTION

Given the limited number of excavation units relative to the total possible within the subject parcel (0.2% sample), the 21 ARU units were concentrated in the eastern portion of the parcel where a USFS test unit and surface concentrations of obsidian tool debitage indicated the possibility of a significant subsurface cultural deposit (Fig. 5). Debitage was particularly dense (more than 25 pieces per m^2) in and around a small enclosure of large granitic glacial erratics in the southeastern quarter of the parcel. A shallow bedrock mortar occurs on one of the erratics. The USFS test unit was located about 10 m north of the enclosure. All 21 1 x 2-m units were excavated in arbitrary 10-cm levels using trowels, whisk brooms, and shovels. Excavated soil was screened through 1/8-in. mesh. Artifacts removed from CA-MNO-561 were washed, sorted, and cataloged for analysis. The collection is currently housed under accession

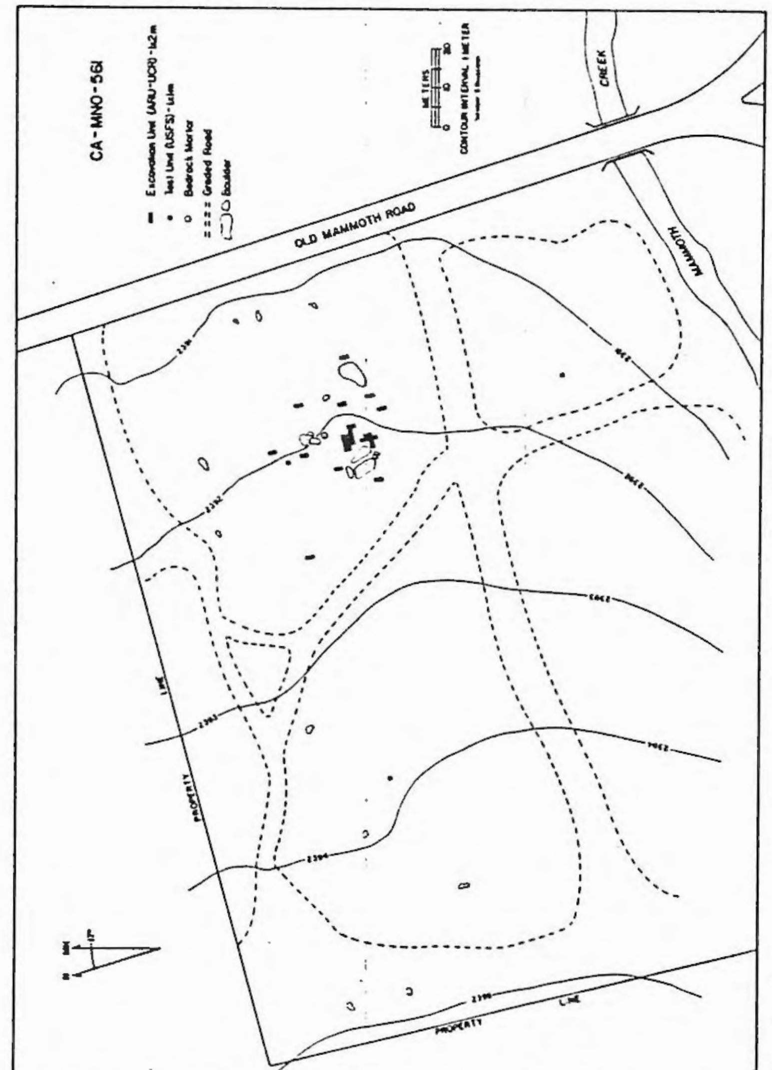


Fig. 5. Contour map showing distribution of 21 ARU 1 x 2-m excavation units and 3 (of 4) USFS 1 x 1-m excavation units at CA-MNO-561.

no. 90 at the Archaeological Research Unit, Department of Anthropology, University of California, Riverside.

To ensure excavation of 21 units in the short field time available (11 days), a maximum effort to recover all subsurface obsidian debitage was attempted in only the first three units excavated (Units 1-3, designated "control" units). Because of the prohibitively long time involved in complete recovery (one 10-cm level in Unit 3 contained nearly 4000 cultural items, most smaller than a thumbnail), debitage smaller than about 1 x 2 cm was usually discarded during the screening process for Units 4-21. As it was, this procedure and a splendid effort by the field crew were required to accomplish the work in the face of foul weather that halted the excavation on several occasions.

The locations for Units 4-21 were determined in the field on the basis of the volume and composition of cultural material recovered in each of the control units. As a starting point, for comparative purposes Unit 1 was located near the USFS test unit. The unit was excavated to a depth of 130 cm below the ground surface (only the northern half [1 x 1 m] of Unit 1 was excavated from 100 to 130 cm). Roughly 3500 cultural items were collected from Unit 1, 99.7% of which are unmodified flakes and other forms of tool debitage. Unit 2 was located 30 m west of Unit 1 to find out if, as suggested by the USFS test excavations, the subsurface cultural deposit diminished in volume and depth from east to west across the parcel. Although this seemed likely judging by the surface distribution of debitage, excavation of Unit 2 (to 100 cm) resulted in the recovery of more than 4300 cultural items (99.9% debitage). The stratigraphic distributions of debitage in Units 1 and 2 were quite

comparable and the observed difference in overall debitage counts is probably not significant. Hence, the western boundary of the subsurface cultural deposit within the CA-MNO-561 parcel must lie somewhere between Unit 2 and the USFS test unit ca. 60 m further west (Fig. 5).

Unit 3, the final control unit, was located on the southeast side of the westernmost cluster of glacial erratics comprising the enclosure mentioned above (see Fig. 6). Surficial debitage density appeared especially high along the eastern side of these erratics. It should be noted, however, that relative comparison of surface densities at CA-MNO-561 is somewhat suspect because the site has been heavily impacted by, among other things, road-grading (Fig. 5), vandalism, assorted construction activities, and frequent off-road vehicular traffic (primarily motorcycle and bicycle riders). The subsurface cultural deposit encountered during the excavation of Unit 3 (to 100 cm) was far more voluminous than in Units 1 and 2 (Fig. 7). Nearly 25,000 cultural items were recovered from Unit 3 (99.8% debitage). Sixty flaked obsidian tools were found in Unit 3, compared to a total of fourteen in Units 1 and 2. Notably, Unit 3 contained nine projectile points suggestive of a long sequence of occupations at CA-MNO-561. Four of these (Rose Spring Corner-notched, Elko Corner-notched [2], Little Lake Split-stem) strongly indicated occupations ca. 4950-650 b.p. (earliest three of the four conventional temporal units discussed earlier). Four of the points can be classified as Humboldt Concave-base (Heizer and Clewlow 1968). This point form, though not established as a useful time-sensitive artifact, tends to occur more often in association with Elko series and Little Lake Split-stem points than with other point forms in the general region

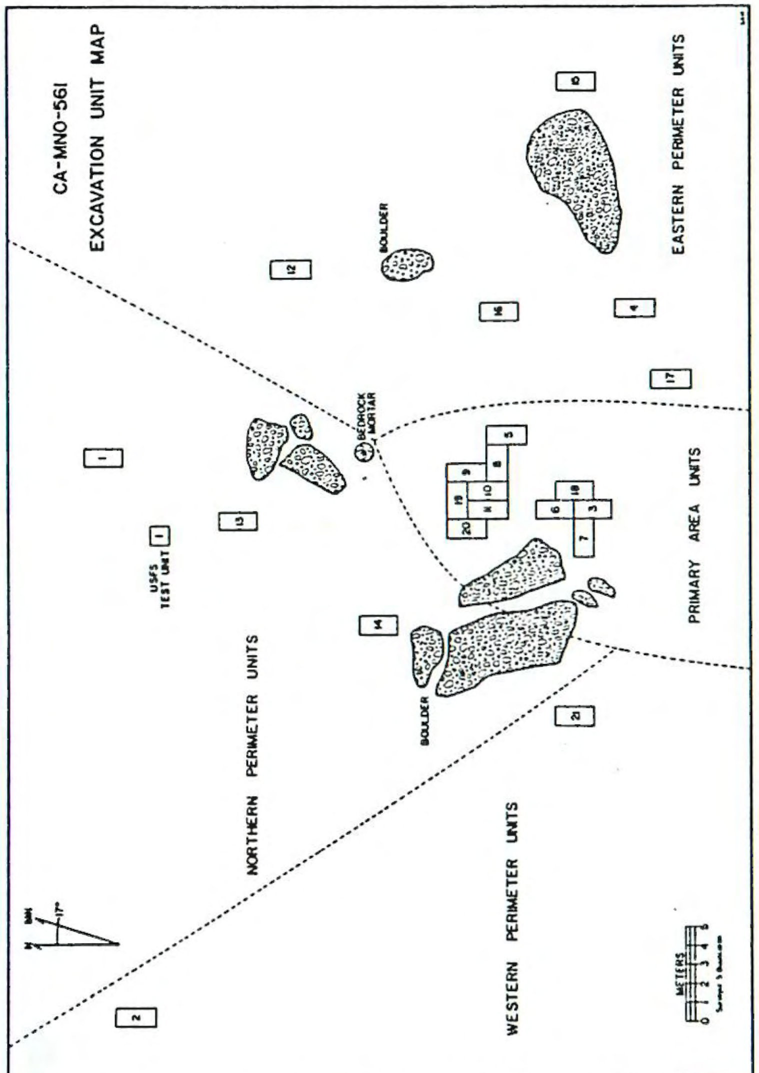


Fig. 6. ARU excavation unit designations at CA-MNO-561.

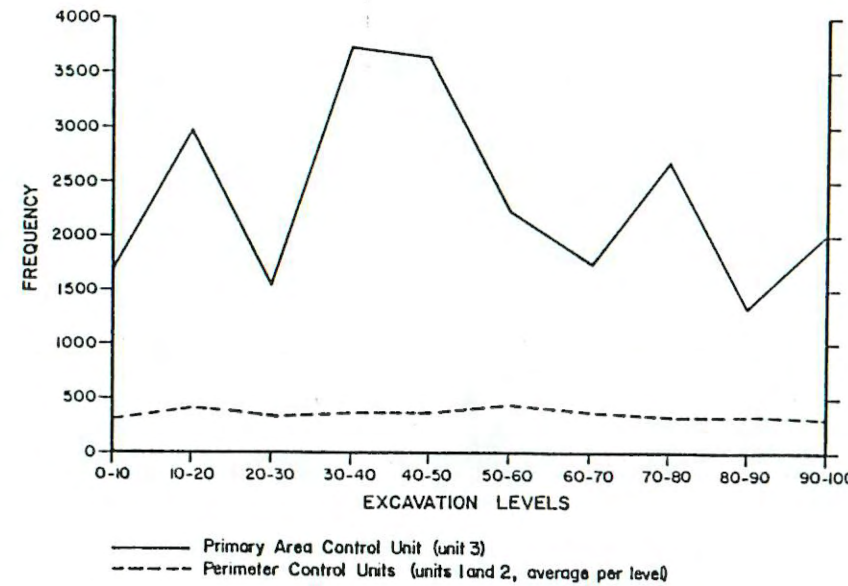


Fig. 7. Stratigraphic curves showing debitage frequencies per 10-cm excavation level, primary area and perimeter control units (defined below).

(Hall in preparation). The ninth point from Unit 3 is a relatively large form with slight shoulders and a broad, thick, slightly constricting stem reminiscent of the Silver Lake point form first defined by Amsden (1937) on the basis of specimens found at Pleistocene Lake Mohave.

Clearly, the deposit in the vicinity of Unit 3 merited additional investigation. To better define the nature and extent of the artifact concentration within the enclosure of granitic boulders, the next two units excavated were located at its eastern edge on the west side of a large erratic (Unit 4) and five meters northeast of Unit 3 at the approximate center of the enclosure (Unit 5; see Fig. 6). Unit 4 was excavated to a depth of 110 cm, and Unit 5 to 90 cm. Over 10,000 cultural items were recovered in Unit 5. Less than half this number of items (4055) were found in Unit 4. At this point in the fieldwork the decision was made, based on the findings in Units 1-5, to use the remaining 16 excavation units (6-21) to further investigate the cultural deposit in the western half of the enclosure and around its perimeter. Along with Units 3 and 5, nine other units (6-11, 18-20) were located in the western half of the enclosure and designated "primary area" units. Units 12-17 and 21, designated "perimeter" units along with Units 1, 2, and 4, were located just outside the enclosure or inside its eastern margin (Fig. 6). Perimeter excavation units at CA-MNO-561 were subdivided into three groups: eastern (Units 4, 12, 15-17), northern (Units 1, 13-14), and western (Units 2, 21). Unit 21 was excavated to a depth of 50 cm, Units 14 and 15 to 60 cm, Unit 17 to 70 cm, Units 12-13, 16, and 18-20 to 80 cm, Units 7-11 to 90 cm, and Unit 6 to 100 cm.

Soil stratigraphy at CA-MNO-561 is similar in many respects to that

observed at other prehistoric sites in the Mammoth Lakes area (Bettinger 1980a; Basgall 1982) and further downstream along Mammoth Creek (Bouscaren, Hall, and Swenson 1982). The surface stratum at CA-MNO-561 consists of a loose, dark brown humus that reached depths of 5 to 15 cm in the ARU excavation units. Hardy bitterbrush, sagebrush, and gooseberry (see below) root systems occupy this soil stratum. Below the surface in most of the units, the roots terminated above 15 cm depth. Occasional bitterbrush and gooseberry root systems extended 60 to 70 cm below the surface. Cultural material was recovered from the humus in all 21 excavation units, but there was a distinct increase in its volume below this soil stratum in the eleven primary area units.

Underlying the surface humus at CA-MNO-561 is a light brown soil stratum, 50 to 70 cm thick in most of the units, characterized by silty sands, poorly graded sand-silt mixtures, and scattered subangular gravels. Soil at the top of the stratum was fairly loose in the excavation units, but it became increasingly more dense and slightly more moist at deeper levels. The stratum contained most of the subsurface archaeological debris recovered from CA-MNO-561, a stratigraphic association also noted at the Triple R and Forest Service Forty sites (Bettinger 1980a:10; Basgall 1982:34). Relative to soil strata above and below this stratum at CA-MNO-561, densities of cultural material per 10-cm excavation level within the stratum were much higher in the primary area units but differed little in the perimeter units (e.g., see Fig. 7). Archaeological evidence from CA-MNO-561 and the Forest Service Forty site (Basgall 1982) suggest that this soil stratum, widespread in the Mammoth Lakes area, developed within the last 4500 radiocarbon years. The stratum is comparable in many ways to the colluvial debris flow units that Lipshie (1976) felt derived from the northeast side of Mammoth Mountain between ca. 25,000 and 1000 B.P.

These silty sands are underlain at CA-MNO-561 by a soil stratum featuring poorly graded, relatively dense, light yellow brown and gray sandy gravel and gravel-sand mixtures with many granitic boulders. The bottom of the stratum was not reached in the excavation units. Previous soil engineering tests on the property (Porter and Saloncai 1982) indicate that it may extend to a depth of 4 m. The stratum may largely consist of Wisconsin-age glacial sediments. Within the excavation units, the stratum was encountered at ca. 80 cm depth as an increasingly dense concentration of small to medium size boulders. Although cultural material was found in all levels in all units, substantially lesser densities occurred in this gravel-boulder stratum. At the deepest levels excavated (Unit 1: 110-120 and 120-130 cm), less than 100 pieces of obsidian debitage were found and all are smaller than about 1 x 2 cm. The size of debitage at this depth probably reflects a downward migration of cultural debris as the result of bioturbation or other processes of stratigraphic mixing. Hence, initial occupation of CA-MNO-561 may have occurred much later than final emplacement of the presumably glacial sediments that underlie and intergrade with the light brown silty sands containing the bulk of the cultural deposit.

A final note regarding pedology at CA-MNO-561 is the likelihood of relatively acidic soil (a consequence of organic decomposition and the weathering of highly acidic lava flows in the area). Since bone decomposes rapidly in acidic soils (Cornwall 1958:42), this may be a factor

in the lack of any faunal remains from CA-MNO-561 save for a few saw-cut fragments of a large mammal (probably domestic).

LOCAL BIOTIC CHARACTERISTICS

Vegetation in the vicinity of CA-MNO-561 and Mammoth Lakes displays a mix of Sierra montane and arid (Basin and Range) interior species that varies along a generally east-to-west, low-to-high elevation gradient. Within the parcel, vegetation is best described as a relatively open stand of Jeffrey pine with a surface stratum dominated by bitterbrush (*Purshia tridentata*) and Basin sagebrush (*Artemisia tridentata*). The site is located near the lower border of a coniferous forest community that occupies well-drained slopes, flats, and ridges at elevations between ca. 2250 and 2800 m in the Long Valley-Mono Basin region. Other conifers in this community in addition to Jeffrey pine are lodgepole pine (*P. murrayana*) and white fir (*Abies concolor*). Sugar pine is presently rare if present at all in western Long Valley, making it notable (see Chapter II) that at least a small community of these conifers existed 900 radiocarbon years ago on White Wing Mountain 14 km northwest of CA-MNO-561. Large, locally dense conifer stands, predominantly Jeffrey pines, from Mammoth Lakes north to the Indiana Summit Area on Bald Mountain carpet the ground with thick pine duff and are in some places virtually devoid of any understory shrubs. Slightly east of and below Mammoth Lakes, a patchy woodland strip of pinyon pine (*P. monophylla*) and juniper (*Juniperus osteosperma*) skirts lower Jeffrey and lodgepole pine treelines between Casa Diablo Hot Springs and the Owens River (e.g., in the vicinity of Little Antelope Valley).

At higher elevations within the coniferous forest, open areas often contain substantial stands of manzanita (*Arctostaphylos patula*), snow bush (*Ceanothus cordulatus*), and mountain mahogany (*Cercocarpus ledifolius*). The bitterbrush-sagebrush surface stratum at CA-MNO-561, however, apparently bridges the transition in shrubs from a pervasive *Artemisia*-dominated sagebrush community throughout Long Valley east of Mammoth Lakes to Sierra montane species north, west, and south of town. Other shrubs of note in the project parcel are gooseberry (*Ribes* sp.) and snowberry (*Ceanothus velutinus*). Common seed-bearing grasses such as needlegrass (*Stipa* sp.) and squirreltail (*Sitanion hystrix*) were exploited in both forest and sagebrush communities by indigenous people. Indian rice grass (*Oryzopsis hymenoides*), Great Basin wild rye (*Elymus cinereus*), wheatgrass (*Agropyron smithii*), redtop (*Agrostis alba*), and chia (*Salvia columbariae*) are among other important seed-bearing plants found in many areas of the sagebrush community. Various sedges and rushes (*Juncus*, *Carex* spp.), willow (*Salix* sp.), quaking aspen (*Populus tremuloides*), and wildrose (*Rosa woodsii*) grow in places along Mammoth Creek and other watercourses draining the Mammoth embayment.

The most prevalent large game animal in the Long Valley-Mono Basin region is Inyo mule deer (*Odocoileus hemionus inyoensis*), although in times past pronghorn antelope (*Antilocapra americana*), and Sierra and desert bighorn sheep (*Ovis canadensis californiana*, *O.c. nelsoni*) may have been more numerous than today. Inyo mule deer range from the Sierra eastward a considerable distance into the Great Basin, and follow a browsing pattern that takes them into different plant communities depending upon season and elevation. Among the small mammals that inhabit

the coniferous forest are various moles and mice (e.g., pinyon mouse [*Perognathus* spp.]), chipmunks (*Eutamias* spp.), and the bushy-tailed woodrat (*Neotoma cinerea*). Predators include black bear (*Ursus americanus*) and weasels (*Mustela* spp.). At lower elevations, pocket gophers (*Thomomys* spp.) and jackrabbits (*Lepus californicus*) are common in the sagebrush community, preyed upon by the wide-ranging coyote (*Canis latrans*). Forested uplands in the general region support other predators such a gray fox (*Urocyon cinereoargenteus*), bobcat (*Lynx rufus*), and mountain lion (*Felis concolor*). As discussed earlier, particularly valued foods among indigenous people in the Long Valley-Mono Basin region were larvae of the Pandora moth and a small brine-fly.

ASSEMBLAGE ANALYSIS

Although an absolute count has not been made, at least 150,000 cultural items of prehistoric origin were recovered in the course of the ARU excavation at CA-MNO-561. All but a dozen of these are obsidian flaked stone tools and debitage. The findings described below, therefore, are hardly exhaustive. Considerable research opportunities remain to be explored with the collection and it will no doubt survive handily as a focus of laboratory research. The goal here is to provide a description and evaluation of the cultural assemblage from CA-MNO-561 with reference to the common categories of archaeological debris encountered at prehistoric sites throughout the eastern Sierra and adjacent areas of the Great Basin (Bettinger 1975, 1977b, 1979a; Hall 1980, in preparation). In-depth, category-specific morphological, technological, and chronological analyses are currently under consideration. Not the least of these are comparative technological and hydration analyses of each of the obsidian tool and debitage categories represented in the collection. Results of source-specific hydration analyses of 79 projectile points and 65 unmodified flakes from the site are given in this chapter and evaluated, along with hydration data from other prehistoric sites in the Long Valley-Mono Basin region, on an absolute chronological basis in Chapter V.

Aside from a massive quantity of debitage, 893 mostly fragmentary flaked stone tools and 8 ground stone tool fragments were found during the excavation. The former total includes 91 projectile points, 335 bifaces, 204 roughouts, 32 cores, 7 drills (or drill/gravers), and 224 unifaces. Five mano and three millingstone fragments comprise the ground stone tools. A small, shallow bedrock mortar is located just north of the northern group of primary area excavation units (Fig. 6). Table 1 summarizes the stratigraphic distributions of flaked and ground stone tools per 10-cm excavation level without regard to unit location. Table 2 indicates the total numbers of flaked and ground stone tools found in each unit without regard to depth. The distributions shown in Table 1 suggest a concentration of flaked stone tools (51.1% of total) and ground stone tools (62.5% of total) between 30 and 60 cm depth. However, as discussed later in the chapter, this is a stratigraphic phenomenon restricted for the most part to excavation levels in the 11 primary area units (Fig. 6). The bulk of the CA-MNO-561 artifact collection derives from these units although they accounted for only slightly more than half (54.9%) of the total volume of soil excavated at the site. Over 80% of the flaked stone tools were found in the primary area units,

Table 1

DISTRIBUTION PER LEVEL OF FLAKED AND GROUND STONE TOOLS

Level (cm)	Number of Units Excavated to This Depth	Projectile Point	Biface	Roughout	Core	Drill	Uniface	Flaked Stone Tools - Total	Millingstone	Mano	Ground Stone Tools - Total
0-10	21	7	35	15	2	2	28	89	-	-	-
10-20	21	18	37	18	3	1	19	96	-	-	-
20-30	21	8	33	23	2	1	19	86	-	-	-
30-40	21	10	50	24	3	-	39	134	2	-	2
40-50	21	14	59	42	4	2	37	156	-	-	-
50-60	20	13	49	42	8	-	52	164	1	2	3
60-70	18	5	32	16	6	-	16	75	-	1	1
70-80	17	5	30	16	2	-	12	65	-	2	2
80-90	11	3	5	5	1	1	2	17	-	-	-
90-100	5	-	5	2	-	-	-	7	-	-	-
100-110	2	-	-	1	1	-	-	2	-	-	-
110-120	1	-	-	-	-	-	-	-	-	-	-
120-130	1	-	-	-	-	-	-	-	-	-	-
Total	21	91	335	204	32	7	224	893	3	5	8

Table 2

DISTRIBUTION PER UNIT OF FLAKED AND GROUND STONE TOOLS

Unit	Lowest 10 cm Level Excavated	Projectile Point	Biface	Roughout	Core	Drill	Uniface	Flaked Stone Tools - Total	Millingstone	Mano	Ground Stone Tools - Total
1	120-130*	2	6	-	-	-	2	10	-	-	-
2	90-100	-	2	1	-	-	1	4	-	-	-
3	90-100	12	29	10	3	-	6	60	-	-	-
4	100-110	2	14	4	1	-	4	25	-	-	-
5	80-90	5	24	9	-	2	7	47	-	-	-
6	90-100	5	31	7	3	-	12	58	-	-	-
7	80-90	4	18	11	5	-	9	47	-	-	-
8	80-90	5	33	16	3	-	20	77	-	-	-
9	80-90	8	27	31	7	1	23	97	-	-	-
10	80-90	14	32	37	3	1	31	118	-	1	1
11	80-90	4	22	20	1	-	14	61	3	1	4
12	70-80	4	12	3	1	-	10	30	-	-	-
13	70-80	3	6	2	-	-	6	17	-	-	-
14	50-60	1	7	-	-	-	9	17	-	-	-
15	50-60	1	2	4	1	1	9	18	-	-	-
16	70-80	3	10	3	-	1	10	27	-	1	1
17	60-70	3	3	5	-	-	9	20	-	-	-
18	70-80	4	16	15	1	-	20	56	-	-	-
19	70-80	4	28	11	3	1	13	60	-	1	1
20	70-80	5	12	15	-	-	8	40	-	1	1
21	40-50	2	1	-	-	-	1	4	-	-	-
Total		91	335	204	32	7	224	893	3	5	8

*Only northern half (1 x 1 m) of unit 1 excavated to this depth

including 90% of the roughouts and cores. Four of the five mano fragments and the three millingstone fragments were also found in the primary area units. Among the 10 perimeter units, nearly 70% of the flaked stone tools were recovered in the five easternmost units, which contained 13.4% of all flaked stone tools from the site (Table 3).

Flaked Stone Tools

With one exception (a drill), all of the flaked stone tools recovered are made of obsidian. Stratigraphic totals per level in each unit are given in Table 4. Trace element analysis (performed on an energy dispersive X-ray flourescence unit by Paul D. Bouey, Volcanic Trace, Davis, CA) revealed that 56 (70.9%) of the 79 projectile points and 63 (96.9%) of the 65 unmodified flakes submitted for examination consist of obsidian from the Casa Diablo source (Ericson, Hagan, and Chesterman 1976:226, Fig. 12.1). As noted in Chapter II, this source is comprised of obsidian flows and inclusions in the large, composite, rhyolitic "resurgent dome" that was extruded ca. 0.6-0.7 m.y. ago in the west-central area of the Long Valley caldera (Bailey, Dalrymple, and Lanphere 1976:732). Vast quantities of culturally modified surface obsidian occur in many places on the dome a few kilometers to the north or northeast of the site (Bettinger 1977b). The proximity of the site to this source, as well as the trace element results from CA-MNO-561 and other prehistoric sites in the Long Valley-Mono Basin region (Bettinger 1973; Cowan and Wallof 1974; Ericson 1977; Garfinkel 1980b; Basgall 1982; Bouey 1982), make it likely that Casa Diablo obsidian accounts for at least 70%, and — based on a crude visual inspection of the specimens —

Table 3

PERCENTAGE DISTRIBUTION OF FLAKED AND GROUND STONE TOOLS AMONG PRIMARY AREA AND PERIMETER EXCAVATION UNITS

Tool	Western Perimeter Units (2, 21)	Northern Perimeter Units (1, 13-14)	Primary Area Units (3, 5-11, 18-20)	Eastern Perimeter Units (4, 12, 15-17)
Projectile point	2.2	6.6	76.9	14.3
Biface	0.9	5.7	81.2	12.2
Roughout	0.5	1.0	89.2	9.3
Core	-	-	90.6	9.4
Drill	-	-	71.4	28.6
Uniface	0.9	7.6	72.8	18.8
Flaked stone tools - total	0.9	4.9	80.7	13.4
Millingstone	-	-	100.0	-
Mano	-	-	80.0	20.0
Ground stone tools - total	-	-	87.5	12.5

Table 4

DISTRIBUTION OF FLAKED STONE TOOLS*

	Western Perimeter Units		Northern Perimeter Units			Primary Area Units											Eastern Perimeter Units					
Level (cm)	2	21	1	13	14	3	5	6	7	8	9	10	11	18	19	20	4	12	15	16	17	Total
0-10	-	1	2	2	4	6	6	4	3	8	5	12	5	1	9	3	3	1	4	6	4	89
10-20	-	2	-	4	3	7	5	7	6	5	10	6	6	6	3	5	5	8	3	3	2	96
20-30	1	-	-	2	1	5	3	8	4	6	4	12	13	6	5	2	3	3	3	3	2	86
30-40	-	-	3	1	3	7	8	8	7	3	20	21	14	11	6	5	-	4	3	7	3	134
40-50	1	1	1	2	3	10	10	8	8	16	23	29	13	7	5	8	4	3	4	1	1	158
50-60	-		2	3	3	6	4	7	11	19	28	20	7	14	18	9	-	3	1	4	5	164
60-70	-		-	2		3	5	7	4	12	5	13	-	4	8	1	3	3		2	3	75
70-80	2		1	1		5	5	4	2	8	1	4	3	7	6	7	3	5		1		65
80-90	-		1			5	1	4	2	-	1	1	-				2					17
90-100	-		-			6		1									-					7
100-110**			-														2					2
110-120**			-																			-
120-130**			-																			-
Total	4	4	10	17	17	60	47	58	47	77	97	118	61	56	60	40	25	30	18	27	20	893

*Flaked stone tools include projectile points, bifaces, roughouts, cores, drills, and unifaces
**Only northern half (1 x 1 m) of unit 1 excavated to this depth

for probably more than 90% of the entire CA-MNO-561 obsidian collection. Relatively greater source diversity among the projectile points from the site may be a regional characteristic of this tool category that becomes apparent in assemblages containing more than just a few points (e.g., Bettinger 1981).

Projectile Points

Gross metric attributes of the projectile points found at CA-MNO-561 are given in Appendix A. The stratigraphic distribution of these tools per unit and level is presented in Table 5. Seventy (76.9%) of the 91 projectile points were recovered in the primary area units (Table 3). Of the total 91, 13 are complete or nearly complete. The remaining points include 29 distal, 13 medial, and 36 basal fragments. Two of the specimens classified here as projectile points might reasonably be considered as bifaces. These are, in particular, the one Humboldt Basal-notched form (see Bettinger 1978b) and possibly one of the nondiagnostic distal fragments (90-3-35). Given the relatively large number of points from the site, however, alternate classification of such specimens has a slight and insignificant effect on intrasite tool frequency measures discussed below. Forty-eight (52.7%) of the points represent, using criteria developed and refined by Thomas (1970, 1981), well-known, widespread Great Basin projectile point forms. Seven points display noteworthy attributes but are otherwise quite different from the recognized forms. The other 36 points possess indistinct morphologies and are simply referred to as nondiagnostic distal (27) and medial (9) fragments. Diagnostic points (55) are organized into three unshouldered and

Table 5

DISTRIBUTION OF PROJECTILE POINTS

	Western Perimeter Units		Northern Perimeter Units			Primary Area Units											Eastern Perimeter Units					
Level (cm)	2	21	1	13	14	3	5	6	7	8	9	10	11	18	19	20	4	12	15	16	17	Total
0-10	-	-	-	-	-	-	2	-	-	1	-	2	-	-	-	-	1	-	-	-	1	7
10-20	-	2	-	1	-	2	-	1	-	1	-	1	4	1	-	1	1	1	-	1	1	18
20-30	-	-	-	-	1	1	-	1	-	-	1	2	-	-	-	1	-	1	-	-	-	8
30-40	-	-	1	1	-	1	-	-	2	-	4	4	-	1	1	1	-	1	-	1	-	18
40-50	-	-	-	-	-	3	2	1	-	1	1	2	-	1	-	1	-	1	1	-	-	14
50-60	-		1	-	-	1	-	1	2	1	2	2	-	-	1	1	-	-	-	1	-	13
60-70	-		-	-	-	1	1	-	-	-	-	-	-	1	1	-	-	-		-	1	5
70-80	-		-	1		1	-	-	-	1	-	1	-	-	1	-	-	-		-		5
80-90	-		-			2	-	1	-	-	-	-	-				-					3
90-100	-		-			-		-									-					-
100-110*			-														-					-
110-120*			-																			-
120-130*			-																			-
Total	-	2	2	3	1	12	5	5	4	5	8	14	4	4	4	5	2	4	1	3	3	91

*Only northern half (1 x 1 m) of unit 1 excavated to this depth

nine shouldered categories. Six of the latter (29 points total) feature established time-sensitive forms that clearly suggest that CA-MNO-561 was occupied ca. 4950-650 b.p. The stratigraphic distributions of specific time-sensitive forms and other points per 10-cm excavation level are summarized in Table 6.

Trace-element and obsidian hydration analyses were performed on 77 of the 91 subsurface projectile points recovered at the site. Source determinations and hydration measurements for these points are listed in Appendix B, along with those for 65 unmodified flakes and two additional points from CA-MNO-561. One of the latter (USFS 1-146) was recovered below 50 cm depth during the USFS test excavations; the other was found on the surface between Units 1 and 2 (90-1-23). Fourteen nondiagnostic distal fragments were not submitted for examination. In addition to the USFS and surface specimens, 54 (70.1%) of the 77 subsurface points are made of Casa Diablo obsidian. At least five other obsidian sources are represented among the remaining 23 points. Fourteen (60.9%) of these are made of obsidian traced by X-ray fluorescene techniques to the Queen (or Truman-Queen) source ca. 60 km to the northeast (Ericson, Hagan, and Chesterman 1976:225-226, Fig. 12.1). Obsidian flows at the source are exposed in only a few localities and surface deposits of this fairly old obsidian (ca. 2-5 m.y. ?) have been extensively redistributed by alluvial action. Secondary deposits are especially concentrated near the upper and lower ends, and bottoms, of steep canyons (e.g., Truman) draining the abrupt northern rim of Queen Valley. Preliminary hydration data for debitage from one prehistoric quarry area near the rim indicate that tool manufacturing activities at Queen began at least 5000 radio-

Table 6

STRATIGRAPHIC DISTRIBUTION OF TIME-SENSITIVE PROJECTILE POINTS AND OTHER POINT FORMS

Level (cm)	Number of Units Excavated to this Depth	Humboldt Concave-base	Humboldt Basal-notched	Bipoint	Rose Spring Corner-notched	Elko Corner-notched	Elko Eared	Elko Corner-notched or Eared Medial Fragment	Little Lake Split-stem	Gypsum Cave Contracting-stem	Unnamed Shouldered Form #1	Unnamed Shouldered Form #2	Unnamed Shouldered Form #3	Non-diagnostic Distal Fragment	Non-diagnostic Medial Fragment	Total
0-10	21	2	-	-	-	-	1	1	-	-	-	-	-	1	2	7
10-20	21	5	-	1	1	2	4	-	-	-	1	-	-	3	1	18
20-30	21	1	1	-	-	2	-	1	-	-	2	-	-	1	-	8
30-40	21	2	-	-	-	5	1	-	2	-	-	-	-	6	2	18
40-50	21	3	-	-	-	1	1	-	1	1	-	1	-	5	1	14
50-60	20	1	-	-	-	1	-	1	1	1	-	1	-	5	2	13
60-70	18	-	-	-	-	-	-	-	-	-	-	-	-	5	-	5
70-80	17	3	-	-	-	-	-	-	-	-	-	-	1	-	1	5
80-90	11	1	-	-	-	-	-	-	1	-	-	-	-	1	-	3
90-100	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
100-110	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
110-120	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
120-130	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	21	18	1	1	1	11	7	3	5	2	3	2	1	27	9	91*

*Total excludes a Rose Spring Corner-notched specimen (90-1-23) found on the surface near unit 1, and an unnamed shouldered form #2 specimen (USFS 1-146) recovered during Forest Service test excavations at the site (USFS unit 1, 50-60 cm) carbon years ago (Hall in preparation). Queen obsidian specimens account for 17.7% of the sourced points from CA-MNO-561. Trace element analysis identified three points as being made of obsidian from either the Mono Craters or Glass Mountain, but could not distinguish between these two sources. Both are much closer (25 and 35 km) than Queen to CA-MNO-561. Three other sources are equally represented among the last six points: Bodie Hills, Mount Hicks, and Fish Springs (Ericson, Hagan, and Chesterman 1976:Fig. 12.1; cf. Singer and Ericson 1977; Hall 1980; Bettinger 1982b). With reference to CA-MNO-561, these sources are, respectively, 68 km to the north-northwest, 71 km to the north-northeast, and ca. 85 km to the southeast. The stratigraphic distributions of specific time-sensitive forms and other points per obsidian source at CA-MNO-561 are given in Table 7.

Hydration analysis of projectile points and unmodified flakes from CA-MNO-561 was conducted by the author using facilities provived by Dr. R. E. Taylor, Director, Archaeometry Laboratory, University of California, Riverside. The procedure takes advantage of the fact that the molecular diffusion of meteoric water into obsidian causes a strain birefringence (a hydrated or perlitic layer) that in cross-section can be seen (hence measured) with an optical microscope (Friedman and Smith 1960). Thus, it is possible to determine the depth of diffusion (i.e., the hydration band) since a given surface was exposed during stoneworking. A considerable amount of research has been devoted to the phenomenon (Taylor 1976) and it is currently understood (Friedman, Smith, and Long 1966; Friedman and Long 1976; Ericson and Berger 1976) that the rate at which hydration proceeds is affected by two variables in addition to

Table 7

STRATIGRAPHIC DISTRIBUTION OF PROJECTILE POINTS PER OBSIDIAN SOURCE[a]

Level (cm)	Humboldt Concave-base			Humboldt Basal-notched	Bipoint	Rose Spring Corner-notched[b]	Elko Series			Little Lake Split-stem			Gypsum Cave Contracting-stem	
	CD	Q	MGM	BH	MH	CD	CD	Q	FS	CD	Q	MGM	CD	Q
0-10	-	1	1	-	-	-	2	-	-	-	-	-	-	-
10-20	3	2	-	-	1	1	3	3	-	-	-	-	-	-
20-30	1	-	-	1	-	-	2	-	1	-	-	-	-	-
30-40	1	1	-	-	-	-	6	-	-	1	-	1	-	-
40-50	2	-	1	-	-	-	1	-	1	-	1	-	1	-
50-60	1	-	-	-	-	-	2	-	-	1	-	-	-	1
60-70	-	-	-	-	-	-	-	-	-	-	-	-	-	-
70-80	3	-	-	-	-	-	-	-	-	-	-	-	-	-
80-90[e]	1	-	-	-	-	-	-	-	-	1	-	-	-	-
0-30	4	3	1	1	1	1	7	3	1	-	-	-	-	-
30-60	4	1	1	-	-	-	9	-	1	2	1	1	1	1
60-90	4	-	-	-	-	-	-	-	-	1	-	-	-	-
Total	12	4	2	1	1	1	16	3	2	3	1	1	1	1

Level (cm)	Unnamed Shouldered Form #1		Unnamed Shouldered Form #2[c]		Unnamed Shouldered Form #3	Nondiagnostic Distal Fragment[d]			Nondiagnostic Medial Fragment			Projectile Points Total					
	CD	Q	CD	Q	CD	CD	Q	MH	CD	Q	BH	CD	Q	MGM	FS	BH	MH
0-10	-	-	-	-	-	1	-	-	1	1	-	4	2	1	-	-	-
10-20	1	-	-	-	-	1	-	1	1	-	-	10	5	-	-	-	2
20-30	1	1	-	-	-	1	-	-	-	-	-	5	1	-	1	1	-
30-40	-	-	-	-	-	-	2	-	2	-	-	10	3	1	-	-	-
40-50	-	-	-	1	-	2	-	-	1	-	-	7	2	1	1	-	-
50-60	-	-	1	-	-	2	-	-	2	-	-	9	1	-	-	-	-
60-70	-	-	-	-	-	2	-	-	-	-	-	2	-	-	-	-	-
70-80	-	-	-	-	1	-	-	-	-	-	1	4	-	-	-	1	-
80-90[e]	-	-	-	-	-	1	-	-	-	-	-	3	-	-	-	-	-
0-30	2	1	-	-	-	3	-	1	2	1	-	19	8	1	1	1	2
30-60	-	-	1	1	-	4	2	-	5	-	-	26	6	2	1	-	-
60-90	-	-	-	-	1	3	-	-	-	-	1	9	-	-	-	1	-
Total	2	1	1	1	-	10	2	1	7	1	1	54	14	3	2	2	2

[a]Sources: CD = Casa Diablo, Q = Queen, MGM = Mono Craters-Glass Mountain, FS = Fish Springs, BH = Bodie Hills, MH = Mount Hicks
[b]Excludes specimen found on surface near unit 1 (CD source)
[c]Excludes specimen recovered during USFS test excavations (unit 1, 50-60 cm, CD source)
[d]Fourteen distal fragments (of a total 27) not submitted for source or hydration analysis
[e]No projectile points found below 90 cm

time: (1) the specific chemical composition (which differs with the source) of the obsidian; and (2) the temperature provenience of the obsidian surface undergoing hydration (e.g., lower vs. upper latitudes, hydrothermal activity, surface vs. subsurface [cf. Layton 1973]). The samples from CA-MNO-561 were prepared using standard thin section techniques (Michels and Bebrich 1971). Each hydration band was measured three separate times at each of six loci, and the resultant 18 values averaged to obtain a mean estimate (in microns [μm]) of the depth of diffusion. In two instances where specimens display double hydration bands (OHL 1754, 1757, see Appendix B), each band was measured three times at three loci (9 values per band). Because of the limits in the resolving power of the microscope and in the mechanical precision of the screw-micrometer eyepiece, each hydration measurement has a baseline error of 0.20 μm. Actual errors (s) accompanying the mean hydration estimates were less than 0.20 μm in all but one case where s = 0.32 (OHL 1766). Source and hydration data for unshouldered and shouldered point forms from CA-MNO-561, and for the nondiagnostic distal and medial fragments, are summarized in Table 8.

Unshouldered Projectile Points

Twenty unshouldered projectile points were recovered at CA-MNO-561. Sixteen (80%) of these were found in the primary area units. Eighteen of the 20 unshouldered points are classified as Humboldt Concave-base. The other two points are both made of obsidian from sources more than 60 km away.

Humboldt Series. Nineteen of the 20 unshouldered points from the

Table 8

SUMMARY OF OBSIDIAN HYDRATION MEASUREMENT AND SOURCE DATA FOR PROJECTILE POINTS FROM CA-MNO-561

(values in microns)

Projectile Point Form	Source**	n	Mean	Median	Range
UNSHOULDERED					
Humboldt Concave-base	CD	12	4.36	4.23	3.52-5.87
	Q	4	3.02	2.62	2.28-4.57
	MGM	2***	4.12	4.27	2.72-5.36
Humboldt Basal-notched	BH	1	3.80	-	-
Bipoint	MH	1	3.24	-	-
SHOULDERED					
Rose Spring Corner-notched	CD	2	3.72	3.72	3.23-4.20
Elko Series****	CD	16	3.92	3.85	2.89-5.79
	Q	3	3.58	3.74	2.85-4.16
	FS	2	4.30	4.30	3.69-4.90
Elko Corner-notched	CD	8	4.07	3.89	3.17-5.79
	Q	1	4.16	-	-
	FS	2	4.30	6.30	3.69-4.90
Elko Eared	CD	5	3.76	3.86	2.89-4.43
	Q	2	3.30	3.30	2.85-3.74
Little Lake Split-stem	CD	3	4.88	4.04	3.75-6.85
	Q	1	3.43	-	-
	MGM	1	5.82	-	-
Gypsum Cave Contracting-stem	CD	1	3.96	-	-
	Q	1	3.86	-	-
Unnamed Shouldered Forms	CD	5	6.03	5.82	4.97-7.24
	Q	2	4.69	4.69	4.56-4.81
Unnamed Shouldered Form #1	CD	2	5.38	5.38	4.97-5.78
	Q	1	4.56	-	-
Unnamed Shouldered Form #2	CD	2	6.78	6.78	6.32-7.24
	Q	1	4.81	-	-
Unnamed Shouldered Form #3	CD	1	5.82	-	-
NONDIAGNOSTIC DISTAL FRAGMENT	CD	10	4.10	4.08	2.94-5.17
	Q	2	3.33	3.33	2.77-2.89
	MH	1	4.61	-	-
NONDIAGNOSTIC MEDIAL FRAGMENT	CD	7	3.89	3.89	2.44-5.29
	Q	1	4.01	-	-
	BH	1	3.56	-	-

*Data per specimen given in Appendix B

**CD = Casa Diablo, Q = Queen, MGM = Mono Craters-Glass Mountain, FS = Fish Springs, BH = Bodie Hills, MH = Mount Hicks

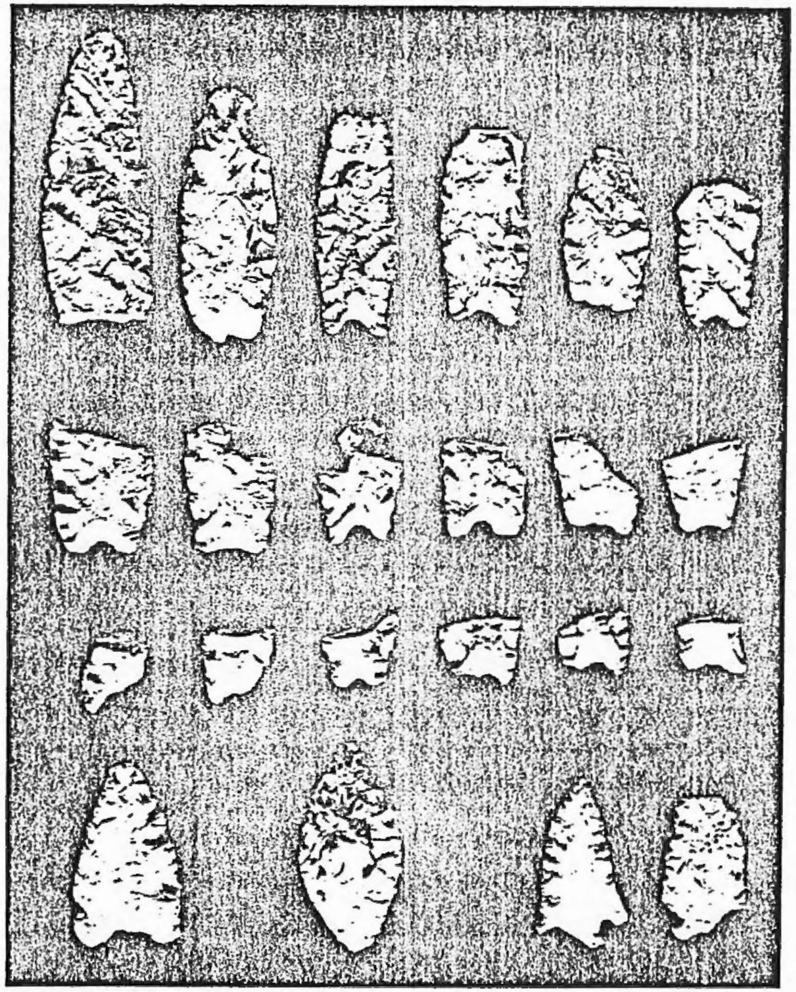
***Two samples, three bands measured; double band specimen: OHL 1757; all bands included in computations

****Includes three Elko series medial fragments traced to CD site are assigned to the Humboldt point series. The series was first identified at the Humboldt Lakebed site in western Nevada by Heizer and Clewlow (1968) who recognized three varieties: Concave-base A, Concave-base B, and Basal-notched. Generally, Humboldt points can be described as unshouldered, lanceolate, with bases that range from being slightly concave and narrow to distinctly notched and broad. The original differentiation between A and B concave-base forms was made purely on the basis of size, with the latter form being smaller but otherwise the same in overall appearance. Some archaeologists (e.g., Roust and Clewlow 1968:108) have felt that there was a progressive reduction over time in the size of the concave-base points. Presumably, the B form (smaller) became the predominant form only in more recent times. However, the distinction in size is not supported by existing morphological data (Thomas 1981:17-18) and it is not recognized here. Even then, its putative temporal significance cannot be effectively evaluated with the limited amount of chronological information available for Humboldt points. This information suggests that the Humboldt series may range in age from ca. 5870 to 1250 b.p. in the Great Basin (Heizer and Hester 1978:Table 6.1; Thomas 1981:Fig. 2). Humboldt points, or points of the same general morphology, have been found at a number of sites in the Long Valley-Mono Basin region (Davis 1964; Michels 1965; Tadlock and Tadlock 1972; Bettinger 1977b, 1980a, 1981; Garfinkel and Cook 1979; Hall 1980; Hildebrandt 1981). In the Teels Marsh-Truman Meadows area north of Queen Valley and east of Mono Basin, Humboldt Concave-base points, when found in association (surficial) with other point forms, frequently co-occur with Elko series and Little Lake Split-stem points (Hall in preparation).

Humboldt Concave-base. The 18 Humboldt Concave-base points found at CA-MNO-561 are illustrated in Fig. 8 (rows 1-3). Four complete or nearly complete specimens were recovered, along with one distal and 13 basal fragments. The distal fragment (Fig. 8, row 1, far left) is provisionally classified as a Humboldt Concave-base given its generally lanceolate, narrow base morphology and its perhaps characteristic diagonal ribbon flaking. Fourteen Humboldt Concave-base points (77.8% of total) were found in the primary area units. The four examples recovered from the perimeter units were all located in the upper 30 cm of the deposit. In the primary area units, 4 points were found in the upper 20 cm, 6 between 30 and 60 cm, and 4 between 70 and 90 cm. Twelve (66.7%) of the 18 Humboldt Concave-base points are made of Casa Diablo obsidian, four (22.2%) are made of Queen obsidian, and the remaining two (11.1%) are made of either Mono Craters or Glass Mountain obsidian (Table 8; Fig. 8). Three of the four Queen obsidian specimens were found in the primary area units, as was the deeper (40-50 cm) of the two Mono Craters-Glass Mountain examples. The four Humboldt Concave-base points found below 60 cm at CA-MNO-561 are all made of Casa Diablo obsidian (Table 7). Points made of obsidian from sources other than Casa Diablo occurred above 50 cm depth in the primary area units, and above 20 cm in the perimeter units. Three of the four points made of Queen obsidian were located in the upper 20 cm at the site, the single exception was found at a depth of 30-40 cm in Unit 9 (primary area).

Hydration measurements on the 12 Humboldt Concave-base points manufactured from Casa Diablo obsidian range from 3.52 µm to 5.87 µm, with a median value of 4.23 µm (Table 8). Ten (83.3%) of the 12 measurements

Fig. 8. (following page) Projectile points from CA-MNO-561 (actual size; coated with ammonium chloride vapor); row 1: Humboldt Concave-base ([90-] 8-5, 16-2, 11-4, 3-40, 10-1, 8-37); row 2: Humboldt Concave-base (9-55A, 3-24, 5-24, 4-3, 3-46, 7-29A); row 3: Humboldt Concave-base (21-2A, 9-53A, 11-5, 10-74A, 14-7A, 3-22A); row 4: Humboldt Basal-notched (9-9), Bipoint (10-5), Rose Spring Corner-notched (3-9, 1-23). Obsidian sources represented: Queen (10-1, 21-2A, 9-53A, 11-5), Mono Craters-Glass Mountain (3-24, 4-3), Bodie Hills (9-9), Mount Hicks (10-5), and Casa Diablo (all others).



fall between 3.52 µm and 4.57 µm (median 4.05 µm). Based on the hydration data, the oldest Humboldt Concave-base points made of Casa Diablo obsidian were found in the primary area units between 40 and 50 cm (5.87 µm, Unit 3) and 70 and 80 cm (5.74 µm, Unit 8). The four Casa Diablo specimens recovered from the upper 30 cm at the site display hydration bands that measure between 3.52 µm and 3.92 µm. On the whole, however, hydration values for the 12 Casa Diablo Humboldt points suggest stratigraphic mixing of the cultural deposit at CA-MNO-561. Hydration measurements on five Casa Diablo Humboldt points exceed that for the deepest specimen found (4.28 µm, 80-90 cm, Unit 3). As will be seen below, the hydration data strongly indicate that subsurface tools and debitage at the site have undergone extensive vertical redistribution.

Hydration measurements on the three Queen Humboldt Concave-base points found in the primary area units correspond well with their stratigraphic proveniences: 2.28 µm (0-10 cm), 2.39 µm (10-20 cm), and 2.84 µm (30-40 cm). The tight clustering of the values also suggests that these points were deposited as the result of a single occupation at CA-MNO-561 or at least successive occupations over a relatively short period of time. A measurement of 4.57 µm was obtained on the one Queen Humboldt point found in the perimeter units (10-20 cm, Unit 21). Assuming relatively contemporaneous deposition of the Casa Diablo and Queen Humboldt points in the upper part of the deposit, the hydration data indicate that Queen obsidian may hydrate at a slightly slower rate than Casa Diablo obsidian.

One of the two Humboldt Concave-base points made of Mono Craters-Glass Mountain obsidian displays two hydration bands, 2.72 µm and 4.27 µm.

This basal fragment (Fig. 8, row 2, second from left) was found in Unit 3 (primary area) at a depth of 40-50 cm. The two bands are suggestive of artifact re-use, but it is not clear whether they represent one or two occupations at CA-MNO-561. The smaller band could reflect re-use of a point (or whatever) already deposited at the site (two occupations). Conversely, the point may have been brought to the site possessing the larger band which then remained partially intact during subsequent tool modification (one occupation). The smaller band might also represent incidental, natural flaking of the point after deposition (one occupation). A hydration measurement of 5.36 µm was obtained on the Mono Craters-Glass Mountain Humboldt point found near the surface (0-10 cm) in Unit 4 (perimeter) a few meters southeast of the primary area units (Fig. 6).

Stratigraphic and hydration data collectively encourage the observation that Humboldt Concave-base points were being made in the Long Valley-Mono Basin region throughout the main period of occupation at CA-MNO-561. This is consistent with the notion that Humboldt Concave-base points were an enduring, perhaps function-specific (hunting) tool form in the Great Basin (Thomas 1981:37).

Humboldt Basal-notched. One complete projectile point in the collection is classified as a Humboldt Basal-notched (Fig. 8, row 4, far left). Though similarly lanceolate in outline, this point is distinguished from the other Humboldt points by its much broader, essentially straight rather than slightly constricting neck. It also has a single slight notch on one of its lower lateral edges. The specimen was found as a depth of 20-30 cm in Unit 9 (primary area), displays a hydration band measuring 3.80 µm, and is made of Bodie Hills obsidian. Humboldt Basal-notched points in the eastern Sierra and southwestern Great Basin are similar in many ways to points from the western and southern Sierra identified as Sierra Concave-base by Moratto (1972:256-258). Existing chronological data for specimens classified in either manner crudely suggest a time-span of ca. 2450-1450 b.p. (McGuire and Garfinkel 1980: 41-42), although Bettinger (1978b) argued that this tool form is a time-sensitive biface dated to ca. 1250-650 b.p. At Gatecliff Shelter in central Nevada, Thomas (1981:39, Fig. 5) found two Humboldt Basal-notched points in deposits that pre-date 1250 b.p.

Bipoint. The last of the 20 unshouldered projectile points recovered from CA-MNO-561 is a relatively large, complete, extensively flaked but thick, leaf-shaped point that is classified simply as a bipoint (Fig. 8, row 4, second from left). Made of Mount Hicks obsidian, the specimen was found at a depth of 10-20 cm in Unit 10 (primary area), and displays a hydration band measuring 3.24 µm.

Shouldered Projectile Points

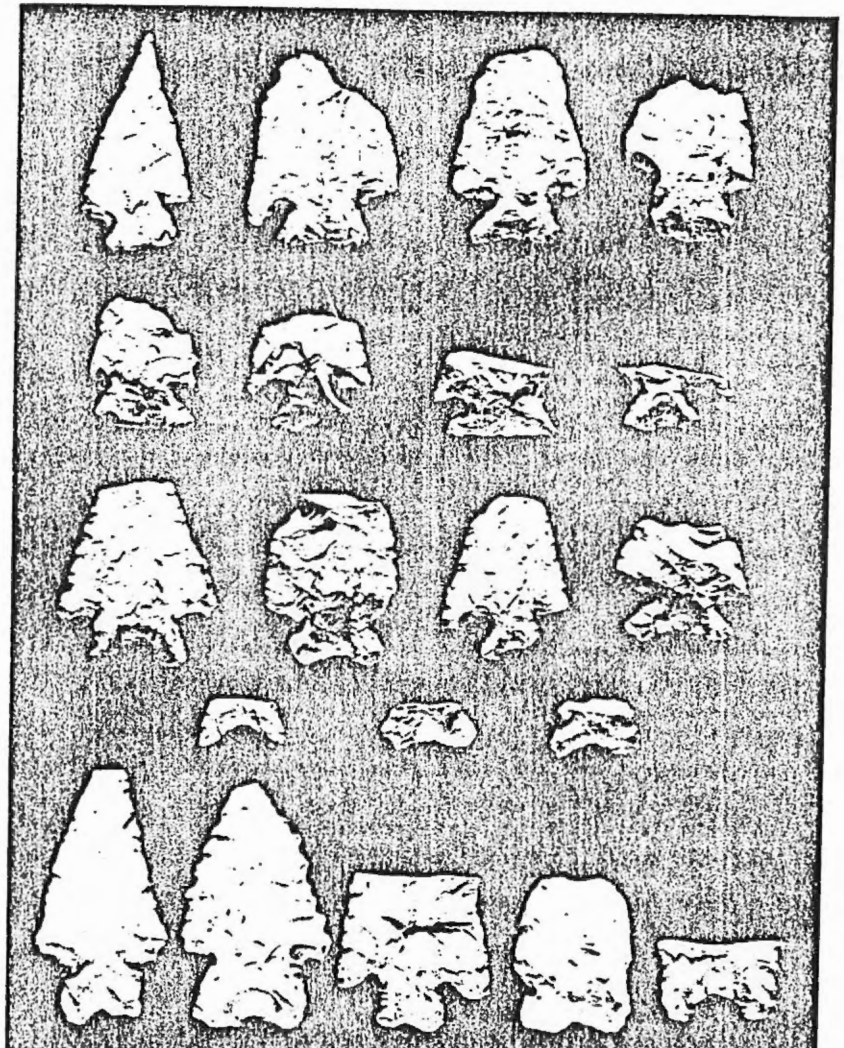
Thirty-five shouldered projectile points were recovered in the ARU excavation units at CA-MNO-561. Of these, 28 (80%) were found in the primary area units. Elko series points comprise 60% of the shouldered points from the site (Table 6). Five of the other 14 points are classified as Little Lake Split-stem. Six of the remaining 9 points are divided into three unnamed categories of shouldered points.

Rose Spring Corner-notched. Including the specimen found on the surface between Units 1 and 2 (northern perimeter), two projectile points

in the collection are classified as Rose Spring Corner-notched (Lanning 1963). As noted earlier, Rose Spring and Eastgate series points may represent the earliest arrow points and are usually considered to date ca. 1250-650 b.p. in the central and western Great Basin. The CA-MNO-561 Rose Spring points are triangular in outline, corner-notched, with expanding stems, and both are made of Casa Diablo obsidian (Fig. 8, row 4). Relative to some of the morphologically similar Elko series points from the site (Fig. 9), the two Rose Spring points are substantially smaller (Appendix A). It should be pointed out, however, that the widths of the stems of these points appear to achieve the critical value of 10 mm that Thomas (1981:20) associated with Elko points from Monitor Valley in central Nevada.

The subsurface Rose Spring point from CA-MNO-561 (Fig. 8, row 4, second from right) is nearly complete although flaking does not extend entirely across the lower portion of one face of the point (illustrated). Found at a depth of 20-30 cm in Unit 3 (primary area), the specimen has a hydration band measuring 3.23 µm. In contrast, the surface Rose Spring point displays a band measuring 4.20 µm. This point lacks a small distal section and one corner (Fig. 8, row 4, far right). The difference in hydration values for the Rose Spring points could possibly reflect enhanced hydration of the surface point deriving from prolonged exposure to solar radiation (Layton 1973). On the other hand, both points display hydration bands larger than the smallest band measured on Casa Diablo Elko points (see below). This suggests that the two Rose Spring points from CA-MNO-561 may simply be relatively old Rose Spring points, or that they should be more properly considered as comparatively small

Fig. 9. (following page) Additional projectile points from CA-MNO-561 (actual size; coated with ammonium chloride vapor); row 1: Elko Corner-notched ([90-] 20-11, 9-10, 3-11, 9-11); row 2: Elko Corner-notched (7-21, 12-7, 20-14, 3-5A); row 3: Elko Eared (9-20, 11-6, 18-4, 10-16); row 4: Elko Eared (8-1, 11-36A, 13-12A); row 5: Little Lake Split-stem (6-37, 3-23, 16-5, 1-14, 19-13). Obsidian sources represented: Queen (3-5A, 18-4, 13-12A, 3-23), Fish Springs (3-11, 12-7), Mono Craters-Glass Mountain (19-13), and Casa Diablo (all others).



Elko points. The latter perspective would be reinforced by an explicit recognition of the minimum 10 mm stem width that Thomas (1981) suggested as a metric characteristic of Elko points.

Elko Series. Twenty-one of the 35 shouldered points found in the ARU excavation units are assigned to the Elko series (Heizer and Baumhoff 1961). Elko series and Humboldt series point forms together comprise 70.2% of all classified points (57) from CA-MNO-561. Chronological data from the central and western Great Basin strongly suggest a time-span of ca. 3250-1250 b.p. for Elko points (Clewlow 1967; O'Connell 1967; Bettinger and Taylor 1974; Heizer and Hester 1978; Thomas 1981). The points from CA-MNO-561 are characteristically large, triangular, corner-notched forms with expanding stems and stem bases that tend to be either straight to slightly convex (Elko Corner-notched) or markedly concave (Elko Eared). Three specimens (not illustrated) found in the primary area units are apparent medial fragments of Elko points but lack sufficient basal portions to permit classification as either the corner-notched or eared form. The three fragments consist of Casa Diablo obsidian and display hydration bands measuring 3.54 μm (50-60 cm), 3.82 μm (20-30 cm), and 3.94 μm (0-10 cm).

Downstream from CA-MNO-561, over 25 Elko points were recovered at the Mammoth Junction site (Michels 1965; Basgall 1982:Table 15). Elko points are generally quite common in the Long Valley-Mono Basin region (Meighan 1955; Davis 1964; Enfield and Enfield 1964; Tadlock and Tadlock 1972; Singer and Ericson 1977; Bettinger 1978a, 1981; Hall 1980; Bouscaren, Hall, and Swenson 1982; Basgall 1982), although Bettinger (1977b) recorded only a single possible specimen at 61 prehistoric sites in the

Long Valley caldera. Northeast of Long Valley, Elko points are frequently encountered at camp and limited activity sites in the pinyon-juniper and upper sagebrush plant communities in the Teels Marsh-Truman Meadows area (Hall in preparation).

Elko Corner-notched. Eleven Elko Corner-notched points were found at CA-MNO-561. Two complete or nearly complete specimens, one medial fragment, and 8 basal fragments were recovered. Eight of the 11 Elko Corner-notched points are illustrated in Fig. 9 (rows 1-2). Three basal fragments (not illustrated) appear to be portions of the stems of Elko Corner-notched points quite similar to fragments classified in the same manner at the Lee Vining Creek site (Bettinger 1981:Fig. 6b-f, h), and the Forest Service Forty site west of CA-MNO-561 (Basgall 1982:Fig. 10c). Nine (81.8%) of the 11 Elko Corner-notched points from the site were found in the primary area units, eight of these between 10 and 40 cm depth, and one between 50 and 60 cm. The two specimens recovered in the perimeter units (1, 12) were located between 30 and 50 cm below the surface. Eight (72.7%) of the Elko Corner-notched points are manufactured from Casa Diablo obsidian, 7 of these occurred in the primary area units. Two points are made of Fish Springs obsidian (Fig. 9, row 1, second from right, row 2, second from left), and one is made of Queen obsidian (Fig. 9, row 2, far right). The latter point was found at 10-20 cm depth in Unit 3 (primary area). One of the Fish Springs points was recovered in the next lowest level (20-30 cm) in Unit 3, and the other was found between 40 and 50 cm in Unit 12 (perimeter).

Hydration measurements on the 8 Casa Diablo Elko Corner-notched points range from 3.17 μm to 5.79 μm, with a median value of 3.89 μm (see

Table 8). Six of these points possess hydration bands measuring between 3.17 µm and 3.96 µm. Stratigraphic mixing at the site is suggested by the fact that the smallest band on a Casa Diablo Elko Corner-notched point (3.17 µm) occurs on the deepest specimen recovered (50-60 cm, Unit 7). Notably, the two largest bands (5.25 µm and 5.79 µm) are displayed by two of the tentatively classified stem fragments. Hydration values of 3.69 µm and 4.90 µm were obtained for the two Fish Spring points, and the hydration band on the single Queen specimen measures 4.16 µm.

Elko Eared. Seven Elko Eared points were found at the site (Fig. 9, rows 3-4). Four of these are relatively large basal fragments, and three are fragments of the stem below the neck. Six of the 7 were recovered in the primary area units. The single Elko Eared point located in the perimeter units (10-20 cm, Unit 13) is made of Queen obsidian. Aside from one other Queen specimen, the remaining Elko Eared points (5) are all made of Casa Diablo obsidian. Four of the points found in the primary area units occurred in the upper 20 cm of the deposit, and 2 between 40 and 50 cm. Without regard to unit location, it may be of interest to note that 5 (71.4%) of the 7 Elko Eared points were recovered above 20 cm depth at CA-MNO-561, whereas 9 (81.8%) of the 11 Elko Corner-notched points were found below 20 cm (Table 6). This could indicate that Elko Eared points were primarily in use toward the latter part of the Elko time-span (3250-1250 b.p.), a temporal pattern also indicated in the stratigraphic distributions of Elko point forms at Gatecliff Shelter (Thomas 1981:Fig. 2). The smallest hydration band displayed by a Casa Diablo Elko point from CA-MNO-561 (2.89 µm) occurs on an Elko Eared specimen (30-40 cm, Unit 10; Fig. 9, row 3, far right), though the

remaining four hydration values on Casa Diablo specimens (3.75-4.43 µm) considerably overlap those obtained for Elko Corner-notched points made of the same obsidian (Table 8). Both Queen Elko Eared points were found between 10 and 20 cm depth and feature hydration bands measuring 2.85 µm (perimeter unit specimen) and 3.74 µm.

In summary, the 21 Elko series points from CA-MNO-561 were all located above 60 cm depth (Table 6). Seventeen (81%) of the specimens were found in the upper 40 cm of the deposit at the site. Including the three Elko medial fragments, 18 (85.7%) Elko series points occurred in the primary area units. Sixteen (76.2%) of the Elko points from the site are made of Casa Diablo obsidian (Table 7). Of the remaining five points, two are made of Fish Springs obsidian and three of Queen obsidian (all of the latter were found between 10 and 20 cm depth [Table 7]). Hydration bands on the Casa Diablo Elko points measure from 2.89 µm to 5.79 µm, with a median value of 3.85 µm (Table 8). Nine (56.3%) of these values fall between 3.17 µm and 3.96 µm. The three Queen obsidian points display bands measuring between 2.85 µm and 4.16 µm, and hydration values of 3.69 µm and 4.90 µm were obtained for the two Fish Springs specimens (Table 8). The stratigraphic and hydration data from CA-MNO-561 suggest that, along with Humboldt Concave-base points, Elko series points are characteristic of the principal period of occupation at CA-MNO-561.

Little Lake Split-stem. Five shouldered points from CA-MNO-561 (Fig. 9, row 5) are classified as Little Lake Split-stem (Lanning 1963; Bettinger and Taylor 1974; Thomas 1981; see above). These corner-notched points are distinguished from Elko series points at the site (and generally) by their comparatively greater thickness and relatively straight rather than expanding stems (Fig. 9; Appendix A). Four of the Little Lake Split-stem points were found between 30 and 60 cm depth. The deepest specimen found occurred between 80 and 90 cm in Unit 6 (primary area) and is made of Casa Diablo obsidian (Fig. 9, row 5, far left). Both of the other two Little Lake Split-stem points recovered in the primary area units are made of nonlocal obsidian. A Mono Craters-Glass Mountain specimen was located between 30 and 40 cm in Unit 19 (Fig. 9, row 5, far right), and a Queen specimen between 40 and 50 cm in Unit 3 (Fig. 9, row 5, second from left). The two Little Lake Split-stem points located in the perimeter units (30-60 cm) are made of Casa Diablo obsidian.

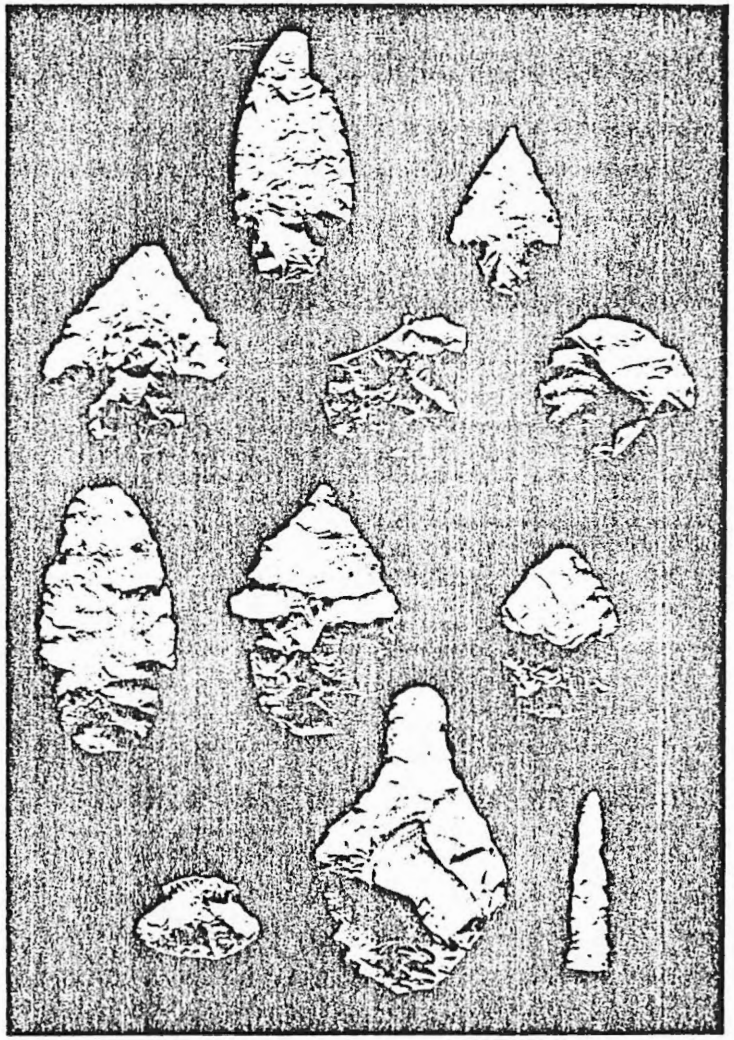
Little Lake Split-stem points, as discussed earlier, appear to date ca. 4950-3250 b.p. (pre-Elko series) in the central and western Great Basin. Hydration data for the five points from CA-MNO-561 (Table 8) suggest that the transition (if that is the right term) from Little Lake to Elko forms took place gradually. Two of the Casa Diablo Little Lake Split-stem points display hydration bands measuring 3.75 µm and 4.04 µm (deepest point), well within the upper range of Elko series points made of the same obsidian from the site (Table 8). Apparently the oldest Little Lake Split-stem point made of Casa Diablo obsidian is a reworked point (Fig. 9, row 5, second from right) found in Unit 1 (50-60 cm) that displays a hydration band measuring 6.85 µm. Hydration values for the Queen and Mono Craters-Glass Mountain points are, respectively, 3.43 µm and 5.82 µm (Table 8).

Gypsum Cave Contracting-stem. Two of the 35 shouldered points recovered from CA-MNO-561 are classified as Gypsum Cave Contracting-stem (Harrington 1933; Clewlow 1967; Thomas 1981; see above). As mentioned, these relatively large, constricting-stem points may temporally coincide to a substantial extent with Little Lake Split-stem points, ca. 4950-3250 b.p., although they do occur in cultural deposits dating somewhat later than 3250 b.p. Both of the Gypsum Cave Contracting-stem specimens were found in the primary area units. One of these is a complete point made of Casa Diablo obsidian with a hydration band measuring 3.96 µm. It was recovered from a depth of 40-50 cm in Unit 8 (Fig. 10, row 1, far right). The other, nearly complete Gypsum Cave Contracting-stem was found in Unit 10 at a depth of 50-60 cm and is made of Queen obsidian (Fig. 10, row 1, far left). This points displays a hydration band measuring 3.86 µm.

Unnamed Shouldered Points. Six shouldered points were recovered during the ARU excavation that cannot be easily assigned to established point series. All of these points are large, relatively broad and thick, with varying basal attributes that crudely suggest three separate categories.

Unnamed Form #1. Three of the six points are large, thick, corner-notched forms with relatively straight stems (Fig. 10, row 2). Two are basal fragments and one is complete. The specimens are similar in overall morphology to other points found in the eastern Sierra and nearby areas (e.g., Meighan 1955:Pl. 3; Hall in preparation; Robert Jackson, personal communication 1983). One such point was located on the surface at the Forest Service Forty site, is made of Fish Springs obsidian, and has a hydration band measuring 4.33 µm (Basgall 1982:48, Fig. 10h). Two comparable points were found at the Sherwin Grade site (Garfinkel and

Fig. 10. (following page) Projectile points and drills from CA-MNO-561 (actual size; coated with ammonium chloride vapor); row 1: Gypsum Cave Contracting-stem ([90-] 10-48, 8-11); row 2: unnamed shouldered form #1 (10-8, 21-3, 10-69A); row 3: unnamed shouldered form #2 (USFS 1-146, [90-] 10-29, 3-29); row 4: unnamed shouldered form #3 (13-18A), two drills. Obsidian sources represented among the points: Queen (10-48, 10-8, 10-29) and Casa Diablo (all others).



Cook 1979:Fig. 161, k). One of the Sherwin Grade specimens was recovered between 50 and 60 cm depth, and Garfinkel and Cook (1979:Tables 5, 13) reported that it is made of Casa Diablo obsidian and features a hydration band measuring 8.18 µm. Several points that apparently resemble this form were found at the Mammoth Junction site (Michels 1965:Pl. 4). Hydration values for these non-sourced specimens range from 5.62 µm to 8.16 µm (Michels 1965:254). Two of the points from CA-MNO-561 were found between 20 and 30 cm in Unit 10 (primary area). One is made of Casa Diablo obsidian and displays a hydration band measuring 4.97 µm. The other point from Unit 10 has a hydration value of 4.56 µm and is made of Queen obsidian (Fig. 10, row 2, far left). A Casa Diablo specimen was located between 10 and 20 cm in Unit 21 (perimeter) and possesses a hydration band measuring 5.78 µm. Relative to most of the other CA-MNO-561 points made of Casa Diablo obsidian, therefore, the hydration data indicate that these three shouldered points were probably deposited during earlier occupations of the site.

Unnamed Form #2. Two of the six unnamed shouldered points are large, thick forms with broad constricting-stems, and shoulders that are decidedly less pronounced than those of the three points described above. Both specimens were found in the primary area units, and one of these (Fig. 10, row 3, far right) is strikingly similar to a Silver Lake point found on the shores of Pleistocene Lake Mohave (Amsden 1937:Pl. 42f). Silver Lake points are usually considered to be older than 5000 b.p. (Bettinger and Taylor 1974). The point from CA-MNO-561 was located between 50 and 60 cm depth in Unit 3, is made of Casa Diablo obsidian, and has a hydration band measuring 6.32 µm. A comparable point, though much larger, occurred between 40 and 50 cm in Unit 10, is made of Queen obsidian, and displays a hydration band measuring 4.81 µm (Table 8). Both of the CA-MNO-561 points in this unnamed category are complete. Also classified in the same category is the point recovered at 50-60 cm depth in a USFS test excavation unit at the site (Fig. 10, row 3, far left). The point is made of Casa Diablo obsidian and possesses the largest hydration band (7.24 µm) of the 79 points from CA-MNO-561 subjected to hydration analysis. Hydration values on the two Casa Diablo obsidian specimens suggest that they may represent the earliest occupations at the site.

Unnamed Form #3. The last of the six unnamed shouldered points recovered in the ARU excavation units consists of the basal fragment of a large corner-notched or side-notched point with an expanding, short stem, and a slightly convex stem base (Fig. 10, row 4, far left). Found at a depth of 70-80 cm in Unit 13 (perimeter), the specimen displays a hydration band measuring 5.82 µm and is made of Casa Diablo obsidian (Table 8).

Nondiagnostic Point Distal Fragments

Twenty-one (77.8%) of the 27 nondiagnostic projectile point distal fragments from CA-MNO-561 were recovered in the primary area units. Of these, 19 (90.5%) were found between 30 and 70 cm depth. The remaining two distal fragments from the primary area units were located at depths of 10-20 cm and 80-90 cm. In contrast, 5 (62.5%) of the 8 distal fragments recovered in the perimeter units occurred in the upper 30 cm of the deposit. Two other fragments were found between 30 and 50 cm depth, and one was found at a depth of 60-70 cm. The lack of but one distal fragment in upper 30 cm in the primary area units becomes more notable given a point basal:distal fragment ratio in these levels of 11:1 and an overall ratio of 5:4 in both primary area and perimeter units (6:5 combined). Although this could reflect a change in the nature of activities involving points in the vicinity of the primary area units (e.g., reduced point production, less distal breakage), hydration data suggest that this stratigraphic pattern is more apparent than real. Thirteen distal fragments were submitted to trace element and hydration analyses. Ten of the thirteen are made of Casa Diablo obsidian (Table 7) and display hydration bands measuring between 2.94 µm and 5.17 µm with a median value of 4.08 µm (Table 8). Half of the ten Casa Diablo obsidian specimens occurred below 30 cm depth in the primary area units. The other five were located in the perimeter units, three of these were found above 30 cm depth.

Hydration values for the Casa Diablo obsidian fragments from the primary area units range from 2.94 µm to 4.87 µm, while values of 3.33 µm, 3.68 µm, and 5.17 µm were obtained for the three Casa Diablo fragments found above 30 cm depth in the perimeter units. The remaining two Casa Diablo specimens from the latter units have bands measuring 4.48 µm (40-50 cm) and 5.07 µm (60-70 cm). Two of the Casa Diablo distal fragments examined from the primary area units, one of which was the lowest specimen found (80-90 cm), possess hydration bands smaller than the smallest observed on Casa Diablo distal fragments located in the perimeter units. Hence, the relative lack of point distal fragments in the upper 30 cm of the deposit in the primary area units may be mostly a

product of stratigraphic redistribution rather than evidence of a chronologically significant change in occupational activities.

Two of the thirteen sourced distal fragments consist of Queen obsidian (Table 7). One of these occurred at a depth of 30-40 cm in Unit 3 (primary area) and displays a hydration band measuring 2.77 µm. The other Queen specimen was located at the same depth in Unit 13 (perimeter) and has a hydration band measuring 3.89 µm. The last distal fragment analyzed consists of Mount Hicks obsidian, features a hydration band measuring 4.61 µm, and occurred at a depth of 10-20 cm in Unit 4 (perimeter).

Nondiagnostic Point Medial Fragments

Nine nondiagnostic projectile point medial fragments were found at CA-MNO-561 (Table 6). Seven (77.8%) of the 9 were recovered in the primary area units; 3 in the upper 20 cm, 3 between 30 and 60 cm, and one at a depth of 70-80 cm. Two medial fragments were located in the perimeter units, one between 30 and 40 cm and another between 50 and 60 cm. Seven of the 9 medial fragments consist of Casa Diablo obsidian and have hydration bands measuring between 2.44 µm and 5.29 µm, with a median value of 3.89 µm (Table 8). One medial fragment made of Queen obsidian was found in the first level (0-10 cm) of Unit 5. This medial fragment has a hydration band measuring 4.01 µm. The deepest medial fragment recovered from CA-MNO-561 (70-80 cm, Unit 19) was also the deepest of the 23 points traced to non-Casa Diablo obsidian sources. Made of Bodie Hills obsidian, the specimen has a hydration band measuring 3.56 µm. All other non-Casa Diablo obsidian points in the trace-element sample occurred above 60 cm depth (Table 7).

CA-MNO-561 Projectile Points: Summary

Subsurface projectile points at CA-MNO-561 were found continuously to a depth of 90 cm in the primary area units, and to a depth of 80 cm in the perimeter units. Of the total 91 points recovered during the ARU excavation, 71 (78%) occurred between 10 and 60 cm below the surface (Table 6). In the primary area units, 52.8% of the points were found between 30 and 60 cm. Over half (52.3%) of the points in the perimeter units occurred in the upper 30 cm of the deposit. Casa Diablo obsidian accounts for 41 (70.7%) of the 58 sourced points found in the primary area units. Eleven (19%) of the 58 are made of Queen obsidian. Mono Craters-Glass Mountain (2), Bodie Hills (2), Fish Springs, and Mount Hicks obsidian sources are represented among the six (10.3%) remaining points from the primary area units. Thirteen (68.4%) of the 19 sourced points from the perimeter units are made of Casa Diablo obsidian. Queen obsidian accounts for 3 (15.8%) of the 19 points. Mono Craters-Glass Mountain, Fish Springs, and Bodie Hills obsidian sources are each represented by a single point from the perimeter units. Including the surface Rose Spring Corner-notched point and the unnamed complete shouldered point found by the USFS, hydration values on 56 Casa Diablo points from CA-MNO-561 range from 2.44 µm to 7.24 µm. The fourteen Queen obsidian points from the site display hydration bands measuring from 2.28 µm to 4.81 µm. Hydration ranges for the other nonlocal obsidian points are: 2.72-5.82 µm, Mono Craters-Glass Mountain (includes measurements for both bands on one of the Humboldt Concave-base points); 3.69-4.90 µm, Fish

Springs; 3.56-3.80 µm, Bodie Hills; and 3.24-4.61 µm, Mount Hicks. All but two of the 23 non-Casa Diablo obsidian points occurred above 50 cm depth at the site (Table 7). The two deeper specimens, one made of Queen obsidian (50-60 cm) and one of Bodie Hills obsidian (70-80 cm), were both found in the primary area units.

In terms of the chronology of prehistoric occupations at CA-MNO-561, the recovery of a substantial number of Elko series points (21) minimally suggests that the site was occupied primarily ca. 3250-1250 b.p. Hydration data for points from the site further indicate the likelihood of earlier, perhaps less frequent or intensive occupations at the site, and sporadic occupations, if any at all, after ca. 1250 b.p. The latter observation is supported by a relative comparison of hydration data from CA-MNO-561 with those reported for the Mammoth Junction site (Michels 1965) and the Forest Service Forty site (Basgall 1982; Jackson 1982). Although the bulk of hydration values from all three sites (regardless of obsidian sources) are quite comparable (see Chapter V), there are proportionately far fewer values below 3.00 µm at CA-MNO-561 than at the other two sites. The hydration data from the site also indicate that the apparent transition in projectile point morphology from Little Lake Split-stem and other early point forms to Elko series point forms took place gradually over a long period of time in the eastern Sierra (Table 8).

The stratigraphic distribution of non-Casa Diablo obsidian points at CA-MNO-561 suggests a pattern of decreasing source diversity with increasing depth. This may be a stratigraphic phenomenon perhaps primarily characteristic of projectile points alone of all other tool and debitage categories (cf. Bettinger 1981:49). Only two of the 65 unmodified flakes submitted for trace-element analysis (5 per 10-cm level to a depth of 130 cm, see below) consist of non-Casa Diablo obsidian. One of these was located at 20-30 cm depth in Unit 3, and the other between 120 and 130 cm in Unit 1. Assuming that it is not purely a consequence of post-depositional stratigraphic redistribution, relatively greater source diversity among the points from the upper part of the deposit may reflect (1) expanding obsidian point (or blank) exchange networks among hunters (Bettinger 1981:51); or (2) increasingly frequent forays into southwestern Long Valley to procure any of a number of material resources and perhaps engage in economic and social interaction by groups of people originating in, or at least carrying obsidian points from outlying areas (e.g., in and around Queen Valley). Ultimate resolution of this stratigraphic pattern among the sourced projectile points from CA-MNO-561, apparently also present at the Lee Vining Creek site (Bettinger 1981), will be dependent upon establishment of hydration rates for each obsidian source thereby permitting integrated chronological analyses of mulitiple-source obsidian assemblages.

Bifaces

Only 9 (2.7%) of the 335 bifaces recovered from CA-MNO-561 are complete. Over 75% (253) of them consist of either distal or medial fragments, and the remaining 73 examples are basal fragments. Nine specimens are illustrated in Fig. 11. The fragments vary in size from relatively small distal sections to large, broad medial or basal portions. Flaking on the bifaces from CA-MNO-561 usually extends across both faces from

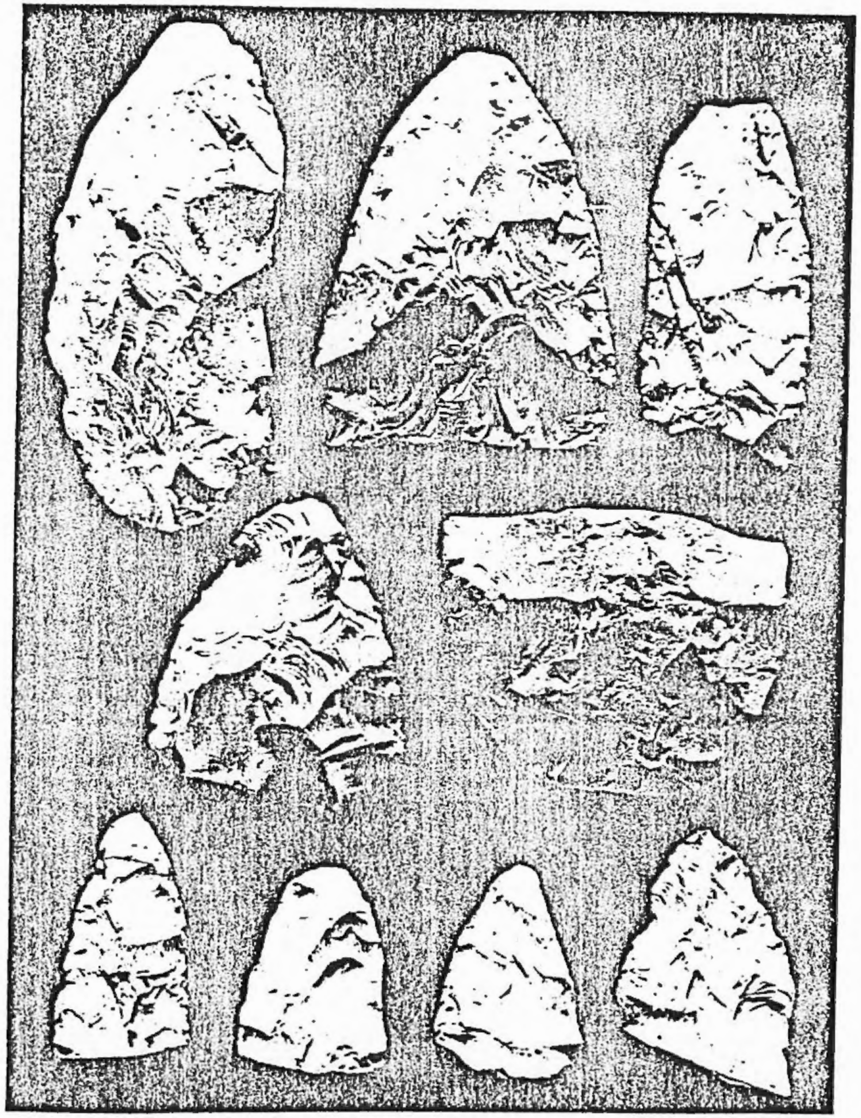


Fig. 11. Bifaces from CA-MNO-561 (actual size; coated with ammonium chloride vapor).

the edges, but in some cases the entire surface of the tool has not been flaked. All of the bifaces are lenticular in cross-section. The complete bifaces and basal fragments display basal configurations that range from being smoothly rounded to abruptly squared-off. Many of the bifaces exhibit use damage in the form of steep, step fractures on one or more edges — presumably indicative of use in various chopping, scraping, and cutting activities. Moreover, given the relatively large number of bifaces found at the site, it is highly probable that some were broken during manufacture for later trade across the Sierra. The notion that biface production for trade took place at CA-MNO-561 is consistent with evidence from several other non-quarry and quarry sites in the eastern Sierra where biface, roughout, and debitage frequencies appear to be much greater than would be expected as a result of purely local patterns of procurement and use (e.g., Singer and Ericson 1977; Bettinger 1980a, 1981; Basgall 1982).

Bifaces were recovered continuously to a depth of 100 cm in the primary area units, where most (81.2%) of the specimens occurred (Table 3), and to a depth of 90 cm in the perimeter units. The stratigraphic distribution of bifaces per unit and level is given in Table 9. Forty-one (65.1%) of the 63 bifaces located in the perimeter units were recovered in the five eastern units (Fig. 6). Nearly half (48.2%) of the bifaces from the primary area units occurred between 30 and 60 cm depth, while 42.9% of the bifaces found in the perimeter units were located in these three levels.

Table 9

DISTRIBUTION OF BIFACES

	Western Perimeter Units		Northern Perimeter Units			Primary Area Units											Eastern Perimeter Units					
Level (cm)	2	21	1	13	14	3	5	6	7	8	9	10	11	18	19	20	4	12	15	16	17	Total
0-10	-	-	-	1	-	5	1	3	2	6	1	3	4	-	6	-	2	-	-	-	1	35
10-20	-	-	-	2	2	3	2	4	3	-	4	2	-	3	2	3	3	3	-	1	-	37
20-30	1	-	-	1	-	2	3	5	1	3	-	3	6	2	2	-	3	-	1	-	-	33
30-40	-	-	2	-	2	5	6	1	3	1	6	3	6	4	3	2	-	1	1	3	1	50
40-50	-	1	1	1	2	3	3	3	3	8	7	11	5	2	3	2	2	1	-	1	-	59
50-60	-		1	-	1	3	1	4	3	7	7	3	1	3	6	3	-	2	-	3	1	49
60-70	-		-	1		1	3	5	2	5	1	5	-	1	3	-	2	2		1	-	32
70-80	1		1	-		2	5	3	-	3	1	2	-	1	3	2	2	3		1		30
80-90	-		1			1	-	2	1	-	-	-	-				-					5
90-100	-		-			4		1									-					5
100-110*			-														-					-
110-120*			-																			-
120-130*			-																			-
Total	2	1	6	6	7	29	24	31	18	33	27	32	22	16	28	12	14	12	2	10	3	335

*Only northern half (1 x 1 m) of unit 1 excavated to this depth

Roughouts

Fifty-six (27.5%) of the 204 roughouts found at CA-MNO-561 are unbroken. Three of these are illustrated in Fig. 12 (upper row). The roughouts are minimally worked (primarily percussion flaking), rarely exhibit use-related edge damage, and were apparently intended for further reduction into other tool forms. The specimens are generally quite thick in comparison to other flaked stone tools from the site. Fifteen of the unbroken roughouts and 39 of the 148 fragments (26.5% of total) retain facets of the original rock cortex, suggesting that at least in some instances largely unworked quarry material (probably from Casa Diablo) was brought to the site for initial or major secondary reduction. This interpretation is encouraged by the presence of over 800 flakes with facets of cortex in the debitage sample recovered in the three control units (1-3, see below).

Almost 90% (182) of the roughouts were found in the primary area units (Table 3) where they occurred continuously to a depth of 100 cm. Nineteen (86.4%) of the 22 roughouts from the perimeter units were located in the five eastern units. In these units, roughouts were found continuously to a depth of 90 cm. One specimen was recovered between 100 and 110 cm in Unit 4. Table 10 gives the stratigraphic distribution of roughouts per unit and level at CA-MNO-561. The bulk of roughouts occurred between 20 and 60 cm depth in both the primary area (64.8%) and perimeter (59.0%) units.

Cores

Of the 32 cores and core fragments recovered during the ARU excava-

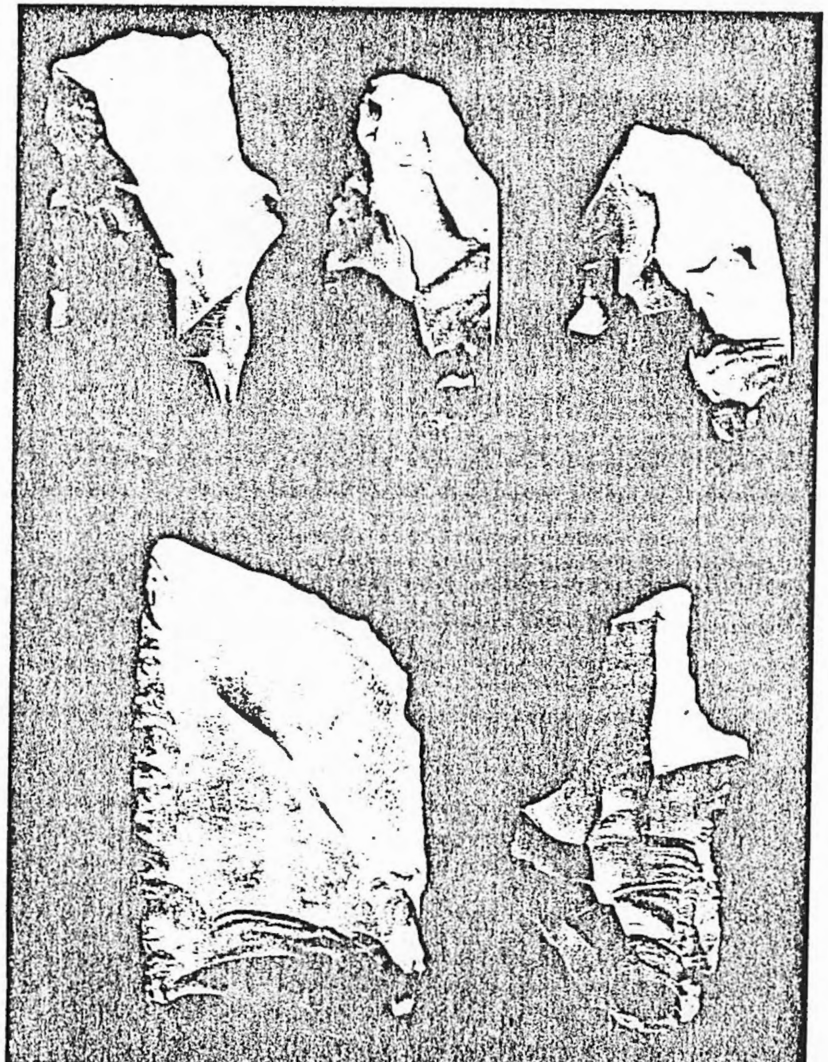


Fig. 12. Roughouts (upper row) and unifaces (lower row) from CA-MNO-561 (actual size; coated with ammonium chloride vapor).

Table 10

DISTRIBUTION OF ROUGHOUTS

	Western Perimeter Units		Northern Perimeter Units			Primary Area Units											Eastern Perimeter Units					
Level (cm)	2	21	1	13	14	3	5	6	7	8	9	10	11	18	19	20	4	12	15	16	17	Total
0-10	-	-	-	-	-	-	2	-	-	-	3	2	1	1	1	3	-	-	-	1	1	15
10-20	-	-	-	-	-	1	3	2	1	3	4	1	-	-	1	-	-	-	1	1	-	18
20-30	-	-	-	1	-	2	-	1	3	2	-	5	6	-	1	-	-	1	1	-	-	23
30-40	-	-	-	-	-	-	1	2	1	1	5	8	3	2	-	-	-	-	-	-	1	24
40-50	1	-	-	1	-	1	1	-	1	4	7	7	6	4	-	5	1	-	2	-	1	42
50-60	-		-	-	-	1	2	-	2	2	9	7	2	5	6	3	-	1	-	-	2	42
60-70	-		-	-		1	-	2	-	2	2	5	-	-	2	1	-	-		1	-	16
70-80	-		-	-		1	-	-	2	2	-	1	2	3	-	3	1	1		-		16
80-90	-		-			1	-	-	1	-	1	1	-				1					5
90-100	-		-			2		-									-					2
100-110*			-														1					1
110-120*			-																			-
120-130*			-																			
Total	1	-	-	2	-	10	9	7	11	16	31	37	20	15	11	15	4	3	4	3	5	204

*Only northern half (1 x 1 m) of unit 1 excavated to this depth

tion at CA-MNO-561, 29 (90.6%) of these were found in the primary area units (Table 3). Three were located in the eastern perimeter units, 2 in the upper 20 cm (Units 12, 15) and one at the bottom of Unit 4 (100-110 cm). No cores were encountered in the northern and western perimeter units. The cores are relatively large, percussion flaked obsidian nodules (or pieces thereof) of variable shape from which large flakes were detached for subsequent modification. Twenty (62.5%) of the cores exhibit facets of the original cortex. In the primary area units, 5 cores were recovered in the upper 30 cm, 21 (72.4%) between 30 and 70 cm, and 3 between 70 and 90 cm. The stratigraphic distribution of cores per unit and level at the site is given in Table 11. Given the tremendous volume of debitage at CA-MNO-561, the number of cores recovered seems low. On the other hand, cores do not account for much of the assemblage at several other sites in the Long Valley-Mono Basin region where stoneworking was an obviously significant activity (e.g., Bettinger 1980a, 1981; Bouscaren, Hall, and Swenson 1982; Basgall 1982). It may be that cores are (expectably) more characteristic of quarry sites, whereas biface and roughout production predominanted at nearby non-quarry workshop sites.

Drills

Two relatively complete drills and five drill tip fragments were recovered at CA-MNO-561. These tools are distinguished by a narrow, relatively thick, usually bifacially flaked working projection. One of the larger specimens is illustrated in Fig. 10 (row 4, second from right). The only non-obsidian flaked stone tool in the CA-MNO-561

Table 11

DISTRIBUTION OF CORES

	Western Perimeter Units		Northern Perimeter Units			Primary Area Units											Eastern Perimeter Units					
Level (cm)	2	21	1	13	14	3	5	6	7	8	9	10	11	18	19	20	4	12	15	16	17	Total
0-10	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	2
10-20	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	3
20-30	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2
30-40	-	-	-	-	-	-	-	1	-	1	-	1	-	-	-	-	-	-	-	-	-	3
40-50	-	-	-	-	-	-	-	-	1	-	2	-	1	-	-	-	-	-	-	-	-	4
50-60	-	—	-	-	-	-	-	1	2	-	3	1	-	-	1	-	-	-	-	-	-	8
60-70	-		-	-	—	-	-	-	1	2	-	1	-	1	1	-	-	-	—	-	-	6
70-80	-		-	-		1	-	-	-	-	-	-	-	-	1	-	-	-		-	—	2
80-90	-		-	—		1	-	-	-	-	-	-	-	—	—	—	-	—		—		1
90-100	-		-			-	—	-	—	—	—	—	—				-					-
100-110*	—		-			—		—									1					1
110-120*			-														—					-
120-130*			-																			-
			—																			—
Total	-	-	-	-	-	3	-	3	5	3	7	3	1	1	3	-	1	1	1	-	-	32

*Only northern half (1 x 1 m) of unit 1 excavated to this depth

collection is a cryptocrystalline drill tip fragment (Fig. 10, row 4, far right) that was found at a depth of 20-30 cm in Unit 19 (primary area). Two of the 6 obsidian drills were located in the eastern perimeter units (0-10, 40-50 cm) and the other four occurred in the primary area units. In the latter units, single specimens were found at depths of 0-10, 10-20, 20-30, 40-50, and 80-90 cm. The stratigraphic distribution of drills per unit and level at the site is given in Table 12.

Unifaces

The 224 unifaces found at CA-MNO-561 consist of 162 complete and 62 fragmentary specimens. Most of the unifaces were fashioned by unifacial retouching on one or more edges of relatively large flakes. Unifacially prepared working edges also occur on a few apparent core fragments (classified here as unifaces). Two of the larger unifaces are illustrated in Fig. 12 (lower row). Of the total 224 unifaces, 163 (72.8%) were recovered in the primary area units (Table 3) although 60.7% of the unifaces located in the upper 10 cm occurred in the northern and eastern perimeter units. Table 13 gives the stratigraphic distribution of unifaces per unit and level at the site. Unifaces were found continuously to a depth of 90 cm in the primary area units, 108 (66.3%) occurred between 30 and 60 cm depth. Only two unifaces were found in the western perimeter units (0-10, 70-80 cm). Thirty-two (54.2%) of the 59 unifaces from the northern and eastern perimeter units were recovered in the upper 30 cm of the deposit.

Flaked Stone Debitage

As discussed earlier, an attempt to recover all debitage could be

Table 12

DISTRIBUTION OF DRILLS

	Western Perimeter Units		Northern Perimeter Units			Primary Area Units											Eastern Perimeter Units					
Level (cm)	2	21	1	13	14	3	5	6	7	8	9	10	11	18	19	20	4	12	15	16	17	Total
0-10	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2
10-20	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1
20-30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1
30-40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40-50	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	2
50-60	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60-70	-		-	-		-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-
70-80	-		-	-		-	-	-	-	-	-	-	-	-	-	-	-	-		-		-
80-90	-		-			-	1	-	-	-	-	-	-				-					1
90-100	-		-			-		-									-					-
100-110*			-														-					-
110-120*			-																			-
120-130*			-																			-
Total	-	-	-	-	-	-	2	-	-	-	1	1	-	-	1	-	-	-	1	1	-	7

*Only northern half (1 x 1 m) of unit 1 excavated to this depth

Table 13

DISTRIBUTION OF UNIFACES

	Western Perimeter Units		Northern Perimeter Units			Primary Area Units											Eastern Perimeter Units					
Level (cm)	2	21	1	13	14	3	5	6	7	8	9	10	11	18	19	20	4	12	15	16	17	Total
0-10	-	1	2	1	4	1	-	-	-	1	1	5	-	-	2	-	-	1	4	4	1	28
10-20	-	-	-	1	1	-	-	-	2	1	1	2	2	2	-	1	1	3	1	-	1	19
20-30	-	-	-	-	-	-	-	1	-	1	1	2	1	4	1	1	-	1	1	3	2	19
30-40	-	-	-	-	1	1	1	4	1	-	5	5	5	4	2	2	-	2	2	3	1	39
40-50	-	-	-	-	1	3	4	4	3	3	6	8	1	-	2	-	1	1	-	-	-	37
50-60	-		-	3	2	1	1	1	2	9	7	7	4	6	4	2	-	-	1	-	2	52
60-70	-		-	1		-	1	-	1	3	2	2	-	1	1	-	1	1		-	2	16
70-80	1		-	-		-	-	1	-	2	-	-	1	3	1	2	-	1		-		12
80-90	-		-			-	-	1	-	-	-	-	-				1					2
90-100	-		-			-		-									-					-
100-110*			-														-					-
110-120*			-																			-
120-130*			-																			-
Total	1	1	2	6	9	6	7	12	9	20	23	31	14	20	13	8	4	10	9	10	9	224

*Only northern half (1 x 1 m) of unit 1 excavated to this depth

made only in Units 1-3 (control units). The quantitative description of debitage from CA-MNO-561 presented below is therefore based on debitage excavated in the three control units. Judging by a crude laboratory assessment, at least 125,000 (if not 150,000) pieces of debitage were removed from the site during the excavations of Units 4-21. Five categories (defined above) of debitage are recognized in the control unit collection: biface retouch flakes, use-modified flakes with or without cortex, and unmodified flakes with or without cortex. Except for three unmodified cryptocrystalline flakes and a single unmodified rhyolite flake, all debitage found at CA-MNO-561 derived from obsidian stoneworking.

Based on frequency, the stratigraphic distribution of debitage in the control units and the percent located in each unit are given in Table 14. Table 15 supplies the same information, but is based on the total weight of debitage. According to the frequency data, unmodified flakes (31,116 total) account for 95.5% of the debitage in Unit 3 and 97.6% of the debitage in Units 1 and 2. Based on the total weight of unmodified flakes these figures are, respectively, 72.4% and 74.2%. The differences in percentages undoubtedly reflect an abundance of small, light unmodified flakes and relatively larger, heavier biface retouch, use-modified, and unmodified (with cortex) flakes. Aside from the sheer volume difference (Fig. 7, Tables 14-15) between Unit 3 (primary area) and Units 1-2 (perimeter), debitage in the control units had a variable, but nonetheless fairly even stratigraphic distribution. Unit 3 had a slight concentration of debitage between 30 and 60 cm depth (40.7% based on frequency, 45.2% based on total weight). Field observations and

Table 14

DISTRIBUTION OF DEBITAGE IN UNITS 1-3 (CONTROL UNITS)

Based on Frequency

Level (cm)	Number of Units Excavated to This Depth	Biface Retouch Flake	Use-modified Flake	Use-modified Flake with Cortex	Unmodified Flake	Unmodified Flake with Cortex	Total
0-10	3	16	44	2	2,297	11	2,370
10-20	3	13	43	7	3,820	153	4,036
20-30	3	13	25	4	2,279	47	2,368
30-40	3	30	37	5	4,490	141	4,703
40-50	3	13	40	2	4,390	121	4,566
50-60	3	15	26	4	3,108	102	3,255
60-70	3	19	29	1	2,519	64	2,632
70-80	3	17	20	1	3,368	43	3,449
80-90	3	4	14	2	2,007	37	2,064
90-100	3	6	20	4	2,629	83	2,742
100-110	1	1	3	-	119	-	123
110-120	1	-	2	-	49	-	51
120-130	1	1	1	-	41	-	43
Total	3	148	304	32	31,116	802	32,402
Percent per Unit							
	1	4.7	15.5	18.8	10.9	2.2	10.7
	2	8.1	29.9	12.5	13.6	0.4	13.4
	3	87.2	54.6	68.8	75.5	97.4	75.9
	Total	100.0	100.0	100.1	100.0	100.0	100.0

Table 15

DISTRIBUTION OF DEBITAGE IN UNITS 1-3 (CONTROL UNITS)

Based on Total Weight (g)

Level (cm)	Number of Units Excavated to This Depth	Biface Retouch Flake	Use-modified Flake	Use-modified Flake with Cortex	Unmodified Flake	Unmodified Flake with Cortex	Total
0-10	3	36.95	213.31	26.77	1,087.01	32.26	1,396.30
10-20	3	30.20	265.37	53.06	1,692.73	263.20	2,304.56
20-30	3	19.43	108.62	50.84	1,096.33	117.92	1,393.14
30-40	3	51.42	224.68	104.44	1,946.81	373.63	2,700.98
40-50	3	25.47	199.09	7.00	1,906.73	357.11	2,495.40
50-60	3	37.09	285.34	44.09	1,310.23	257.92	1,934.67
60-70	3	73.41	184.53	11.90	870.28	79.80	1,219.92
70-80	3	22.54	264.24	58.15	1,146.97	228.91	1,720.81
80-90	3	5.67	75.68	7.47	518.38	24.49	631.69
90-100	3	6.70	150.27	119.54	766.55	99.52	1,142.58
100-110	1	0.60	11.22	-	50.40	-	62.22
110-120	1	-	6.05	-	17.31	-	23.36
120-130	1	0.50	4.12	-	6.19	-	10.81
Total	3	309.98	1,992.52	483.26	12,415.92	1,834.76	17,036.44
Percent per Unit							
1		1.3	17.4	22.3	15.9	3.9	14.7
2		7.0	25.6	19.9	11.2	0.7	11.9
3		91.7	57.0	57.9	72.9	95.3	73.4
	Total	100.0	100.0	100.1	100.0	99.9	100.0

flaked stone tool distributions in the eleven primary area units suggest that this concentration at 30-60 cm would become more outstanding given complete debitage counts and weights from all units.

Estimates of the mean weights for each of the five debitage categories in the control unit collection are given, on an overall and stratigraphic basis, in Table 16. Ideally, debitage mean weight estimates would entail the separate weighing of each piece of debitage in order to estimate the variance accompanying each mean estimate. This is a tremendously time-consuming effort and it is unlikely that the gain in precision would be all that useful. However, it is possible to obtain with much less effort estimates of overall mean weights and variances by treating the 10-cm excavation levels in each control unit as sample units and deriving a ratio mean estimate (r) based on two variables: debitage frequency and total weight per level (cf. Kish 1965:186; Cochran 1977: 31). Since, in this instance, the number (n) of sample (level) units per control unit is equal to the actual population (N) of sample units, a finite population correction (1 - f, where f = n/N) is not required in the computation of variances for the ratio estimates. Thus, for a given category of debitage in Unit 3:

$r = x/y$

where

$x = \Sigma x_i$ = sum of debitage weights per level

$y = \Sigma y_i$ = sum of debitage counts per level

and

x_i = total debitage weight in level i

Table 16

MEAN WEIGHTS (g) FOR DEBITAGE IN UNITS 1-3 (CONTROL UNITS)

Level (cm)	Biface Retouch Flake PA	Biface Retouch Flake P	Use-modified Flake PA	Use-modified Flake P	Use-modified Flake with Cortex PA	Use-modified Flake with Cortex P	Unmodified Flake PA	Unmodified Flake P	Unmodified Flake with Cortex PA	Unmodified Flake with Cortex P
0-10	2.65	1.28	4.35	5.16	13.39	-	0.45	0.54	1.20	5.96
10-20	2.44	0.89	5.52	7.39	8.28	3.40	0.45	0.44	1.73	1.57
20-30	1.47	1.81	4.00	5.43	-	12.71	0.43	0.59	2.38	4.44
30-40	1.71	-	6.77	4.62	20.89	-	0.43	0.44	2.61	3.92
40-50	2.14	0.96	4.59	5.77	3.50	-	0.41	0.56	2.98	1.77
50-60	2.24	3.13	9.45	13.41	13.53	3.50	0.41	0.45	2.55	0.52
60-70	3.86	-	8.01	5.50	11.90	-	0.33	0.38	1.26	0.19
70-80	1.47	0.25	18.57	6.66	-	58.15	0.33	0.37	5.05	10.95
80-90	1.77	0.37	6.12	5.01	1.80	5.67	0.21	0.35	0.66	-
90-100	1.32	0.71	8.97	6.54	18.71	41.06	0.28	0.32	1.20	-
100-110	-	0.60	-	3.74	-	-	-	0.42	-	-
110-120	-	-	-	3.03	-	-	-	0.35	-	-
120-130	-	0.50	-	4.12	-	-	-	0.15	-	-
r or r_w	2.20±0.71*	1.10(-)	6.84±2.43	6.61±1.49	12.71(-)	20.58(-)	0.39±0.05	0.47±0.05	2.24±0.65	4.23(-)

PA - primary area control unit 3
P - perimeter control units 1-2

*Estimated 95% confidence limits; (-) indicates limits not estimated where cv(x) or cv(y) is >0.25 (see text)

y_i = total debitage count in level i

This ratio mean estimate is equivalent to the weighted mean of the mean debitage weights per level (Kish 1965:186). The variance (var) of the estimate is approximated (Kish 1965:187-188; Cochran 1977:31-33) by:

$$\text{var}(r) = [\text{var}(x) + r^2\text{var}(y) - 2r\text{cov}(x,y)]/y^2$$

$$= n[s_x^2 + r^2 s_y^2 - 2rs_{xy}]/y^2$$

where

$$s_x^2 = [\Sigma x_i^2 - (x^2/n)]/(n-1)$$

$$s_y^2 = [\Sigma y_i^2 - (y^2/n)]/(n-1)$$

$$s_{xy} = [\Sigma x_i y_i - (xy/n)]/(n-1)$$

also,

$$\text{var}(r) = s_r^2/n$$

where

$$s_r^2 = s_z^2/(y/n)^2$$

and

$$s_z^2 = \Sigma z_i^2/(n-1)$$

with

$$z_i = x_i - ry_i$$

thus

$$s_r^2 = n\text{var}(r)$$

The estimate of var(r) is weighted by $y_i/(y/n)$, the relative sum of debitage per level i. A standard error (se) for r is equal to the square root of var(r).

Because both numerator and denominator vary from level to level (Tables 14-15), the sampling distribution of r is more complicated than that for a simple univariate mean estimate (Cochran 1977:31). Effective use of r, therefore, requires good control over the variation in debitage weights and frequencies between levels. In the present case, this control is measured by the coefficients of variation (cv) of x and y:

$$cv(x) = se(x)/x$$

$$cv(y) = se(y)/y$$

and

se(x) = square root of var(x)

se(y) = square root of var(y)

Cv(x) and cv(y) values less than 0.10 are most preferable, but higher values can sometimes be tolerated (Kish 1965:186, 218; Cochran 1977:153). Relatively low coefficients are necessary to hold the bias of the estimate to a negligible level and to ensure valid approximation of the variance (Kish 1965:218). Controlling cv(x) and cv(y) improves with increased sample size since the distribution of r tends toward normality (Cochran 1977:31). In small samples, the distribution of r is usually skewed, resulting in higher cv values and a more biased estimate of R. Taking this into account, cv(x) and cv(y) values less than 0.25 are considered here as reasonably low enough to attempt computation of a variance for a given ratio estimate of mean debitage weight. Confidence limits for r can then be estimated as:

$$r \pm t\,se(r)$$

where

t = the percentage point of a given confidence probability $(1 - \alpha)$ obtained from a Student's t table with n - 1 degrees of freedom

For the two perimeter control units, a weighted ratio mean (r_w) combining data from both units was derived to estimate overall debitage mean weights in each category. (There is a slight, but probably insignificant bias in this procedure since only half of each level was excavated below 100 cm in Unit 1). Weighted ratio estimates for Units 1 and 2 were computed as follows:

$$r_w = \Sigma W_p r_p$$

where

W_p = proportion of all excavated levels in unit p (1 or 2)

r_p = ratio estimate of mean debitage weight in unit p

thus

$$var(r_w) = \Sigma W_p^2 var(r_p)$$

The se of r_w is equal to the square root of $var(r_w)$. Confidence limits for r_w can be computed as:

$$r_w \pm t\,se(r_w)$$

where

t = the percentage point of a given confidence probability $(1 - \alpha)$ obtained from a Student's t table with degrees of freedom equal (cf. Cochran 1977:96) to:

$$(\Sigma s^2_{r_p})^2/[\Sigma s^4_{r_p}/(n_p - 1)]$$

As can be seen in Table 16, biface retouch flakes and unmodified flakes with cortex are usually heavier than unmodified flakes without cortex, but lighter than use-modified flakes (with or without cortex).

These differences can probably be attributed to the use of larger flakes with more durable edges for simple flake tools, and to a classification system in which all sizes of unmodified tool shaping and retouching flakes, and fragments of these therein, are lumped together into the same category. This results in estimates of the mean weight of unmodified flakes that are necessarily biased toward small light flakes (cf. Bettinger 1981:38). Unmodified flakes with cortex tend to be heavier than unmodified flakes without cortex, and the same distinction holds between use-modified flakes with and without cortex. The observed difference in mean weights relative to the presence or absence of cortex probably reflects a tool reduction sequence that initially involved removal of relatively large flakes many of which retained part of the original cortex. Overall, biface retouch, use-modified, and unmodified flakes in the CA-MNO-561 control unit collection appear to be much heavier on the average than flakes given the same labels at the Triple R and Lee Vining sites (Bettinger 1980a, 1981). Moreover, despite the larger number of unmodified flakes in the CA-MNO-561 sample, Bettinger (1980a, 1981) reported far more biface retouch and use-modified flakes at Triple R, and far more biface retouch flakes at Lee Vining. Although it is reasonable to assume that these differences reflect, to a limited extent, functional differences between sites, most of the variation in flake counts and weights can probably be attributed to slightly contrasting definitions of debitage categories. Finally, the data arrayed in Table 16 suggest that, with one notable exception, debitage weights in each category do not exhibit any particular stratigraphic pattern. Unmodified flakes (without cortex) from Unit 3 progressively decrease in

size with increasing depth, a trend less well-defined but nonetheless evident in the stratigraphic distribution of mean weights of unmodified flakes from the two perimeter control units. This most likely represents a tendency for extremely small flakes and flake fragments to continually migrate downwards in the deposit, thereby forming an increasingly greater proportion of the unmodified flakes at deeper levels.

To explicitly evaluate stratigraphic integrity at CA-MNO-561, 65 unmodified flakes (5 per 10-cm level) were subjected to trace-element and hydration analyses. Fifty specimens were selected from Unit 3 (0-100 cm), five from Unit 4 (100-110 cm), and ten from Unit 1 (110-130 cm). Unmodified flakes were chosen over other debitage and tool categories on the basis of two assumptions: (1) these flakes probably derived from the working of local (Casa Diablo) obsidian (hence, maximum relative comparability of hydration data); and (2) these flakes are probably least likely to have been affected by re-use and other processes of curate behavior (hence, minimum cultural disturbance of the stratigraphic record [cf. Binford 1973; Bettinger 1980b]). Because of the apparent downward migration of small unmodified flakes, specimens larger than 16 cm^2 were selected whenever possible (few of the flakes available from below 100 cm depth meet this requirement).

The expectation that the 65 unmodified flakes consist of Casa Diablo obsidian was nearly realized. Aside from two (3.1%) Mono Craters-Glass Mountain specimens, the remaining 63 (96.9%) unmodified flakes are of Casa Diablo origin. Though separated by a meter of deposit (20-30 cm, Unit 3; 120-130 cm, Unit 1), the two Mono Craters-Glass Mountain flakes possess hydration bands of similar thicknesses: 5.35 μm and 5.66 μm —

clearly an indication of extensive stratigraphic mixing. One of the four Casa Diablo specimens from 120-130 cm in Unit 1 (OHL 1754, see Appendix B for unmodified flake hydration measurements) displays two hydration bands measuring 4.07 μm and 5.96 μm. Since it cannot be determined, as discussed earlier with respect to a double-banded Humboldt Concave-base point, whether the two hydration values for this unmodified flake reflect one or two occupational episodes at CA-MNO-561, it is assumed that the measurements document separate periods of stoneworking activity at the site.

Hydration values (64) for the 63 unmodified flakes of Casa Diablo obsidian range from 1.92 μm to 7.50 μm. The two largest bands measured occur on specimens found below 70 cm depth at CA-MNO-561. Hydration bands measuring 7.10 μm and 7.50 μm are displayed by, respectively, unmodified flakes recovered at 70-80 cm depth in Unit 3 and between 110 and 120 cm in Unit 1. Sixty (93.8%) of the 64 hydration values for Casa Diablo obsidian unmodified flakes fall between 3.37 μm and 5.96 μm. The two most recent hydration measurements on Casa Diablo obsidian artifacts from CA-MNO-561 occur on unmodified flakes found at depths of 10-20 cm (2.14 μm) and 70-80 cm (1.94 μm) in Unit 3. Using only hydration data for specimens consisting of Casa Diablo obsidian, the mean, median, and range of hydration values per 10-cm level at CA-MNO-561 are given in Table 17 for unmodified flakes and projectile points, and for the two artifact categories combined. The figures shown in Table 17 are persuasive evidence of extensive stratigraphic mixing of the cultural deposit, although there are a few indications of some stratigraphic integrity (e.g., hydration means for unmodified flakes are lowest in the upper two

Table 17

STRATIGRAPHIC DISTRIBUTION OF HYDRATION MEASUREMENT DATA FOR OBSIDIAN SAMPLES TRACED TO THE CASA DIABLO SOURCE

(values in microns)

	Unmodified Flakes				Projectile Points*				Combined			
Level (cm)	n	Mean	Median	Range	n	Mean	Median	Range	n	Mean	Median	Range
0-10	5	3.66	3.65	3.55-3.85	4	3.37	3.54	2.44-3.94	9	3.53	3.65	2.44-3.94
10-20	5	3.85	4.26	2.14-4.40	10	4.21	3.94	3.23-5.78	15	4.09	4.09	2.14-5.78
20-30	4	4.58	4.70	3.80-5.11	5	4.01	3.82	3.67-4.97	9	4.26	3.93	3.67-5.11
30-40	5	4.59	4.52	4.40-4.83	10	4.14	3.80	2.89-5.79	15	4.29	4.42	2.89-5.79
40-50	5	4.59	4.91	3.39-5.08	7	4.26	3.96	2.94-5.87	12	4.40	4.48	2.94-5.87
50-60	5	4.40	4.48	3.80-4.99	9	4.47	3.97	3.17-6.85	14	4.44	4.31	3.17-6.85
60-70	5	4.14	4.13	3.95-4.37	2	4.97	4.97	4.87-5.07	7	4.38	4.14	3.95-5.07
70-80	5	4.25	4.12	1.94-7.10	4	4.86	4.96	3.69-5.82	9	4.52	4.16	1.94-7.10
80-90	5	4.06	3.94	3.37-4.73	3	3.87	4.04	3.30-4.28	8	3.99	3.99	3.30-4.73
90-100	5	4.09	4.05	3.82-4.59	-				5	4.09	4.05	3.82-4.59
100-110	5	4.35	4.43	3.74-5.02	-				5	4.35	4.43	3.74-5.02
110-120	5	5.66	5.40	4.38-7.50	-				5	5.66	5.40	4.38-7.50
120-130	4**	4.73	4.74	4.07-5.96	-				5	4.73	4.74	4.07-5.96
0-30	14	3.99	3.97	2.14-5.11	19	3.98	3.86	2.44-5.78	33	3.98	3.86	2.14-5.78
30-60	15	4.53	4.52	3.39-5.08	26	4.28	3.93	2.89-6.85	41	4.37	4.47	2.89-6.85
60-90	15	4.15	4.12	1.94-7.10	9	4.55	4.28	3.30-5.82	24	4.30	4.14	1.94-7.10
90+	20	4.71	4.51	3.74-7.50	-				20	4.71	4.51	3.74-7.50
Total	64	4.38	4.36	1.94-7.50	54	4.22	3.94	2.44-6.85	118	4.31	4.09	1.94-7.50

*Excludes hydration data for a Rose Spring Corner-notched specimen (OHL 1776: 4.20 ± 0.20) found on the surface near unit 1, and for an unnamed shouldered form #2 specimen (OHL 1811: 7.24 ± 0.20) recovered during USFS test excavations (unit 1, 50-60 cm); both specimens traced to Casa Diablo source

**Four samples, five bands measured; double band specimen: OHL 1754; all bands included in computations levels [0-20 cm, Unit 3] and highest in the lower two levels [110-130 cm, Unit 1]). A disturbed but somewhat intact stratigraphy is also evident in the hydration means, medians, and ranges obtained by consolidating the level data into four stratigraphic groups: 0-30, 30-60, 60-90, and 90-130 cm (Table 17). Hydration results for other prehistoric sites in in the Long Valley-Mono Basin region also suggest well-mixed subsurface cultural deposits — an apparent characteristic of most open sites in the eastern Sierra (Michels 1965, 1969; Bettinger 1981; Bouscaren, Hall, and Swenson 1982; Basgall 1982). It should be noted, however, that obsidian flows within the Casa Diablo source (the post-caldera "resurgent dome" in Long Valley) were extruded over perhaps 100,000 years. Hence, there are probably slight, intra-source variations in the chemical compositions of exploited obsidian outcrops and deposits. For example, Casa Diablo obsidian in the area of Lookout Mountain (north side of dome) has a sugary appearance that does not seem to characterize obsidian in the area of Casa Diablo Hot Springs (south side of dome). Although the effect of intra-source chemical variation on hydration rates has not been determined, it is possible that tools and debitage consisting of obsidian from different areas on the Casa Diablo dome hydrate at slightly different rates. In turn, this might account for at least part of the generally poor correspondence between stratigraphic provenience and hydration values at CA-MNO-561 and other sites in the region where Casa Diablo obsidian predominates. But even with obsidian source provenience controlled for, it is not anticipated that an intact stratigraphy will emerge from the CA-MNO-561 hydration data since hydration values for non-Casa Diablo obsidian specimens at the site (see Appendix B) also indicate

stratigraphic mixing.

The overall ranges in hydration values for Casa Diablo unmodified flakes (1.94-7.50 µm) and projectile points (2.44-7.24 µm) from CA-MNO-561 are quite similar. Of possible interest is the fact that only two (3.1%) of the 64 hydration values for the flakes are less than 3.37 µm, whereas 8 (16.7%) of the 56 points display bands smaller than 3.37 µm. Though most likely a product of sampling error, the contrast in hydration values could reflect occupations of the site that followed earlier occupations during which the bulk of obsidian stoneworking at the site took place.

Bedrock Mortar

As mentioned earlier, a single, small, round bedrock mortar occurs on one of the glacial erratics just north of the northernmost group of primary area units at CA-MNO-561 (Fig. 6). The mortar has a well-polished surface, is 9 cm in diameter, and its depression has a maximum depth of ca. 0.7 cm. It was probably used in conjunction with a basketry hopper to process (pound and grind) vegetal foods such as pinyon pine nuts, acorns, grass seeds, or berries. The age of the mortar relative to the surface and subsurface deposit at CA-MNO-561 cannot be determined.

Ground Stone Tools

Eight fragmentary rhyolite or rhyodacite ground stone tools were recovered during the ARU excavation at CA-MNO-561. The stratigraphic distributions of the three millingstone and five mano fragments per unit and level at the site are given in Tables 18 and 19. Seven (87.5%) of the ground stone tools were found in the westernmost four units (10-11, 19-20) of the northern group of primary area units (Fig. 6). These units

Table 18

DISTRIBUTION OF MILLINGSTONES

	Western Perimeter Units		Northern Perimeter Units			Primary Area Units											Eastern Perimeter Units					
Level (cm)	2	21	1	13	14	3	5	6	7	8	9	10	11	18	19	20	4	12	15	16	17	Total
0-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20-30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30-40	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	2
40-50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50-60	-		-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1
60-70	-		-	-		-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-
70-80	-		-	-		-	-	-	-	-	-	-	-	-	-	-	-	-		-		-
80-90	-		-			-	-	-	-	-	-	-	-				-					-
90-100	-		-			-		-									-					-
100-110*			-														-					-
110-120*			-																			-
120-130*			-																			-
Total	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	3

*Only northern half (1 x 1 m) of unit 1 excavated to this depth

Table 19

DISTRIBUTION OF MANOS

	Western Perimeter Units		Northern Perimeter Units			Primary Area Units											Eastern Perimeter Units					
Level (cm)	2	21	1	13	14	3	5	6	7	8	9	10	11	18	19	20	4	12	15	16	17	Total
0-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20-30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30-40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40-50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50-60	-		-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	2
60-70	-		-	-		-	-	-	-	-	-	-	-	-	-	-	-	-		1	-	1
70-80	-		-	-		-	-	-	-	-	-	-	-	-	1	1	-	-		-		2
80-90	-		-			-	-	-	-	-	-	-	-				-					-
90-100	-		-			-		-									-					-
100-110*			-														-					-
110-120*			-																			-
120-130*			-																			-
Total	-	-	-	-	-	-	-	-	-	-	-	1	1	-	1	1	-	-	-	1	-	5

*Only northern half (1 x 1 m) of unit 1 excavated to this depth

were located on the east side of a large erratic that together with adjacent boulders forms a wall ca. 1.0-2.5 m high extending northwards ca. 8 m from its south end. To avoid confusion, it should be noted here that the boulders comprising this wall are somewhat incorrectly depicted in Fig. 6. The distance between the wall and the rectilinear, irregular western edge of the two groups of primary area units was about half that indicated in Fig. 6.

All of the millingstone fragments occurred in Unit 11. Two fragments were located between 30 and 40 cm depth. One of these has a well-pitted, relatively flat working surface (10 x 6 cm), the other is a small fragment (6 x 3 cm working surface) consisting of similar, but probably different lithic material. The largest millingstone fragment was found at a depth of 50-60 cm in Unit 11 and has a relatively smooth, concave working surface (16 x 11 cm). A unifacial mano fragment was also found in this level. Two bifacial mano fragments occurred between 70 and 80 cm depth in Units 19 and 20. A small fragment of what was probably a unifacial mano was located at 50-60 cm depth in Unit 10. The remaining mano fragment recovered from the site was found at a depth of 60-70 cm in Unit 16 (eastern perimeter).

Stratigraphic Distributions

Table 20 summarizes the relative (percentage) stratigraphic distributions of flaked and ground stone tools in the 21 ARU excavation units at CA-MNO-561. Relative distributions within the primary area and perimeter units are given in Tables 21 and 22. Tables 23 and 24 describe the relative stratigraphic distributions of debitage in the three control

Table 20

FLAKED AND GROUND STONE TOOLS: PERCENT PER LEVEL IN EACH CATEGORY

Percentages Based on All Units

Level (cm)	Number of Units Excavated to This Depth	Projectile Point	Biface	Roughout	Core	Drill	Uniface	Flaked Stone Tools - Total	Millingstone	Mano	Ground Stone Tools - Total
0-10	21	7.7	10.4	7.4	6.3	28.6	12.5	10.0	-	-	-
10-20	21	19.8	11.0	8.8	9.4	14.3	8.5	10.8	-	-	-
20-30	21	8.8	9.9	11.3	6.3	14.3	8.5	9.6	-	-	-
30-40	21	19.8	14.9	11.8	9.4	-	17.4	15.0	66.7	-	25.0
40-50	21	15.4	17.6	20.6	12.5	28.6	16.5	17.7	-	-	-
50-60	20	14.3	14.6	20.6	25.0	-	23.2	18.4	33.3	40.0	37.5
60-70	18	5.5	9.6	7.8	18.8	-	7.1	8.4	-	20.0	12.5
70-80	17	5.5	9.0	7.8	6.3	-	5.4	7.3	-	40.0	25.0
80-90	11	3.3	1.5	2.5	3.1	14.3	0.9	1.9	-	-	-
90-100	5	-	1.5	1.0	-	-	-	0.8	-	-	-
100-110	2	-	-	0.5	3.1	-	-	0.2	-	-	-
110-120	1	-	-	-	-	-	-	-	-	-	-
120-130	1	-	-	-	-	-	-	-	-	-	-
Total	21	100.1	100.0	100.1	100.2	100.1	100.0	100.1	100.0	100.0	100.0

Table 21

FLAKED AND GROUND STONE TOOLS: PERCENT PER LEVEL IN EACH CATEGORY

Percentages Based on Primary Area Units*

Level (cm)	Number of Units Excavated to This Depth	Projectile Point	Biface	Roughout	Core	Drill	Uniface	Flaked Stone Tools - Total	Millingstone	Mano	Ground Stone Tools - Total
0-10	11	7.1	11.4	7.1	6.9	20.0	6.1	8.6	-	-	-
10-20	11	15.7	9.6	8.8	3.4	20.0	6.7	9.2	-	-	-
20-30	11	8.6	9.9	11.0	6.9	20.0	7.4	9.4	-	-	-
30-40	11	20.0	14.7	12.6	10.3	-	18.4	15.3	66.7	-	28.6
40-50	11	17.1	18.4	19.8	13.8	20.0	20.9	19.0	-	-	-
50-60	11	15.7	15.1	21.4	27.6	-	27.0	19.8	33.3	50.0	42.9
60-70	11	5.7	9.6	8.2	20.7	-	6.7	8.6	-	-	-
70-80	11	5.7	8.1	7.7	6.9	-	6.1	7.2	-	50.0	28.6
80-90	8	4.3	1.5	2.2	3.4	20.0	0.6	1.9	-	-	-
90-100	2	-	1.8	1.1	-	-	-	1.0	-	-	-
Total	11	99.9	100.1	99.9	99.9	100.0	99.9	100.0	100.0	100.0	100.1

*Units 3, 5-11, 18-20

Table 22

FLAKED AND GROUND STONE TOOLS: PERCENT PER LEVEL IN EACH CATEGORY

Percentages Based on Perimeter Units*

Level (cm)	Number of Units Excavated to This Depth	Projectile Point	Biface	Roughout	Core	Drill	Uniface	Flaked Stone Tools - Total	Millingstone	Mano	Ground Stone Tools - Total
0-10	10	9.5	6.3	9.1	-	50.0	29.5	15.7	-	-	-
10-20	10	33.3	17.5	9.1	66.7	-	13.1	17.4	-	-	-
20-30	10	9.5	9.5	13.6	-	-	11.5	10.5	-	-	-
30-40	10	19.0	15.9	4.5	-	-	14.8	14.0	-	-	-
40-50	10	9.5	14.3	27.3	-	50.0	4.9	12.2	-	-	-
50-60	9	9.5	12.7	13.6	-	-	13.1	12.2	-	-	-
60-70	7	4.8	9.5	4.5	-	-	8.2	7.6	-	100.0	100.0
70-80	6	4.8	12.7	9.1	-	-	3.3	7.6	-	-	-
80-90	3	-	1.6	4.5	-	-	1.6	1.7	-	-	-
90-100	3	-	-	-	-	-	-	-	-	-	-
100-110	2	-	-	4.5	33.3	-	-	1.2	-	-	-
110-120	1	-	-	-	-	-	-	-	-	-	-
120-130	1	-	-	-	-	-	-	-	-	-	-
Total	10	99.9	100.0	99.8	100.0	100.0	100.0	100.1	-	100.0	100.0

*Units 1-2, 4, 12-17, 21

Table 23

DEBITAGE IN UNITS 1-3 (CONTROL UNITS): PERCENT PER LEVEL IN EACH CATEGORY

Percentages Based on Frequency

	Biface Retouch Flake		Use-modified Flake		Use-modified Flake with Cortex		Unmodified Flake		Unmodified Flake with Cortex		Total	
Level (cm)	PA	P	PA	P	PA	P	PA	P	PA	P	PA	P
0-10	9.3	21.1	10.2	19.6	9.1	-	7.1	8.1	0.9	19.0	7.0	8.4
10-20	9.3	5.3	16.9	10.9	27.3	10.0	12.7	10.9	19.2	14.3	12.9	10.9
20-30	9.3	5.3	11.4	4.3	-	40.0	6.7	9.4	5.6	14.3	6.7	9.3
30-40	23.3	-	15.1	8.7	22.7	-	15.8	10.2	17.5	19.0	15.9	10.1
40-50	8.5	10.5	16.3	5.4	9.1	-	15.4	10.2	15.1	14.3	15.3	10.2
50-60	8.5	21.1	9.6	7.2	13.6	10.0	9.4	11.8	12.9	4.8	9.5	11.7
60-70	14.7	-	6.0	13.8	4.5	-	7.4	10.2	8.1	4.8	7.5	10.2
70-80	11.6	10.5	6.6	6.5	-	10.0	11.4	9.1	5.2	9.5	11.1	9.1
80-90	2.3	5.3	3.0	6.5	4.5	10.0	5.5	9.2	4.7	-	5.5	9.2
90-100	3.1	10.5	4.8	8.7	9.1	20.0	8.6	8.1	10.6	-	8.6	8.1
100-110	-	5.3	-	2.2	-	-	-	1.6	-	-	-	1.6
110-120	-	-	-	1.4	-	-	-	0.6	-	-	-	0.7
120-130	-	5.3	-	0.7	-	-	-	0.5	-	-	-	0.6
Total	99.9	100.2	99.9	99.9	99.9	100.0	100.0	99.9	99.8	100.0	100.0	100.1

PA - primary area control unit 1
P - perimeter control units 1-2

Table 24

DEBITAGE IN UNITS 1-3 (CONTROL UNITS): PERCENT PER LEVEL IN EACH CATEGORY

Percentages Based on Total Weight

	Biface Retouch Flake		Use-modified Flake		Use-modified Flake with Cortex		Unmodified Flake		Unmodified Flake with Cortex		Total	
Level (cm)	PA	P	PA	P	PA	P	PA	P	PA	P	PA	P
0-10	11.2	19.9	6.5	16.3	9.6	-	8.3	9.9	0.5	27.9	7.1	11.1
10-20	10.3	3.5	13.6	12.9	17.8	1.7	14.7	10.8	14.8	5.5	14.6	10.6
20-30	6.2	7.1	6.7	3.8	-	25.0	7.5	12.4	6.0	15.6	7.0	11.4
30-40	18.1	-	14.9	6.5	37.4	-	17.7	10.1	20.5	18.3	18.3	9.1
40-50	8.3	7.5	10.9	8.8	2.5	-	16.2	13.0	20.1	6.2	15.8	11.5
50-60	8.6	48.8	13.3	15.7	14.5	1.7	10.0	11.9	14.7	0.6	11.1	12.2
60-70	25.8	-	7.1	12.2	4.3	-	6.4	8.7	4.6	0.2	6.6	8.8
70-80	7.7	2.0	18.0	7.0	-	28.5	9.8	7.7	11.8	25.6	10.6	8.8
80-90	1.9	1.4	2.7	5.3	0.6	2.8	3.0	7.3	1.4	-	2.7	6.5
90-100	1.9	5.5	6.3	9.2	13.4	40.3	6.3	5.9	5.7	-	6.3	7.9
100-110	-	2.3	-	1.3	-	-	-	1.5	-	-	-	1.4
110-120	-	-	-	0.7	-	-	-	0.5	-	-	-	0.5
120-130	-	2.0	-	0.5	-	-	-	0.2	-	-	-	0.2
Total	100.0	100.0	100.0	100.2	100.1	100.0	99.9	99.9	100.1	99.9	100.1	100.0

PA - primary area control unit 1
P - perimeter control units 1-2

units based on frequency and on total weight. The figures arrayed in Tables 20-22 indicate that nearly 90% of the flaked stone tools in the collection occurred above 70 cm depth at the site. They also document clearly a pronounced concentration of flaked and ground stone tools between 30 and 60 cm depth in the primary area units, and a fairly even stratigraphic distribution of flaked stone tools in the perimeter units. The difference in flaked stone tool distributions between primary area and perimeter units is also evident when mean tool frequencies per 10-cm level are plotted for each set of excavation units (Fig. 13). In the primary area units, over half (54.1%) of the flaked stone tools occurred between 30 and 60 cm depth, although these levels accounted for only a third (33.7%) of the total volume of earth, rock, and cultural fill excavated in the eleven units. Thus, the number of flaked stone tools from 30-60 cm (390) in the primary area units was 60.6% greater than could be expected assuming constant rates of cultural deposition and soil formation above the lowest level excavated (90-100 cm). This subsurface concentration of flaked stone tools in the primary area units characterizes projectile points (52.8%), bifaces (48.2%), roughouts (53.8%), cores (51.7%), and unifaces (66.3%) (Table 21). It is well-shown by a plotting of the mean frequencies of each of these tools per 10-cm level in the primary area units (Fig. 14). Since only five drills were recovered in the primary area units, their stratigraphic distribution provides minimal information.

The relative proportions of each of the six flaked stone tool categories per level without regard to unit location are summarized on a percentage basis in Table 25, and for primary area and perimeter units

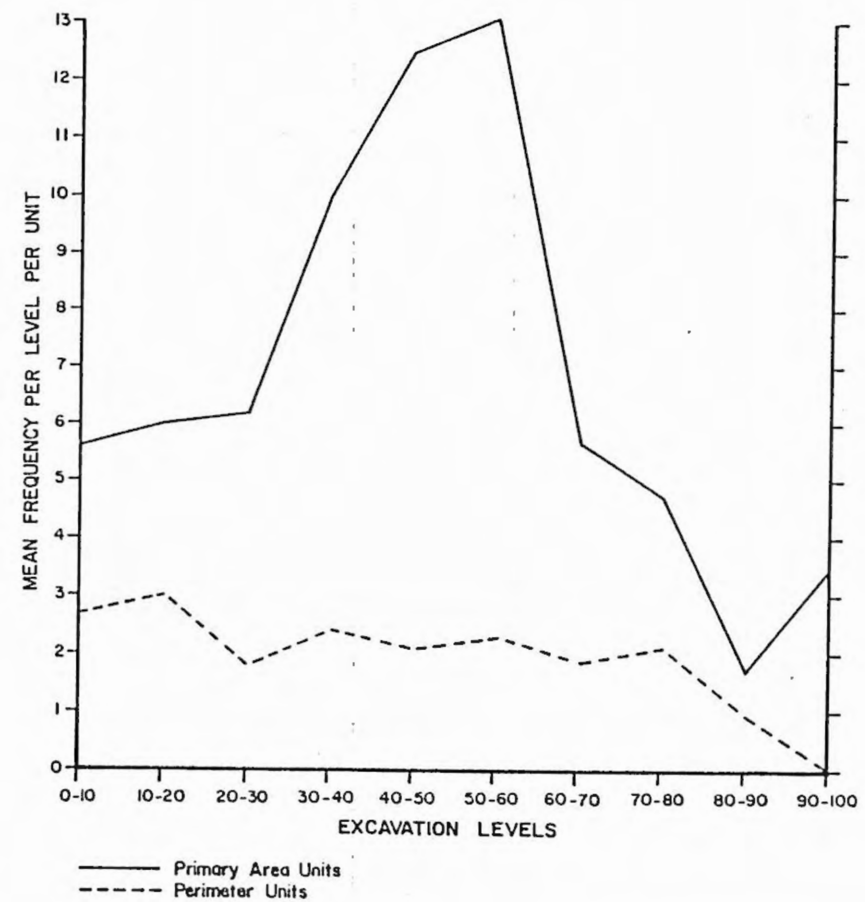


Fig. 13. Stratigraphic curves showing mean frequencies of flaked stone tools (projectile points, bifaces, roughouts, cores, drills, unifaces) per 10-cm level per excavation unit, primary area (11) vs. perimeter (10) units.

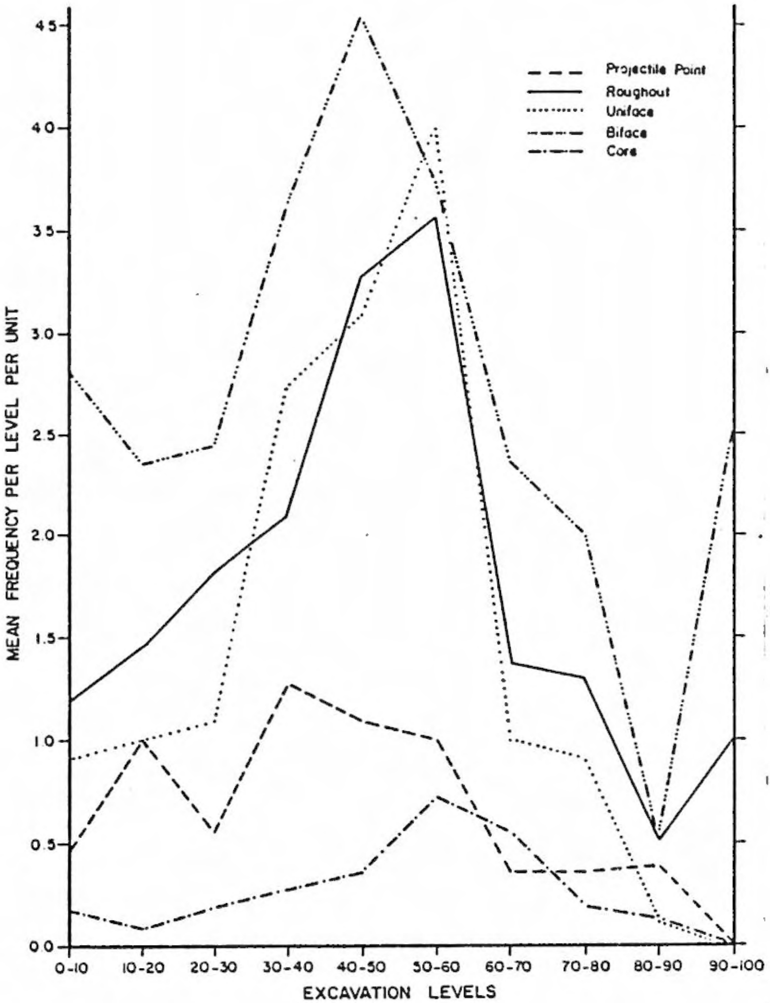


Fig. 14. Stratigraphic curves showing mean frequencies of specific flaked stone tools per 10-cm level per excavation unit, primary area units only.

Table 25

FLAKED STONE TOOLS: PERCENT PER CATEGORY IN EACH LEVEL

Percentages Based on All Units

Level (cm)	Number of Units Excavated to This Depth	Projectile Point	Biface	Roughout	Core	Drill	Uniface	Total	Index of Evenness
0-10	21	7.9	39.3	16.9	2.2	2.2	31.5	100.0	0.78
10-20	21	18.8	38.5	18.8	3.1	1.0	19.8	100.0	0.82
20-30	21	9.3	38.4	26.7	2.3	1.2	22.1	100.0	0.79
30-40	21	13.4	37.3	17.9	2.2	-	29.1	99.9	0.78
40-50	21	8.9	37.3	26.6	2.5	1.3	23.4	100.0	0.79
50-60	20	7.9	29.9	25.6	4.9	-	31.7	100.0	0.79
60-70	18	6.7	42.7	21.3	8.0	-	21.3	100.0	0.78
70-80	17	7.7	46.2	24.6	3.1	-	18.5	100.1	0.74
80-90	11	17.6	29.4	29.4	5.9	5.9	11.8	100.0	0.90
90-100	5	-	71.4	28.6	-	-	-	100.0	0.33
100-110	2	-	-	50.0	50.0	-	-	100.0	0.39
110-120	1	-	-	-	-	-	-	-	-
120-130	1	-	-	-	-	-	-	-	-
Total	21	10.2	37.5	22.8	3.6	0.8	25.1	100.0	0.80

separately in Tables 26 and 27. Tables 28 and 29 supply the same information, based on frequency and total weight per level, for each of the five debitage categories in the control unit sample. Overall, bifaces, roughouts, and unifaces account for 85.5% of the flaked stone tools recovered in the primary area units (Table 26, see Fig. 14), and for 84.9% of the tools in the perimeter units (Table 27). As indicated in Tables 25-28, an "index of evenness" (Wood 1978:260) has been computed for tool and debitage categories per level and without regard to depth. This index is based on frequency data and measures observed diversity relative to maximum diversity:

$$J = -\Sigma p_i \log p_i / \log k$$

where

k = number of categories

p_i = proportion in category i

A value of 0 reflects minimum diversity (all tools/debitage fall in one of the defined categories). Maximum diversity ($J = 1$) occurs when totals in each category are identical.

Diversity indices for flaked stone tools in both primary area and perimeter units suggest consistent archaeological site formation processes (Schiffer 1976); i.e., though stratigraphic frequencies may vary (as in the primary area units [Fig. 14]), prehistoric activities that resulted in the deposition of the various flaked stone tools remained more-or-less the same throughout most of the occupational period at the site. On a stratigraphic basis, the indices are highest and most consistent for flaked stone tools in the primary area units (Table 26), and

Table 26

FLAKED STONE TOOLS: PERCENT PER CATEGORY IN EACH LEVEL

Percentages Based on Primary Area Units*

Level (cm)	Number of Units Excavated to This Depth	Projectile Point	Biface	Roughout	Core	Drill	Uniface	Total	Index of Evenness
0-10	11	8.1	50.0	21.0	3.2	1.6	16.1	100.0	0.75
10-20	11	16.7	39.4	24.2	1.5	1.5	16.7	100.0	0.80
20-30	11	8.8	39.7	29.4	2.9	1.5	17.6	99.9	0.79
30-40	11	12.7	36.4	20.9	2.7	-	27.3	100.0	0.79
40-50	11	8.8	36.5	26.3	2.9	0.7	24.8	100.0	0.79
50-60	11	7.7	28.7	27.3	5.6	-	30.8	100.1	0.80
60-70	11	6.5	41.9	24.2	9.7	-	17.7	100.0	0.79
70-80	11	7.7	42.3	26.9	3.8	-	19.2	99.9	0.76
80-90	8	21.4	28.6	28.6	7.1	7.1	7.1	99.9	0.90
90-100	2	-	71.4	28.6	-	-	-	100.0	0.33
Total	11	9.7	37.7	25.2	4.0	0.7	22.6	99.9	0.80

*units 3, 5-11, 18-20

Table 27

FLAKED STONE TOOLS: PERCENT PER CATEGORY IN EACH LEVEL

Percentages Based on Perimeter Units*

Level (cm)	Number of Units Excavated to This Depth	Projectile Point	Biface	Roughout	Core	Drill	Uniface	Total	Index of Evenness
0-10	10	7.4	14.8	7.4	-	3.7	66.7	100.0	0.59
10-20	10	23.3	36.7	6.7	6.7	-	26.7	100.1	0.79
20-30	10	11.1	33.3	16.7	-	-	38.9	100.0	0.71
30-40	10	16.7	41.7	4.2	-	-	37.5	100.1	0.65
40-50	10	9.5	42.9	28.6	-	4.8	14.3	100.1	0.76
50-60	9	9.5	38.1	14.3	-	-	38.1	100.0	0.69
60-70	7	7.7	46.2	7.7	-	-	38.5	100.1	0.62
70-80	6	7.7	61.5	15.4	-	-	15.4	100.0	0.60
80-90	3	-	33.3	33.3	-	-	33.3	99.9	0.61
90-100	3	-	-	-	-	-	-	-	-
100-110	2	-	-	50.0	50.0	-	-	100.0	0.39
110-120	1	-	-	-	-	-	-	-	-
120-130	1	-	-	-	-	-	-	-	-
Total	10	12.2	36.6	12.8	1.7	1.2	35.5	100.0	0.77

*Units 1-2, 4, 12-17, 21

Table 28

DEBITAGE IN UNITS 1-3 (CONTROL UNITS): PERCENT PER CATEGORY IN EACH LEVEL

Percentages Based on Frequency

	Biface Retouch Flake		Use-modified Flake		Use-modified Flake with Cortex		Unmodified Flake		Unmodified Flake with Cortex		Total		Index of Evenness	
Level (cm)	PA	P	PA	P	PA	P	PA	P	PA	P	PA	P	PA	P
0-10	0.7	0.6	1.0	4.1	0.1	-	97.8	94.6	0.4	0.6	100.0	99.9	0.08	0.15
10-20	0.4	0.1	0.9	1.8	0.2	0.1	93.8	97.6	4.7	0.4	100.0	100.0	0.17	0.08
20-30	0.7	0.1	1.2	0.8	-	0.6	95.4	98.1	2.7	0.4	100.0	100.0	0.14	0.07
30-40	0.8	-	0.6	1.5	0.1	-	95.0	98.0	3.5	0.5	100.0	100.0	0.15	0.07
40-50	0.3	0.3	0.7	1.6	0.1	-	95.8	97.7	3.1	0.4	100.0	100.0	0.13	0.08
50-60	0.5	0.4	0.7	1.1	0.1	0.1	94.4	98.2	4.3	0.1	100.0	99.9	0.16	0.07
60-70	1.0	-	0.5	2.4	0.1	-	94.9	97.5	3.4	0.1	99.9	100.0	0.15	0.08
70-80	0.5	0.3	0.4	1.3	-	0.1	97.6	98.0	1.5	0.3	100.0	100.0	0.09	0.07
80-90	0.2	0.1	0.4	1.3	0.1	0.1	96.6	98.5	2.7	-	100.0	100.0	0.11	0.06
90-100	0.2	0.3	0.4	1.9	0.1	0.3	95.4	97.5	3.9	-	100.0	100.0	0.13	0.08
100-110	-	0.8	-	2.4	-	-	-	96.7	-	-	-	99.9	-	0.10
110-120	-	-	-	3.9	-	-	-	96.1	-	-	-	100.0	-	0.10
120-130	-	2.3	-	2.3	-	-	-	95.3	-	-	-	99.9	-	0.14
Total	0.5	0.2	0.7	1.8	0.1	0.1	95.5	97.6	3.2	0.3	100.0	100.0	0.14	0.08

PA - primary area control unit 3
P - perimeter control units 1-2

Table 29

DEBITAGE IN UNITS 1-3 (CONTROL UNITS): PERCENT PER CATEGORY IN EACH LEVEL

Percentages Based on Total Weight

Level (cm)	Biface Retouch Flake		Use-modified Flake		Use-modified Flake with Cortex		Unmodified Flake		Unmodified Flake with Cortex		Total	
	PA	P	PA	P	PA	P	PA	P	PA	P	PA	P
0-10	3.6	1.0	8.3	27.7	3.0	-	84.2	66.5	0.9	4.7	100.0	99.9
10-20	1.6	0.2	8.5	23.0	2.7	0.7	73.0	75.1	14.2	1.0	100.0	100.0
20-30	2.0	0.4	8.7	6.3	-	9.8	77.4	80.9	11.9	2.6	100.0	100.0
30-40	2.2	-	7.4	13.4	4.6	-	70.2	82.7	15.6	3.8	100.0	99.9
40-50	1.2	0.4	6.3	14.4	0.4	-	74.4	84.2	17.8	1.0	100.1	100.0
50-60	1.8	2.3	10.9	24.3	2.9	0.6	65.8	72.7	18.6	0.1	100.0	100.0
60-70	8.9	-	9.7	26.3	1.4	-	70.2	73.7	9.7	0.1	99.9	100.1
70-80	1.7	0.1	15.5	15.0	-	14.5	67.2	64.9	15.7	5.5	100.1	100.0
80-90	1.6	0.1	9.1	15.2	0.5	1.9	81.5	82.7	7.3	-	100.0	99.9
90-100	0.7	0.4	9.2	21.8	4.8	22.8	72.7	54.9	12.7	-	100.1	99.9
100-110	-	1.0	-	18.0	-	-	-	81.0	-	-	-	100.0
110-120	-	-	-	25.9	-	-	-	74.1	-	-	-	100.0
120-130	-	4.6	-	38.1	-	-	-	57.3	-	-	-	100.0
Total	2.3	0.6	9.1	18.9	2.2	4.5	72.4	74.2	14.0	1.9	100.0	100.1

PA - primary area control unit 3
P - perimeter control units 1-2

lowest and least consistent for debitage in the two perimeter control units (Table 28). Regardless of unit location, debitage diversity indices are lower than those for flaked stone tools primarily because unmodified flakes dominate the debitage assemblage from each control unit. Flaked stone tool diversity indices are lower in the perimeter (Table 27) than in the primary area units. The difference here is apparently the result of the relatively greater proportion of roughouts and cores in the primary area units. This would support the obvious conclusion, judging by the volume and composition of the cultural deposit in the primary area units, that prehistoric activities in this area of CA-MNO-561 are characteristic of a repeatedly occupied stone-working camp. These activities included the manufacture and repair of obsidian tools, the use of them in working plant and animal material, the milling and no doubt preparation of plant foods, and probably the staging of hunting and trans-Sierra trading expeditions. Less regular but similar activities occurred concurrently or at separate intervals around the perimeter of the camp. It also seems reasonable to expect that frequently used, comparable camp locations may exist in nearby areas along Mammoth Creek within the larger confines of CA-MNO-561 as it is presently defined.

SUMMARY OF CA-MNO-561 EXCAVATION

Time-sensitive projectile point forms from CA-MNO-561 and a relative appraisal of the obsidian hydration data for the site suggest intermittent but activity-intensifying occupations between ca. 4950 and 3250 b.p., followed by the main period of occupations ca. 3250-1250 b.p., and sporadic occupations if any at all after ca. 1250 b.p. Using the hydration data and a proposed hydration rate for Casa Diablo obsidian, absolute chronologies for CA-MNO-561 and several other prehistoric sites in the Long Valley-Mono Basin region are offered in Chapter V.

The archaeological investigations at CA-MNO-561 indicate that the major prehistoric activity at the site was obsidian stoneworking and the production of tools both for local use and probably as a valued commodity in trans-Sierra economic exchange. Within the eastern portion of the project parcel, a well-used prehistoric stoneworking camp location occurs in the western half of a small enclosure of glacial erratics (primary area units, see Fig. 6). The wall formed by the boulders on the western side of the enclosure may have afforded some protection against cold winds sweeping down off the flanks of Mammoth Mountain and the surrounding Sierra. In the absence of any floral or faunal data on site seasonality, exchange-oriented tool production may suggest that CA-MNO-561 was occupied during the summer and early fall when Sierran trading routes were snow-free and passable (Bettinger 1981:65). The relatively small number of ground stone tools recovered and the lack of any indication of significant domestic features (e.g., structures, hearths) make it likely that occupations at CA-MNO-561 were of limited duration and probably involved small groups of people (stoneworkers, hunters, traders). Numerous projectile points in the CA-MNO-561 collection may indicate that the site served as well as a base camp for hunting operations along Mammoth Creek and in southwestern Long Valley. This is not directly confirmed, however, by the presence of faunal remains in the sampled portions of the subsurface cultural deposit — perhaps simply a reflection of

rapid processes of organic decomposition and butchering activities that took place predominantly at (limited activity) kill sites. Finally, the 23 projectile points from CA-MNO-561 manufactured of obsidian from at least five sources (principally Queen) other than Casa Diablo (local source) may represent a tool-specific exchange system and possibly procurement or socioeconomic forays into southwestern Long Valley by groups originating in nearby areas of the Great Basin.

curation or trade?

Chapter V

PREHISTORY IN THE LONG VALLEY-MONO BASIN REGION: CHRONOLOGY, VOLCANISM, AND CULTURE CHANGE

Archaeological research in the eastern Sierra and adjacent areas of the Great Basin suggest that the land-use activities ascribed historic Paiute and Shoshone populations (Kroeber 1925; Steward 1933, 1938; Davis 1965; see Chapter III) provide useful analogies for the reconstruction of prehistoric economic, demographic, and sociocultural patterns over the last five or six millennia. Notwithstanding long-term adaptive similarities, however, substantial data are emerging that argue against the absence of major prehistoric culture change. Current interpretations propose, among other things, changes in the location and intensity of particular land-use activities, temporal variations in obsidian procurement and tool production patterns, technological improvements, diachronic fluctuations in overall settlement densities, demographic expansions, and socioecologic developments in adaptive strategies. These postulations reflect an increasingly fine-grained appreciation of the variables influencing prehistoric cultural behavior as measured over thousands of years of time. The tentative nature of most prehistoric reconstructions is an indication of the difficulties involved in detecting and evaluating culture change given hunter-gatherer material culture and depositional processes that often produce indistinct stratigraphic records. Exceptions can occur when natural circumstances or research methods bring about a concentration of cultural materials suitable for meaningful temporal analysis (e.g., productive site deposits, large-scale surveys).

It is assumed here that obsidian hydration dating, provided that sample source and temperature provenience are taken into account, will ultimately "unearth" prehistoric cultural stratigraphy in its theoretical sense throughout the Long Valley-Mono Basin region and neighboring regions of the Great Basin and Sierra Nevada (cf. Cowan and Wallof 1974:65; Bettinger 1979a:127-128). In this final chapter an effort is made to use source-specific obsidian hydration dating in constructing precise cultural chronologies for CA-MNO-561 and other prehistoric sites in the region that can be easily integrated with the volcanic and climatic chronologies developed in Chapter II. The chapter concludes with a discussion of the potential cultural significance of late Holocene volcanism in the eastern Sierra.

CURRENT INTERPRETATIONS OF CULTURE CHANGE: 5000-1500 B.P.

As noted in the previous chapter, consistent chronological data for the Long Valley-Mono Basin region are available for about the last 5000 years or so. Minimal evidence of earlier cultural activity probably reflects not only the pervasive erosion of older deposits, but also (1) considerably smaller hunter-gatherer populations than in more recent times and (2) a limited amount of problem-specific archaeological research. Two observations suggest that significant human settlement of the general region began ca. 5000 B.P. or soon thereafter. First, sites characterized by the presence of Little Lake Split-stem projectile points dated ca. 4950-3250 b.p. (Thomas 1981:33), such as CA-MNO-561, are fairly widespread in the general region in contrast to localized occrrences of presumably older cultural remains. Second, available obsidian hydration data appear to place the onset of regular tool quarrying and production activities at local obsidian sources (e.g., Casa Diablo, Bodie Hills, Queen, Fish Springs, Sugarloaf [Coso]) at about 5000 b.p. (Michels 1965; Singer and Ericson 1977; Bettinger 1980b; Meighan 1981; Ericson 1982; Hall in preparation).

In the Long Valley area, Little Lake Split-stem points have been found at the Mammoth Junction site (Michels 1965; Basgall 1982:Table 15), the Forest Service Forty site (Basgall 1982:28-30), possibly the Hot Creek Hatchery site (Tadlock and Tadlock 1972:Figs. 8-9), and at the Watterson Troughs site in the foothills above eastern Long Valley (Cowan and Wallof 1974:Pl. II). Obsidian hydration dating results indicate that materials of relatively similar age may be present at the Sherwin Grade site (Garfinkel and Cook 1979:Table 13) and at CA-MNO-389 near June Lake Junction (Garfinkel 1980b:Table 4). Southwest of Mono Lake, a Little Lake Split-stem point was recovered at the Lee Vining Creek site (Bettinger 1981:26) and these points occur at two upland limited activity sites in the Bodie Hills above Mono Basin (Hall 1980:Appendix C). East of Long Valley, three Little Lake Split-stem points were found at an apparent hunting camp (Ridge site) in the Benton Range (Cowan and Wallof 1974:Pl. II). East of Mono Basin in the Teels Marsh-Truman Meadows area, Little Lake Split-stem points occur at 5 of 27 recorded pinyon-juniper camp sites containing time-sensitive point forms and at four similarly datable upper sagebrush camp sites (Hall in preparation). If Gypsum Cave Contracting-stem points can be associated with a time-span somewhat comparable to Little Lake Split-stem (see Chapter IV), three additional pinyon-juniper camp sites in the Teels Marsh-Truman Meadows area may

feature temporal components as old or older than ca. 3250 b.p. Three upland limited activity sites in the same area (one pinyon-juniper, two upper sagebrush) also contain Little Lake Split-stem points, and Gypsum Cave Contracting-stem points occur at three other similar sites (Hall in preparation). To the south, Little Lake Split-stem points are poorly represented at sites in central Owens Valley examined by Bettinger (1975). This is somewhat surprising given the presence of such points north of Owens Valley at the sites mentioned above, and at the Little Lake and Rose Spring sites just south of Owens Valley (Harrington 1957; Lanning 1963). Obsidian hydration data suggest that the Little Lake (type) site was initially inhabited ca. 5000-4000 b.p., followed by the main period of occupation ca. 3400-2100 b.p. (Meighan 1981:209).

Based on the distribution of Little Lake Split-stem points and the cultural materials found in association with them, the image is created of widely scattered, relatively small, but probably growing populations of hunter-gatherers exploiting a variety of lowland and upland environments in the eastern Sierra and adjacent regions. According to the obsidian tool production curves reconstructed by Ericson (1982:Fig. 6.8), gradual but nonetheless distinct increases in tool manufacturing were underway by ca. 4000 b.p. at the Bodie Hills and Casa Diablo sources. This upward trend in production continued for two millennia and clearly documents the development of an extensive trans-Sierra obsidian exchange system (Jackson 1974; Ericson 1977, 1982). It also appears to have coincided (roughly) with an overall expansion in regional cultural activity relative to earlier times. Sites that may be affiliated with this expansion, perhaps CA-MNO-561 for one, typically display assemblages containing Elko series point forms dated ca. 3250-1250 b.p. in the central and western Great Basin (Thomas 1981; Bettinger and Taylor 1974; O'Connell 1967). As discussed earlier, Elko points are often found in the general region. In the Teels Marsh-Truman Meadows area, these points occur at 20 of the 27 pinyon-juniper camp sites noted above, at 3 of the 4 datable upper sagebrush camp sites, and at 26 of 38 recorded upland limited activity sites (14 pinyon-juniper, 24 upper sagebrush) containing recognized point forms. Also, not including Gypsum Cave Contracting-stem points, seven other pinyon-juniper camp sites in the Teels Marsh-Truman Meadows area feature large, shouldered points that were probably attached to atlatl darts (i.e., older than ca. 1250 b.p.) but that cannot be assigned to any established point category. A number of these points resemble the unnamed shouldered point forms found at CA-MNO-561 (Fig. 10). Notably, as discussed more fully below, reasonably large (30+) samples of obsidian hydration measurements from seven sites in the Long Valley-Mono Basin region (Mammoth Junction, Forest Service Forty, Lee Vining Creek, CA-MNO-11, -561, -823, -1645) suggest occupational episodes that fall primarily within the time-span associated with Elko series points.

Judging by the variety of sites bearing chronological information, a general increase in cultural activity ca. 3250-1250 b.p. also seems apparent in the Owens Valley region (e.g., Lanning 1963; Bettinger 1975, 1979a, 1980b; Garfinkel 1980a; Meighan 1981; Hall 1982a) and in the southern Sierra Nevada (Moratto, King, and Woolfenden 1978; McGuire and Garfinkel 1980). In central Owens Valley, Bettinger (1977a:14) has proposed that an "adaptive shift" in the location of lowland occupation

(habitation) sites from riverine (along Owens River) to desert scrub environs (away from Owens River) occurred ca. 3450-1350 B.P. and that it reflects a change in plant procurement emphasis from riverine to desert scrub species. As potential underlying causal factors, Bettinger (1979a: 105-106) suggested that (1) local population growth generated subsistence demands beyond what had been previously met by riverine resources, thereby forcing a locational shift in procurement and settlement activities away from Owens River (cf. Bouey 1979); or that (2) increased effective moisture accompanying climatic change after ca. 3500 B.P. enhanced the productivity of desert scrub food plants which, in turn, heightened their role in shaping subsistence-settlement strategies. The notion that most habitation sites, at least in more recent times, were located at some distance from Owens River is well-supported by existing ethnographic data on the distribution of Owens Valley Paiute villages (Steward 1933:Map 2; Bettinger 1979a:95). Nearly all of the villages Steward (1933) recorded were situated in the vicinity of major Sierran tributaries of Owens River. Nevertheless, there are evident shortcomings in the statistical manipulations carried out by Bettinger (1975, 1976, 1977a, 1979c) in an effort to document, among other things, a significant prehistoric change in lowland habitation site locations rather than perhaps simply an increase in their abundance and locational diversity. Some, but not all, of these manipulations (cf. Bettinger 1975:140-141) have been previously discussed (Munday and Lincoln 1979; Hall 1981).

Specific statistical issues aside, however, there are additional quantitative and qualitative considerations involved in evaluating the occupational chronology of lowland habitation sites in Owens Valley.

First, as reviewed earlier, there is strong paleoclimatic evidence indicating a change toward cool, moist climate ca. 3400-2200 B.P. (period encompasses Recess Peak neoglacial advance in the Sierra). Archaeological data suggest that this climatic change can be temporally, perhaps causally correlated with an overall increase in cultural activity in the Sierra Nevada, western and southwestern Great Basin (e.g., Grosscup 1960; Wallace 1962; Heizer and Napton 1970; Elston 1971; Cowan 1972; Davis and Elston 1972; Moratto, King, and Woolfenden 1978; McGuire and Garfinkel 1980; Hall et al. 1981; Rusco and Davis 1982). Although causal linkage of prehistoric climatic and culture changes are difficult to define and document, an apparent broadening of land-use activities after ca. 3500 B.P. throughout Owens Valley (Bettinger 1975:Tables 37-41) is consistent with available diachronic cultural data from the general region.

A second, critical consideration in examining the proposed shift in habitation site locations in central Owens Valley focuses on the particular chronology of settlement activities along Owens River. Specifically, the question is not whether there was an increase in long-term settlement activity away from the river, but whether there was a concomitant reduction in such activity along Owens River. Phrased another way, the question is whether or not there is a distinctive chronological pattern characterizing riverine habitation sites in Owens Valley. Bettinger has previously referred to a riverine-desert scrub locational shift that, though qualified as gradual (1980b:290), resulted in the "abandonment of riparian [riverine] villages in central Owens Valley" (1979a:110) or "replacement of riverine occupation sites by desert scrub occupation sites" (1980b:289-290). Albeit limited, available chronological data for riverine sites do not provide definitive support for such conclusions. Three of the six riverine habitation sites recorded by Bettinger (1975:Table 37) contain time-sensitive projectile point forms. Two sites, A-1/2 and A-2/1, feature dart point fragments (older than ca. 1250 b.p.), and an arrow point fragment (more recent than ca. 1250 b.p.) was found at A-2/1. A Klondike phase projectile point (ca. 650-100 b.p.) was found at the third datable habitation site, A-3/3, which is the largest riverine site recorded by Bettinger (1975:Table 37). On the basis of projectile points, then, one of the three datable riverine habitation sites may be older than 1250 b.p., one may feature temporal components (cf. Hall 1981:650) both earlier and later than 1250 b.p., and the third may be no older than 600 or 700 years.

Obsidian hydration dating results have also been reported by Bettinger (1980b) for two riverine (A-1/2, A-2/1) and two desert scrub habitation sites in central Owens Valley. Interestingly, these results may indicate that site A-2/1 is substantially older than site A-1/2, but that the latter was occupied (if a single, apparently divergent hydration reading of 7.70 μm can be ignored) over a period of time virtually identical to that associated with hydration data for the two desert scrub habitation sites. Moreover, riverine site A-1/2 also features Owens Valley Brown Ware ceramics (Bettinger 1975:Table 37), clearly suggesting the possibility of an occupation within only the last few hundred years. Thus, based on the existing chronological data, it is not evident that riverine habitation sites were "abandoned" in favor of desert scrub habitation sites, or that there are significantly fewer riverine sites dating to the last 1250 radiocarbon years than to earlier times. A more parsimonius interpretation of these data might recognize an expansion of cultural activity into desert scrub localities ca. 3250-1250 b.p., and a subsistence-settlement pattern in the confined area along Owens River that did not substantially change over the last three or four millennia (cf. Hall 1981).

As further support for the proposed riverine-desert scrub site location shift, Bettinger (1979a:110) correlated the "abandonment" of the Little Lake site with the initial occupation of the Rose Spring site slightly to the north. In that the former is a lakeside site (Little Lake is largely a spring-fed body of water [Mehringer and Sheppard 1978: 155]), Bettinger (1979a:93-94) classified it as a "riparian" village and the Rose Spring site (located at a seep spring) as a "desert scrub" village. In this particular case, then, Bettinger equated "riparian" with "riverine," implying that the termination of occupation at the Little Lake site came about for the same reason(s) that led to the "abandonment" of riverine habitation sites in central Owens Valley. Two comments are appropriate with regard to this reconstruction. First, when compared to radiocarbon dates from the Rose Spring site (Clewlow, Heizer, and Berger 1970), obsidian hydration dating of the Little Lake site (Meighan 1981) suggests a substantial chronological overlap in the occupational histories of each site. Second, the end of occupation at the Little Lake site appears to coincide with a climatic change after ca. 2200 B.P. that reduced effective moisture and may have caused the replacement of Little Lake by a saltgrass meadow (see Chapter II). The effects of tectonic activity on local hydrologic patterns (e.g., a reduction in spring discharge rates) may have also influenced water availability at Little Lake

(Mehringer and Sheppard 1978:164). Therefore, as opposed to population pressure or increased desert scrub plant productivity, changes in hydrologic conditions may have been the crucial variable affecting non-riverine habitation site locations south of Owens Valley. The Rose Valley-Little Lake area has a rich archaeological record that remains to be investigated on a systematic basis with a particular concern for the nature of prehistoric subsistence-settlement strategies.

Perhaps among the most sensitive indicators of prehistoric culture change in the eastern Sierra are changes in the frequency and perhaps nature of obsidian tool production activities over time. Although the diachronic definition of these changes is at present dependent upon hydration data from only a few localities, there appears to be a strong temporal concordance of these changes at several sites in the Long Valley-Mono Basin region displaying relatively long hydration records. At present, it seems that future research will no doubt refine but not necessarily reject an emerging model of the eastern Sierra obsidian industry that suggests an overall simultaneity in tool production trends throughout much of the region. Though somewhat simplified, tool production curves offered by Ericson (1982:Fig. 6.8) on the basis of hydration data nonetheless document an abrupt decline in Bodie Hills and Casa Diablo obsidian quarrying following a long period of steadily increasing tool manufacturing. The dating and explanation of this decline represent significant archaeological questions because (1) it appears that tool production never again resumed to an extent comparable to that prior to the decline; and because (2) it may precede or temporally overlap periods of major prehistoric culture change postulated for nearby regions in the

Great Basin and Sierra Nevada.

Assuming hydration rates of 650 and 1000 years per micron for Bodie Hills and Casa Diablo obsidian, respectively, Ericson (1982:143-144, Fig. 6.8) constructed frequency curves of obsidian hydration measurements from the Bodie Hills quarry (Singer and Ericson 1977; see Meighan and Vanderhoeven 1978) and the Mammoth Junction site on the south side of the Casa Diablo resurgent dome (Michels 1965). These curves suggest a peak period of tool production ca. 3500-2000 b.p. and a rapid decline in production after 2000 b.p. that reached its lowest level shortly after ca. 1000 b.p. As presented by Ericson, the Bodie Hills and Casa Diablo curves are virtually identical in form and display a close temporal concordance.

An overall form-similarity in these hydration-derived tool production curves is not surprising since both sources emerged as major supply centers in an extensive trans-Sierra obsidian exchange system that developed during, and perhaps most intensively toward the latter end of, the Middle Horizon in central California generally dated ca. 3000-1500 b.p. (Jackson 1974; Ericson 1977, 1982; Elsasser 1978; Bennyhoff and Hughes 1979). There are, however, some problems with the precise chronological calibration of each of the two hydration curves that, in turn, make the processual implications of changes in tool production trends more difficult to integrate with existing models of culture change in the general region. For example, available hydration measurements on time-sensitive projectile points fashioned from Casa Diablo obsidian strongly indicate that a source-specific rate of 1000 years per micron is far too slow (e.g., Garfinkel and Cook 1979; Garfinkel 1980a; Bettinger 1981; Basgall 1982). On the basis of this rate, the most recent Elko series point from

CA-MNO-561 made of Casa Diablo obsidian is nearly 2900 years old and the remaining 15 specimens represent a period of time between ca. 5800 and 3150 b.p. — clearly in conflict with a well-established temporal range of ca. 3250-1250 b.p. for Elko points in the central and western Great Basin (Thomas 1981:32). A faster, probably more accurate hydration rate (e.g., Garfinkel 1980a; Basgall 1982; see below) would place the apparent tool production peak at the Mammoth Junction site in a slightly more recent time-frame. This raises the possibility that the Bodie Hills and Casa Diablo production curves drawn by Ericson (1982:Fig. 6.8) do not, though similar in form, coincide temporally. In this case, the production peak and subsequent decline at Bodie Hills may have occurred somewhat earlier than at the Mammoth Junction site. Unfortunately, there are insufficient hydration data on time-sensitive Bodie Hills obsidian artifacts to carefully evaluate the source-specific rate of 650 years per micron determined by Ericson (1975:Fig. 8). The single Humboldt Basal-notched point/biface from CA-MNO-561, made of Bodie Hills obsidian, is roughly 2500 radiocarbon years old according to this rate, which is consistent with a principal occupational period at the site ca. 3250-1250 b.p. It is, perhaps, of importance that a date of ca. 2500 b.p. for this artifact is at the extreme early end of the maximum temporal range that others have considered associated with the Humboldt Basal-notched form (Bettinger 1978b; McGuire and Garfinkel 1980). If it is possible that eastern Sierra obsidians hydrate at generally comparable rates (Meighan 1981:211), then the Bodie Hills rate used by Ericson (1977, 1982; Singer and Ericson 1977) may be slightly too slow in light of the recently derived rates for Casa Diablo obsidian.

Other chronological difficulties with the reconstruction of tool production trends offered by Ericson (1982) stem from (1) its dependence on hydration data from only two sites (Basgall 1982:155), (2) a minimal integration of these data with existing information on prehistoric chronology in the eastern Sierra, and (3) the fact that the 453 hydration measurements on flaked stone tools from the Mammoth Junction site (Michels 1965:253-279) were obtained on samples not subjected to trace-element analysis. Of the 453 Mammoth Junction hydration values, 138 (30.5%) apply to artifacts classified as projectile points. If the findings at CA-MNO-561 are any guide, therefore, there may be at least 30 or 40 projectile points in the Mammoth Junction site collection that are not made Casa Diablo obsidian.

To account for the production decline at Bodie Hills and Casa Diablo, Ericson (1982:144-146) proposed that the introduction of the bow and arrow generated overwhelming consumer needs west of the Sierra for eastern Sierra obsidian that, in turn, encouraged production away from quarry workshops or nearby stoneworking camps (e.g., Mammoth Junction, Lee Vining Creek, Forest Service Forty, CA-MNO-561 sites). In other words, increased demand made it more efficient to procure obsidian from Bodie Hills and Casa Diablo sources without significant local lithic reduction, and to conduct actual tool production at sites far removed from these sources but closer to areas of principal use. There are several flaws in this explanation. First, it remains to be shown that the most efficient system of moving usable obsidian in large quantities across the Sierra required minimal lithic reduction at quarry workshops or nearby stoneworking camps, and maximum tool production elsewhere. It would seem

that the opposite is true since local lithic reduction could minimize the cost of initial tool manufacturing error and prevent the exporting of raw quarry nodules that, during reduction, proved to be unsuitable tool material. Second, although the appearance of the bow and arrow in the western Great Basin is generally thought to have coincided with the appearance of Rose Spring and Eastgate series projectile points ca. 1250 b.p., its appearance west of the Sierra is not established as early as 2000 or 2500 b.p. as would be required to account for a tool production decline in the manner advocated by Ericson (1982; cf. Elsasser 1978:57). Finally, if an overwhelming demand for obsidian discouraged local/quarry tool production for exchange in the eastern Sierra, then it should have likewise inhibited the expansion of quarry production at obsidian sources west of the Sierra. This was apparently not the case at the St. Helens source in northern California where, according to the production curve reconstructed by Ericson (1982:Fig. 6.2), tool manufacturing activities expanded dramatically in late prehistoric times *after* the production collapse at Casa Diablo and Bodie Hills in the eastern Sierra.

Basgall (1982:160-161) suggested some other noteworthy potential factors that may help explain or at least relate to the production decline at Casa Diablo and Bodie Hills. These include (1) a demographic disruption in the western Sierra that largely eliminated consumer demand for eastern Sierra obsidian (cf. Singer and Ericson 1977); (2) the late prehistoric (after ca. 1500 b.p.) introduction of "cheaper" northern California obsidian into the markets in the Central Valley and western Sierra that also reduced the demand for eastern Sierra obsidian; and (3) the late prehistoric expansion of ancestral Numic-speaking populations into the eastern Sierra (Lamb 1958; Bettinger and Baumhoff 1982) that Basgall speculated may have been far more territorial than earlier groups with regard to regional resources, thereby removing the opportunity for western Sierra groups to directly procure obsidian at eastern Sierra sources. Basgall has struck on a number of important aspects of the problem here and the suggestions offered merit some discussion. Initially, to support movement of obsidian across the Sierra on a regular basis, it seems reasonable to assume that a relatively well-established trans-Sierra economic network existed during the peak period of tool production at Casa Diablo and Bodie Hills (cf. Bettinger and King 1971). Thus, whether brought about by demographic, economic, or other changes, a significant decline in tool production must relate in a systemic sense to either a sharp drop in demand west of the Sierra or a major reduction in the availability of eastern Sierra obsidian.

The problem is recognizing and explaining causal relationships; e.g., the production decline may reflect events and processes related to population shifts in the western Sierra (Basgall 1982:160), but short of massive regional abandonment it is not clear why such shifts should necessarily involve a drop in demand for a previously important raw material at its nearest sources in the eastern Sierra. The suggestion that "cheaper" (but more distant) northern California obsidian flooded the western Sierra market, though intriguing, conflicts with an often observed direct relationship between distance to an obsidian source and the extent to which that source is represented in local tool assemblages (Jack 1976; Ericson 1977, 1982; Bettinger 1982b). It would be expected, however, that a reduction in the availability of eastern Sierra obsidian would

increase its cost and lower the relative cost of acquiring northern California obsidian. The third factor Basgall (1982:161) cited as possibly underlying the tool production decline at Casa Diablo and Bodie Hills, occupation of the eastern Sierra by territorial Numic groups less inclined to export obsidian or tolerate its direct procurement by other groups (from the western Sierra), contradicts ethnographic data on inter-group relations, exchange commodities, and subsistence-settlement activities (Chapter III). Not the least of these are accounts of extensive social and economic interaction between Mono Lake Paiute and Sierra Miwok (Steward 1933:257) and of Northfork Monache apparently traveling to Long Valley to procure pinyon nuts (and no doubt other resources) and on occasion remaining east of the crest of the Sierra for a considerable period of time (Gifford 1932:19). What is notable about the ethnographic data regarding economic exchange is the relatively few specific references to obsidian (Bettinger 1979a:131-132). This may reflect the nearly complete lack of ethnographic information on hunter-gatherer populations near the Casa Diablo source in Long Valley (Bettinger 1977b:53) or near the Bodie Hills source above Mono Basin (Hall 1980:18-20). But it also suggests that these somewhat hypothetical populations were never of much size — or that their late prehistoric/early historic densities were substantially lower than during earlier periods of peak obsidian tool production (cf. Bettinger and King 1971).

Thus, based on the hydration curves constructed by Ericson (1982: Fig. 6.8) there was an apparent decline in obsidian tool production at the Bodie Hills quarry and the Mammoth Junction site (Casa Diablo) sometime after ca. 2000 b.p. Explanations of the decline have so far correlated it with evident cultural developments in the general region, but have not established the particular roles of these developments in determining tool production trends in the eastern Sierra. There has also been a complete disregard of the role of a dynamic environmental history in the eastern Sierra (Chapter II). In the following section of this chapter, obsidian hydration curves are presented for several prehistoric sites in the Long Valley-Mono Basin region. As constructed, the curves suggest steadily increasing Casa Diablo obsidian tool production at sites in western Long Valley after ca. 3500 b.p., a sharp decline in production ca. 1750-1250 b.p., and much reduced, intermitted periods of tool manufacturing in the area since 1250 b.p. with perhaps another relatively sharp decline in this activity ca. 750-500 b.p.

Because this chronology is based on archaeological data, it is considered of significance here that independent geologic data indicate an episode of recurrent volcanism in the Long Valley-Mono Basin region between roughly 1900 and 500 radiocarbon years ago. A number of the eruptions appear to have begun with violent pyroclastic explosions that mantled nearby areas with thick deposits of tephra and more distant areas with lesser quantities of fine ash. Radiocarbon determinations and perhaps obsidian dome hydration analysis (Chapter II; Figs. 2-3) suggest that this volcanic episode in the Long Valley-Mono Basin region began with the moderate to major eruption of the South Coulee in the Mono Craters ca. 1695 ± 200 b.p. As described earlier, the eruption of the South Coulee produced a 0.56 km^3 ash flow, ca. 0.20 km^3 in local tephra, and distant tephra the volume of which has been conservatively estimated at ca. 0.10-0.20 km^3 (Wood 1977b:Table 1). According to a preliminary

assessment of current volcanic hazards in the Long Valley-Mono Basin region prepared by the United States Geological Survey (USGS), moderate or major eruptions of volcanoes such as the South Coulee may be associated with a "flowage-hazard zone" that extends some 20 km from a vent (Miller et al. 1982). Within this zone can occur pyroclastic flows and surges, hot ash clouds, lava flows, perhaps mudflows and floods, and dome extrusions (Miller et al. 1982). Depending upon wind direction, accumulations of 20 cm or more of ash may develop 35 km from a vent, and perhaps 5 cm or more at a distance of 85 km (Miller et al. 1982). Notably, along with the Casa Diablo obsidian source, the Mono Craters and Inyo Dome sources and several investigated prehistoric sites fall within or near the border of the flowage-hazard zones of late Holocene volcanoes in the Long Valley-Mono Basin region. The Bodie Hills, Mount Hicks, and Glass Mountain obsidian sources are for the most part located outside these zones but are closer than 35 km to many of the volcanoes. The Queen and Fish Spring obsidian sources lie within the 85 km/5+ cm ashfall limit determined by the USGS assessment (Miller et al. 1982).

It stands to reason, then, that recurrent volcanism for much of the last two millennia may have had persistent direct and indirect, and cumulative effects on prehistoric economic, demographic, and land-use patterns in the eastern Sierra and adjacent regions. There is, however, no intention here or in the remaining pages to evoke late Holocene volcanism as a panacea for causal explanations of prehistoric culture change. It is simply to consider the potential role of volcanism in the eastern Sierra as a dynamic environmental variable that contributed to the course of regional cultural development. Eruptions in the Mono

Craters and later in the Inyo Craters and Domes did not permanently end obsidian tool production or trans-Sierra economic exchange, nor did they prevent renewed exploitation of the multiple resources available in the Long Valley-Mono Basin region. Plants and animals did return to areas devastated or at least seriously affected by volcanic eruptions, but what needs to be determined in the eastern Sierra are (1) how long it was before humans returned to specific localities after an eruption, and (2) the relationships of volcanic phenomena to potential changes in the long-term nature of land-use patterns in these localities. Generally speaking, the eruptions may have periodically forced economic and demographic adjustments of varying severity among populations dependent to some extent on the impacted areas and resources. Intervals between eruptive events may in some instances have been long enough to permit a measurable increase in occupational and procurement activities. On the other hand, the effects of a moderate or major eruption or of a series of closely-spaced eruptions could have generated a period of major economic and demographic disruption for both directly affected populations or for those in less affected, outlying regions (cf. Binford 1968).

CASA DIABLO OBSIDIAN HYDRATION RATE

A variety of empirical and theoretical hydration rates have been proposed for obsidian from the Casa Diablo source. The earliest, 1000 years per micron (Michels 1965), was discussed earlier and clearly does not work well with source-specific hydration data from sites in the general region. Recently, Michels (1982) has proposed a new rate of $3.51 \mu m^2/1000$ years based on an induced hydration experiment. According

to this rate, one of the unmodified flakes from CA-MNO-561 is over 16,000 years old, and the Mammoth Junction (Michels 1965) and Sherwin Grade (Garfinkel and Cook 1979) sites were first occupied 19,000 years ago. Needless to say, the new rate proposed by Michels (1982) is not employed here. Using hydration data on temporally diagnostic points from the Forest Service Forty site, Basgall (1982:131, Table 14) evaluated and dismissed the value of several theoretical rates (see Ericson 1977:Table 1-12) and determined, instead, that a simple, empirical, linear rate proposed by Garfinkel (1980a) showed a high degree of success in producing acceptable dates for the point forms. The hydration rate proposed by Garfinkel, Years b.p. = $665.41 \mu m - 745.00$, is based on a linear regression of (1) the midpoints in the range of hydration values obtained by Michels (1965) for time-sensitive projectile point forms from the Mammoth Junction site; and (2) the assumed midpoints of the time-spans (temporal units, see above) associated with these point forms in the general region. Basgall (1982) noted some possible problems in the manner that Garfinkel had classified the Mammoth Junction points with the data originally reported by Michels (1965). Consequently, Basgall (1982:133) repeated the procedure correcting for these problems and arrived at a slightly different linear rate for Casa Diablo obsidian: Years b.p. = $700.0 \mu m - 933.6$.

Because of the apparent utility of the rates proposed by Garfinkel (1980a) and Basgall (1982), and in light of the availability of hydration values on 16 Elko series points made of Casa Diablo obsidian in the CA-MNO-561 collection, the rate used below is derived in a somewhat analogous fashion with two particular restrictions on the hydration data used to conduct the regression. First, only hydration values for projectile points made of obsidian sourced by trace-element analysis to Casa Diablo were considered. This completely ruled out use of the data from the Mammoth Junction site. As noted earlier, as many as 30 or 40 of the 138 points from the site may be made of non-Casa Diablo obsidian given the findings at CA-MNO-561 (Chapter IV). Second, consideration was given only to sourced specimens recovered from a subsurface context since Layton (1973) has shown that prolonged exposure to solar radiation may create a warmer temperature environment over time and enhance the hydration process. (It should be noted here, however, that the depositional history of CA-MNO-561 — and thus the burial history of all of the subsurface points recovered from the site — cannot be determined.)

These criteria, of course, reduce an already limited quantity of hydration values for time-sensitive projectile points in the general region (a shortage that will be greatly alleviated in the near future by ongoing studies [Hall in preparation; Robert Jackson, personal communication 1983]). A Desert Side-notched point (ca. 650-100 b.p.) made of Casa Diablo obsidian and displaying a hydration band measuring 1.21 μm was found at the Sherwin Grade site at a depth of 20-30 cm below the surface (Garfinkel and Cook 1979:Tables 10, 13). A radiocarbon date of 455 ± 140 b.p. was reported for a hearth located at 30-40 cm depth at the site (Garfinkel and Cook 1979:50). This suggests that the specimen may be less than ca. 450 radiocarbon years old. Relative to hydration data on non-sourced or surface Desert Side-notched points from other sites in the region (Michels 1965; Basgall 1982), the Sherwin Grade point has one of the smallest hydration values. Aside from this specimen and

the one relatively large Rose Spring Corner-notched (or relatively small Elko Corner-notched) point from CA-MNO-561 (3.23 μm), no other source-specific hydration data are available for subsurface projectile points considered to date within the last 1250 radiocarbon years. Elko series points (ca. 3250-1250 b.p.) that meet the above criteria include the 16 specimens from CA-MNO-561 (2.89-5.79 μm), two from the Lee Vining Creek site (3.02 μm, 5.31 μm) southwest of Mono Lake (Bettinger 1981:Appendix II), and one from the Forest Service Forty site (5.32 μm; Basgall 1982: 45). For the earliest generally recognized temporal unit, ca. 4950-3250 b.p., three Little Lake Split-stem points from CA-MNO-561, and (possibly) two Gypsum Cave Contracting-stem points (one each from CA-MNO-561 and the Lee Vining Creek site [Bettinger 1981:Appendix II]) meet the stated criteria. All but one of these points have hydration values that considerably overlap the hydration range of sourced, subsurface Elko series points. The exception is a band measuring 6.85 μm on one of the specimens from CA-MNO-561.

Clearly, the available hydration data are at present inadequate to conduct a regression analysis of the form done by Garfinkel (1980a) and Basgall (1982). Nonetheless, it is assumed for this research that controlling for source and, perhaps, temperature provenience are important and worth the effort to use the most appropriate hydration data possible. Thus, somewhat arbitrary but not necessarily unreasonable decisions are made to equate the Desert Side-notched point (1.21 μm) from the Sherwin Grade site with an age of 200 b.p., and the most recent and oldest hydration values (2.89-5.79 μm) for Elko series points made of Casa Diablo obsidian with respective ages of 1250 and 3250 b.p. Since the existing hydration data suggest a substantial, relative temporal overlap between Elko series and Little Lake Split-stem points, the most recent value for the latter point form cannot be reliably equated with an age of 3250 b.p. A linear regression of the three pairs of variates yields the hydration rate: Years b.p. = 668.54µm - 637.30 (r^2 = 0.99). A qualification accompanying this rate is the fact that several of the older Elko series points (from CA-MNO-561, Forest Service Forty, and Lee Vining Creek sites) used to establish the Elko hydration range are small stem fragments. However, use of the rate is encouraged by its close similarity to the rates proposed by Garfinkel (1980a) and Basgall (1982). For a given hydration measurement, the dates supplied by each of the three rates vary by no more than 200 or 300 years with an average divergence of ca. 145 (±30) years for values between 2 µm and 10 µm.

DATING THE CA-MNO-561 ASSEMBLAGE

On the basis of a hydration rate of: Years b.p. 668.54µm - 637.30 for obsidian traced to the Casa Diablo source, the hydration results described in Chapter IV for CA-MNO-561 suggest that the site was occupied primarily between ca. 4400 and 1300 b.p. According to this rate, the 16 Elko series points made of Casa Diablo obsidian in the CA-MNO-561 collection represent a time-span of ca. 3230-1290 b.p., which fits well with the established chronology for these point forms (Thomas 1981). Both Rose Spring Corner-notched points (Casa Diablo obsidian) from the site are older than expected (1520 b.p., subsurface; 2170 b.p., surface) and for the reasons discussed earlier might be best considered relatively small Elko Corner-notched points. The 12 Casa Diablo obsidian Humboldt

Concave-base points from CA-MNO-561 appear to range in age from ca. 3300 to 1700 b.p. Along with the oldest Little Lake Split-stem point made of Casa Diablo obsidian (3950 b.p.; Fig. 9, row 5, second from right), among the older points found at the site are several of the unnamed large shouldered points (ca. 4200-3200 b.p.; Fig. 10).

Fifty-eight (90.6%) of the 64 hydration values from CA-MNO-561 for unmodified flakes consisting of Casa Diablo obsidian fall between ca. 3000 and 1600 b.p. Four others may represent a time-span of ca. 4400-3200 b.p., and two values a time-span of ca. 800-650 b.p. The single unmodified flake (Casa Diablo obsidian) with two hydration values may have bands differing in age by more than 1000 years (ca. 3350-2100 b.p.). These results on unmodified flakes from CA-MNO-561 suggest that possibly obsidian tool production at the site stopped at about the time of the eruption of the South Coulee (ca. 22.5 km north of CA-MNO-561) and the beginning of a late Holocene volcanic episode in the Long Valley-Mono Basin region (Figs. 2-3). Most notable in this regard is that, with the above hydration rate, 8 (14.3% of total) projectile points made of Casa Diablo obsidian in the CA-MNO-561 collection date between ca. 1600 and 1300 b.p. (one Rose Spring Corner-notched, 3 Elko series, 4 nondiagnostic distal fragments). An age of ca. 1000 b.p. is obtained for one nondiagnostic distal fragment. Of the remaining 47 Casa Diablo obsidian points from the site, 39 (69.6% of total) date between ca. 3000 and 1600 b.p. and 8 (14.3%) between ca. 4400 and 3200 b.p. These results may indicate relatively brief occupations ca. 1600-1300 b.p. of CA-MNO-561 after the main period of stoneworking occupations had ended ca. 1600 b.p.

SITE-SPECIFIC OBSIDIAN HYDRATION CURVES

In an effort to integrate as well as possible the chronological results of obsidian hydration analyses at prehistoric sites in the Long Valley-Mono Basin region, several site-specific "obsidian hydration curves" are provided in this section using an assumed Casa Diablo hydration rate of: Years b.p. = 668.54µm - 637.30. Obsidian samples from some of the sites in western Long Valley (e.g., Mammoth Junction) have not been subjected to trace-element analysis. Nonetheless, given the likelihood that Casa Diablo is the predominant obsidian source represented at sites in the area, it is considered of value to proceed on this assumption. To construct the curves, hydration values from each site were converted to their calendar equivalents and grouped into 250-year intervals. A relative frequency curve was then drawn based on the proportion of hydration sample dates falling within each 250-year interval. This enables easy comparison of curves derived from hydration samples of varying size. In those instances where two hydration values are reported for a single specimen, values differing by 0.5 µm or more were both used in the frequency analysis. Though arbitrary, the figure of 0.5 µm reflects a desire to recognize at least a certain amount of inherent variability in the depth of the diffusion front. Double hydration values differing by less than 0.5 µm were averaged before conversion to an absolute data. Also, since the curves do not take into account sample stratigraphic provenience, disproportional stratigraphic representation in the data from a given site may bias its hydration curve to some extent. This would not appear to be of major concern, however, because relative comparison of hydration values from these sites suggests frequent, often

substantial stratigraphic mixing (see Chapter IV). Finally, the possible interpretations offered for the following hydration curves are highly tentative for two reasons: (1) the hydration rate used in the frequency analysis of Casa Diablo obsidian hydration data, though it appears to be generally reliable given the data available for rate calibration, is likely to be superceded by more accurate rates that will be developed as the result of current and future investigations into the prehistoric use of Casa Diablo obsidian; and (2) successful use of obsidian hydration dating as a diachronic tool of prehistoric analysis will require far more detailed hydration data than presently available for specific categories of tools and debitage (cf. Bettinger 1979a:127).

Obsidian hydration curves for projectile points and unmodified flakes made of Casa Diablo obsidian in the CA-MNO-561 collection are shown, both separately and as a combined sample, in Fig. 15. Hydration curves are given in Fig. 16 for points found in the primary area units and in the perimeter units at CA-MNO-561 (Fig. 6; see Chapter IV). The five curves for CA-MNO-561 display highly similar shapes, and may indicate increasingly frequent stoneworking and other occupational activities at the site after ca. 3500 b.p. All of the curves drop abruptly ca. 1750-1250 b.p., and the site may have been largely abandoned for a period of time after ca. 1250 b.p. The limited hydration data suggest incidental use of the site ca. 1000-500 b.p.

Hydration curves are given in Fig. 17 for 138 projectile points and 315 other flaked stone tools from the Mammoth Junction site based on hydration measurements reported by Michels (1965). Although these specimens have not been sourced, the findings at CA-MNO-561 and at the Forest

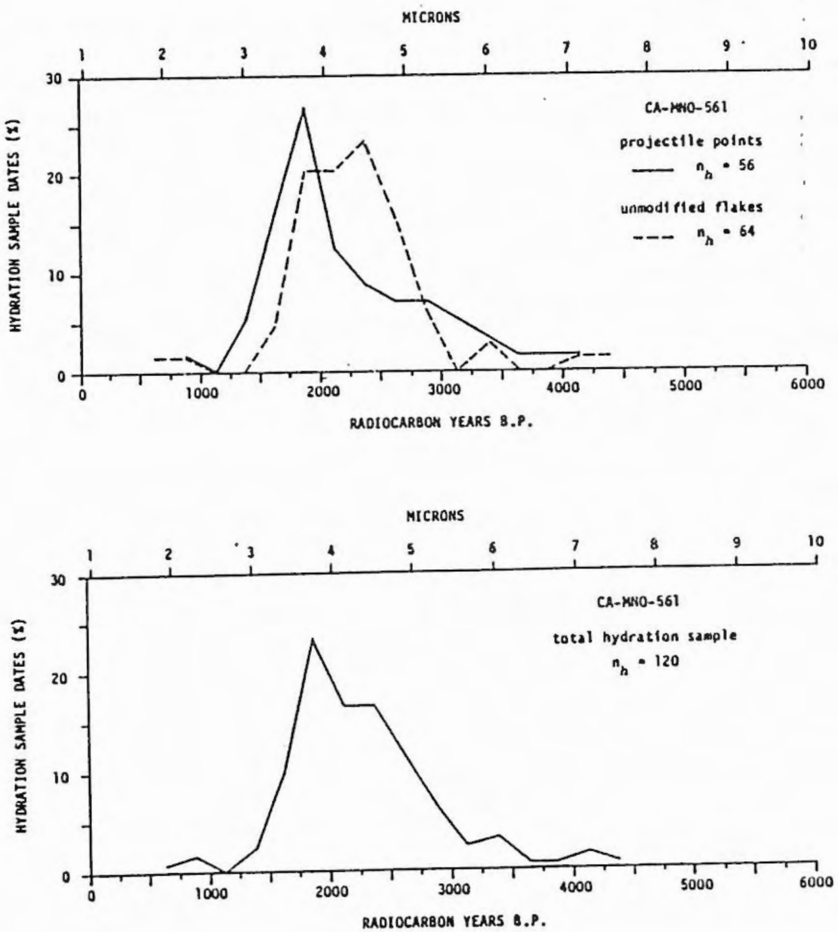


Fig. 15. Obsidian hydration curves for projectile points and unmodified flakes from CA-MNO-561 (upper Mammoth Creek). One unmodified flake displays two hydration bands that differ by more than 0.5 μm. All specimens (119) traced by X-ray fluorescence to the Casa Diablo obsidian source. Hydration rate: Years b.p. = 668.54μm − 637.30 (n_h = number of hydration sample dates).

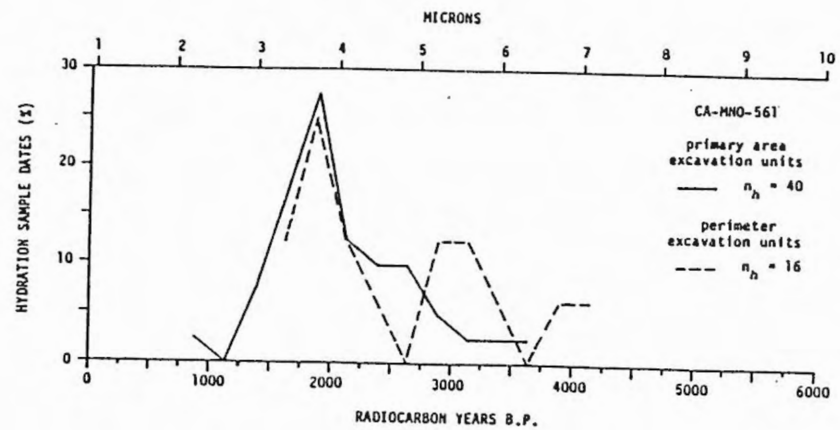


Fig. 16. Obsidian hydration curves for projectile points from CA-MNO-561, primary area vs. perimeter excavation units. All specimens (56) traced by X-ray fluorescence to the Casa Diablo obsidian source. Hydration rate: Years b.p. = 668.54μm − 637.30 (n_h = number of hydration sample dates).

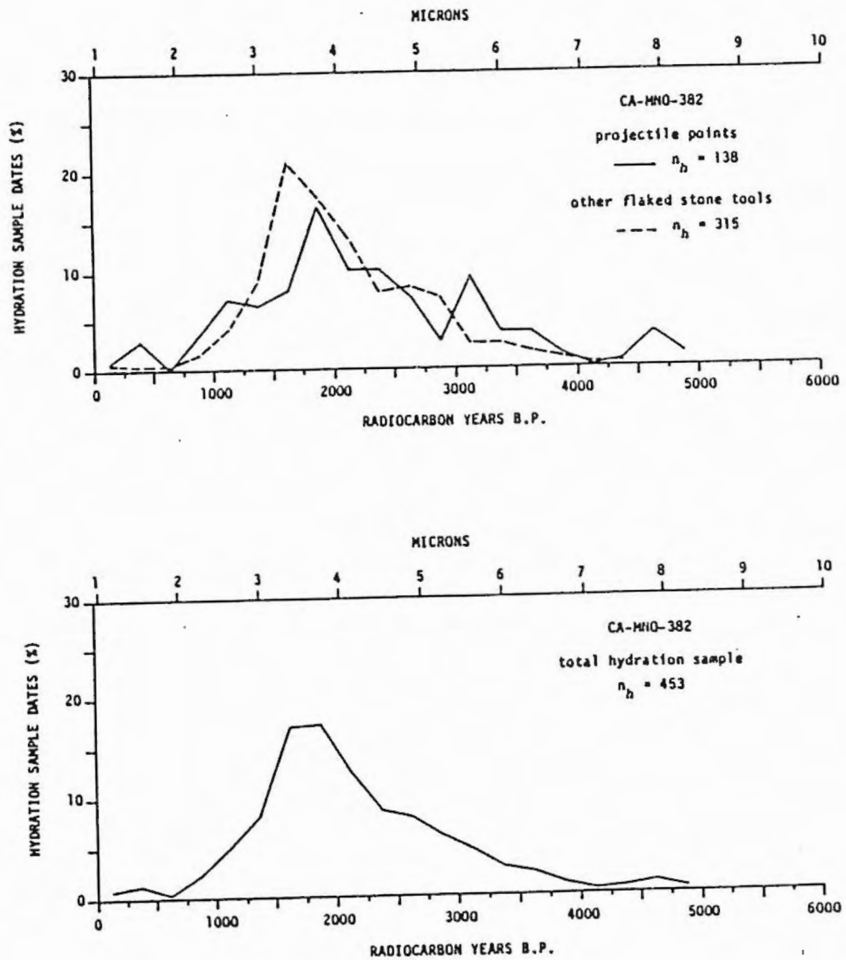


Fig. 17. Obsidian hydration curves for projectile points and other flaked stone tools from the Mammoth Junction site (Michels 1965). Obsidian source(s) undetermined, probably 70-90% or more Casa Diablo. Hydration rate: Years b.p. = 668.54µm - 637.30 (n_h = number of hydration sample dates).

Service Forty site (Basgall 1982) may indicate that at least 70% of the points and perhaps 90% of the other tools from Mammoth Junction are made of Casa Diablo obsidian. Based on the hydration data reported by Michels (1965), the site was initially occupied ca. 5000 b.p. As at CA-MNO-561, the Mammoth Junction hydration curves for points and other flaked stone tools (and combined) may reflect increasingly frequent stoneworking and other occupational activities at the site after ca. 3500 b.p. The curve for projectile points drops markedly ca. 1750-1250 b.p., while the other curve sharply declines ca. 1500-1000 b.p. Occupations continued after ca. 1000 b.p. at the Mammoth Junction site, but on an apparently much reduced and declining basis. The hydration curves (Fig. 17) create the strong impression that the Mammoth Junction site was abandoned for a period of time ca. 750-500 b.p. (cf. Michels 1965:172). Of potential relevance here are at least ten tephra eruptions from the Glass Creek vents ca. 1040-720 b.p. (perhaps ca. 900-720 b.p.), and the massive, well-dated eruption of the vent south of Deadman Creek ca. 720 ± 60 b.p. (Fig. 2). The latter blanketed much of western Long Valley with abundant pumice lapilli that today remains over 1.5 m thick in places. Both CA-MNO-561 and the Mammoth Junction site are well within the 20 km flowage-hazard zone of the Deadman Creek vent. (At a minimum, this sort of eruption must have buried with tephra for some time important obsidian outcrops and deposits on the Casa Diablo resurgent dome.)

Source-specific hydration curves for flaked stone tools and debitage from the Forest Service Forty site west of CA-MNO-561 in Mammoth Lakes are given in Fig. 18 based on hydration data reported by Jackson (1982; see Basgall 1982). Again, a generally steady increase in site use and

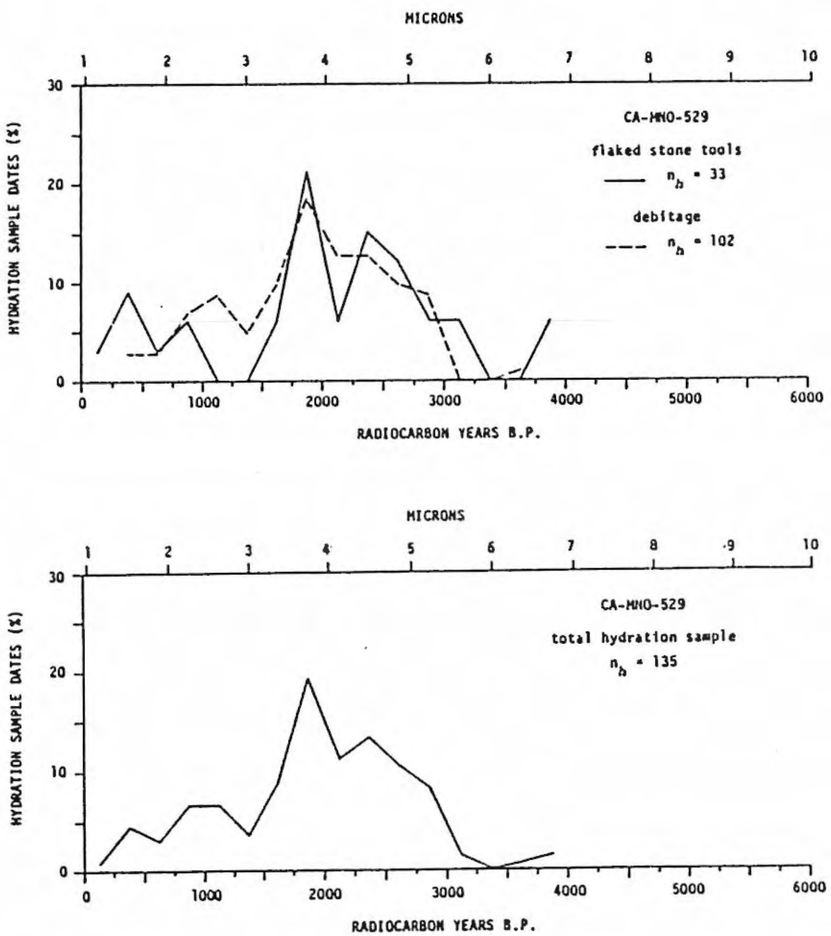


Fig. 18. Obsidian hydration curves for flaked stone tools and debitage from the Forest Service Forty site (Basgall 1982; Jackson 1982). Eight specimens display two hydration bands that differ by 0.5 µm or more. All specimens (127) traced by X-ray fluorescence to the Casa Diablo obsidian source. Hydration rate: Years b.p. = 668.54µm − 637.30 (n_h = number of hydration sample dates).

stoneworking activity is suggested after ca. 3500 b.p., with an apparent abrupt reduction in this activity ca. 1750-1250 b.p. There is also an indication in these curves of a reduced or non-increasing level of activity just prior to its peak at the site ca. 2000-1750 b.p. (Fig. 18). This brief slowing ca. 2250 b.p. in an otherwise rising level of activity is also apparent in the CA-MNO-561 hydration curves (Fig. 15) and perhaps those for the Mammoth Junction site (Fig. 17). After ca. 1250 b.p., the Forest Service Forty hydration curves suggest a limited resurgence of stoneworking activity at the site before, as at the Mammoth Junction site, a sharp drop in site use ca. 750-500 b.p.

For comparative purposes, Fig. 19 contrasts the hydration curves for projectile points from CA-MNO-561 and the Mammoth Junction site (CA-MNO-382), and those for debitage from CA-MNO-561 and the Forest Service Forty site (CA-MNO-529). The similarity in these curves is striking, as it is when the overall hydration curves for the three sites are contrasted (Fig. 20). The similarity is all the more convincing in light of the fact that the original hydration data for each site were obtained by separate technicians working in different laboratories. To measure the temporal concordance among the curves shown in Fig. 20, a Kendall's W (Mendenhall, Ott, and Larson 1974:376-380) can be computed by separately ranking the 250-year intervals used to construct each of the hydration curves (e.g., rank 1 interval at each site is 2000-1750 b.p.). To minimize bias, only those intervals falling within the maximum common time range at the three sites (4000-500 b.p.) are included in the procedure. Given this restriction, a significant ($p < 0.01$) coefficient of concordance, $W = 0.85$, is obtained for the overall hydration curves

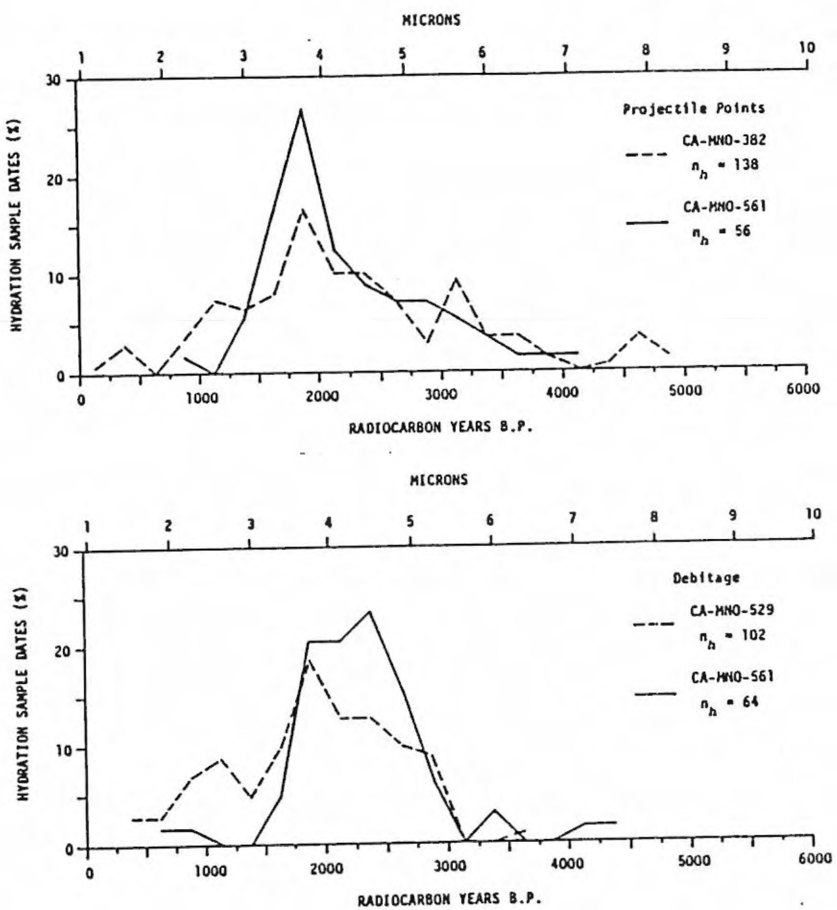


Fig. 19. Obsidian hydration curves for projectile points from CA-MNO-561 and the Mammoth Junction site (CA-MNO-382), and for debitage from CA-MNO-561 and the Forest Service Forty site (CA-MNO-529). Seven debitage specimens (six from CA-MNO-529, one from CA-MNO-561) display two hydration bands that differ by 0.5 µm or more. CA-MNO-382 specimen source(s) undetermined, perhaps 70% or more Casa Diablo. Specimens (159) from the other two sites traced by X-ray fluorescence to Casa Diablo. Hydration rate: Years b.p. = 668.54µm − 637.30 (n_h = number of hydration sample dates).

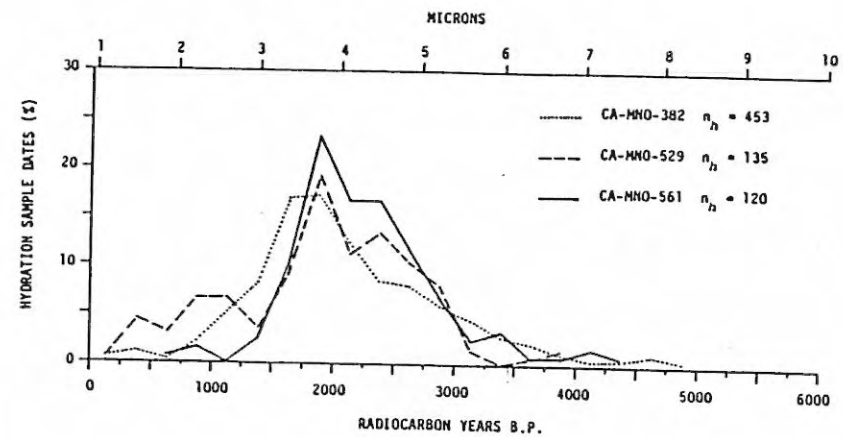


Fig. 20. Obsidian hydration curves for all hydration samples attributed to the Casa Diablo obsidian source from CA-MNO-382 (Mammoth Junction), CA-MNO-529 (Forest Service Forty), and CA-MNO-561. CA-MNO-382 specimen source(s) undetermined, probably 70-90% or more Casa Diablo. Specimens (246) from the other two sites traced by X-ray fluorescence to Casa Diablo. Eight specimens from CA-MNO-529 and one from CA-MNO-561 display two hydration bands that differ by 0.5 µm or more. Hydration rate: Years b.p. = 668.54µm − 637.30 (n_h = number of hydration sample dates).

from the three sites.

Although sample sizes are in some cases rather small, and the relative frequencies of hydration dates therefore subject to radical fluctuation, Figs. 21-23 present obsidian hydration curves for six other prehistoric sites in western Long Valley (Triple R, CA-MNO-11, -722, -823, -1644, -1645) and for CA-MNO-389 north of Wilson Butte. With one exception (Triple R), the curves all suggest ca. 3500-1500 b.p. as the principal occupational period at these sites. The limited hydration data from the Triple R site (Jackson 1982; see Bettinger 1980a) may reflect intermittent occupations over the last 1500 radiocarbon years with possibly a significant reduction in site use ca. 750-500 b.p. (Fig. 21).

The final pair of hydration curves presented here (Fig. 24) are based on source-specific (Casa Diablo) hydration data from the Lee Vining Creek site (Bettinger 1981), and hydration measurements for the Bodie Hills quarry reported by Meighan and Vanderhoeven (1978). A highly variable Lee Vining hydration curve nonetheless would appear to place the greater majority of occupations of the site between ca. 3500 and 1500 b.p., with perhaps most occurring toward either the early or recent end of this time-span (cf. Bettinger 1981). For the period 4000-500 b.p., a significant ($p < 0.01$) coefficient of concordance, $W = 0.64$, is obtained using the procedure above for the overall hydration curves from CA-MNO-561 and the Lee Vining, Mammoth Junction, and Forest Service Forty sites. Though essentially the same in many respects, using the same hydration rate (Ericson 1975) and data (Meighan and Vanderhoeven 1978) the Bodie Hills hydration curve depicted in Fig. 24 appears much different from that drawn by Ericson (1977, 1982; Singer and Ericson 1977).

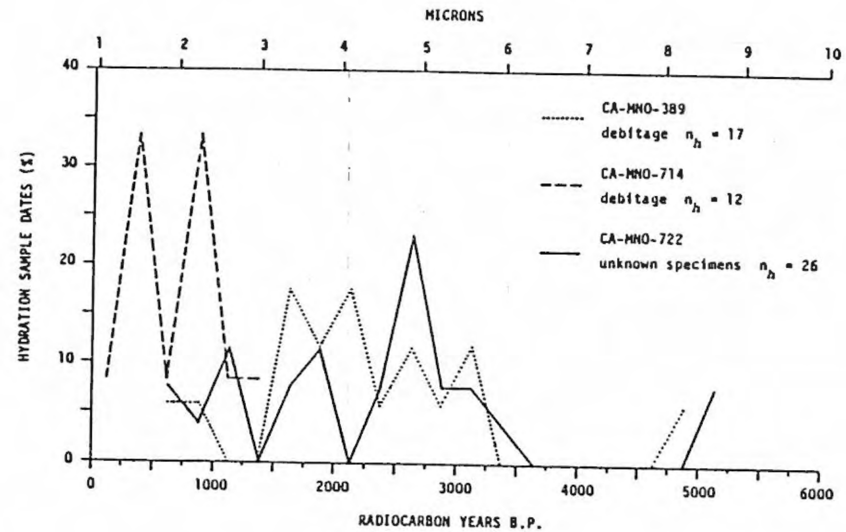


Fig. 21. Obsidian hydration curves for debitage from CA-MNO-389 (Garfinkel 1980a) and CA-MNO-714 (Triple R; Jackson 1982), and for unknown specimen types from CA-MNO-722 (Ericson 1977; Meighan and Vanderhoeven 1978). One specimen from CA-MNO-722 displays two hydration bands that differ by more than 0.5 µm. All specimens (54) traced by X-ray fluorescence or neutron activation to the Casa Diablo obsidian source. Hydration rate: Years b.p. = 668.54µm - 637.30 (n_h = number of hydration sample dates).

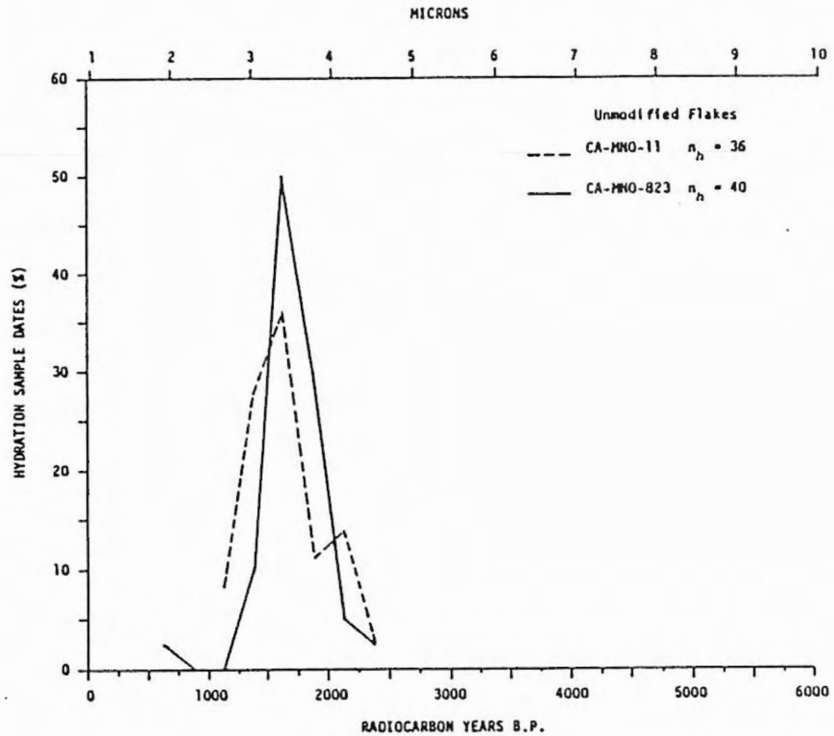


Fig. 22. Obsidian hydration curves for unmodified flakes from CA-MNO-11 and CA-MNO-823 (Bouscaren, Hall, and Swenson 1982). One specimen from CA-MNO-11 displays two hydration bands that differ by more than 0.5 µm. Specimen source(s) undetermined, probably 90% or more Casa Diablo. Hydration rate: Years b.p. = 668.54µm − 637.30 (n_h = number of hydration sample dates).

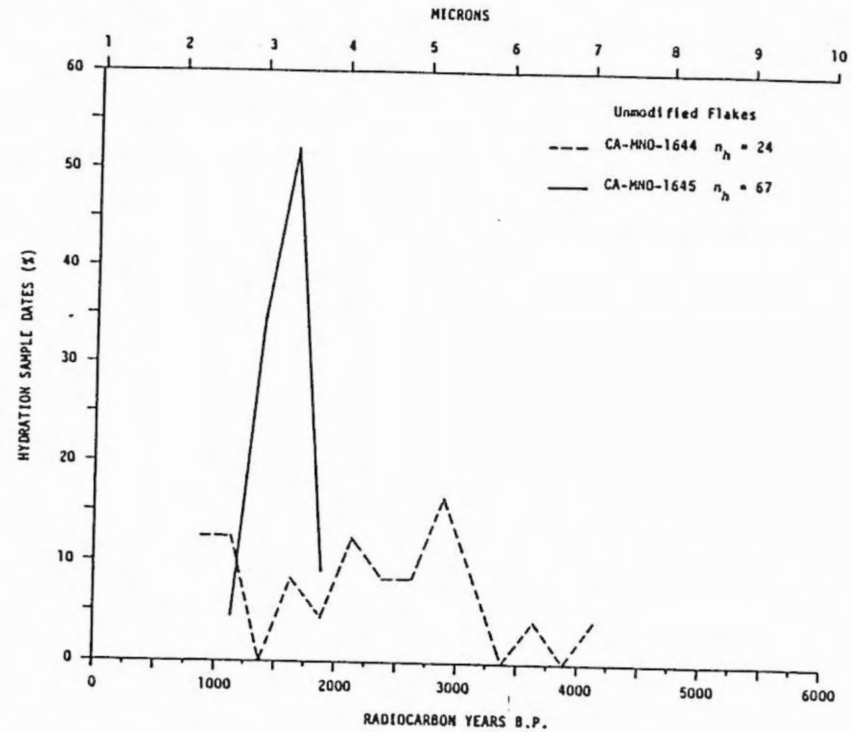


Fig. 23. Obsidian hydration curves for unmodified flakes from CA-MNO-1644 and CA-MNO-1645 (Bouscaren, Hall, and Swenson 1982). Specimen source(s) undetermined, probably 90% or more Casa Diablo. Hydration rate: Years b.p. = 668.54µm − 637.30 (n_h = number of hydration sample dates).

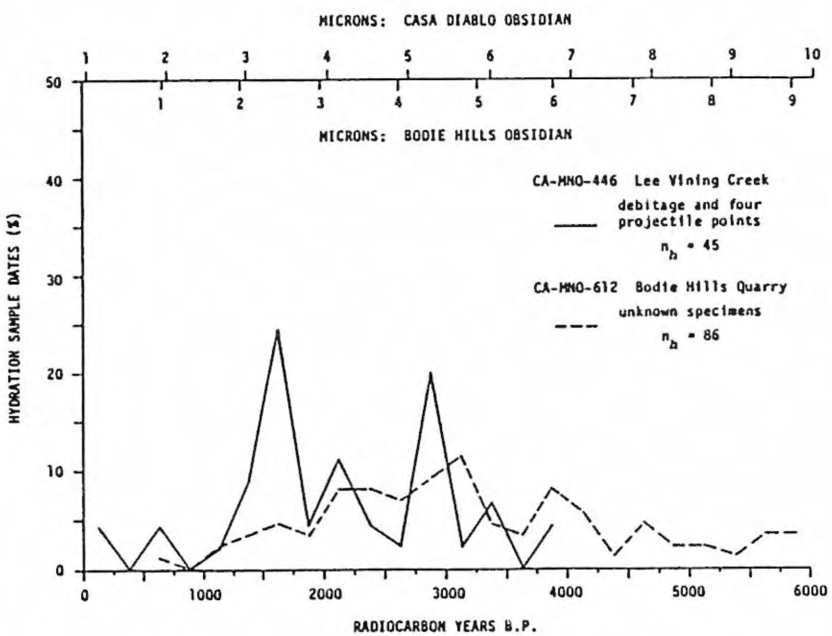


Fig. 24. Obsidian hydration curves for debitage and four projectile points from CA-MNO-446 (Bettinger 1981) and for unknown specimen types from CA-MNO-612 (Singer and Ericson 1977; Meighan and Vanderhoeven 1978). Two specimens from CA-MNO-612 display two hydration bands that differ by more than 0.5 µm. All specimens from CA-MNO-446 traced by X-ray fluorescence to the Casa Diablo obsidian source. Hydration rate: Years b.p. = 668.54µm − 637.30. CA-MNO-612 specimen source(s) undetermined, presumably 90% or more Bodie Hills. Hydration rate: Years b.p. = 650µm (Ericson 1975, 1977). Number of hydration sample dates indicated by n_h.

Moreover, if it is assumed that the Casa Diablo and Bodie Hills tool production declines began at roughly the same time, which could be quite likely, then the temporal divergence evident in Fig. 24 between the Lee Vining Creek site and the Bodie Hills quarry hydration curves ($W = 0.66$, $p > 0.10$) may indicate that a hydration rate of 650 years per micron is ca. 500-700 years too slow for Bodie Hills obsidian.

In summary, obsidian hydration curves (Figs. 15-24) for ten prehistoric sites (CA-MNO-11, -382, -389, -446, -529, -561, -722, -823, -1644, -1645) in the general vicinity of the Long Valley-Mono Basin volcanoes suggest that obsidian stoneworking, and perhaps subsistence-settlement activities on the whole, increased substantially in the region after ca. 3500 b.p., declined abruptly ca. 1750-1250 b.p., and continued thereafter on a much reduced, intermittent basis until historic contact. Relatively frequent or intense obsidian stoneworking after ca. 3500 b.p. appears to coincide with (1) an apparent period of minimal volcanic activity in the eastern Sierra (Figs. 2-3; see Chapter II); (2) a predominantly cool, moist climatic regime (Recess Peak neoglacial advance) that may correlate with an overall increase in cultural activity in the Sierra Nevada, and in the western and southwestern Great Basin (see above); and (3) the growth of an extensive trans-Sierra obsidian exchange system during the Middle Horizon in central California. The decline in obsidian stoneworking in the Long Valley-Mono Basin region, ca. 1750-1250 b.p., appears to have begun at about the time of the South Coulee eruption in the Mono Craters (ca. 1695 ± 200 b.p.). Another relatively sharp drop ca. 750-500 b.p. in the hydration curves for sites in western Long Valley may temporally correlate with the multiple tephra eruptions from the

Glass Creek vents after ca. 900 b.p. and the eruption of tephra 1 ca. 720 ± 60 b.p. from the vent just south of Deadman Creek. The latter event involved a moderate magma release on the order of 0.1 km^3 (including a 5.5 km^2 ash flow) that produced abundant local deposits of pumice lapilli in western and southwestern Long Valley (Wood 1977a:94). Between ca. 1900 and 500 b.p., perhaps ten or more volcanoes erupted in the Mono Craters in addition to the South Coulee. Among these were Wilson Butte, the North Coulee, Panum Pumice Pit (ca. 1190 ± 80 b.p.), the Northwest Coulee, and Panum Crater (ca. 640 ± 40 b.p.) (Figs. 2-3). Compared to the volume of tephra 1 erupted (not including the Deadman Creek ash flow), the South Coulee eruption may have generated three to five times as much or more in local and distant tephra, and the eruption of the Panum Pumice Pit (tephra 2) perhaps twice as much or more (Wood 1977a:94, 1977b:Table 1). The North and Northwest coulee obsidian domes appear to be the largest extruded in the Mono Craters, though the volume of tephra ejected before or during these extrusions has not been estimated (cf. Wood 1977b: Table 1). Given the apparent temporal correlations in the Long Valley-Mono Basin region between archaeological data that suggest reduced obsidian stoneworking after ca. 1750 b.p. and volcanic data that suggest an increase in the frequency and magnitude of eruptions after ca. 1900 b.p., some preliminary comments are offered in the following section about the cultural implications of recurrent late Holocene volcanism in the eastern Sierra.

CONCLUDING REMARKS: CULTURAL IMPLICATIONS OF LATE HOLOCENE VOLCANISM IN THE EASTERN SIERRA

The results of archaeological investigations in the eastern Sierra

and surrounding regions suggest significant changes in prehistoric cultural behavior over the last two millennia. Current interpretations of these changes incorporate a variety of cultural and climatic data. Recurrent late Holocene volcanism in the Long Valley-Mono Basin region, however, has not been seriously considered as a persistent factor that affected, to a greater or lesser extent, regional economic and demographic patterns. In many ways the research and analysis presented here, if of merit, constitute but a crude, initial appraisal of a complex interdisciplinary problem in prehistoric research. The objective in these final pages is to briefly examine how volcanism may have contributed to the diachronic processes underlying apparent or proposed changes in prehistoric cultural behavior.

In the Chowchilla River area of the western Sierra ca. 80-90 km west-southwest of Long Valley, Moratto, King, and Woolfenden (1978:155-156) proposed that an interval of warm, dry climate after ca. 1400 B.P. critically reduced food resources and caused a period of economic, social, and political disruption characterized by population fragmentation, increased violence, an expanding emphasis on the exploitation of acorns, and a cessation of exchange activities with groups further to the west and southwest. This period of disruption, known as the Raymond Phase (Moratto 1972), continued for 900 years until, according to Moratto, King, and Woolfenden (1978:155), a cool, moist climate returned ca. 500 B.P. and increased the food supply which in turn permitted population growth, social stability, and economic development including the resumption of trade relations reaching to the California coast. As reviewed earlier (Chapter II), paleoclimatic data from the Sierra Nevada and

and adjacent regions of the southwestern Great Basin suggest warm-moist then warm-dry climatic conditions after the end of the Recess Peak neoglacial advance ca. 2200 B.P.; a more-or-less dominant cooling trend after ca. 1700 B.P.; a brief period of cool, moist climate ca. 1100-950 B.P. that was accompanied by an unnamed neoglacial surge in the Sierra; a possibly severe drought ca. 950-750 B.P.; and unusually cold temperatures and increased moisture after ca. 750 B.P. that correlate with the Matthes neoglacial advance dated ca. 750-200 B.P. (though annual precipitation may have been somewhat lower than during the earlier Recess Peak advance [LaMarche 1973:656-657]).

Hence, rather than consistently warm and dry, climate ca. 1400-500 B.P. seems to have been highly variable (at least in the eastern Sierra). This could suggest that climatic variability created temporal irregularities in the food supply of sufficient magnitude to precipitate the economic difficulties in the western Sierra during the Raymond Phase. Subsistence problems under such conditions escalate rapidly when a critical component breaks down in an economic exchange system that might otherwise have been able to alleviate irregularities in the food supply (cf. Bettinger and King 1971). In this context, it may be significant that, as it is chronologically defined, the Raymond Phase encompasses a large portion of the late Holocene volcanic episode in the eastern Sierra. If it can be assumed that prehistoric hunter-gatherers in the western Sierra prospered economically and otherwise ca. 3000-1500 b.p. as merchants in an extensive east-west exchange system dependent upon the westward flow of obsidian from the eastern Sierra, then multiple eruptions ca. 1900-500 b.p. in the Long Valley-Mono Basin region may have often

interrupted — or eliminated for significant periods of time — the availability of and access to this vital commodity. Coupled with a highly variable climate, the economic impact of volcanism in the eastern Sierra may well have forced fundamental subsistence-settlement changes in the western Sierra to compensate for the demographic disequilibrium of a general economic depression. Given the distance between the Chowchilla River area and the eastern Sierra volcanoes (80-90 km), it is not suggested here that direct volcanic effects on the local environment were severe or recurrent enough to cause the long-term instability recognized by Moratto, King, and Woolfenden (1978). Nonetheless, it is likely that ashfalls of at least a few centimeters depth occurred on more than one occasion in the foothills of the western Sierra.

A relatively rapid breakdown of economic, social, and political organization in the western Sierra would probably have had serious ramifications for hunter-gatherer populations in adjacent regions of central California (cf. King 1976). Traditional adaptive strategies may have been inadequate to deal with uncertainties in the supply of stressed, critical resources. A careful review of central California prehistory from such a perspective, though, is far beyond the scope or purpose of this work and it remains as a line of inquiry for further research. At a minimum, it would seem logical that volcanic interruptions of the westward flow of eastern Sierra obsidian may have played a pivotal role in accelerating the apparent growth after ca. 1500 b.p. of an obsidian exchange system in central California that was centered on northern California obsidian sources (cf. Moratto, King, and Woolfenden 1978:158; Ericson 1982:Fig. 6.8). In this regard, it is of interest to note that based on the distributions and sources of time-sensitive marine shell bead and ornament types at prehistoric sites in the Great Basin, Bennyhoff and Hughes (1979:25) postulated a "shift" from an "early dominance" of exchange relationships between central California and the Great Basin to a "late dominance" of northern California in the economic interactions between Great Basin populations and those occupying regions further to the west. Although it is unclear as to exactly when this shift began (it may be evident by ca. 1000-600 b.p.), Bennyhoff and Hughes (1979:25) suggested that the shift occurred "in response to uncertain passage of central California beads through the Sierra." If it is reasonable to assume that late Holocene volcanic eruptions in the Long Valley-Mono Basin region may have substantially curtailed the westward movement of obsidian from the eastern Sierra into central California, then the observations made by Bennyhoff and Hughes (1979) may indicate a not unsurprising, related reduction in the eastward movement of shell artifacts from central California through the central Sierra into the Great Basin. Finally, it is quite conceivable that the direct and indirect effects of the Long Valley-Mono Basin eruptions were in part responsible for creating conditions (e.g., low population densities) on the upper western slopes of the Sierra that allowed ancestral Western Mono speakers to migrate westward over the crest of the Sierra after ca. 500 b.p. (cf. Bettinger 1979a:136-137).

The cultural significance of late Holocene volcanism in the eastern Sierra in surrounding areas of the Great Basin is difficult to assess on the basis of available archaeological data. To a great extent, this reflects the lack of archaeological studies in large areas lying immediately

to the east, northeast, and north of the volcanoes (e.g., Adobe Valley, Walker River drainage). In the Teels Marsh-Truman Meadows area, ca. 55-75 km east-northeast of the Long Valley-Mono Basin volcanoes, preliminary diachronic settlement density curves (weighted for the amount of time represented by a given temporal unit [see Chapter IV]) suggest a peak in pinyon pine nut gathering after ca. 3250 b.p. that was followed by a comparatively sharp drop in upland land-use activity after ca. 1500-1250 b.p., though resource procurement clearly continued in the area on a fairly regular basis until historic contact (Hall in preparation). It is not, however, evident at this stage in the research that eruptions in the eastern Sierra ca. 1900-500 b.p. were a major factor in an apparent, relative reduction in upland land-use activity after ca. 1500 b.p. in the Teels Marsh-Truman Meadows area. Nonetheless, it may be significant that there appears to have been a pronounced increase after ca. 1500 b.p. in the exploitation of pine nuts 100 km to the south-southeast in the Inyo Mountains above central Owens Valley (Bettinger 1975, 1976, 1977a).

Thus, a general implication of the eastern Sierra eruptions that may merit consideration in the evaluation of archaeological records for adjacent Great Basin areas is the possibility that the eruptions periodically created local shortages in the food supply that could only be alleviated by shifting subsistence-settlement activities to less affected, outlying areas perhaps already the focus of increasingly intensive patterns of resource procurement (e.g., Owens Valley). In turn, the cumulative impact of periodic, excessive demands on existing resources (possibly aggravated by the effects of highly variable climate on resource predictability and availability) may have contributed to a regional intensification and diversification of land-use activities. Recurrent late Holocene volcanism in the Long Valley-Mono Basin region, therefore, may have played a significant role not only in the collapse of the trans-Sierra obsidian economy, but also in further stimulating the evolution of adaptive strategies in nearby areas of the Great Basin that Bettinger and Baumhoff (1982) felt ultimately enabled Numic-speaking peoples from central-eastern California to rapidly occupy most of the Great Basin within the last thousand years or so. Specific causal relationships in this regard, however, remain to be explored on a careful, systematic basis.

In conclusion, it is obvious that a great deal more research will be required to fully appreciate the impact of multiple late Holocene volcanic eruptions in the eastern Sierra Nevada on local and regional cultural development. The present research has been at most a quite cursory review of complex interdisciplinary data that, from the perspective of archaeological reconstruction and explanation, would seem to be of critical importance to an accurate understanding of the fundamental ecological interactions that took place between prehistoric human societies and the environments they occupied in the eastern Sierra. An attempt has been made in this work to build a chronological model of potential correlations between cultural and environmental phenomena — a model that can be tested for its reliability with the results of ongoing and future investigations. Given that the model is derived from diverse prehistoric records, it is recognized that the cultural, volcanic, and climatic chronologies developed here can be easily questioned by those

pursuing research on these topics in several separate disciplines. In particular, the proposal that late Holocene volcanic eruptions may have significantly influenced prehistoric cultural behavior in the Long Valley-Mono Basin region and, perhaps, in adjacent areas of the Great Basin and central Sierra Nevada, can be directly examined in light of discoveries about (1) land-use strategies over time in specific localities; (2) obsidian quarrying and tool production trends at obsidian sources both in the eastern Sierra and elsewhere in the Far West; (3) the organization of trans-Sierra economic exchange systems; and (4) the spatial and temporal patterns characterizing the movement of important exchange commodities (e.g., obsidian, and shell beads and ornaments). Finally, there appears to be an outstanding opportunity for archaeological research in the eastern Sierra to contribute meaningfully to geologic efforts to determine the chronology and magnitude of prehistoric volcanic eruptions in the Long Valley-Mono Basin region.

REFERENCES

Adam, D.P.
1967 Late Pleistocene and Recent Palynology in the Central Sierra Nevada, California. In: Quaternary Paleoecology, E.J. Cushing and H.E. Wright, Jr., eds., pp. 207-302. New Haven: Yale University Press.

Aikens, C.M.
1970 Hogup Cave. University of Utah Anthropological Papers No. 93.

1977 Interdisciplinary Models and Great Basin Prehistory: A Comment on Current Orientations. In: Models and Great Basin Prehistory: A Symposium, D.D. Fowler, ed. Desert Research Institute Publications in the Social Sciences No. 12:211-213.

1978 The Far West. In: Ancient Native Americans, J.D. Jennings, ed., pp. 131-181. San Francisco: Freeman and Co.

Alfors, J.T.
1980 Regional Geology of the Mammoth Lakes Region, California. In: Mammoth Lakes, California: Earthquakes of May 1980, R.W. Sherburne, ed. California Division of Mines and Geology Special Report 150:1-6.

Ahler, S.A.
1970 Projectile Point Form and Function at Rogers Shelter, Missouri. Missouri Archaeological Survey Research Series No. 8.

Amsden, C.A.
1935 The Pinto Basin Artifacts. In: The Pinto Basin Site, E.W.C. Campbell and W.H. Campbell. Southwest Museum Papers No. 9: 33-51.

1937 The Lake Mohave Artifacts. In: The Archaeology of Pleistocene Lake Mohave: A Symposium, E.W.C. Campbell et al. Southwest Museum Papers No. 11:51-97.

Antevs, E.
1948 Climatic Changes and Pre-White Man. University of Utah Bulletin 38(20) Biological Series 10(7):167-191.

1953 The Postpluvial or Neothermal. Berkeley: University of California Archaeological Survey Reports No. 22:9-23.

Aschmann, H.H.
1958 Great Basin Climates in Relation to Human Occupance. Berkeley: University of California Archaeological Survey Reports No. 47:23-40.

Bailey, R.A., G.B. Dalrymple, and M.A. Lanphere
1976 Volcanism, Structure, and Geochronology of Long Valley Caldera, Mono County, California. Journal of Geophysical Research 81:725-746.

Barrett, S.A., and E.W. Gifford
1933 Miwok Material Culture. Public Museum of the City of Milwaukee Bulletin 2(4):117-376.

Basgall, M.E.
1979 To Trade or Not to Trade: A Pomo Example. Journal of California and Great Basin Anthropology 1(1):178-182.

1982 Archaeology of Forest Service Forty Site (CA-Mno-529), Mono County, California. Manuscript on file at the Inyo National Forest, Bishop.

Batchelder, G.L.
1970a Post-glacial Ecology at Black Lake, Mono County, California. Ph.D. dissertation, Arizona State University, Tempe.

1970b Post-glacial Fluctuations of Lake Level in Adobe Valley, Mono County, California. First Meeting of the American Quaternary Association, Abstracts, p. 7.

Bateman, P.C.
1965 Geology and Tungsten Mineralization of the Bishop District, California. United States Geological Survey Professional Paper 470.

Baumhoff, M.A., and J.S. Byrne
1959 Desert Side-notched Points as a Time Marker in California. Berkeley: University of California Archaeological Survey Reports No. 48:32-65.

Baumhoff, M.A., and R.F. Heizer
1965 Postglacial Climate and Archaeology in the Desert West. In: The Quaternary of the United States, H.E. Wright, Jr., and David G. Frey, eds., pp. 697-707. Princeton: Princeton University Press.

Bedwell, S.F.
1973 Fort Rock Basin: Prehistory and Environment. Eugene: University of Oregon Press.

Benedict, J.B.
1968 Recent Glacial History of an Alpine Area in the Colorado Front Range, II: Dating Glacial Deposits. Journal of Glaciology 7:77-87.

1973 Chronology of Cirque Glaciation, Colorado Front Range. Quaternary Research 3:584-599.

Bennyhoff, J.A.
1956 An Appraisal of the Archaeological Resources of Yosemite National Park. Berkeley: University of California Archaeological Survey Reports No. 34:1-71.

Bennyhoff, J.A., and R.E. Hughes
1979 Shell Beads and Ornaments from Gatecliff Shelter, Nevada: Variability in Marine Shell Exchange in the Western Great Basin. Manuscript on file at the Inyo National Forest, Bishop.

Berger, R., and W.F. Libby
1966 UCLA Radiocarbon Dates. Radiocarbon 8:494.

Bettinger, R.L.
1973 The Archaeology of Portillo's Drill, Site 05-04-51-16, Mono County, California. Manuscript on file at the Archaeological Research Unit, University of California, Riverside.

1975 The Surface Archaeology of Owens Valley, Eastern California: Prehistoric Man-Land Relationships in the Great Basin. Ph.D. dissertation, University of California, Riverside.

1976 The Development of Pinyon Exploitation in Central Eastern California. Journal of California Anthropology 3(1):81-95.

1977a Aboriginal Human Ecology in Owens Valley, Eastern California: Prehistoric Change in the Great Basin. American Antiquity 42(1):3-17.

1977b The Surface Archaeology of the Long Valley Caldera, Mono County, California. Riverside: University of California Archaeological Research Unit Monograph No. 1.

1978a Archaeology of the Blue Flag Site (FS-05-04-53-37) (CA-MNO-34), Mono County, California. Manuscript on file at the Archaeological Research Unit, University of California, Riverside.

1978b Humboldt Basal-notched Bifaces as Time Markers in the Great Basin. Tebiwa, n.s., 10:1-7.

1979a Archaeology East of the Range of Light: Aboriginal Human Ecology of the Inyo-Mono Region of California. Manuscript on file at the United States Forest Service, San Francisco.

1979b Multivariate Statistical Analysis of a Regional Subsistence-Settlement Model for Owens Valley. American Antiquity 44(3): 455-470.

1979c Curation, Statistics, and Settlement Studies: A Reply to Munday and Lincoln. American Antiquity 44(2):352-359.

1980a Archaeology of the Triple R Site, FS-05-04-52-10 (CA-MNO-714), Mono County, California. Manuscript on file at the Inyo National Forest, Bishop.

1980b Obsidian Hydration Dates for Owens Valley Settlement Categories. Journal of California and Great Basin Anthropology 2(2):286-292.

1981 Archaeology of the Lee Vining Site, FS∅-05-04-51-219 (CA-Mno-446), Mono County, California. Manuscript on file at the Inyo National Forest, Bishop.

1982a Crooked Forks and Its Implications for the Numic Problem. Paper presented at the Great Basin Anthropological Conference, Reno.

1982b Aboriginal Exchange and Territoriality in Owens Valley, California. In: Contexts for Prehistoric Exchange, J.E. Ericson and T.K. Earle, eds., pp. 103-127. New York: Academic Press.

Bettinger, R.L., and M.A. Baumhoff
1982 The Numic Spread: Great Basin Cultures in Competition. American Antiquity 47(3):485-503.

Bettinger, R.L., and T.F. King
1971 Interaction and Political Organization: A Theoretical Framework for Archaeology in Owens Valley. Los Angeles: University of California Archaeological Survey Annual Report 13: 138-150.

Bettinger, R.L., and R.E. Taylor
1974 Suggested Revisions in Archeological Sequences of the Great Basin Interior in Southern California. Nevada Archeological Survey Research Paper No. 5:1-26.

Bicchieri, M.G., ed.
1972 Hunters and Gatherers Today. New York: Holt, Rinehart, and Winston.

Binford, L.R.
1968 Post-Pleistocene Adaptations. In: New Perspectives in Archaeology, L.R. Binford and S. Binford, eds., pp. 314-342. Chicago: Aldine.

1973 Interassemblage Variability — The Mousterian and the "Functional" Argument. In: The Explanation of Culture Change: Models in Prehistory, C. Renfrew, ed., pp. 227-253. London: Duckworth.

1980 Willow Smoke and Dogs' Tail: Hunters-Gatherer Settlement Systems and Archaeological Site Formation. American Antiquity 45(1):4-20.

Birkeland, P.W., D.R. Crandell, and G.M. Richmond
1971 Status of Correlation of Quaternary Stratigraphic Units in the Western Conterminous United States. Quarternary Research 1(2):208-227.

Birman, J.H.
1964 Glacial Geology Across the Crest of the Sierra Nevada, California. Geological Society of America Special Report No. 75.

Blackwelder, E.
1931 Pleistocene Glaciation in the Sierra Nevada and Basin Ranges. Geological Society of America Bulletin 42:865-922.

Blinman, E., P.J. Mehringer, Jr., and J.C. Sheppard
1979 Pollen Influx and the Deposition of Mazama and Glacier Peak Tephra. In: Volcanic Activity and Human Ecology, P.D. Sheets and D.K. Grayson, eds., pp. 393-425. New York: Academic Press.

Bouey, P.D.
1979 Population Pressure and Agriculture in Owens Valley. Journal of California and Great Basin Anthropology 1(1):162-170.

1982 Obsidian Source Analysis: Methods and Data Presentation. Appendix 2 in: Archaeology of Forest Service Forty Site (CA-Mno-529), Mono County, California, M.E. Basgall, pp. 192-199. Manuscript on file at the Inyo National Forest, Bishop.

Bouscaren, S., M.C. Hall, and J.D. Swenson
1982 Archaeological Test Excavations at Four Sites (CA-MNO-11, 823, 1644, 1645) near Mammoth Creek, Mono County, California. Manuscript on file at the Archaeological Research Unit, University of California, Riverside.

Boylan, R.T.
1982 Mammoth Lakes/Long Valley Microearthquake Project. California Geology 35(9):187-190.

Bright, R.C.
1966 Pollen and Seed Stratigraphy of Swan Lake, Southeastern Idaho: Its Relation to Regional Vegetational History and to Lake Bonneville History. Tebiwa, o.s., 9(2):1-47.

Brook, R.A.
1980 Inferences Regarding Aboriginal Hunting Behavior in the Saline Valley, Inyo County, California. Journal of California and Great Basin Anthropology 2(1):60-79.

Bryan, A.L., and R. Gruhn
1964 Problems Relating to the Neothermal Climatic Sequence. American Antiquity 29(3):307-315.

Bryson, R.A., and F.K. Hare
1974 World Survey of Climatology, Vol. 11: Climates of North America. New York: Elsevier Scientific.

Butler, B.R.
1972 The Holocene or Postglacial Ecological Crisis on the Eastern Snake River Plain. Tebiwa, o.s., 15(1):49-63.

Campbell, E.W.C.
1949 Two Ancient Archaeological Sites in the Great Basin. Science 109:340.

Chalfant, W.A.
1933 The Story of Inyo. (Revised Edition.) Los Angeles: Citizens Print Shop.

Chesterman, C.W.
1971 Volcanism in California. California Geology 28(8):139-147.

Christensen, M.N.
1966 Late Cenozoic Crustal Movements in the Sierra Nevada of California. Geological Society of America Bulletin 77:163-182.

Clewlow, C.W., Jr.
1967 Time and Space Relations of Some Great Basin Projectile Points. Berkeley: University of California Archaeological Survey Reports No. 70:141-149.

Clewlow, C.W., Jr., R.F. Heizer, and R. Berger
1970 An Assessment of Radiocarbon Dates from the Rose Spring Site (CA-Iny-372), Inyo County, California. Berkeley: University of California Archaeological Research Facility Contributions No. 7:19-27.

Cochran, W.G.
1977 Sampling Techniques. (Third Edition.) New York: Wiley and Sons.

Cooper, W.S.
1958 Terminology of Post-Valders Time. Geological Society of America Bulletin 69:941-945.

Cornwall, I.W.
1958 Soils for the Archaeologist. London: Phoenix House.

Cowan, R.A.
1972 The Archaeology of Barrel Springs Site (NV-PE-104), Pershing

County, Nevada. Berkeley: University of California Archaeological Research Facility.

Cowan, R.A., and K. Wallof
1974 Final Report, Fieldwork and Artifact Analysis: Southern California Edison No. 2 Control-Casa Diablo 115 Kv Transmission Line. Manuscript on file at the Archaeological Research Unit, University of California, Riverside.

Crandell, D.R., and D. Mullineaux
1978 Potential Hazards from Future Eruptions of Mt. St. Helens Volcano, Washington. United States Geological Survey Bulletin 1383-C.

Curry, R.R.
1966 Glaciation About 3,000,000 Years Ago in the Sierra Nevada. Science 154:770-771.

1969 Holocene Climatic and Glacial History of the Central Sierra Nevada, California. Geological Society of America Special Paper 123.

1971 Glacial and Pleistocene History of the Mammoth Lakes Sierra, California: A Geologic Guidebook. University of Montana Department of Geology Geological Series Publication No. 11.

Dalrymple, G.B.
1963 Potassium-Argon Dates of Some Cenozoic Volcanic Rocks of the Sierra Nevada, California. Geological Society of America Bulletin 74:379-390.

1964a Cenozoic Chronology of the Sierra Nevada, California. University of California Publications in Geological Sciences 47.

1964b Potassium-Argon Dates of Three Pleistocene Interglacial Basalt Flows from the Sierra Nevada, California. Geological Society of America Bulletin 75:753-758.

Dalrymple, G.B., A. Cox, and R.R. Doell
1965 Potassium-Argon Age and Paleomagnetism of the Bishop Tuff, California. Geological Society of America Bulletin 76:665-674.

Davis, C.A., and G.A. Smith
1981 Newberry Cave. Redlands: San Bernardino County Museum Association.

Davis, E.L.
1959 A Child Burial near Mono Lake, California. Los Angeles: University of California Archaeological Survey Annual Report 1:69-70.

1963 The Desert Culture of the Western Great Basin: A Lifeway of Seasonal Transhumance. American Antiquity 29(2):202-212.

1964 An Archaeological Survey of the Mono Lake Basin and Excavations of Two Rockshelters, Mono County, California. Los Angeles: University of California Archaeological Survey Annual Report 6:225-353.

1965 An Ethnography of the Kuzedika Paiute of Mono County, California. University of Utah Anthropological Papers 75:1-55.

Davis, J.T.
1961 Trade Routes and Economic Exchange Among the Indians of California. Berkeley: University of California Archaeological Survey Reports No. 54.

Davis, J.O.
1978 Quaternary Tephrachronology of the Lake Lahontan Area, Nevada and California. Nevada Archeological Survey Research Paper No. 7.

Davis, J.O., and R. Elston
1972 New Stratigraphic Evidence of Late Quaternary Climatic Change in Northwestern Nevada. In: Great Basin Cultural Ecology: A Symposium, Don D. Fowler, ed. Desert Research Institute Publications in the Social Sciences No. 8:43-56.

Deevey, E.S., and R.F. Flint
1957 Postglacial Hypsithermal Interval. Science 125:182-184.

Denton, G.H., and W. Karlén
1973 Holocene Climatic Variations — Their Pattern and Possible Causes. Quaternary Research 3(2):155-205.

Doell, R.R., G.B. Dalrymple, and A. Cox
1966 Geomagnetic Polarity Epochs: Sierra Nevada, 3. Journal of Geophysical Research 71:531-541.

Doyle, H.M.
1934 A Child Went Forth. New York: Gotham House.

Elsasser, A.B.
1960 The Archaeology of the Sierra Nevada in California and Nevada. Berkeley: University of California Archaeological Survey Reports No. 51:1-93.

1978 Development of Regional Prehistoric Cultures. In: Handbook of North American Indians, Vol. 8: California, R.F. Heizer, ed., pp. 37-57. Washington, D.C.: Smithsonian Institution.

Elston, R.G.
1971 A Contribution to Washo Archeology. Nevada Archeological Survey Research Paper No. 2.

Elston, R.G., ed.
1976 Holocene Environmental Change in the Great Basin. Nevada Archeological Survey Research Paper No. 6.

Enfield, R., and G. Enfield
1964 Mammoth Creek Cave, Mono County, California. Los Angeles: University of California Archaeological Survey Annual Report 6:395-426.

Ericson, J.E.
1975 New results in obsidian hydration dating. World Archaeology 7:151-159.

1977 Prehistoric Exchange Systems in California: The Results of Obsidian Dating and Tracing. Ph.D. dissertation, University of California, Los Angeles.

1982 Production for Obsidian Exchange in California. In: Contexts for Prehistoric Exchange, J.E. Ericson and T.K. Earle, eds., pp. 129-148. New York: Academic Press.

Ericson, J.E., and R. Berger
1976 Physics and Chemistry of the Hydration Process in Obsidians II: Experiments and Measurements. In: Advances in Obsidian Glass Studies: Archaeological Geochemical Perspectives, R.E. Taylor, ed., pp. 46-62. Park Ridge: Noyes Press.

Ericson, J.E., T.A. Hagan, and C.W. Chesterman
1976 Prehistoric Obsidian in California II: Geologic and Geographic Aspects. In: Advances in Obsidian Glass Studies: Archaeological and Geochemical Perspectives, R.E. Taylor, ed., pp. 218-239. Park Ridge: Noyes Press.

Evernden, J.F., and R.W. Kistler
1970 Chronology of Emplacement of Mesozoic Batholithic Complexes in California and Western Nevada. United States Geological Survey Professional Paper 623.

Fenenga, Franklin
1953 The Weights of Chipped Stone Points: A Clue to Their Functions. Southwestern Journal of Anthropology 9(3):309-323.

Fenneman, M.N.
1939 Physiography of the Western United States. New York: McGraw-Hill.

Flannery, K.V.
1968 Archeological Systems Theory and Early Mesoamerica. In: Anthropological Archeology in the Americas, B.J. Meggers, ed., pp. 67-87. Washington, D.C.: Anthropological Society of Washington.

Fowler, D.D.
1966 Great Basin Social Organization. In: The Current Status of Anthropological Research in the Great Basin: 1964, W.L. d'Azevedo, W.A. Davis, D.D. Fowler, and W. Suttles, eds. Desert Research Institute Publications in the Social Sciences No. 1:57-74.

Friedman, I.
1968 Hydration Rind Dates Rhyolite Flows. Science 159:878-881.

Friedman, I., and W. Long
1976 Hydration Rate of Obsidian. Science 191:347-352.

Friedman, I., and R.L. Smith
1960 A New Dating Method Using Obsidian: Part I, The Development of the Method. American Antiquity 25(4):476-493.

Friedman, I., R.L. Smith, and W. Long
1966 Hydration of Natural Glass and the Formation of Perlite. Geological Society of America Bulletin 77:323-328.

Fritts, H.C., and G.A. Gordon
1980 Annual Precipitation for California since 1600 Reconstructed from Western North American Tree Rings. California Department of Water Resources Agreement No. B53367.

Garfinkel, A.P.
1980a An Initial Archaeological Evaluation of CA-Iny-2146, Inyo County, California. California Department of Transportation Environmental Studies Branch Archaeological Reports.

1980b An Archaeological Survey along Highway 395 and Excavation of CA-Mno-389. California Department of Transportation Environmental Studies Branch Archaeological Reports.

Garfinkel, A.P., and R.A. Cook
1979 Aspects of Prehistoric Culture Change in Central Eastern California: The Sherwin Grade Site (09-Mno-395). California Department of Transportation Occasional Papers in Archaeology No. 1.

Gifford, E.W.
1932 The Northfork Mono. Berkeley: University of California Publications in American Archaeology and Ethnology 31(2):15-65.

Gilbert, C.M.
1938 Welded Tuff in Eastern California. Geological Society of America Bulletin 49:1829-1862.

Gilbert, C.M., M.N. Christensen, Y. Al-Rawi, and K.R. Lajoie
1968 Structural and Volcanic History of Mono Basin, California-Nevada. In: Studies in Volcanology: A Memoir in Honor of Howell Williams, R.R. Coats, R.L. Hay, and C.A. Anderson, eds. Geological Society of America Memoir 116:275-329.

Goss, J.A.
1977 Linguistic Tools for the Great Basin Prehistorian. In: Models and Great Basin Prehistory: A Symposium, D.D. Fowler, ed. Desert Research Institute Publications in the Social Sciences No. 12:49-70.

Grayson, D.K.
1979 Mount Mazama, Climatic Change, and Fort Rock Basin Archaeofauna. In: Volcanic Activity and Human Ecology, P.D. Sheets and D.K. Grayson, eds., pp. 427-457. New York: Academic Press.

Grosscup, G.L.
1960 The Culture History of Lovelock Cave, Nevada. Berkeley: University of California Archaeological Survey Reports No. 52.

1977 Notes on Boundaries and Culture of the Panamint Shoshone and Owens Valley Paiute. Berkeley: University of California Archaeological Research Facility Contributions No. 35:109-150.

Hall, M.C.
1980 Surface Archaeology of the Bodie Hills Geothermal Area, Mono County, California: A Cultural Resource Inventory. Manuscript on file at the Bureau of Land Management, Bakersfield District Office.

1981 Land-use Changes in Owens Valley Prehistory: A Matter of Statistical Inference. American Antiquity 46(3):648-656.

1982a Report on an Archaeological Survey Near Five Bridges, Owens Valley, California. Eastern Sierra Archaeological Services Technical Report Series.

1982b Report on an Archaeological Survey of Upper Queen Canyon in the Northern White Mountains, Esmeralda County, Nevada. Eastern Sierra Archaeological Services Technical Report Series.

n.d. Surface Archaeology in the Teels Marsh-Truman Meadows Area, Mineral County, Nevada, and Mono County, California (in preparation).

Hall, M.C., P.J. Wilke, D.L. Cart, and J.D. Swenson
1981 An Archaeological Survey of the Proposed Southern California Edison Ivanpah Generating Station Plant Site, and Related Rail, Coal Slurry, Water, and Transmission Line Corridors, San Bernardino County, California, and Clark County, Nevada. Manuscript on file at the Archaeological Research Unit, University of California, Riverside.

Harper, K.T., and G.M. Alder
1972 Paleoclimatic Inferences Concerning the Last 10,000 Years From a Resampling of Danger Cave, Utah. In: Great Basin Cultural Ecology: A Symposium, D.D. Fowler, ed. Desert Research Institute Publications in the Social Sciences No. 8: 13-23.

Harrington, M.R.
1933 Gypsum Cave, Nevada. Southwest Museum Papers No. 8.

1957 A Pinto Site at Little Lake. Southwest Museum Papers No. 17.

Heizer, R.F.
1966 Languages, Territories, and Names of California Indian Tribes. Berkeley: University of California Press.

Heizer, R.F., and M.A. Baumhoff
1961 The Archaeology of Two Sites at Eastgate, Churchill County, Nevada: Wagon Jack Shelter. Berkeley: University of California Anthropological Records 20(4):119-149.

Heizer, R.F., and C.W. Clewlow, Jr.
1968 Projectile Points from Site NV-CH-15, Churchill County, Nevada. Berkeley: University of California Archaeological Survey Reports No. 71:59-88.

Heizer, R.F., and T.R. Hester
1978 Great Basin. In: Chronologies in New World Archaeology, R.E. Taylor and C.W. Meighan, eds., pp. 147-199. New York: Academic Press.

Heizer, R.F., and L.K. Napton
1970 Archaeology and the Prehistoric Great Basin Lacustrine Subsistence Regime as Seen from Lovelock Cave, Nevada. Berkeley: University of California Archaeological Research Facility Contributions No. 10.

Heizer, R.F., and M.A. Whipple
1971 The California Indians: A Source Book. Berkeley: University of California Press.

Hester, T.R.
1973 Chronological Ordering of Great Basin Prehistory. Berkeley:

University of California Archaeological Research Facility Contributions No. 17.

Hildebrandt, W.
1981 Interlaken Right of Way Project Archaeological Impact Study, Final Report. Manuscript on file at the Inyo National Forest, Bishop.

Hindes, M.G.
1959 The Archaeology of the Huntington Lake Region in the Southern Sierra Nevada, California. Berkeley: University of California Archaeological Survey Reports No. 58:1-79.

Huber, N.K., and C.D. Rinehart
1967 Cenozoic Volcanic Rocks of the Devils Postpile Quadrangle, Eastern Sierra Nevada, California. United States Geological Survey Professional Paper 554-D.

Hunt, C.B., and D.R. Mabey
1966 Stratigraphy and Structure, Death Valley, California. United States Geological Survey Professional Paper 494-A.

Jack, R.N.
1976 Prehistoric Obsidian in California, I: Geochemical Aspects. In: Advances in Obsidian Glass Studies: Archaeological and Geochemical Perspectives, R.E. Taylor, ed., pp. 183-217. Park Ridge: Noyes Press.

Jack, R.N., and I.S.E. Carmichael
1968 The Chemical "Fingerprinting" of Acid Volcanic Rocks. California Division of Mines and Geology Special Report 100:17-32.

Jackson, R.J.
1982 Obsidian Hydration Analysis: Methods and Data Presentation. Appendix 1 in: Archaeology of Forest Service Forty site (CA-Mno-529), Mono County, California, M.E. Basgall, pp. 177-191. Manuscript on file at the Inyo National Forest, Bishop.

Jackson, T.L.
1974 The Economics of Obsidian in Central California Prehistory: Applications of X-Ray Fluorescence Spectography in Archaeology. M.A. thesis, San Francisco State University, San Francisco.

Janetski, J.C.
1979 Implications of Snare Bundles in the Great Basin and Southwest. Journal of California and Great Basin Anthropology 1(2):306-321.

Jennings, J.D., A.R. Schroedl, and R.N. Holmer
1980 Sudden Shelter. University of Utah Anthropological Papers 103.

Johnson, D.L.
1977 The Late Quaternary Climate of Coastal California: Evidence for an Ice Age Refugium. Quaternary Research 8:154-179.

Johnson, E.C.
1975 Walker River Paiutes: A Tribal History. Schurz: Walker River Paiute Tribe.

Kautz, R.R., and D.H. Thomas
1972 Palynological Investigations of Two Prehistoric Cave Middens in Central Nevada. Tebiwa, o.s., 15(2):43-54.

Kilbourne, R.T., and C.L. Anderson
1981 Volcanic History and "Active" Volcanism in California. California Geology 34(8):159-168.

Kilbourne, R.T., C.W. Chesterman, and S.H. Wood
1980 Recent Volcanism in the Mono Basin-Long Valley Region of Mono County, California. In: Mammoth Lakes, California, Earthquakes of May 1980, R.W. Sherburne, ed. California Division of Mines and Geology Special Report 150:7-22.

King, T.F.
1973a Archaeological Impact Evaluation: Control-Casa Diablo Transmission Line, Southern California Edison Company, Phase I Survey. Manuscript on file at the Archaeological Research Unit, University of California, Riverside.

1973b Archaeological Impact Evaluation: Control-Casa Diablo Transmission Line, Southern California Edison Company, Phase II Survey. Manuscript on file at the Archaeological Research Unit, University of California, Riverside.

1976 Political Differentiation Among Hunter-Gatherers: An Archaeological Test. Ph.D. dissertation, University of California, Riverside.

Kish, L.
1965 Survey Sampling. New York: Wiley and Sons.

Kistler, R.W.
1966 Structure and Metamorphism in the Mono Craters Quadrangle, Sierra Nevada, California. United States Geological Survey Bulletin 1221-E.

Kowta, M.
1969 The Sayles Complex: A Late Milling Stone Assemblage from Cajon Pass and the Ecological Implications of Its Scraper Planes. Berkeley: University of California Publications in in Anthropology 6.

Kroeber, A.L.
1925 Handbook of the Indians of California. Bureau of American Ethnology Bulletin No. 78.

1959 Recent Ethnic Spreads. Berkeley: University of California Publications in American Archaeology and Ethnology 47(3): 259-281.

Lajoie, K.R.
1968 Late Quaternary Stratigraphy and Geologic History of Mono Basin, Eastern California. Ph.D. dissertation, University of California, Berkeley.

LaMarche, V.C., Jr.
1973 Holocene Climatic Variations Inferred from Treeline Fluctuations in the White Mountains of California. Quaternary Research 3(4):632-660.

1974 Paleoclimatic Inferences from Long Tree-Ring Records. Science 183:1043-1048.

1978 Tree-Ring Evidence of Past Climatic Variability. Nature 276:334-338.

LaMarche, V.C., Jr., and H.A. Mooney
1967 Altithermal Timberline Advance in Western North America. Nature 213:980-982.

Lamb, S.N.
1958 Linguistic Prehistory in the Great Basin. International Journal of American Linguistics 24(2):95-100.

Lanning, E.P.
1963 Archaeology of the Rose Spring Site, Iny-372. Berkeley: University of California Publications in American Archaeology and Ethnology 49(3):237-336.

Lawton, H.W., P.J. Wilke, M. DeDecker, and W.M. Mason
1976 Agriculture Among the Paiute of Owens Valley. Journal of California Anthropology 3(1):13-50.

Layton, T.N.
1970 High Rock Archaeology: An Interpretation of the Prehistory of the Northwestern Great Basin. Ph.D. dissertation, Harvard University, Cambridge.

1973 Temporal Ordering of Surface Collected Obsidian Artifacts by Hydration Measurement. Archaeometry 15:129-132.

Lee, R.B., and I. DeVore, eds.
1968 Man the Hunter. Chicago: Aldine.

Levy, R.
1978 Eastern Miwok. In: Handbook of North American Indians, Vol. 8: California, R.F. Heizer, ed., pp. 398-413. Washington, D.C.: Smithsonian Institution.

Lipshie, S.R.
1976 Geologic Guidebook to the Long Valley-Mono Craters Region of Eastern California. Los Angeles: University of California Geological Society Field Guide No. 5.

Mack, R.N., N.W. Rutter, V.M. Bryant, Jr., and S. Valastro
1978 Reexamination of Postglacial Vegetation History in Northern Idaho: Hager Pond, Bonner Co. Quaternary Research 10(2): 241-255.

MacNeish, R.S.
1964 Ancient Mesoamerican Civilization. Science 143:531-537.

Madsen, D.B.
1972 Paleoecological Investigations in Meadow Valley Wash, Nevada. In: Great Basin Cultural Ecology: A Symposium, D.D. Fowler, ed. Desert Research Institute Publications in the Social Sciences No. 8:57-65.

Mayo, E.B.
1934 The Pleistocene Long Valley Lake in Eastern California. Science 80:95-96.

Mayo, E.B., L.C. Conant, and J.R. Chelikowsky
1936 Southern Extension of the Mono Craters, California. American Journal of Science 32:81-91.

McGuire, K.R., and A.P. Garfinkel
1980 Archaeological Investigations in the Southern Sierra Nevada: The Bear Mountain Segment of the Pacific Crest Trail. Bureau of Land Management Cultural Resources Publication.

Mehringer, P.J., Jr.
1967 Pollen Analysis of the Tule Springs Area, Nevada. Nevada State Museum Anthropological Papers 13:130-200.

1977 Great Basin Late Quaternary Environments and Chronology. In: Models and Great Basin Prehistory: A Symposium, D.D. Fowler, ed. Desert Research Institute Publications in the Social Sciences No. 12:113-167.

Mehringer, P.J., Jr., and J.C. Sheppard
1978 Holocene History of Little Lake, Mojave Desert, California. In: The Ancient Californians: Rancholabrean Hunters of the Mojave Lakes Country, E.L. Davis, ed. Los Angeles County Museum of Natural History Science Series 29:153-166.

Meighan, C.W.
1955 Notes on the Archaeology of Mono County, California. Berkeley: University of California Archaeological Survey Reports No. 28:6-28.

1981 The Little Lake Site, Pinto Points, and Obsidian Dating in the Great Basin. Journal of California and Great Basin Anthropology 3(2):200-214.

Meighan, C.W., and P.I. Vanderhoeven, eds.
1978 Obsidian Dates II: A Compendium of the Obsidian Hydration Determinations Made at the UCLA Obsidian Hydration Laboratory. Los Angeles: University of California Institute of Archaeology Monograph No. 6.

Mendenhall, W., L. Ott, and R.F. Larson
1974 Statistics: A Tool for the Social Sciences. North Scituate: Duxbury.

Merriam, C.H.
1955 Studies of California Indians. Berkeley: University of California Press.

Michels, J.W.
1964 Archaeological Investigations of the Mammoth Junction Site (Mno-382). Manuscript on file at the Archaeological Survey, University of California, Los Angeles.

1965 Lithic Serial Chronology through Obsidian Hydration Dating. Ph.D. dissertation, University of California, Los Angeles.

1969 Testing Stratigraphy and Artifact Reuse through Obsidian Hydration Dating. American Antiquity 34(1):15-22.

1982 The Hydration Rate for Casa Diablo Obsidian at Archaeological Sites in the Mammoth Junction Area of Mono County, California. MOHLAB Technical Report No. 6.

Michels, J.W., and C.A. Bebrich
1971 Obsidian Hydration Dating. In: Dating Techniques for the Archaeologist, H.N. Michael and E.K. Ralph, eds., pp. 164-221. Cambridge: MIT Press.

Miller, C.D., et al.
1982 Preliminary Assessment of Potential Volcanic Hazards in the Long Valley-Mono Lake Area, East-Central California and Southwestern Nevada. United States Geological Survey Open-file Report No. 82-583.

Miller, R.R.
1948 The Cyprinodont Fishes of the Death Valley System of Eastern California and Southwestern Nevada. University of Michigan Museum of Zoology Miscellaneous Publications 68:86-98.

1973 Two New Fishes, *Gila bicolor snyderi* and *Catostomus fumeiventris*, from the Owens River Basin, California. University of Michigan Museum of Zoology Occasional Papers 667.

Moratto, M.J.
1972 A Study of Prehistory in the Southern Sierra Nevada Foothills, California. Ph.D. dissertation, University of Oregon, Eugene.

Moratto, M.J., T.F. King, and W.B. Woolfenden
1978 Archaeology and California's Climate. Journal of California Anthropology 5(2):147-161.

Morrison, R.B.
1965 Quaternary Geology of the Great Basin. In: The Quaternary of the United States, H.E. Wright, Jr., and D.G. Frey, eds., pp. 265-285. Princeton: Princeton University Press.

Muir, J.
1917 The Mountains of California. New York: Century.

Munday, F.C., and T.R. Lincoln
1979 A Comment on Bettinger: Problems in Archaeological Interpretation. American Antiquity 44(2):345-351.

Nokleberg, W.J., and R.W. Kistler
1980 Paleozoic and Mesozoic Deformation in the Central Sierra Nevada, California. United States Geological Survey Professional Paper 1145.

O'Connell, J.F.
1967 Elko Eared/Elko Corner-notched Projectile Points as Time-Markers in the Great Basin. Berkeley: University of California Archaeological Survey Reports No. 70:129-140.

1975 The Prehistory of Surprise Valley. Ballena Press Anthropological Papers No. 4.

Orans, M.
1975 Domesticating the Functional Dragon: An Analysis of Piddockes's Potlatch. American Anthropologist 77(2):312-328.

Ore, H.T., and C.N. Warren
1971 Late Pleistocene-Early Holocene Geomorphic History of Lake Mojave, California. Geological Society of America Bulletin 82:2553-2562.

Pakiser, L.C., M.F. Kane, and W.H. Jackson
1964 Structural Geology and Volcanism of the Owens Valley Region, California: A Geophysical Study. United States Geological Survey Professional Paper 438.

Pakiser, L.C., F. Press, and M.F. Kane
1960 Geophysical Interpretation of Mono Basin, California. Geological Society of America Bulletin 71:416-448.

Parcher, F.M.
1930 The Indians of Inyo County. The Masterkey 4(1):146-153.

Payen, L.A.
1982 The Pre-Clovis of North America: Temporal and Artifactual Evidence. Ph.D. dissertation, University of California, Riverside.

Plog, F.T.
1973 Diachronic Anthropology. In: Research and Theory in Current Archeology, C.L. Redman, ed., pp. 181-198. New York: Wiley and Sons.

1974 The Study of Prehistoric Change. New York: Academic Press.

Porter, E.J., and G.J. Salontai
1982 Preliminary Soils Investigation for Apartment and Condominium Development, Mammoth Lakes, California. Geotechnical report submitted to Ryder Homes, Walnut Creek, California.

Porter, S.C., and G.H. Denton
1967 Chronology of Neoglaciation in the North American Cordillera. American Journal of Science 265:177-210.

Putnam, W.C.
1938 The Mono Craters, California. Geographical Review 38:68-82.

1949 Quaternary Geology of the June Lake District, Calif. Geological Society of America Bulletin 60:1281-1302.

Rahm, D.A.
1964 Glacial Geology of the Bishop Area, Sierra Nevada, California [abstract]. Geological Soceity of America Special Paper 76:221.

Riddell, H.S., Jr.
1951 The Archaeology of a Paiute Village Site in Owens Valley. Berkeley: University of California Archaeological Survey Reports No. 12:14-28.

Rinehart, C.D., and N.K. Huber
1965 The Inyo Crater Lakes: A Blast in the Past. California Division of Mines and Geology Mineral Information Service 18(9):169-172.

Rinehart, C.D., and W.C. Smith
1982 Earthquakes and Young Volcanoes Along the Eastern Sierra Nevada. Palo Alto: Genny Smith Books.

Roust, N.L., and C.W. Clewlow, Jr.
1968 Projectile Points from Hidden Cave (NV-CH-16), Churchill County, Nevada. Berkeley: University of California Archaeological Survey Reports No. 71:103-116.

Rubin, M., and C. Alexander
1960 USGS Radiocarbon Dates V. Radiocarbon 2:155-156.

Rusco, M.K., and J.O. Davis, eds.
1982 The Humboldt Project, Rye Patch Reservoir — Phase IV: Archaeological Data Synthesis Final Report. Carson City: Nevada State Museum Archaeological Services.

Russell, I.C.
1889 Quaternary History of Mono Valley, California. United States Geological Survey Annual Report No. 8:261-394.

Ryall, A., and F. Ryall
1983 Spasmodic Tremor and Possible Magma Injection in Long Valley Caldera, Eastern California. Science 219:1432-1433.

Sample, L.L.
1950 Trade and Trails in Aboriginal California. Berkeley: University of California Archaeological Survey Reports No. 8.

Savage, J.C., and M.M. Clark
1982 Magmatic Resurgence in Long Valley Caldera: Possible Cause of the 1980 Mammoth Lakes Earthquakes. Science 217:531-533.

Schiffer, M.B.
1976 Behavioral Archaeology. New York: Academic Press.

Sears, P.B., and A. Roosma
1961 A Climatic Sequence from Two Nevada Caves. American Journal of Science 259:669-678.

Šercelj, A., and D.P. Adam
1975 A Late Holocene Pollen Diagram from near Lake Tahoe, El Dorado County, California. United States Geological Survey Journal of Research 3(6):737-745.

Sharp, R.P.
1968 Sherwin Till-Bishop Tuff Geological Relationships, Sierra Nevada, California. Geological Society of America Bulletin 79:351-364.

Sharp, R.P., and J.H. Birman
1963 Addition to the Classical Sequence of Pleistocene Glaciations, Sierra Nevada, California. Geological Society of America Bulletin 74:1079-1086.

Sherburne, R.W., ed.
1980 Mammoth Lakes, California, Earthquakes of May 1980. California Division of Mines and Geology Special Report 150.

Sheridan, M.F.
1971 Guidebook to the Quaternary Geology of the East-Central Sierra Nevada. Phoenix: Lebeau.

Silverman, M.L., C.W. Chesterman, F.J. Kleinhampl, and C.H. Gray, Jr.
1972 K-Ar Ages of Volcanic Rocks and Gold-bearing Quartz-Adularia Veins in the Bodie Mining District, Mono County, California. Economic Geology 67:597-604.

Singer, C.A., and J.E. Ericson
1977 Quarry Analysis at Bodie Hills, Mono County, California: A Case Study. In: Exchange Systems in Prehistory, T.K. Earle and J.E. Ericson, eds., pp. 171-188. New York: Academic Press.

Slemmons, D.B.
1966 Cenozoic Volcanism of the Central Sierra Nevada, California. California Division of Mines and Geology Bulletin 190:199-208.

Smith, E.I.
1973 Mono Craters, California: A New Interpretation of the Eruptive Sequence. Geological Society of America Bulletin 84:2685-2690.

Smith, G.I.
1967 Field Guide to Examples of Later Quaternary Geology, Searles Valley, California. In: Guidebook for Friends of the Pleistocene, Pacific Coast Section, pp. 1-51. Menlo Park: United States Geological Survey.

1968 Late-Quaternary Geologic and Climatic History of Searles Lake, Southeastern California. In: Means of Correlation of Quaternary Successions, R.B. Morrison and H.E. Wright, Jr., eds., pp. 293-310. Salt Lake City: University of Utah Press.

Smith, R.L., and R.A. Bailey
1968 Resurgent Cauldrons. Geological Society of America Memoir 116:613-662.

Speth, L.K.
1969 Possible Fishing Cliques Among the Northern Paiute of the Walker River Reservation, Nevada. Ethnohistory 16:235-236.

Spier, R.F.G.
1978 Monache. In: Handbook of North American Indians, Vol. 8: California, R.F. Heizer, ed., pp. 426-436. Washington, D.C.: Smithsonian Institution.

Sterud, G.L.
1964 Preliminary Report of Archaeological Investigations at the Mammoth Junction Site: A Second Season (1964). Manuscript on file at the Archaeological Survey, University of California, Los Angeles.

Steward, J.H.
1928 Pottery from Deep Springs Valley, Inyo County, California. American Anthropologist 30(2):348.

1930 Irrigation without Agriculture. Michigan Academy of Science, Arts, and Letters, Papers 12:149-156.

1933 Ethnography of the Owens Valley Paiute. Berkeley: University of California Publications in American Archaeology and Ethnology 33(3):233-350.

1934 Two Paiute Autobiographies. Berkeley: University of California Publications in American Archaeology and Ethnology 34(5):355-440.

1938 Basin-Plateau Aboriginal Sociopolitical Groups. Bureau of American Ethnology Bulletin No. 120.

1955 Theory of Culture Change. Urbana: University of Illinois Press.

1970 The Foundations of Basin-Plateau Shoshonean Society. In: Languages and Cultures of Western North America: Essays in Honor of Sven Liljebad, E.H. Swanson, ed., pp. 113-151. Pocatello: Idaho State University Press.

Stewart, O.C.
1939 The Northern Paiute Bands. Berkeley: University of California Anthropological Records 2(3):127-149.

1941 Culture Element Distributions XIV: Northern Paiute. Berkeley: University of California Anthropological Records 4(3):361-446.

Struever, S.
1968 Problems, Methods, and Organization: A Disparity in the

Growth of Archeology. In: Anthropological Archeology in the Americas, B.J. Meggers, ed., pp. 131-151. Washington, D.C.: Anthropological Society of Washington.

Stuiver, M., and H.A. Polach
1977 Discussion: Reporting of ^{14}C Data. Radiocarbon 19:355-363.

Suess, H.E.
1968 Climatic Changes, Solar Activity, and the Cosmic-ray Production Rate of Natural Radiocarbon. Meteorological Monographs No. 8:146-150.

Tadlock, W.L., and J. Tadlock
1972 Preliminary Report of Archeological Investigations at the Hot Creek Hatchery Site, Mono County, California, Mno-611. Manuscript on file at the Inyo National Forest, Bishop.

Taylor, R.E., ed.
1976 Advances in Obsidian Glass Studies: Archaeological and Geochemical Perspectives. Park Ridge: Noyes Press.

Thomas, D.H.
1970 Archaeology's Operational Imperative: Great Basin Projectile Points as a Test Case. Los Angeles: University of California Archaeological Survey Annual Report No. 12:27-60.

1978 Arrowheads and Atlatl Darts: How the Stones Got the Shaft. American Antiquity 43(3):461-472.

1981 How to Classify the Projectile Points from Monitor Valley, Nevada. Journal of California and Great Basin Anthropology 3(1):7-43.

United States Geological Survey
1976 Geological Survey Research in 1975. United States Geological Survey Professional Paper 950.

Wahrhaftig, C., and J.H. Birman
1965 The Quaternary of the Pacific Mountain System in California. In: The Quaternary of the United States, H.E. Wright, Jr., and D.G. Frey, eds., pp. 299-340. Princeton: Princeton University Press.

Wallace, W.J.
1962 Prehistoric Cultural Development in the Southern California Deserts. American Antiquity 28(2):172-180.

Warren, C.N., and T.H. Hearne
1974 Preliminary Report on Archaeological Investigations, Route 09-Iny-395-118.3/129.4. Manuscript on file at the California Department of Transportation, Sacramento.

Warren, C.N., and A.J. Ranere
1968 Outside Danger Cave: A View of Early Man in the Great Basin. In: Early Man in Western North America, C. Irwin-Williams, ed. Eastern New Mexico University Contributions in Anthropology 1(4):6-18.

Weide, D.L.
1976 The Altithermal as an Archaeological "Non-problem" in the Great Basin. In: Holocene Environmental Change in the Great Basin, R. Elston, ed. Nevada Archeological Survey Research Paper No. 6:174-184.

Wilke, P.J.
1978 Late Prehistoric Human Ecology at Lake Cahuilla, Coachella Valley, California. Berkeley: University of California Archaeological Research Facility Contributions No. 38.

1983 An Archaeological Assessment of Certain Sites on Lower Cottonwood Creek, Inyo County, California. Manuscript on file at the Archaeological Research Unit, University of California, Riverside.

Wilke, P.J., and H.W. Lawton, eds.
1976 The Expedition of Capt. J.W. Davidson from Fort Tejon to the Owens Valley in 1859. Ballena Press Publications in Archaeology, Ethnology, and History No. 8.

Wood, J.J.
1978 Optimal Location in Settlement Space: A Model for Describing Location Strategies. American Antiquity 43(2):258-270.

Wood, S.H.
1975 Holocene Stratigraphy and Chronology of Mountain Meadows, Sierra Nevada, California. Ph.D. dissertation, California Institute of Technology, Pasadena.

1977a Distribution, Correlation, and Radiocarbon Dating of Late Holocene Tephra, Mono and Inyo Craters, Eastern California. Geological Society of America Bulletin 88:89-95.

1977b Chronology of Late Pleistocene and Holocene Volcanics, Long Valley and Mono Basin Geothermal Areas, Eastern California. Final Technical Report, United States Geological Survey Contract No. 14-08-0001-15166, Reston, Virginia.

1977c Mono Craters, California: History of Rhyolite Volcanism. Geological Society of America Abstract with Programs 9:528-529.

Wood, S.H., and R. Brooks
1979 Panum Crater Dated 640 ± 40 yrs. B.P., Mono Craters, California. Geological Society of America Abstract with Programs 11: 543.

Workman, W.B.
1979 The Significance of Volcanism in the Prehistory of Subarctic Northwest North America. In: Volcanic Activity and Human Ecology, P.D. Sheets and D.K. Grayson, eds., pp. 339-371. New York: Academic Press.

Wright, H.E., Jr.
1976 The Dynamic Nature of Holocene Vegetation: A Problem in Paleoclimatology, Biogeography, and Stratigraphic Nomenclature. Quaternary Research 6(4):581-596.

Yellen, J.E.
1977 Long Term Hunter-Gatherer Adaptation to Desert Environments: A Biogeographical Perspective. World Archaeology 8(3):262-274.

Appendix A

METRIC ATTRIBUTES OF PROJECTILE POINTS RECOVERED FROM CA-MNO-561

Projectile Point Form	Catalog Number	Length (cm)	Width (cm)	Thickness (cm)	Weight (g)
UNSHOULDERED					
Humboldt Concave-base	90-3-22A	1.11	1.39	0.51	0.57
	90-3-24	2.52	1.69	0.63	2.71
	90-3-40*	3.82	1.65	0.70	4.71
	90-3-46	2.38	1.41	0.62	1.39
	90-4-3	1.91	1.90	0.59	1.72
	90-5-24	2.46	1.56	0.67	2.03
	90-7-29A	1.69	1.61	0.47	1.34
	90-8-5	5.62	2.04	0.93	10.77
	90-8-37	2.78	1.59	0.68	2.63
	90-9-53A	1.48	1.39	0.58	1.11
	90-9-55A	2.61	1.92	0.58	2.77
	90-10-1*	3.17	1.61	0.59	2.73
	90-10-74A	1.41	1.58	0.56	0.87
	90-11-4*	4.28	1.52	0.68	4.41
	90-11-5	1.39	1.54	0.58	0.84
	90-14-7A	1.27	1.36	0.52	0.68
	90-16-2*	4.88	1.81	0.62	6.89
	90-21-2A	1.69	1.12	0.59	0.74
Humboldt Basal-notched	90-9-9*	3.58	2.06	0.54	3.37
Bipoint	90-10-5*	4.03	1.93	0.71	4.53
SHOULDERED					
Rose Spring Corner-notched	90-1-23	2.74	1.61	0.40	1.63
	90-3-9*	3.42	1.73	0.39	1.64
Elko Corner-notched	90-1-7**	2.89	1.96	0.55	2.78
	90-3-5A	1.32	2.27	0.44	0.93
	90-3-11	3.73	2.49	0.52	4.34
	90-6-5**	1.42	1.51	0.52	1.31
	90-7-21	2.56	2.05	0.74	3.94
	90-9-10	3.77	2.93	0.62	5.27
	90-9-11	3.16	2.36	0.48	3.44

Projectile Point Form	Catalog Number	Length (cm)	Width (cm)	Thickness (cm)	Weight (g)
	90-9-53B***	1.89	1.58	0.53	1.38
	90-12-7	2.35	2.38	0.71	3.47
	90-20-11*	4.29	2.09	0.52	3.54
	90-20-14	1.69	2.39	0.56	2.02
Elko Eared	90-8-1	1.01	1.62	0.37	0.41
	90-9-20	3.66	3.11	0.57	5.50
	90-10-16	2.38	2.52	0.66	3.11
	90-11-6	3.34	2.51	0.72	6.22
	90-11-36A	0.99	1.82	0.51	0.69
	90-13-12A	1.19	1.71	0.43	0.67
	90-18-4	3.17	2.36	0.44	2.88
Elko Corner-notched or Elko Eared Medial Fragment	90-6-7	2.02	2.68	0.44	2.97
	90-10-2	2.71	1.59	0.67	2.57
	90-20-33	3.43	2.73	0.56	3.42
Little Lake Split-stem	90-1-14	3.01	2.21	0.82	6.06
	90-3-23*	4.74	2.83	0.88	8.93
	90-6-37*	5.04	2.55	0.78	8.12
	90-16-5	3.14	2.89	0.61	5.07
	90-19-13	1.59	2.41	0.44	1.68
Gypsum Cave Contracting-stem	90-8-11*	3.30	2.02	0.57	2.72
	90-10-48*	4.91	2.26	0.62	6.88
Unnamed Shouldered Form #1	90-10-8	4.09	3.54	0.81	8.32
	90-10-69A	2.86	2.94	0.78	5.66
	90-21-3*	2.87	2.61	0.82	6.47
Unnamed Shouldered Form #2	90-3-29*	3.29	2.23	0.72	4.83
	90-10-29*	4.87	3.29	0.96	12.66
	USFS 1-146*	5.19	2.62	1.22	9.11
Unnamed Shouldered Form #3	90-13-18A	1.66	2.36	0.61	1.88
NONDIAGNOSTIC DISTAL FRAGMENT	90-3-21	2.48	1.17	0.45	1.12
	90-3-35	4.72	2.72	0.60	8.01

Projectile Point Form	Catalog Number	Length (cm)	Width (cm)	Thickness (cm)	Weight (g)
	90-3-45	1.96	1.43	0.39	0.72
	90-4-8	3.18	1.40	0.29	1.73
	90-5-25	2.96	2.26	0.52	2.94
	90-5-35	2.22	1.66	0.38	0.91
	90-6-23	2.67	1.63	0.49	1.49
	90-6-44A	2.14	1.41	0.39	0.83
	90-7-10	2.51	1.89	0.49	1.77
	90-7-20	1.87	1.68	0.52	1.44
	90-8-23	2.69	1.68	0.48	1.67
	90-9-34	2.61	1.43	0.54	1.72
	90-10-18	3.07	1.62	0.38	1.69
	90-10-19	2.49	1.41	0.44	1.21
	90-10-30	2.86	2.14	0.43	2.01
	90-12-1	2.01	1.39	0.33	0.69
	90-12-18A	1.73	1.31	0.41	0.53
	90-13-4	1.44	1.04	0.39	0.48
	90-15-16A	2.07	1.42	0.44	0.68
	90-17-1	3.89	2.08	0.44	2.38
	90-17-4	1.32	1.11	0.31	0.47
	90-17-12	2.42	1.62	0.36	0.96
	90-18-7	2.72	2.39	0.39	2.05
	90-18-35A	1.58	1.17	0.39	0.48
	90-19-30	1.77	1.22	0.49	0.94
	90-19-37	3.11	2.11	0.51	2.51
	90-20-17	3.78	2.73	0.59	4.22
NONDIAGNOSTIC MEDIAL FRAGMENT	90-5-4	1.78	2.56	0.39	2.69
	90-5-5	1.96	1.93	0.54	2.44
	90-10-70A	1.83	2.57	0.56	2.68
	90-10-72A	1.82	2.18	0.74	2.61
	90-12-6	1.87	2.02	0.59	2.78
	90-16-20A	1.49	1.13	0.43	0.57
	90-18-14	3.54	1.98	0.49	3.44
	90-19-47	2.13	1.84	0.59	2.61
	90-20-5A	1.57	0.95	0.48	0.52

*complete or nearly complete specimen
**appears to be the stem of an Elko Corner-notched point
***appears to be a portion of the stem of an Elko Corner-notched point

Appendix B

OBSIDIAN HYDRATION MEASUREMENTS AND SOURCES FOR UNMODIFIED FLAKES AND PROJECTILE POINTS FROM CA-MNO-561

UCR OHL	Catalog Number	Unit	Level	Sample	Micron Measurement	Obsidian Source
1691	90-3-1	3	0-10	unmodified flake	3.85 ± 0.20	Casa Diablo
1692	90-3-1	3	0-10	unmodified flake	3.55 ± 0.20	Casa Diablo
1693	90-3-1	3	0-10	unmodified flake	3.65 ± 0.20	Casa Diablo
1694	90-3-1	3	0-10	unmodified flake	3.57 ± 0.20	Casa Diablo
1695	90-3-1	3	0-10	unmodified flake	3.69 ± 0.20	Casa Diablo
1696	90-3-5	3	10-20	unmodified flake	4.40 ± 0.20	Casa Diablo
1697	90-3-5	3	10-20	unmodified flake	4.34 ± 0.20	Casa Diablo
1698	90-3-5	3	10-20	unmodified flake	2.14 ± 0.20	Casa Diablo
1699	90-3-5	3	10-20	unmodified flake	4.26 ± 0.20	Casa Diablo
1700	90-3-5	3	10-20	unmodified flake	4.09 ± 0.20	Casa Diablo
1701	90-3-10	3	20-30	unmodified flake	3.80 ± 0.20	Casa Diablo
1702	90-3-10	3	20-30	unmodified flake	4.81 ± 0.20	Casa Diablo
1703	90-3-10	3	20-30	unmodified flake	5.35 ± 0.20	Mono Craters-Glass Mountain
1704	90-3-10	3	20-30	unmodified flake	5.11 ± 0.20	Casa Diablo
1705	90-3-10	3	20-30	unmodified flake	4.58 ± 0.20	Casa Diablo
1706	90-3-15	3	30-40	unmodified flake	4.78 ± 0.20	Casa Diablo
1707	90-3-15	3	30-40	unmodified flake	4.42 ± 0.20	Casa Diablo
1708	90-3-15	3	30-40	unmodified flake	4.40 ± 0.20	Casa Diablo
1709	90-3-15	3	30-40	unmodified flake	4.52 ± 0.20	Casa Diablo
1710	90-3-15	3	30-40	unmodified flake	4.83 ± 0.20	Casa Diablo
1711	90-3-22	3	40-50	unmodified flake	3.39 ± 0.20	Casa Diablo
1712	90-3-22	3	40-50	unmodified flake	4.57 ± 0.20	Casa Diablo
1713	90-3-22	3	40-50	unmodified flake	4.91 ± 0.20	Casa Diablo
1714	90-3-22	3	40-50	unmodified flake	5.02 ± 0.20	Casa Diablo
1715	90-3-22	3	40-50	unmodified flake	5.08 ± 0.20	Casa Diablo
1716	90-3-28	3	50-60	unmodified flake	4.99 ± 0.20	Casa Diablo

UCR OHL	Catalog Number	Unit	Level	Sample	Micron Measurement	Obsidian Source
1717	90-3-28	3	50-60	unmodified flake	4.48 ± 0.20	Casa Diablo
1718	90-3-28	3	50-60	unmodified flake	4.51 ± 0.20	Casa Diablo
1719	90-3-28	3	50-60	unmodified flake	3.80 ± 0.20	Casa Diablo
1720	90-3-28	3	50-60	unmodified flake	4.22 ± 0.20	Casa Diablo
1721	90-3-34	3	60-70	unmodified flake	3.95 ± 0.20	Casa Diablo
1722	90-3-34	3	60-70	unmodified flake	4.14 ± 0.20	Casa Diablo
1723	90-3-34	3	60-70	unmodified flake	4.12 ± 0.20	Casa Diablo
1724	90-3-34	3	60-70	unmodified flake	4.13 ± 0.20	Casa Diablo
1725	90-3-34	3	60-70	unmodified flake	4.37 ± 0.20	Casa Diablo
1726	90-3-39	3	70-80	unmodified flake	1.94 ± 0.20	Casa Diablo
1727	90-3-39	3	70-80	unmodified flake	7.10 ± 0.20	Casa Diablo
1728	90-3-39	3	70-80	unmodified flake	3.94 ± 0.20	Casa Diablo
1729	90-3-39	3	70-80	unmodified flake	4.16 ± 0.20	Casa Diablo
1730	90-3-39	3	70-80	unmodified flake	4.12 ± 0.20	Casa Diablo
1731	90-3-44	3	80-90	unmodified flake	3.37 ± 0.20	Casa Diablo
1732	90-3-44	3	80-90	unmodified flake	4.73 ± 0.20	Casa Diablo
1733	90-3-44	3	80-90	unmodified flake	4.58 ± 0.20	Casa Diablo
1734	90-3-44	3	80-90	unmodified flake	3.94 ± 0.20	Casa Diablo
1735	90-3-44	3	80-90	unmodified flake	3.68 ± 0.20	Casa Diablo
1736	90-3-50	3	90-100	unmodified flake	4.59 ± 0.20	Casa Diablo
1737	90-3-50	3	90-100	unmodified flake	3.82 ± 0.20	Casa Diablo
1738	90-3-50	3	90-100	unmodified flake	4.07 ± 0.20	Casa Diablo
1739	90-3-50	3	90-100	unmodified flake	3.94 ± 0.20	Casa Diablo
1740	90-3-50	3	90-100	unmodified flake	4.05 ± 0.20	Casa Diablo
1741	90-4-22	4	100-110	unmodified flake	4.43 ± 0.20	Casa Diablo
1742	90-4-22	4	100-110	unmodified flake	4.67 ± 0.20	Casa Diablo
1743	90-4-22	4	100-110	unmodified flake	5.02 ± 0.20	Casa Diablo
1744	90-4-22	4	100-110	unmodified flake	3.87 ± 0.20	Casa Diablo
1745	90-4-22	4	100-110	unmodified flake	3.74 ± 0.20	Casa Diablo
1746	90-1-21	1	110-120	unmodified flake	5.09 ± 0.20	Casa Diablo
1747	90-1-21	1	110-120	unmodified flake	7.50 ± 0.20	Casa Diablo
1748	90-1-21	1	110-120	unmodified flake	5.40 ± 0.20	Casa Diablo
1749	90-1-21	1	110-120	unmodified flake	5.93 ± 0.20	Casa Diablo

UCR OHL	Catalog Number	Unit	Level	Sample	Micron Measurement	Obsidian Source
1750	90-1-21	1	110-120	unmodified flake	4.38 ± 0.20	Casa Diablo
1751	90-1-22	1	120-130	unmodified flake	4.80 ± 0.20	Casa Diablo
1752	90-1-22	1	120-130	unmodified flake	5.66 ± 0.20	Mono Craters-Glass Mountain
1753	90-1-22	1	120-130	unmodified flake	4.74 ± 0.20	Casa Diablo
1754	90-1-22	1	120-130	unmodified flake	1) 5.96 ± 0.20 2) 4.07 ± 0.20	Casa Diablo
1755	90-1-22	1	120-130	unmodified flake	4.09 ± 0.20	Casa Diablo
1756	90-3-22A	3	40-50	Humboldt Concave-base	5.87 ± 0.20	Casa Diablo
1757	90-3-24	3	40-50	Humboldt Concave-base	1) 4.27 ± 0.20 2) 2.72 ± 0.20	Mono Craters-Glass Mountain
1758	90-3-40	3	70-80	Humboldt Concave-base	3.69 ± 0.20	Casa Diablo
1759	90-3-46	3	80-90	Humboldt Concave-base	4.28 ± 0.20	Casa Diablo
1760	90-4-3	4	0-10	Humboldt Concave-base	5.36 ± 0.20	Mono Craters-Glass Mountain
1761	90-5-24	5	40-50	Humboldt Concave-base	4.78 ± 0.20	Casa Diablo
1762	90-7-29A	7	30-40	Humboldt Concave-base	4.51 ± 0.20	Casa Diablo
1763	90-8-5	8	10-20	Humboldt Concave-base	3.76 ± 0.20	Casa Diablo
1764	90-8-37	8	70-80	Humboldt Concave-base	5.74 ± 0.20	Casa Diablo
1765	90-9-53A	9	30-40	Humboldt Concave-base	2.84 ± 0.20	Queen
1766	90-9-55A	9	50-60	Humboldt Concave-base	4.39 ± 0.32	Casa Diablo
1767	90-10-1	10	0-10	Humboldt Concave-base	2.28 ± 0.20	Queen
1768	90-10-74A	10	70-80	Humboldt Concave-base	4.17 ± 0.20	Casa Diablo
1769	90-11-4	11	10-20	Humboldt Concave-base	3.52 ± 0.20	Casa Diablo
1770	90-11-5	11	10-20	Humboldt Concave-base	2.39 ± 0.20	Queen
1771	90-14-7A	14	20-30	Humboldt Concave-base	3.67 ± 0.20	Casa Diablo
1772	90-16-2	16	10-20	Humboldt Concave-base	3.92 ± 0.20	Casa Diablo
1773	90-21-2A	21	10-20	Humboldt Concave-base	4.57 ± 0.20	Queen
1774	90-9-9	9	20-30	Humboldt Basal-notched	3.80 ± 0.20	Bodie Hills
1775	90-10-5	10	10-20	Bipoint	3.24 ± 0.20	Mount Hicks
1776	90-1-23	-	surface	Rose Spring Corner-notched	4.20 ± 0.20	Casa Diablo
1777	90-3-9	3	10-20	Rose Spring Corner-notched	3.23 ± 0.20	Casa Diablo
1778	90-1-7	1	30-40	Elko Corner-notched	5.79 ± 0.20	Casa Diablo

UCR OHL	Catalog Number	Unit	Level	Sample	Micron Measurement	Obsidian Source
1779	90-3-5A	3	10-20	Elko Corner-notched	4.16 ± 0.20	Queen
1780	90-3-11	3	20-30	Elko Corner-notched	3.69 ± 0.20	Fish Springs
1781	90-6-5	6	10-20	Elko Corner-notched	3.96 ± 0.20	Casa Diablo
1782	90-7-21	7	50-60	Elko Corner-notched	3.17 ± 0.20	Casa Diablo
1783	90-9-10	9	30-40	Elko Corner-notched	3.37 ± 0.20	Casa Diablo
1784	90-9-11	9	30-40	Elko Corner-notched	3.28 ± 0.20	Casa Diablo
1785	90-9-53B	9	30-40	Elko Corner-notched	5.25 ± 0.20	Casa Diablo
1786	90-12-7	12	40-50	Elko Corner-notched	4.90 ± 0.20	Fish Springs
1787	90-20-11	20	20-30	Elko Corner-notched	3.93 ± 0.20	Casa Diablo
1788	90-20-14	20	30-40	Elko Corner-notched	3.84 ± 0.20	Casa Diablo
1789	90-8-1	8	0-10	Elko Eared	3.75 ± 0.20	Casa Diablo
1790	90-9-20	9	40-50	Elko Eared	3.89 ± 0.20	Casa Diablo
1791	90-10-16	10	30-40	Elko Eared	2.89 ± 0.20	Casa Diablo
1792	90-11-6	11	10-20	Elko Eared	4.43 ± 0.20	Casa Diablo
1793	90-11-36A	11	10-20	Elko Eared	3.86 ± 0.20	Casa Diablo
1794	90-13-12A	13	10-20	Elko Eared	2.85 ± 0.20	Queen
1795	90-18-4	18	10-20	Elko Eared	3.74 ± 0.20	Queen
1796	90-6-7	6	20-30	Elko series medial fragment	3.82 ± 0.20	Casa Diablo
1797	90-10-2	10	0-10	Elko series medial fragment	3.94 ± 0.20	Casa Diablo
1798	90-20-33	20	50-60	Elko series medial fragment	3.54 ± 0.20	Casa Diablo
1799	90-1-14	1	50-60	Little Lake Split-stem	6.85 ± 0.20	Casa Diablo
1800	90-3-23	3	40-50	Little Lake Split-stem	3.43 ± 0.20	Queen
1801	90-6-37	6	80-90	Little Lake Split-stem	4.04 ± 0.20	Casa Diablo
1802	90-16-5	16	30-40	Little Lake Split-stem	3.75 ± 0.20	Casa Diablo
1803	90-19-13	19	30-40	Little Lake Split-stem	5.82 ± 0.20	Mono Craters-Glass Mountain
1804	90-8-11	8	40-50	Gypsum Cave Contracting-stem	3.96 ± 0.20	Casa Diablo
1805	90-10-48	10	50-60	Gypsum Cave Contracting-stem	3.86 ± 0.20	Queen
1806	90-10-8	10	20-30	Unnamed shouldered form #1	4.56 ± 0.20	Queen
1807	90-10-69A	10	20-30	Unnamed shouldered form #1	4.97 ± 0.20	Casa Diablo
1808	90-21-3	21	10-20	Unnamed shouldered form #1	5.78 ± 0.20	Casa Diablo
1809	90-3-29	3	50-60	Unnamed shouldered form #2	6.32 ± 0.20	Casa Diablo
1810	90-10-29	10	40-50	Unnamed shouldered form #2	4.81 ± 0.20	Queen

UCR OHL	Catalog Number	Unit	Level	Sample	Micron Measurement	Obsidian Source
1811	USFS 1-146	-	50-60	Unnamed shouldered form #2	7.24 ± 0.20	Casa Diablo
1812	90-13-18A	13	70-80	Unnamed shouldered form #3	5.82 ± 0.20	Casa Diablo
1813	90-3-21	3	30-40	Nondiagnostic distal fragment	2.77 ± 0.20	Queen
1814	90-3-35	3	60-70	Nondiagnostic distal fragment	4.87 ± 0.20	Casa Diablo
1815	90-3-45	3	80-90	Nondiagnostic distal fragment	3.30 ± 0.20	Casa Diablo
1816	90-4-8	4	10-20	Nondiagnostic distal fragment	4.61 ± 0.20	Mount Hicks
1817	90-6-23	6	50-60	Nondiagnostic distal fragment	3.36 ± 0.20	Casa Diablo
1818	90-12-18A	12	20-30	Nondiagnostic distal fragment	3.68 ± 0.20	Casa Diablo
1819	90-13-4	13	30-40	Nondiagnostic distal fragment	3.89 ± 0.20	Queen
1820	90-15-16A	15	40-50	Nondiagnostic distal fragment	4.48 ± 0.20	Casa Diablo
1821	90-17-1	17	0-10	Nondiagnostic distal fragment	3.33 ± 0.20	Casa Diablo
1822	90-17-4	17	10-20	Nondiagnostic distal fragment	5.17 ± 0.20	Casa Diablo
1823	90-17-12	17	60-70	Nondiagnostic distal fragment	5.07 ± 0.20	Casa Diablo
1824	90-19-30	19	50-60	Nondiagnostic distal fragment	4.78 ± 0.20	Casa Diablo
1825	90-20-17	20	40-50	Nondiagnostic distal fragment	2.94 ± 0.20	Casa Diablo
1826	90-5-4	5	0-10	Nondiagnostic medial fragment	2.44 ± 0.20	Casa Diablo
1827	90-5-5	5	0-10	Nondiagnostic medial fragment	4.01 ± 0.20	Queen
1828	90-10-70A	10	30-40	Nondiagnostic medial fragment	5.29 ± 0.20	Casa Diablo
1829	90-10-72A	10	50-60	Nondiagnostic medial fragment	3.81 ± 0.20	Casa Diablo
1830	90-12-6	12	30-40	Nondiagnostic medial fragment	3.39 ± 0.20	Casa Diablo
1831	90-16-20A	16	50-60	Nondiagnostic medial fragment	3.97 ± 0.20	Casa Diablo
1832	90-18-14	18	40-50	Nondiagnostic medial fragment	3.89 ± 0.20	Casa Diablo
1833	90-19-47	19	70-80	Nondiagnostic medial fragment	3.56 ± 0.20	Bodie Hills
1834	90-20-5A	20	10-20	Nondiagnostic medial fragment	4.43 ± 0.20	Casa Diablo