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The Last Days of Lake Cahuilla: The Elmore Site

Don Laylander

Abstract

For more than a century, it has been recognized that an immense freshwater lake filled much of the Coachella and Imperial valleys very late in the region's prehistory. Archaeologists have attempted to define and interpret this phenomenon. When was the lake present, and when did it disappear? How had Native Americans adapted to the opportunities and challenges created by the presence of the lake? How had they responded to its disappearance? The following study looks at those questions, partly from the perspective of investigations at a single archaeological site--the Elmore Site--and partly from the gradually accumulated body of regional scholarship.

The Elmore Site (CA-IMP-6427): The Investigations

The Elmore Site lies at the meeting point between Imperial Valley's rich agricultural fields and the encircling and still-forbidding desert. In terms of regional landmarks, it is about 4 km southwest of the present shore of the Salton Sea; 4 km north of the low but rugged Superstition Hills; 3 km south of the lower course of usually-dry San Felipe Creek, the major west-side tributary into the basin; and 18 km northwest of the nearest town, the small agricultural center of Westmorland (Fig. 1).

The site's elevation of 180 feet below sea level puts it 220 feet below Lake Cahuilla's former maximum 40-foot shoreline and only about 100 feet above the basin's lowest point (now under the Salton Sea).The lake bed in the vicinity of the site is, in general, very flat. A subtle break in the slope of the land is distinguishable near the site: to the south, the ground surface slopes down from south-southwest to north-northeast at a rate of about 14 m per km, or a 1.4% slope, whereas to the north of the site, the slope is only about 5 m per km, or 0.5%. The site lies in undeveloped desert, with a sparse scattering of desert saltbush scrub (Figs. 2 and 3). Occasional hummocks of mesquite dot the horizon. However, immediately to the north of the site, irrigation has transformed the land into agricultural fields.

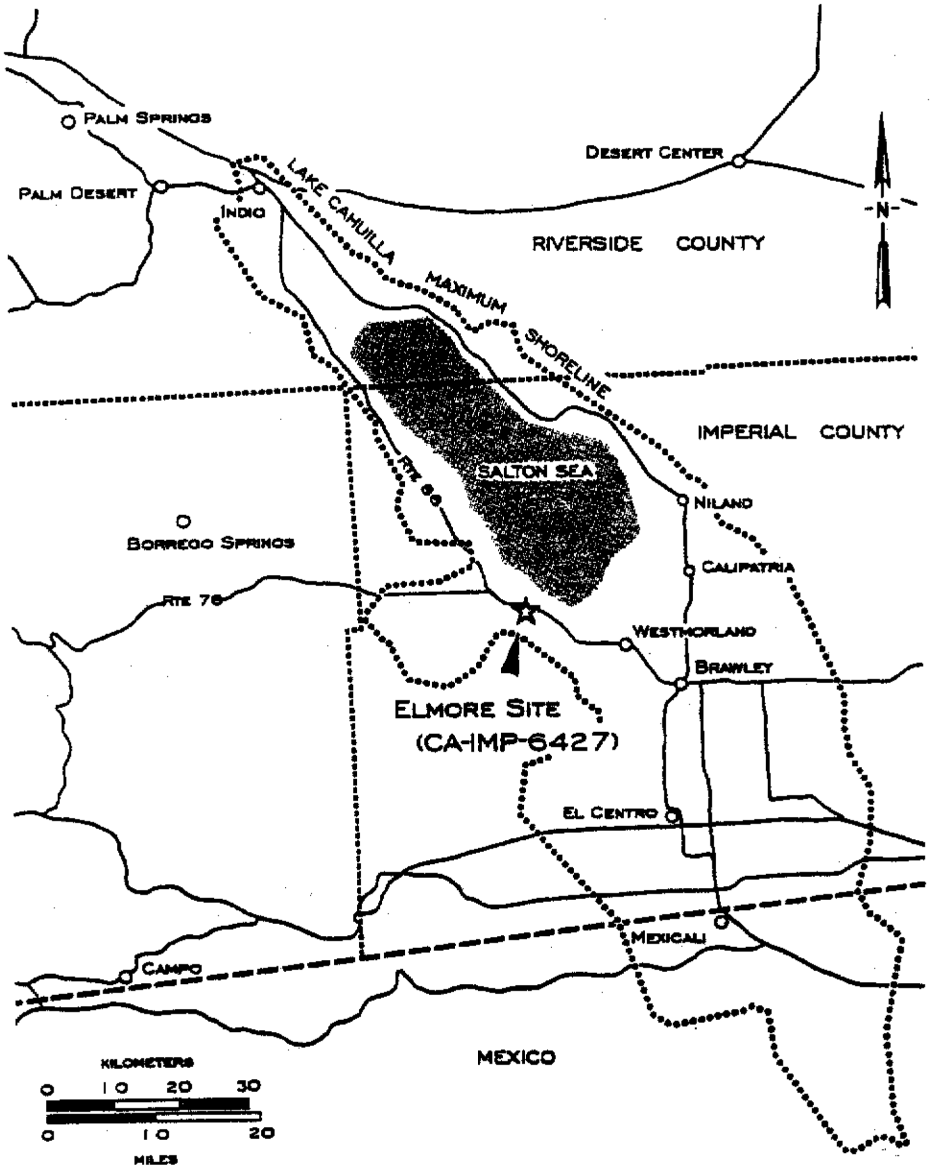

Fig.1. Location of the Elmore Site.

The Elmore Site became a focus of particular archaeological attention because of a highway development project. The California Department of Transportation (Caltrans) initiated plans to improve State Route 86, which runs along the western side of the Salton Sea, linking the cities of the Imperial and Coachella Valleys. An archaeological survey of the corridor for the proposed highway was carried out by RECON under the direction of James

Eighmey (Eighmey and Cheever 1990). The Elmore Site was initially recorded in February 1990 by Eighmey and Cheryl Bowden, as one of 21 prehistoric sites of various sorts which were identified during the survey. Eighmey and Bowden noted the presence at the site of a dense scatter of ceramics sherds and lithic artifacts, including two projectile points and an assortment of debitage from tool-working.

A plan for testing the sites was prepared (Laylander 1990), and fieldwork was carried out in August and September 1990 by a Caltrans crew (Laylander 1991a). The results of the test indicated that the Elmore Site had the potential to yield significant additional information concerning the chronology of Lake Cahuilla and the nature of prehistoric adaptations to it. Because preservation of the Elmore Site in place was impractical, a data recovery plan was prepared identifying specific research domains which appeared to be addressable at the site. Testable hypotheses concerning those domains, empirical test implications, data requirements, and the scope and procedures for the data recovery program (Laylander 1991b) were presented. Hypotheses proposed concerned the chronological placement of Lake Cahuilla's final full stand, the hydration rate for Obsidian Butte obsidian, the chronological significance of Lower Colorado Buff ware ceramic types and traits, adaptations to various lacustrine and nonlacustrine faunal and floral resources during low stands of Lake Cahuilla, and regional settlement strategies.

A variety of archaeological field techniques were used during the testing and data recovery investigations at the site. Systematic surface collections in the testing and the data recovery phases employed essentially identical methods. The site area was walked at close intervals, usually about 3 to 4 m between transects. Any observed prehistoric cultural materials were marked with pin flags; multiple cultural items within a 1 m radius were grouped together at a single flag. Flagged collection points were mapped. Materials were then collected, with the exceptions of possible fire-affected rocks (red-brown sandstone), pieces of freshwater marine shell (which were interpreted as probably being natural rather than cultural remains), and modern cultural items.

Shovel tests were used during the testing phase to help assess the extent of the subsurface deposit. Shovel test locations were judgmentally selected, in areas which appeared optimal for the occurrence and preservation of cultural deposits. Each test was approximately 35 cm in diameter, was excavated by shovel and trowel, and was continued as deep as practicable, until limited by deposit compactness or by the difficulty of recovering the soil from any greater depth. All soil was sorted with 3.2-mm (1/8-inch) mesh screen, and all observed prehistoric or historic cultural material was collected, except possible fire-affected rock and small, very diffuse pieces of charcoal.

Fig. 2. The Elmore Site looking toward its core area.

Fig. 3. Excavations in progress at the Elmore Site.

During the testing phase, 8 1-m-square excavation units were dug in judgmentally-selected locations, using selection criteria similar to those for shovel tests. Excavation was done in 10-cm-thick, surface-parallel levels. Digging continued through at least three levels and through at least two levels which lacked any cultural material, or until the underlying, culturally-sterile lacustrine sediments were reached. Shovel probes were excavated into the floors of most completed units to test for any major stratigraphic changes or possible buried cultural deposits at greater depths. In one case (unit 8), in which cultural material was encountered in a shovel probe, the excavation of full levels was resumed. Soil was removed from the units by shovel and trowel. Sorting was done in the same manner as with the shovel tests. When completed, each excavation unit was photographed and a stratigraphic profile of one sidewall was prepared.

Locations for the unit excavations of the data recovery phase were selected to maximize the yield of cultural materials and to clarify the distribution of subsurface features (Fig. 4). Most of the excavation consisted of uncovering two large block exposures in 1-m-square increments. One half-unit (24), 50 cm by 1 m in area, was excavated in order to complete the exposure of a pit feature. Unit 11 partially overlapped the area of testing-phase unit 6. Excavation was performed by trowel, with care being taken to recover and record significant finds in situ and to distinguish natural strata. When possible, arbitrary 10 cm levels were subdivided according to major depositional strata. These were primarily the charcoal-rich cultural stratum and the relatively clean sands which both overlie and underlie the cultural stratum. In one unit (34), as an experiment, excavation was entirely by the major natural strata rather than by arbitrary levels. (Excavation time was cut by about 50% at this unit.) Excavation in all units was continued until the consolidated lacustrine sandstone, silts, and fine sands were reached, except in unit 38, where excavation continued several levels into these underlying sediments, to expose a profile of the natural lake deposit for sedimentary analysis. Numerous judgmentally-selected soil samples, primarily from richer portions of the deposit or from features, were collected for later laboratory sorting.

The archaeological deposit samples which were collected at the site were subsequently processed at the Caltrans District 11 archaeological laboratory. Two different techniques were used on different samples. Some were dry-sorted, by gently sifting the soil through a set of nested US Standard Testing Sieve 4, 8, 16, and 30 screens (with opening sizes of 4.75, 2.36, 1.18, and 0.60 mm, respectively). The material retained by each screen was carefully inspected, and all cultural material except for very fine charcoal was collected. Other samples were sorted by flotation and wet-screening. The contents of these samples were put into a small water flotation device. The light fraction, consisting primarily of charcoal, was lifted by the turbulence of the water flowing into the bottom of the device, plus some manual stirring, and was carried out of the flotation device with overflowing water at the top. The overflow passed through fine-mesh fabric, which let the water, silt, and clay pass but collected the other materials. The heavy fraction of the soil sample either passed through or was caught by 1.6-mm mesh screen near the bottom of the device. The retained light and heavy fractions were carefully inspected, and all cultural material (except very fine charcoal) was collected.

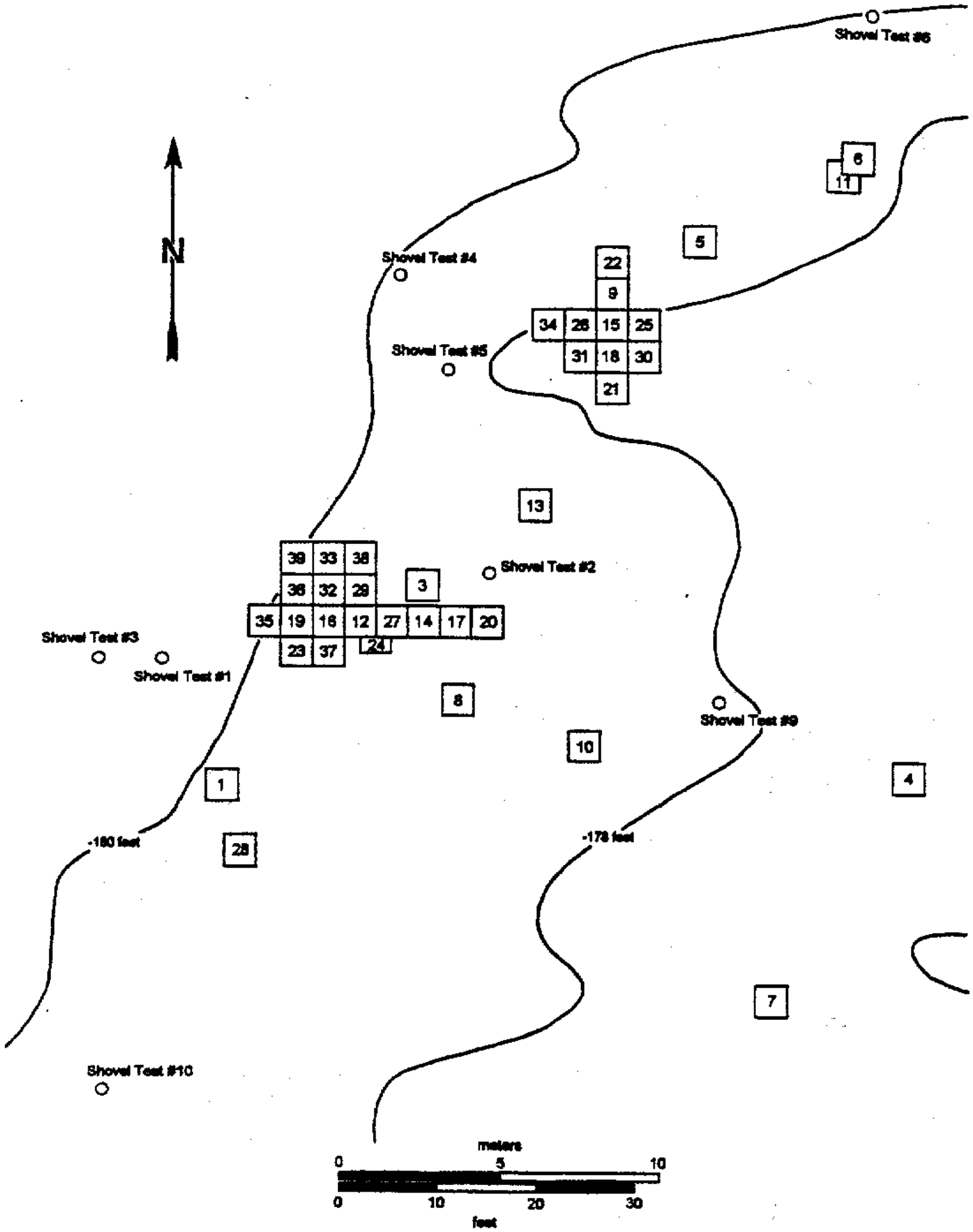

Fig.4. Map of excavation units and shovel tests in the core area *(drawn by author)*.

The initial laboratory processing of recovered artifactual materials included washing and basic cataloging. (Projectile points, ground stone, and a ceramic pipe fragment were not washed, in case it might be desirable to perform special residue analyses on them.) Further studies were carried out on the various types of cultural material which were recovered, including lithics, ceramics, bone, and shell materials. The observations and the methods which were employed in these studies are discussed in the sections which follow. The artifact collection from the Elmore Site will be permanently curated at the Imperial Valley College Museum in Ocotillo, California, under accession number 1990-23. There, the materials will be available for future researchers to study.

Subsequent to the investigations described here, in 1996, final archaeological work at the site was done under the direction of Jerry Schaefer. A report on the additional investigations is in preparation (Jerry Schaefer and Martin D. Rosen, personal communication, 1997). Some preliminary results of that work are noted in subsequent sections on features and shell beads.

The Nature of the Site Deposit

To understand and interpret the artifacts and features at the Elmore Site, it is necessary to understand their immediate physical contexts. Two natural depositional processes are evident at the site: the settling of sediments, mostly clay, silt, and fine sand, from the overlying waters of Lake Cahuilla and its Pleistocene predecessors; and the formation of dunes by wind-blown sand during nonlacustrine periods. The relation of the episode of cultural deposition to these processes is important.

Regional Context

Two geological units underlie the vicinity of the Elmore Site (Morton 1977). The most extensive unit is composed of clays, silts, sands, and gravels of Quaternary lake bed deposits laid down by Lake Cahuilla. The second unit, the older Pleistocene-age Brawley Formation, is also composed of lacustrine clays, sandstone, and gravels. The mapped presence of the Brawley Formation at the Elmore Site indicates that no extensive mantle of Lake Cahuilla sediments ever accumulated in this area, or, if one was deposited, it did not survive subsequent erosion.

Pedological mapping in the area just north of the Elmore Site recognized several soils series (Zimmerman 1981). Of these, the Meloland series seems to match most closely the observed characteristics of the Elmore Site deposit. A representative Meloland profile includes four main horizons: at the base, a pink silty clay (IIIC3 and IIIC4); overlying that, and separate in its depositional origin, a very pale brown silt loam (IIC2); next, and also independent of either of the underlying horizons, a very pale brown loamy fine sand (C1); and uppermost, a light brown, disturbed, very fine sandy loam (Ap). The parent material for the lower layers is lake bed sediment, while the upper layers derive from wind-blown and river-channel sediments. "All layers are calcareous, mildly alkaline or moderately alkaline, and nonsaline to strongly saline" (Zimmerman 1981:56).

Observational Methods

Observations concerning the character of the Elmore Site deposit were made at several different stages: in the course of shovel test and unit excavation, during the preparation of excavation unit sidewall profiles, through specialized soils field studies, and by analyses conducted at the San Diego State University pedological laboratory.

During unit excavations, crew members filled out excavation forms as each level was dug. The excavators were asked to record soil color, compactness, moistness, and grain size. One sidewall profile was prepared for each excavation unit. The profiles showed the location and configuration of contacts between distinguishable strata, as well as large elements within the strata, such as rocks, roots, or rodent tunnels. Forms accompanying the profiles were used to record, for each stratum, the maximum and minimum stratum thickness; soil color; texture or grain size; structure; compactness; moistness; abundance of large and small rocks, large roots, and rodent tunnels; and the configuration and sharpness of the contacts with other strata.

Additional soils studies were carried out in the field under the direction of Ned Greenwood of the Department of Geography, San Diego State University. Greenwood made further stratigraphic observations, and also soil compaction measurements. An MC-3 Portaprobe Nuclear Gauge was used to test soil compaction, in order to evaluate whether the cultural deposit had been subjected to subsequent burial under the waters of Lake Cahuilla. Soil samples were processed at the San Diego State University pedological laboratory under Greenwood's direction. The techniques which were used included sieve analysis, mechanical (settling rate) analysis, and Munsell color readings.

Description of the Strata

Five strata are distinguishable within the main archaeological deposit at the Elmore Site (Figs. 5, 6, and 7). The characteristics of these strata, as reported by Greenwood, are summarized in Table 1.

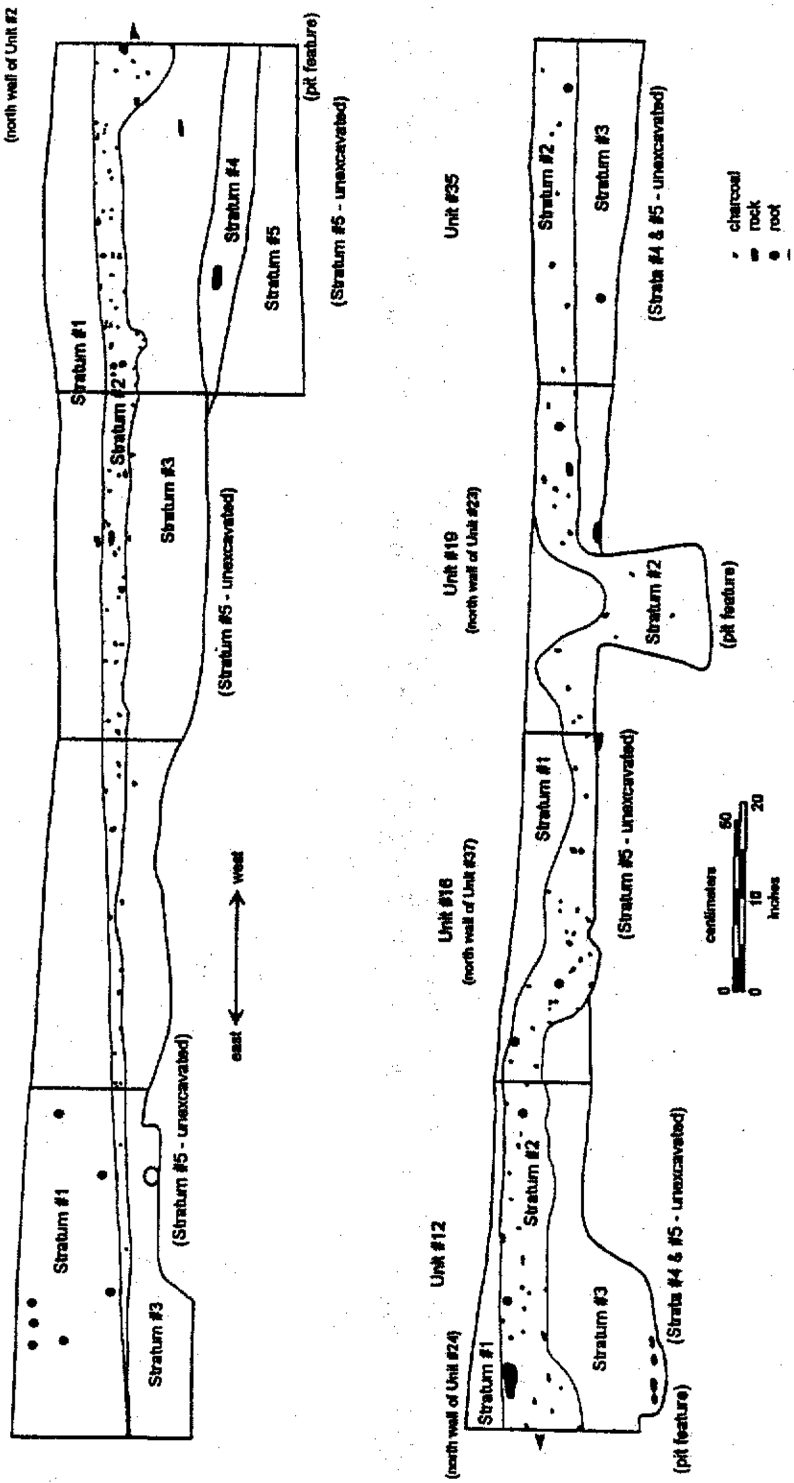

Fig.5. Stratigraphic profile of the south walls of the southwestern block units.

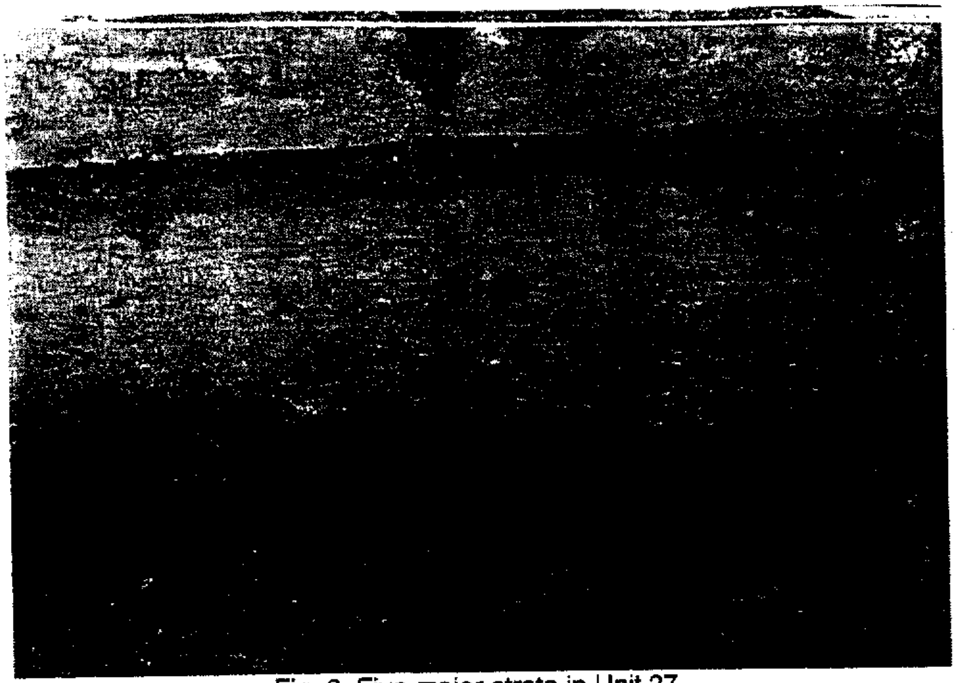

Fig. 6. Five major strata in Unit 27.

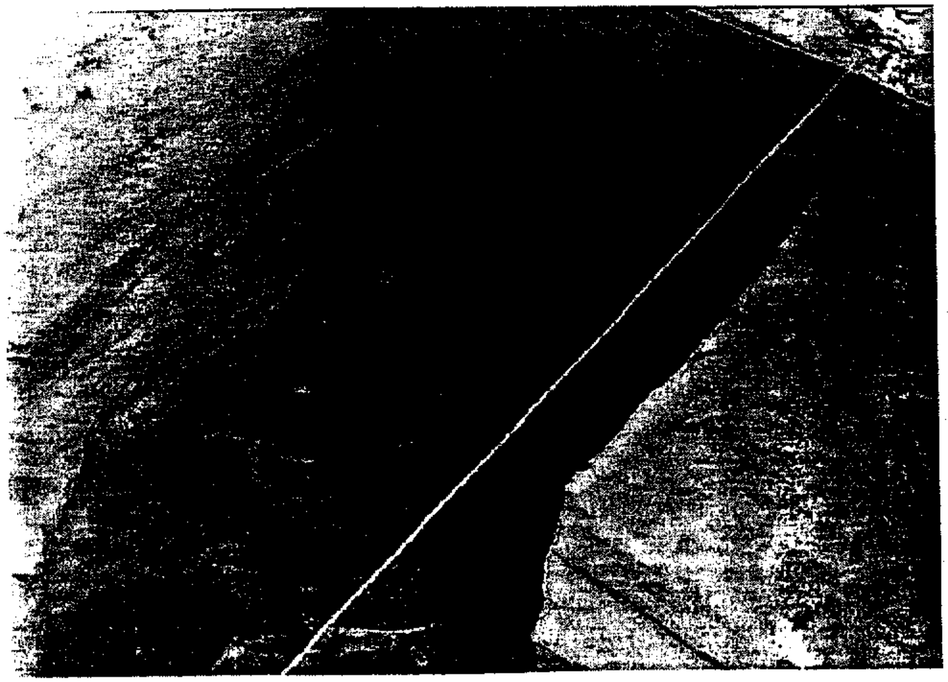

Fig.7. Strata in Unit 25.

Table 1. Soils analysis of a representative profile.

Trait	Stratum # 1	# 2	# 3	# 4	# 5
Horizon	Ap	C1	C2	IIC	IIIC
Depth	0-20 cm	20-28 cm	28-48 cm	48-56 cm	56+ cm
Munsell Color	10YR 6/4	--	10YR 7/4	10YR 5/6	10YR 6/4
Color (verbal)	light yellowish brown	--	very pale brown	yellowish brown	light yellowish brown
Texture Class	Sand	Sand	Sand	Sandy Clay Loam	Sandy Loam
Mechanical Analysis					
Sand	97.3 %	94.0 %	95.6 %	79.0 %	71.6 %
Silt	0.4	4.4	0.9	0.0	19.7
Clay	2.4	1.4	3.5	21.0	8.7
Organic Matter/ Volatile Salts	0.58%	1.45 %	0.42 %	2.91 %	2.35%
Sieve Analysis					
Very Coarse Sand	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Coarse Sand	0.3	0.7	2.8	0.0	0.0
Medium Sand	3.8	2.6	8.5	3.0	0.2
Fine Sand	33.3	17.5	14.8	10.9	9.2
Very Fine Sand	60.1	77.0	72.7	57.1	28.9
Extremely Fine Sand, Silt, & Clay	2.5	2.2	1.1	29.1	61.7
Relative Compaction	85%	83 %	91 %	well-cemented sandstone	98 %

The lowest stratum, here referred to as Stratum 5, was observed in the field as a fine-grained, light chocolate-brown sediment. Stratum 5 was thought by the excavators to be clay-rich, but laboratory analysis subsequently indicated that it is a sandy loam. This stratum seems to be entirely lacking in cultural materials. In most instances, excavation ceased when either this layer or Stratum 4 was reached. While Stratum 5 is evidently lacustrine in origin, it is not clear whether the deposit was laid down by a recent stand of Lake Cahuilla or by some earlier lake stand, dating from the Pleistocene.

The second stratum (4) is a light yellowish-brown sediment, which appeared in the field to be richer than Stratum 5 in either silt or very fine sand. Laboratory analysis indicated that this stratum is a sandy clay loam. A depositional unconformity separates Stratum 4 from Stratum 5. In some locations, Stratum 4 is cemented into well-indurated rock. The stratum is fairly thin in all cases, and is often entirely absent. Like Stratum 5, Stratum 4 was observed to contain no cultural material.

Stratum 3 is a fairly loose, very pale brown sand. In a few instances, discontinuous concentrations of well-rounded pebbles were found just above the contact between Stratum 3 and either Stratum 4 or Stratum 5. At some locations, the contact between Stratum 3 and either Stratum 4 or Stratum 5 is highly irregular. The fine bedding within Stratum 3 was generally found to be horizontal or nearly so. Stratum 3 may be either eolian or alluvial in origin, or some combination of the two. Small amounts of charcoal and other cultural material in Stratum 3 were probably originally deposited in Stratum 2 and subsequently mixed downward, by means of human trampling, root growth, and the activity of small burrowing animals. In some areas, Stratum 3 pinches out, and Stratum 2 directly overlies Stratum 4 or 5.

Stratum 2 contains the prehistoric cultural deposit at the site. The color of the stratum, which defines it, varies from light grey to black and is derived from its moderate to strong enrichment with charcoal. The contact between Strata 2 and 3 is rather irregular but sharp. Culturally-excavated features penetrate into Stratum 3 and, in several cases, into Strata 4 and 5, as is discussed below. Stratum 2 contains some internal bedding, perhaps related at least in part to postdepositional reworking of the sediments and cultural material by slope wash or by wind. However, in no case were multiple cultural lenses encountered, separated by culturally-sterile sand, such as might have resulted from multiple periods of prehistoric occupation at the site.

Finally, Stratum 1 consists of sand, sometimes in considerable thickness, overlying the cultural deposit. Some cultural material was encountered in this stratum. This material appears to reflect either postdepositional mixing through rodent or root activities or localized redeposition of material from areas of erosion, rather than primary cultural deposition contemporaneous with the natural deposition of Stratum 1.

Postdepositional Alterations

Two issues relating to postdepositional alterations of the deposit at the Elmore Site are important in interpreting the site. The first is whether or not the site area was ever buried under a substantial column of water subsequent to the deposition of Stratum 2. This issue links the site's chronology to the chronology of the final rise and fall of Lake Cahuilla. The second issue concerns the extent to which the site's contents have been altered or displaced by postdepositional disturbance.

To determine whether the site was ever subsequently inundated, general soils observations and compaction testing were employed. No indications of any lacustrine deposition or reworking of sediments in the portions of the site deposit which overlie Stratum 4 were observed. The results of the compaction tests indicate that no substantial column of water has ever overlain the upper strata of the site, according to Greenwood. The conclusion is that the cultural deposit at the Elmore Site postdates the most recent period at which Lake Cahuilla's waters reached an elevation above 180 feet below sea level.

One form of postdepositional disturbance to the cultural deposit was erosion of the site, probably by both wind and localized slope wash. Stratum 2 is exposed on the surface at the western edge of the central site area, adjacent to a shallow wash. The density of artifacts on the surface was highest in that area. These cultural materials are strongly concentrated in their distribution. They include many small or delicate items and, unlike artifacts at some other probably earlier sites in the general vicinity (Laylander 1991a), they contain few pieces with any evidence of postdepositional wear such as wind or water polishing. These circumstances indicate that, although the charcoal which presumably accompanied the artifacts has been winnowed away, the artifacts may not have been exposed at the surface for any very long period and have probably moved very little since their original deposition. How much of the western portion of the site beyond this surface concentration may have been destroyed by erosion is unknown.

The deposition of the cultural stratum at the site evidently postdates any stand of Lake Cahuilla higher than about 180 feet below sea level. Postdepositional disturbance probably has included some loss of western portions of the site, but very little horizontal or vertical displacement of artifactual materials seems to have occurred within the surviving portions. The abundant preservation of fine charcoal in the subsurface deposit probably indicates that the cultural stratum began to be capped by wind-blown sand a short time after the site was abandoned. Stratigraphic and artifactual evidence indicates that a single subsurface cultural deposit is present, without interpretively meaningful vertical patterning. For that reason, minimal attention will be paid to the vertical provenience of cultural materials in the discussions contained in subsequent sections.

Features

Three sorts of evidence for prehistoric features were identified at the Elmore Site: the residues from hearths or other fire features; slabs of sandstone rock; and pits excavated into deposits underlying the level of occupation. A fourth type of feature, interpreted as the remains of a "clothes burning" or mourning anniversary ceremony, was identified by subsequent work at the site in 1996 (Jerry Schaefer and Martin D. Rosen, personal communication, 1997).

Fires

The construction of fires at the site is attested by the abundant charcoal and burnt bone in the cultural deposit (Stratum 2), as well as by a scattering of apparent fire-affected rock throughout the main site area. Distinguishing fire-affected rock from rock which has not been so affected is problematic at this site. A large majority of the rock found within or above the cultural deposit does not appear to show any indication of fire alteration, although its presence at these levels, where it would not occur naturally, may indicate that it was used in hearths. Some rocks show a grey or black tinge on one or more surfaces, which may indicate fire alteration. However, this discoloration may merely indicate physical contact with the charcoal-rich deposit of Stratum 2. While the rocks in the deposits are generally composed of a fine sandstone which is yellow in color, portions of some specimens are reddish in color. Some investigators in the region have suggested that this color may be the result of heating in a fire (Martin D. Rosen, personal communication, 1990).

The evidence from fires, although it is not completely homogeneous within the site area, is not tightly clustered. The charcoal lens was found to be moderately uniform over distances of several meters, and possible fire-affected rocks were not found to be abundant at any one location. It seems likely that any original clustering has become blurred, possibly through the actions of the site's occupants themselves, or by natural processes of wind and water immediately after the site was abandoned.

Sandstone Slabs

Some of the large, tabular pieces of unmodified sandstone which are found at the site constitute a second (if somewhat enigmatic) class of evidence for features. Such slabs occur naturally in the upper portion of Stratum 4, where they were formed by the cementation of lacustrine sediments. A number of sandstone slabs were also found within or just above the cultural deposit (Stratum 2). The presence of the slabs in the higher strata evidently reflects intentional prehistoric cultural activity of some sort.

Fig. 8. Sandstone slabs overlying and underlying the cultural deposit.

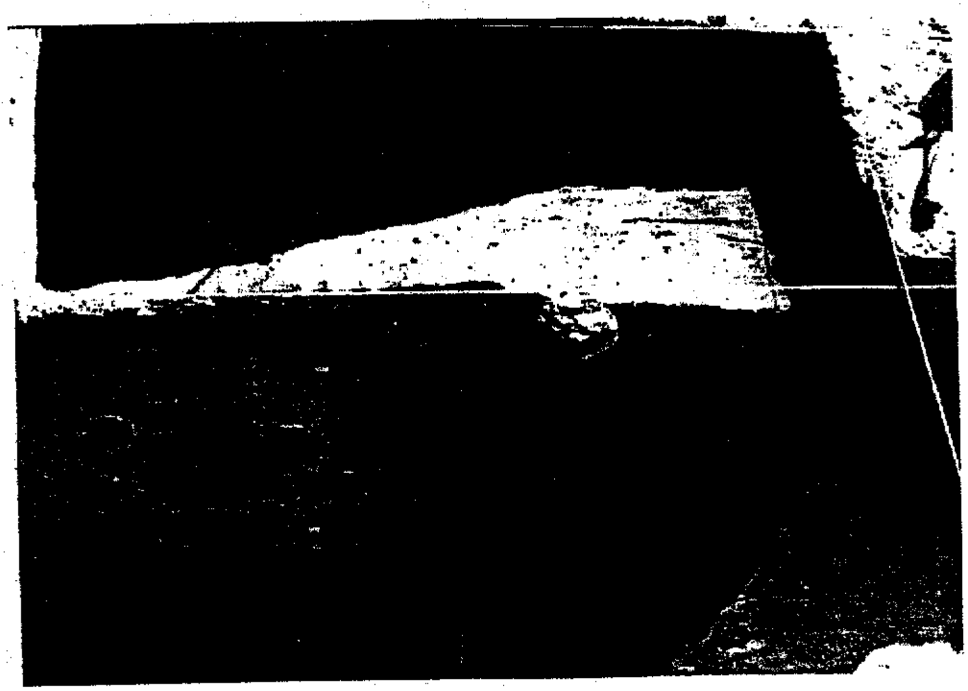

Fig. 9. Conical pit feature.

Several single sandstone slabs or clusters of slabs were found in culturally significant contexts. Units 13, 26, and 31, in particular, contained clusters of large sandstone slabs lying horizontally on top of Stratum 2 (Fig. 8). It is not clear what the function of the slabs was (cf. Pigniolo 1994b). One possibility is that they were originally erected vertically as windbreaks, to provide shelter for fires or for the site's occupants, perhaps as part of a casual dwelling structure. Another possibility is that they may have served as solid surfaces on which were carried out some sort of manufacturing or processing tasks, such as shell bead working.

Pits

Excavated pits extending below the prehistoric occupation level of Stratum 2 constitute a third class of features. Three different pit types seem to be represented (Table 2). The function of these features is enigmatic, but the issue is worth considering.

Table 2. Estimated pit feature dimensions.

Pit Type*	Unit	Block Exposure	Diameter	Total Depth below Stratum 2	Total Depth within Stratum 4 / 5
# 1	12, 24, 27	southwest	50cm	15cm	--
# 2	16	southwest	10	20	6
# 2	16	southwest	10	20	6
# 2	16	southwest	10	20	9
# 2	16	southwest	10	10	4
# 2	16	southwest	10	10	3
# 2	18	northeast	10	15	8
# 2	21	northeast	10	25	10
# 2	25	northeast	10	20	12
# 2	33	southwest	10	5	5
# 2	36	southwest	10	25	10
# 3	9	northeast	19	50	25
# 3	15, 25	northeast	30	35	18
# 3	16	southwest	40	15	15
# 3	19, 23	southwest	30	35	30
# 3	19, 35	southwest	30	25	10
# 3	32	southwest	30	20	15
# 3	35	southwest	30	25	10

* Type # 1 = conical, extending into Stratum 3 only; Type # 2 = cylindrical, small diameter, extending into Stratum 4/5; Type # 3 = cylindrical, large diameter, extending into Stratum 4/5

Pits of the first type are roughly conical in shape, excavated from Stratum 2 down into but not beneath the sands of Stratum 3. A particularly clear example of this variety of pit was exposed in the sidewalls between units 12, 24, and 27 (Fig. 9). Other such pits were apparently present in the excavation area but were less clearly defined. A second type consists of relatively small pits, about 10 cm in diameter, with vertical sides, excavated from Stratum 2 down into the lacustrine deposits of Strata 4/ No.5 (Fig. 10). Ten of these features were identified, varying in shape from cylindrical to somewhat irregular. No clear patterning is evident in the horizontal distribution of these pits. The soil within the pits was not found to differ in content from the normal Stratum 2 contents.

A third pit type consists of larger pits, usually about 30 cm in diameter. Seven of these pits were identified. These pits were also cylindrical in shape and excavated from Stratum 2 down into the lacustrine sediments. Shapes in plan section were round, and the bottoms ranged from flat to concave. One of the features, in units 19 and 23, expanded downward within the lacustrine sediments, from a diameter of about 30 cm at the top to about 37 cm at the flat base (Fig. 11). In the southwest block exposure, five of these features seem to be arrayed in a semicircle, about 2 m in diameter (Fig. 12). The contents of these pits were also found to be indistinguishable from the normal contents of Stratum 2.

In an attempt to identify the specific activity or activities which are represented by the pit features at the Elmore Site, the relevant ethnographic testimony was reviewed. Because of possible late ethnic shifts in the region and because of probable cultural changes relating to the disappearance of Lake Cahuilla, the ethnographic review was not limited to the desert Kumeyaay-Diegueño. Potentially relevant information from the western Kumeyaay-Diegueño, Cahuilla, Luiseño, Mohave, Quechan, and Cocopa was considered. Also considered were some general speculations about possible pit functions, in part derived from discussions ensuing from a preliminary presentation of the problem at a regional archaeological conference (Laylander 1993a).

Excavation of pits is recorded as having served, or may be speculated as serving, a fair range of different objectives:

Pits were sometimes dug to collect clay for pottery making. This was initially considered as a possible function of the Elmore Site features, but was subsequently rejected. Laboratory analysis revealed that the sediments at the site contain little clay, and therefore would not have been suitable for this purpose.

Other uses of relatively fine sediments removed from strata 4 and 5 are possible. Aboriginally, a mud plaster was applied to the hair to keep it free from lice. Mud was used to seal baskets. Hearths may have been lined with fine sediments. Daub was applied to seal the walls of structures (Barrows 1900:36; Drucker 1937, 1941). Archaeological evidence to support these uses of the material, such as chunks of fine sediment within the upper strata, was not found at the Elmore Site.

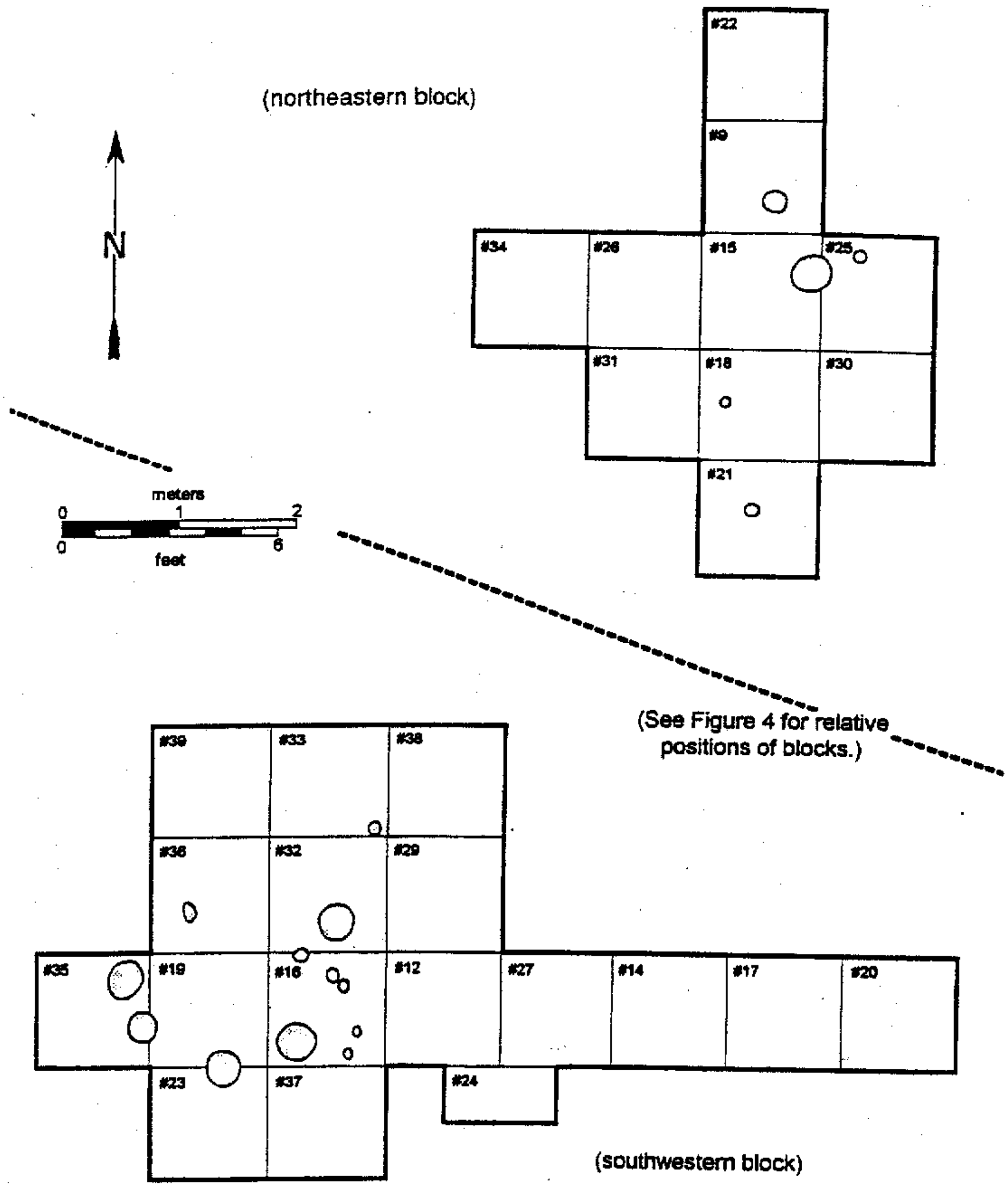

Fig.10. Map of pit features extending into strata 4 and 5 .

Several uses were made of larger excavated features in the region. Included in this class are semisubterranean dwelling floors and sweat house floors; human "baking" or "roasting" pits for postpartum mothers and for girls' and boys' puberty rites; earth ovens; ceramic firing pits; and pits under funeral pyres (Drucker 1937, 1941). The features at the Elmore Site are all too small to have served such functions. No evidence of burning in the pits was observed.

The use of some of the small pits at the Elmore Site as foundation holes for the erection of vertical structural posts is possible. Several types of structures made use of such posts, including "permanent" dwellings, more casual seasonal dwellings, ramadas, and granary platforms. Major dwellings often had semisubterranean floors excavated 30 cm or more below the natural ground surface. Vertical support posts were sunk into the corners of these floors, and also sometimes midway along the sides and/or in the center of the floor (Drucker 1937:11, 1941:104; Sparkman 1908:212-213; Kelly 1977:46). The small holes at the Elmore Site do not appear to have been placed into an excavated floor. Several types of short-term habitation structures have been described (Drucker 1941; Kelly 1977:47-48). One variety of summer house was conical in section and round or oval in plan, slightly excavated, with six poles buried in the ground. Another type, the driftwood house, had four posts. Smaller brush shelters were also used. Basket granaries were often set on platforms which were elevated with vertical posts. The posts might form a square or a double square, with spacing of 1 m or 2.5 m between posts (Kelly 1977; Spier 1923). In one photograph of a Cocopa granary, the posts appear to be at least 15 cm in diameter (Kelly 1977:42).

Screwbeans were ripened in pits. The pits were lined with arrowweed and were sometimes heated first with a fire. The ripened screwbeans might be removed after about six weeks, or they might be stored in the pit through the winter (Kelly 1977). However, screwbean pits were reported to be relatively large, about 1.5 m wide and 1.2 m deep, with sloping sides.

Storage pits were used in the region for several plant foods (Table 3, Appendix). In most cases, no detailed information is available concerning the size, shape, or use of such pits. To store watermelons (an Hispanic introduction), a family might dig a pit which was large enough to hold its entire harvest; that harvest was variously estimated as "five or six piles, breast high" or "50 to 100" of the cantaloupe-sized melons (Kelly 1977). Pits to store watermelons appear to have been similar in size to the screwbean-ripening pits. Pumpkins were less often stored in pits. Smaller pits may have been used for caching small quantities of other food materials, although there does not seem to be specific ethnographic testimony for such practices. Storage appears to be one of the most plausible functions for the Elmore Site pits, although the very ephemeral character of the site occupation argues against any extended-term storage.

Pit mortars were used, together with long wooden pestles, often to process mesquite beans. No specific information is available concerning the characteristics of these mortars. Deep wooden mortars, with pestles often 60 cm in length, were sunk into the ground and used to process mesquite beans (Castetter and Bell 1951; Kroeber 1925:697).The possible use of pits as evaporation features, for the collection of salt, also has been suggested.

As the discussion above indicates, the question of the function or functions of the pits at the Elmore Site remains unresolved. About a dozen additional pit features were identified at the site in 1996, but without as yet shedding any further light on their function.

Fig. 11. Downward-expanding pit feature .

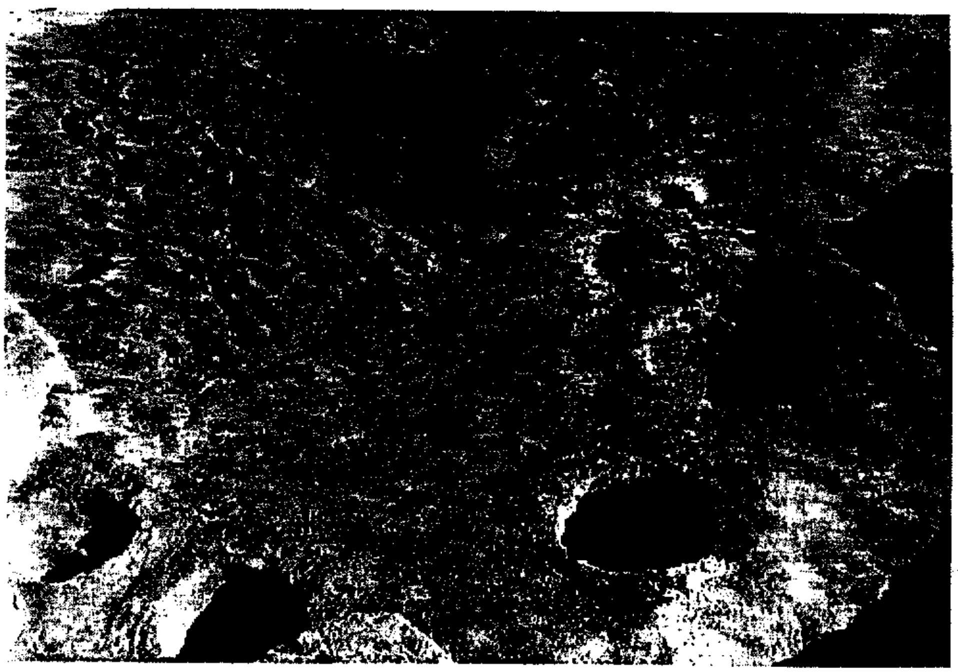

Fig. 12. Semicircle of pit features.

Clothes Burning Feature

In 1996, an additional feature was encountered, consisting of a shallow pit about 1 m by 50 cm by 15 cm deep--dug into Stratum 3. It contained burnt plant fibers, interpreted as fragments of a bark skirt, cordage carrying net, and perhaps sandals. Also present were fragments of a painted ceramic vessel and about 330 burnt *Olivella* sp. shell beads. The feature has tentatively been identified as remains of a clothes burning or mourning anniversary ceremony (Jerry Schaefer and Martin D. Rosen, personal communication, 1997).

Lithic Artifacts

The assemblage of lithic artifacts from the Elmore site includes 2 metates, 10 manos, 33 projectile points, 8 bifaces, 17 worked unifacial tools, 49 unifacially use-damaged tools, 7 chopping tools, 16 hammerstones, 42 cores, and 5,151 pieces of lithic waste. These items are of interest for what they indicate about site functions, lithic resource procurement and use, and regional chronology.

Rock Material Types

Volcanic materials represented at the Elmore Site include obsidian, volcanic porphyry, and nonporphyritic volcanic rock. At least some of the cryptocrystalline silica at the site is probably of volcanic origin; for convenience, it is discussed under this heading.

Obsidian found at the site is black or grey in color. Specimens range from very opaque to fairly translucent. Most contain the large crystalline inclusions which are often characteristic of obsidian from the Obsidian Butte source in Imperial County (Fig. 13). The assignment of the obsidian at the Elmore Site to the Obsidian Butte source is discussed further in a later section.

The largest group of volcanics are blue in color and may perhaps be andesite; also present are black (probably basalt) and red to buff (perhaps rhyolite) specimens. Cryptocrystalline silica encompasses variously-defined chert, chalcedony, jasper, and other forms. Most of the recovered cryptocrystalline silica specimens are opaque, and the most common colors are white and pink, although a wide range of colors is represented. It is not unlikely that some of the cryptocrystalline silica specimens are of sedimentary rather than volcanic origin.

The generalized geological mapping available for the Imperial Valley area (Gastil et al. 1971; Jennings 1967; Morton 1977; Rogers 1965; Strand 1962) suggests several possible sources for the volcanic materials which were found at the Elmore Site:

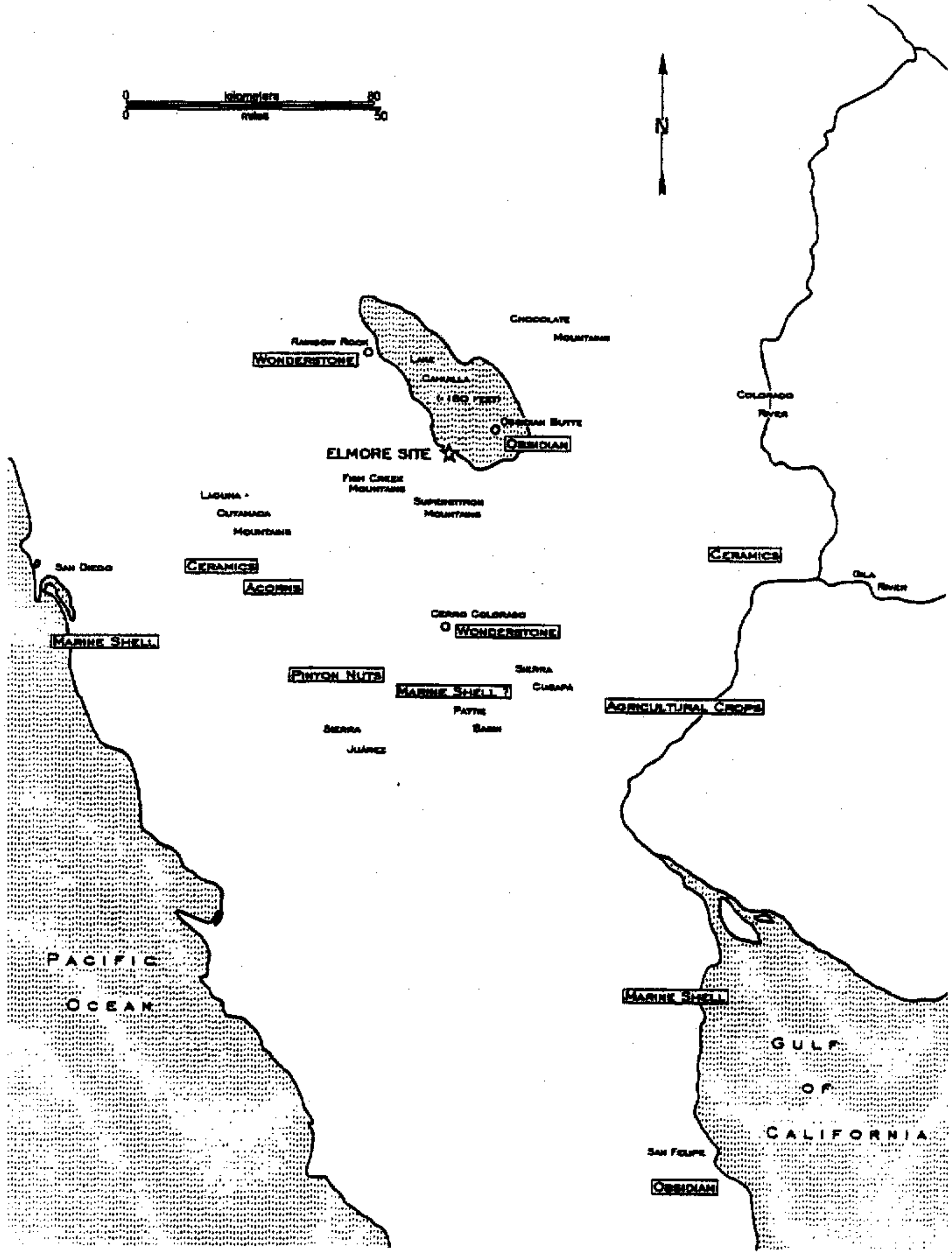

Fig. 13. Map of regional resource areas.

The southeastern end of the present Salton Sea, around Obsidian Butte and Red Island, contains obsidian and rhyolite. These outcrops are about 18 km northeast of the Elmore Site. Obsidian may have been quarried at outcrops as high as the top of Obsidian Butte, which is about 130 feet below sea level.

South and southwest of the Elmore Site are several small areas with outcrops of the Alverson Canyon Formation and of the Jacumba Pyroclastics, consisting primarily of andesite. The nearest outcrops include an area in the Superstition Mountains, 16 km south of the site, and an area southwest of the Fish Creek Mountains, 28 km to the southwest. However, according to Andrew Pigniolo (personal communication, 1994), volcanic cobbles which are probably from the Alverson Canyon Formation occur naturally within easy walking distance of the Elmore Site and were prehistorically tested and used as cores.

Near Travertine Point, 40 km northwest of the Elmore Site, are outcrops of the varicolored Truckhaven rhyolite flow. The Wonderstone West-Rainbow Rock locality is "one of the largest, if not the largest and most intensive bedrock lithic procurement area in the Colorado Desert" (Pigniolo 1994a). Recent studies suggest that the formation is not volcanic, but represents sediments which have been silicified by hydrothermal action. Quarried material ranges from translucent cryptocrystalline silica to relatively dull, coarse rock.

The Sierra Cucapá in northern Baja California includes a few areas of volcanic or related rock. Particularly noteworthy is Cerro Colorado, west of the northern end of the range and about 50 km south of the Elmore Site. Cerro Colorado contains a prehistoric quarry yielding "wonderstone" material similar to that at Rainbow Rock. Although there is considerable overlap in the characteristics of material from Cerro Colorado and from Rainbow Rock, the cryptocrystalline silica artifacts recovered from the Elmore Site more closely match the material at Cerro Colorado than that at Rainbow Rock, according to Pigniolo (personal communication, 1994).

In the Chocolate Mountains on the east side of the Salton Basin, at least 45 km east or northeast of the Elmore Site, are extensive exposures of andesite, basalt, and pyroclastic rocks. Plutonic and metamorphic rocks which are represented at the Elmore Site include quartz, granitic rock, metaquartzite, and gneiss. The quartz ranges from entirely colorless and transparent to white and opaque. Granitic and metamorphic rocks are exposed in large areas on both sides of the Salton Basin, for instance, in the Superstition, Fish Creek, and Chocolate ranges. The closest such areas are in the Superstition Mountains, about 16 km south of the Elmore Site.

The major sedimentary rock represented in the cultural inventory of the site is sandstone. Often fine-grained, it grades into siltstone. Slabs of sandstone which had formed naturally in place were observed in the lacustrine deposits underlying the site. These deposits, or similar ones nearby, were presumably the source for at least some of the culturally-utilized sandstone.

Obsidian Studies

Obsidian constitutes a minor but a not-insignificant part of the lithic assemblage at the Elmore Site. A total of 214 pieces of the material, including 196 lithic waste items, 1 core, 8 projectile points, 2 bifaces, and 7 unifacially use-damaged tools, were recovered. An initial evaluation of the obsidian specimens was made by Martin D. Rosen on the basis of visual inspection. He identified 203 of the specimens as confidently assignable to the Obsidian Butte source area, 10 as probably from that source, and 1 small specimen as undeterminable. (All of the uncertain specimens were small flakes less than 10 mm in length, too small for x-ray fluorescence analysis).

To confirm the assignment of the obsidian to the Obsidian Butte source, a limited sample of specimens was analyzed by Richard Hughes, using x-ray fluorescence analysis. The sample was confined to specimens which were also selected for hydration measurement as part of the data recovery program and which were large enough for x-ray fluorescence analysis. Of the qualifying specimens, one-third were chosen (in a statistically random manner, using computer-generated random numbers) for the sourcing study. This sample was augmented by additional hydration-measured surface collection specimens, making a total sample of 12 specimens. All were found to have the trace-element characteristics of glass from Obsidian Butte.

A total of 38 specimens were submitted for hydration measurement (Table 4 Appendix). Ten specimens recovered in the testing phase of work at the site were analyzed by Janet Scalise at the University of California, Los Angeles. The remaining 28 specimens, from the data recovery program, were analyzed by Glenn S. Russell, also at UCLA. The interpretation of these obsidian hydration values is discussed in some detail in a later section.

Lithic Artifact Types

Functionally, the lithic artifacts from the Elmore Site appear to represent a substantial range of activities. Metates and manos are respectively the nether and upper surfaces on which floral, faunal, or mineral materials were ground. Projectile points evidence hunting, warfare, or ceremonial activity. The bifaces from the site, on the basis of size, symmetry, and refinement of shaping, mostly appear to be crude knives or knife-preforms, although some may be large projectile points or point preforms. Likely uses for the worked and use-damaged unifacial tools include various operations involving the scraping or cutting of plant and animal materials; merely use-damaged specimens probably reflect more casual and expedient use. Chopping tools and hammerstones were probably used for processing floral or faunal resources, and hammerstones may also have been used for knapping. Cores and lithic wastes reflect the production and reworking of stone tools; both early- and late-stage work seems to be represented.

The projectile point assemblage analyzed from the Elmore Site contains 33 small points or point fragments (Fig. 14). Such points reflect a bow-and-arrow projectile technology, and they are generally thought to date between about A.D. 900 and the historic period (e.g., Warren 1984). Three main types of small projectile points have conventionally been distinguished in the region. The Cottonwood Triangular type is characterized by straight sides and a base which is most frequently concave but may also be straight or convex. Six specimens from the Elmore Site are assignable to this taxon. The Desert Side-notched type has sides and a base similar to the Cottonwood form with the addition of notching on the sides; the Elmore Site yielded 14 such specimens. A less common type in the region, labelled Dos Cabezas Serrated (Wilke and McDonald 1986) or Sonoran (Koerper and Drover 1983), is similar to the preceding types but distinguished by pronounced serration of its sides. One serrated specimen was recovered from the Elmore Site.

A fourth point type, or at least another significant dimension of variation in projectile point forms, may be represented at the Elmore Site. Several of the points have very small apical angles. Narrow points such as these seem to be rare in other Southern California assemblages (Table 5; but see also True 1970:85). On the other hand, similarly narrow points have been identified in Arizona. For example, Gumerman and Haury (1979:82) illustrate five such specimens recovered from Snaketown and ranging in apical angles from about 9 degrees to about 19 degrees. Four of the specimens are from the Sedentary period (ca. A.D. 900-1100), and one, the narrowest, is from the Colonial period (A.D. 550-900). Schroeder (1979:106) illustrates a narrow point from Coconino County in western Arizona.

Table 5. Apical angles on projectile points from the Elmore Site and selected other sites.

Site	Point Type[1]	No. of Points	Apical Angle (degrees) Low	High	Mean	Standard Deviation	Reference
IMP-6427	CT	6	12	44	28	10	
IMP-6427	DSN	13	18	39	26	6	
IMP-6427	DCS	1	11	11	11	-	
IMP-6427	Unkn	11	10	58	26	14	
IMP-6427	All	31	10	58	26	11	
IMP-5267	CT	8	30	61	48	9	Schaefer 1988
IMP-5267	DCS	1	50	50	50	-	Schaefer 1988
SDI-217	CT	12	17	51	38	8	Waugh 1986
SDI-731	CT	32	22	57	38	9	Schaefer 1988
SDI-2537	CT	21	26	55	36	7	McDonald 1992
SDI-2537	DSN	26	20	49	35	7	McDonald 1992
SDI-2537	DCS	8	29	51	40	6	McDonald 1992

1- CT = Cottonwood Triangular; DSN = Desert Side-notched; DCS = Dos Cabezas Serrated; Unkn = unknown

Fig.14. Projectile points. Top row includes catalog numbers 744, 196, 697, 331, 586, and 038. Second row includes numbers 743, 092, 573, 689. Third row includes numbers 287, 435, 032, 694, 598, 541, 751, and 670. Bottom row includes numbers 039, 147, 627, 296, 519, 572, 195, and 318 which was cut for a hydration measurement.

A variety of interpretations might be offered for the observed typological variation. As will be discussed below, chronological differences in the initiation of Cottonwood Triangular, Desert Side-Notched, and Dos Cabezas Serrated forms have been suggested. The co-occurrence of these types at the Elmore Site seems to indicate that their use coexisted in the late period. Ethnic variation in the use of different point types has been suggested for the region to the west (True 1966). Different point types may have reflected functional differences, in the lithic materials employed, the characteristics of shaft and binding material, or the intended use of the points, for instance on different types of game or in warfare. The very narrow points appear to be fragile and may have had a basically "ceremonial" rather than technomic function.

Relative Emphasis in Activities

The proportions of the different classes of lithic artifacts recovered from the Elmore Site may provide an index of sorts to the relative importance at the site of the various activities which are represented by the artifacts. There are several potential problems with making such interpretations. One consideration is that recovery methods influence the results. Surface collection maximizes the recovery of larger items and perhaps also of more formalized items. Another problem is that absolute counts, by themselves, do not tell the story. The vast majority of artifacts from the Elmore Site are lithic wastes. This should not suggest that lithic reduction was the main concern there; lithic wastes will be found to predominate in virtually any assemblage in the region. A standard for comparison is needed. A third problem concerns possible differences in the ways in which artifacts have been classified in different investigations.

Table 6 compares the assemblage from the Elmore Site with seven other Colorado Desert assemblages. The assemblage from the Kane Spring sites (CA-IMP-6297/6298, -6417, -6419, and -6422/6423) comes almost entirely from surface collections, in a habitation area which was associated (at least in part) with a late-stage recession of Lake Cahuilla (Laylander 1991a). The assemblage from the IT sites also comes almost entirely from surface collections, at apparent camps relating to a late-stage recession of the lake. The assemblage from the San Felipe sites includes material recovered in surface collections, surface scrapes, and shovel tests, at temporary camps associated with a recessional shoreline (Clewlow et al. 1992). The assemblage from the Superstition Mountain alkali pan sites includes both surface and excavated material and has been interpreted as relating to temporary camps contemporary with a full lake stand (Schaefer 1988). The Dry Lake sites assemblage includes items recovered from surface collections, surface scrapes, and unit excavations; the sites are temporary camps apparently associated with a full lake stand (Eighmey and Cheever 1992). The assemblage from Dunaway Road sites was taken primarily from the surface of temporary camps on the maximum Lake Cahuilla shoreline and early-stage recessional locations (Schaefer 1986). At site CA-RIV-1179, on the Lake Cahuilla maximum shoreline near La Quinta, the recovered assemblage came from excavation, with minor amounts of surface material (Sutton 1988b); the site was interpreted as a temporary camp.

The Elmore Site assemblage is generally consistent with the pattern of the other assemblages selected for comparison. At least at this level of analysis, the site can be considered fairly typical of the short-term residential bases of the region. There is no convincing evidence in the lithic assemblage either of a particular activity given disproportionate emphasis or a major category of activity which was omitted. Ground stone artifacts are somewhat underrepresented at the Elmore Site, but not drastically so. The low frequency of ground stone may reflect an emphasis on processing food resources, such as waterfowl and screwbeans, which would not have required stone-on-stone grinding.

Table 6. Counts of lithic artifacts from selected Lake Cahuilla sites.

Artifact Class	Elmore Site	Kane Spring Sites	IT Sites	San Felipe Sites	Superstition Mtn. Alk. Pan Sites	Dry Lake Sites	Dunaway Road Sites	La Qunita Site
Metates	2	-	5	17	77	5	4	5
Manos	10	9	23	24	72	8	4	17
Pestles	-	-	-	-	-	-	1	-
Projectile Points	33	6	5	1	48	5	1	11+
Bifaces	8	-	11	2	1	1	1	3+
Drills, etc. [1]	-	1	5	1	-	-	-	-
Unifaces [2]	66	77	36	30	5	7	18	2
Choppers	7	4	23	7	13	-	9	-
Hammers	16	16	74	24	16	-	11	1
Cores	41	75	58	1	2	38	62	2
Wastes	5,151	725	1,061	653	5,921	3,089	805	551

1 Includes perforators, borers, and gravers
2 Includes both worked and use-damaged tools, at least for some sites

Sources: Kane Springs sites, Laylander 1991a; IT sites, Phillips 1982; San Felipe sites, Clewlow et al. 1992; Supersitition Mountain Alkali Pan sites, Schaefer 1988; Dry Lake sites, Eighmey and Cheever 1992; Dunaway Road sites, Schaefer 1986; La Quinta site, Sutton 1988b.

Uses for Specific Materials

Another point of interest is the way in which various lithic materials were used at the Elmore Site. The range of lithic materials which were brought to the site and their relative frequencies have already been indicated. It remains to consider how that selection fits within a larger regional picture and the specific uses to which the various lithic resources were put.

Table 7 summarizes the proportions of various rock types represented in the lithic wastes recovered from the Elmore Site and from other Colorado Desert sites. The table shows strong variability among the sites in the proportions of various rock types. This may be attributable primarily to differences in the accessability of specific lithic sources, rather than to differences in site functions or in cultural preferences. The Elmore Site assemblage is most conspicuous, in this context, for its relative abundance of cryptocrystalline silica and its scarcity of quartz. The use of metamorphic rock (gneiss) at the site is also notable.

Table 7. Lithic wastes from selected Lake Cahuilla sites, percentages by rock type.

	Rock Type [1]								
Study	OB	CC	VL	QZ	GR	MQ	GN	SS	Count
Elmore Site	3.8	30.9	44.7	9.3	1.2	6.6	3.5	-	5,151
Kane Spring Sites	3.2	1.7	89.9	1.5	1.2	2.3	0.1	-	725
Superst. Mtn.									
Alk. Pan Sites	0.3	0.8	14.9	52.9	6.9	10.3	-	13.9	5,714
Dry Lake Sites	-	18.8	65.0	4.6	2	6.3	2	2	3,086
Dunaway Road Sites	-	-	76.7	21.2	-	2.1	-	-	794
La Quinta Site	0.4	3.6	-	95.3	-	0.5	0.2	-	551
RIV 86 Sites	8.0	30.6	28.7	16.6	3	14.5	3	3	2,067

1 OB = obsidian; CC = cryptocrystalline silica; VL = volcanic rock (including porphyry); QZ = quartz; GR = granitic rock; MQ = metaquartzite; GN = gneiss; SS = sandstone

2 5.2% listed as "other"

3 1.6% listed as "other"

Sources: Kane Springs sites, Laylander 1991a; Supersitition Mountain Alkali Pan sites, Schaefer 1988; Dry Lake sites, Eighmey and Cheever 1992; Dunaway Road sites, Schaefer 1986; La Quinta site, Sutton 1988b; RIV 86 sites, Dominici 1987.

The next question is to consider the ways in which various rock types were used at the Elmore Site (Table 8). Not unexpectedly, sandstone and granitic rock were used for ground stone tools. Obsidian and cryptocrystalline silica were used for projectile points and bifaces in particular, although cryptocrystalline silica was used nearly as much for unifacial and use-damaged tools. Flakes of these two materials are proportionately more frequent than cores, and small, non-cortical flakes predominate, all of which suggests that early-stage reduction of obsidian and cryptocrystalline silica was commonly done at a location other than the Elmore Site. Volcanic rock and quartz were used for hammerstones, choppers, unifaces, and use-damaged tools, as well as for projectile points. Metaquartzite received some use for unifaces, use-damaged tools, hammerstones, and choppers. Gneiss, somewhat surprisingly, was used for bifaces, although only two specimens are involved.

Table 8. Lithic artifact classes at the Elmore Site, by rock type.

	Percentages of Rock Types [1]								
Artifact Class	OB	CC	VL	QZ	GR	MQ	GN	SS	Count
Metates	-	-	-	-	-	-	-	100.0	3
Manos	-	-	-	-	50.0	-	-	50.0	10
Projectile Points	24.2	33.3	39.4	3.0	-	-	-	-	33
Bifaces	25.0	50.0	-	-	-	-	25.0	-	8
Unifaces	-	29.4	41.2	5.9	-	17.6	5.9	-	17
Use-Damaged Tools	14.3	32.7	38.8	4.1	-	10.2	-	-	49
Hammerstones	-	-	87.5	6.3	-	6.3	-	-	16
Chopping Tools	-	14.3	71.4	-	-	14.3	-	-	7
Cores	2.4	26.2	52.4	11.9	-	4.8	2.4	-	42
Lithic Wastes	3.8	30.9	44.7	9.3	1.2	6.6	3.5	0.0	5151

1 OB = obsidian; CC = cryptocrystalline silica; VL = volcanic rock (including porphyry); QZ = quartz; GR = granitic rock; MQ = metaquartzite; GN = gneiss; SS = sandstone

Intensity of Artifact Use

A final point worth considering briefly is whether the lithic assemblage from the Elmore Site indicates anything about the duration of site use. It can be argued that an assemblage of heavily-used artifacts would tend to indicate that a site was occupied or reoccupied over a relatively long period of time. Under such conditions, a high proportion of tools might be finally discarded only after they had been used to exhaustion. Conversely, an assemblage of lightly-used tools might indicate that a site was abandoned after only a short time span.

One measure of use intensity might be derived from unifacial edge tools. The ratio of unshaped to shaped tools, the number of worked or utilized edges per tool, and the extent of use damage on the edges might all be indices of the intensity of unifacial tool use. Unfortunately, these variables may be difficult to measure objectively, and comparative data sets are generally lacking. On an impressionistic level, the ratio of unifacially use-damaged to unifacially worked tools at the Elmore Site (2.9:1) seems fairly high, and the average number of worked edges (1.8) or use-damaged edges (1.4) per tool seems moderate to low.

Comparisons for ground stone are somewhat easier. Table 9 summarizes the frequencies of unifacial and bifacial manos at selected sites in the Colorado Desert and at sites in the mountain and coastal areas of San Diego County, to the west. Although the sample of manos from the Elmore Site is small, it is notable for its high proportion of unifacial manos.

Table 9. Mano types from selected Colorado Desert and western sites.

	Unifacial		Bifacial		Nondiagnostic
	Count	Percent	Count	Percent	
Colorado Desert					
Elmore Site	6	60.0%	4	40.0%	-
Kane Spring sites (Laylander 1991a)	7	77.8	2	22.2	-
IT Project sites (Phillips 1982)	10	43.5	13	56.5[1]	-
San Felipe sites (Clewlow et al. 1992)	13	59.1	9	40.9[1]	2
Superstition Mtn Alkali Pan sites (Schaefer 1988)	13	29.5	31	70.5	28
Dunaway Road sites (Schaefer 1986)	1	25.0	3	75.0[1]	-
Indian Hill Rockshelter (McDonald 1992)	23	25.8	63	74.2	62
La Quinta site (Sutton 1988b)	3	37.5	5	62.5	9
Western (Mountain/Coastal)					
Spring Valley sites (Laylander 1992)	18	13.2	118	86.8	51
SDI-5383 (Norwood 1982; Laylander 1989)	14	16.1	73	83.9	17
Nelson Site (Dominici 1985)	22	22.7	75	77.3[2]	53
Avocado Highlands (Cardenas and Van Wormer 1984)	15	7.4	188	92.6[3]	251
Ystagua (Carrico and Taylor 1983)	8	21.6	29	78.4	12
Moosa Canyon (Cook 1978)	16	50.0	16	50.0	-
Santee (Corum 1986; Corum and White 1986)	15	17.0	73	83.0	35
Pío Pico Site (Hector 1984)	4	26.7	11	73.3	2
Reading Site (Norwood 1980)	10	14.9	57	85.1	-
Corte Madera sites (Phillips 1986)	11	20.0	44	80.0	15
Jacumba Valley sites (Townsend 1986b)	10	40.0	15	60.0	7
McGowan Site (McDonald et al. 1993)	2	10.5	17	89.5	5

1 Includes one trifacial specimen

2 Includes four multifacial specimens

3 Includes eight multifacial specimens

The evidence from the lithic assemblage at the Elmore Site seems to support stratigraphic and other indications that the span of site use was brief.

Ceramic Artifacts

Investigations at the Elmore Site resulted in the recovery of 727 pieces of aboriginal pottery, weighing 2,792.3 g. These remains provide a basis for making inferences about the chronology of the site, the activities which occurred there, and the links between the site's prehistoric occupants and other groups within a wider region. Analytical methods used to extract this information include type/ware classification and the partial reconstruction of vessel forms from rim sherds.

Wares and Types

Several different classification schemes have been suggested for the aboriginal ceramics of southern California. These schemes, and some of the problems with them, are discussed further in a later section. For purposes of describing the ceramic collection from the Elmore Site, a rough working typology has been employed. This is based primarily on the typology of Michael R. Waters (1982a, 1982b, 1982c). Type sherd collections at the San Diego Museum of Man which were prepared by Waters and by Malcolm J. Rogers were examined in designing and applying the present scheme.

Five provisional ceramic types have been distinguished:

Type BT corresponds, to some extent, to Waters' Black Mesa Buff and Tumco Buff types, within his Lower Colorado Buff ware. The formal criteria for distinguishing between Black Mesa Buff and Tumco Buff in Waters' descriptions appear to be minimal, and the sherd type collection at the Museum of Man also shows minimal differentiation. However, because of their late date and their occurrence in the western portion of the Salton Basin, sherds such as those typed as BT here would probably be considered Tumco Buff rather than Black Mesa Buff by most analysts. Sherds have been assigned to the present type BT on the basis of having angular clay or sherd inclusions and an absence or near absence of any other temper or inclusions. The area of most likely ambiguity surrounding this type is in its relationship with type C, discussed below. Type BT sherds are generally less well-fired, thicker, and have fewer mineral inclusions than type C sherds.

Type C corresponds to Waters' Colorado Buff type, within Lower Colorado Buff ware. Sherds have been assigned to this category on the basis of having definite but fairly meager amounts of quartz and feldspar temper or inclusions. Type C sherds are also generally characterized by relatively uniform, hard matrix, and by walls which are thin and uniform in thickness. Specimens with very scarce mineral temper or inclusions or which are poorly fired may be difficult to distinguish from type BT. Specimens with greater amounts of temper or inclusions intergrade with type CPPT and possibly with type S, both discussed below.

Type CPPT corresponds roughly to Waters Colorado Beige, Palomas Buff, Parker Buff, and Topoc Buff types, within Lower Colorado Buff ware. As with type BT, a basis for confidently distinguishing the several different original types within this group seems to be lacking. Sherds have been assigned to type CPPT on the basis of abundant angular to rounded temper or inclusions, primarily of quartz and feldspar, and fairly crumbly texture. Distinctions between this type and type C, type S, and type Tz may all pose some difficulties. It is likely that some of the sherds here classified as type CPPT would have been classified by some other analysts as Salton Brown (cf. Schaefer et al. 1987; Wade 1988).

Type S corresponds to Waters' Salton Buff type, within Lower Colorado Buff ware. Sherds have been assigned to this category on the basis of having abundant sand temper or inclusions. The sand grains are fairly uniform in size, rounded, and sometimes frosted. Distinctions between this type and Type CPPT are the ones most likely to be problematical.

Type Tz corresponds to the Tizon Brown ware of Waters, Ronald V. May (1978b), and others. Sherds have been assigned to this category on the basis of brown surface color, rough and poorly-sorted matrix, crumbly fracture, and temper or inclusions which are abundant, angular, poorly sorted, and micaceous. Surface color has not been given much weight in this typology. Some of the brown sherds which are here assigned to types C, CPPT, and S might have been classified by other analysts as Tizon Brown ware, or as belonging to a Salton Brown type.

Of 725 plainware sherds recovered from the Elmore Site, 550 have been classified as type C, 114 as type CPPT, 29 as type BT, 21 as type Tz, and 11 as type S. Although type C strongly predominates, the diversity within the assemblage is notable, particularly in light of the short use-life associated with the site. Some of the implications of the type frequencies for chronology and for exchange and travel are considered in a later section.

One sherd from the surface of the site may be exotic to the region (Fig. 15). This item, which appears to be the inside of a plate or saucer, was formed by the coil-and-scrape method and is buff with black or purplish paint applied to the inside surface. According to Larry Leach of San Diego State University, the sherd may belong to the Anasazi ceramic tradition, and may come from the Kayenta region of northeastern Arizona and southeastern Utah. However, some other archaeologists with experience in the Southwest have expressed doubts as to this identification, suggesting that the sherd may be an anomalous Lower Colorado Buff ware item.

Vessel Forms

Rogers (1945), Waters (1982a, 1982b), and others have suggested that certain elements of southern California ceramic vessel form may be chronologically diagnostic. Additionally, vessel form is likely to be indicative of vessel function. Identification of vessel functions would in turn enable some evaluation to be made of the range and the relative importance of the activities involving ceramics which occurred prehistorically at the Elmore Site.

Although the sherds tend to be highly fragmented, something of the original vessel forms can be inferred from the characteristics of the recovered rim sherds. The rim traits which have been recorded include the following:

rim angle, expressed as 0 degrees for a vessel with the exterior surface of its rim down and horizontal, through 90 degrees for a vertical rim, to 180 degrees if the exterior rim surface is up and horizontal; rim recurving, an outward flaring (or localized decrease in the rim angle) in the rim area; rim radius, as estimated by comparing the rim fragment with a set of concentric circles; sherd length, as measured along the rim, an indicator of the degree of fragmentation of the rim sherd; vessel form, categorized as jar (for a specimen having a relatively high or moderate rim angle and a relatively small rim radius) or as bowl (potentially also including scoops and plates; for a specimen having a relatively low or moderate rim angle and a relatively large rim radius); lip form, classified as rounded, slightly flattened, or flattened;

lip incising, indicated by linear indentations made on the lip prior to vessel firing; and

lip thickening, categorized as occurring on the interior of the vessel, on the exterior, on both sides, or on neither.

Aboriginal ceramic vessels in the region were often somewhat roughly made or asymmetrical, so allowance must be made for probable inconsistencies which would occur in the observed characteristics of sherds from a single vessel.

Of the 67 Elmore Site rims, 20 are assignable to the "jar" category, 43 are assigned to the "bowl" category, and 4 are indeterminate (Table 10, Appendix). This may give some indication of the relative prominence of different activities occurring at the site. Jars would generally have been associated with storage or transportation of materials (particularly water and food). Bowls would generally have been associated with processing tasks or with consumption.

A comparison of jar and bowl frequencies, based on simple counts of sherds, might be misleading. Bowls tend to have rims of larger radius, and therefore, they may tend to have more rim sherds per vessel, than do jars. The mean radii for the Elmore Site bowl and jar rim sherds are 12.4 cm and 9.1 cm, respectively (if bowl radii larger than 15 cm are arbitrarily counted as 20 cm). To make comparisons between vessel types more meaningful, the number of whole vessel-equivalents of each type represented by the sherds recovered from the Elmore Site can be estimated, using the following equation:

$$V = \sum_{i=1}^{n} \frac{L_i}{2 \pi R_i}$$

Here V is the estimated number of vessels represented by n rim sherds; R is the estimated rim radius; and L is the estimated length along the arc of the rim on the sherd. This statistic undoubtedly underestimates the actual number of vessels represented in the collection, which includes partial rims of a considerable variety of vessels. The function of the statistic is merely to provide a relatively unbiased estimate of the proportions of different vessel types represented in the collection.

The results suggest that the rim sherd collection could correspond to about 1.19 jars and 2.37 bowls, or a ratio of jars to bowls of 1 : 2. For a full interpretation of the implications of this ratio, it would be necessary to consider similarly-analyzed data from other sites. It would also be helpful to have ethnographic or experimental data on the typical use-lives of various ceramic forms.

Among the jars, the mean rim angle is estimated as 100 degrees, or slightly turned inward from the vertical. Bowls have a mean rim angle of 62 degrees but the distribution is bimodal. One mode, at 20 to 30 degrees, apparently represents nearly flat forms, such as plates; the second mode, between 70 and 90 degrees, represents bowls with nearly vertical sides.

Other rim characteristics are of uncertain interpretive significance; some of these issues are discussed further in a later section. The Elmore Site assemblage includes 19 recurved rim sherds (30%). Most of the rims (73%) have some lip flattening. Rim lips are thickened outward on 61% of the sherds, and inward on 30%. Three of the rims (4%) have incising on the lips.

Ceramic Pipe Fragment

A single ceramic pipe fragment was recovered from the surface of the Elmore Site (Fig. 15). The specimen is most of a "Yuman" flanged bow pipe. It consists of a gently-curved tube and a squarish, concave-based, perforated flange handle. The proximal end (mouth) is slightly broken, and a considerable portion of the distal end (bowl) is also missing.

The material from which the pipe was made appears to be Tizon Brown ware rather than Lower Colorado Buff ware, although no freshly-broken cross sections were exposed. The surfaces are brown. The cross sections show incomplete oxidation of the core. Inclusions are fairly abundant, show a size range from coarse to fine, and include mica.

The pipe fragment's present dimensions are 7.3 by 3.8 by 1.8 cm, with a weight of 23.1 g. Before breakage, the full length was probably at least 10 cm, and the bowl thickness was probably somewhat greater than the present 1.8-cm maximum. The main tube of the pipe, from the mouth end to approximately the distal end of the flange handle, or about 6 cm of its length, is solid except for a narrow inner breathing tube. Beyond the handle end, the tube abruptly opens out into the bowl.

The squarish flange handle has convex sides, a convex cross section, and a broadly concave "bird's beak" base. A hole (with a minimum diameter of 0.4 cm) has been biconically punched through the flange prior to firing. No indications of painting, incising, punctation, or polishing are evident on the surface of the artifact. The bowl and breathing tube are blackened, as are irregular portions of the outer pipe surface.

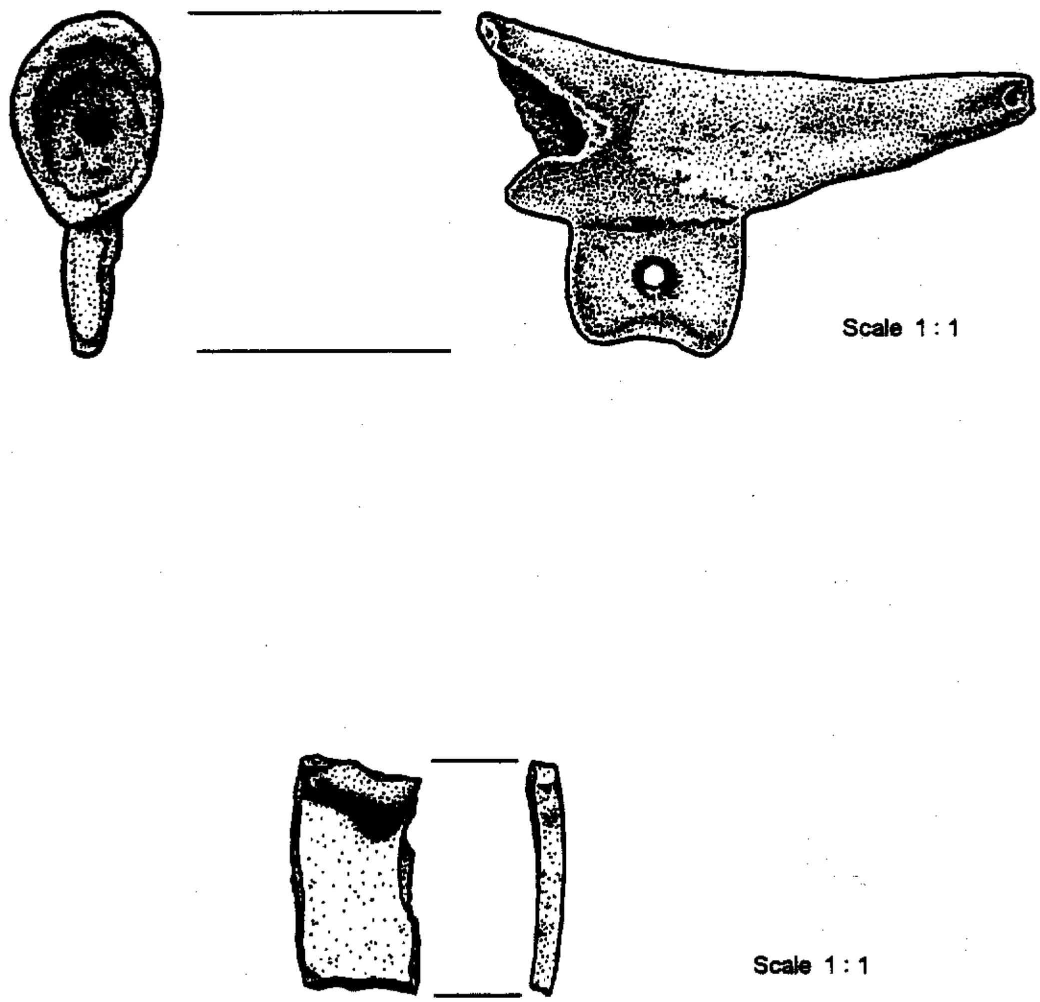

Fig.15. Ceramic pipe and painted sherd (drawn by Chris Andrews).

The pipe was presumably used to smoke native tobacco. Smoking may have occurred in association with curing or in some other ritualized context, or it may have been a purely recreational activity. The presence of the pipe fragment at the Elmore Site does not necessarily indicate its use there; pipes would probably have been carried by their owners and used intermittently, until accidentally broken.

Shell

Small amounts of freshwater gastropod, oyster, and clam shell were observed at the Elmore Site. Although some of this shell was recovered during the archaeological investigations (Table 11), it was not systematically collected. Similar amounts of shell were also observed in non-site areas in the vicinity. *Anodonta* sp. (freshwater clam) was a prehistorically exploited resource at some +40-foot Lake Cahuilla shoreline sites (cf. Wilke 1978), but the freshwater shell at the Elmore Site appears more likely to represent natural deposition from the lake, rather than cultural deposition.

Table 11. Identified shell.

Source Area	Taxon	Common Name	Number of Specimens	Weight (g)
Freshwater	*Anodonta* sp.	clam	729	12.25
Freshwater	--	oyster	30	1.35
Freshwater / Marine	*Rangia* sp.	--	1	3.29
Marine (West coast only)	cf. *Argopecten aequisulcatus*	speckled scallop	4	0.99
Marine (West coast only)	*Cerithidea californica*	California horn shell	1	0.08
Marine (West coast only)	*Conus californicus*	California cone shell	3	2.21
Marine (Gulf coast only)	*Glycymeris* sp.[1]	bittersweet	8	2.27
Marine (West coast only)	*Cypraea spadicea*	chestnut cowry	2	4.74
Marine	cf. *Fissurella volcano*	cf. volcano limpet	1	0.22
Marine	*Haliotis* sp.	abalone	1	0.71
Marine	*Laevicardium elatum*	giant egg cockle	22	80.64
Marine (West coast only)	*Olivella biplicata*	purple olive	7	1.11
Marine (Gulf coast only)	*Olivella dama*	dama olive	23	5.53
Marine	*Olivella* sp.	olive	198	15.64
Total			1030	131.03

1 Not *Glycymeris subobsoleta*; misidentified in previous reports (Laylander 1994; Rosen 1995) as *Cooperella subdiaphana*.

Marine shell at the site includes at least ten species. In origin, this shell is attributable both to the Gulf of California and to the western coast of southern California or northern Baja California. Two of the species are exclusive to the Gulf of California, five are exclusive to the western coast of southern California or northern Baja California, and three occur on both coasts. Some of the marine shell may be food refuse. However, shell ornaments, tools, beads, and detritus from bead manufacturing predominate (Table 12). Worked marine shell includes both western coast and gulf species. *Olivella* sp. spire-lopped and barrel beads are most common, and detritus from their manufacturing is well-represented.

Table 12. Shell beads, ornaments, tools, and manufacturing wastes.

Taxon	Common Name	Type	Count
Conus californica	California cone shell	cap bead	2
Conus californica	California cone shell	disk bead	1
Glycymeris sp.[1]	bittersweet	ornament	5
Haliotis sp.	abalone	ornament	1
Laevicardium elatum	giant egg cockle	tool	4
Olivella biplicata	purple olive	spire-lopped bead	3
Olivella biplicata	purple olive	detritus	4
cf. *Olivella biplicata*	cf. purple olive	barrel bead	30
Olivella dama	dama olive	spire-lopped bead	14
Olivella dama	dama olive	barrel bead	2
Olivella dama	dama olive	detritus	7
Olivella sp.	olive	spire-lopped or barrel bead	9
Olivella sp.	olive	tiny saucer bead	2
Olivella sp.	olive	detritus	158
--	unidentified clam or gastropod	ornament	1
--	unidentified gastropod	ornament	1
--	unidentified mother-of-pearl-lke shell	ornament	1
Total			245

1 Misidentified in previous reports (Laylander 1994; Rosen 1995) as *Cooperella subdiaphana*.

The presence of wastes from the manufacturing of shell beads at the Elmore Site casts interesting light on the function of the site. In simple geographical terms, the site is not an obvious location for such manufacturing. The straight-line distance from the site to the California coast is about 135 km, and the distance to the head of the Gulf of California is about 185 km. (If the Laguna Macuata basin was connected to the Gulf of California at the time of the site's occupation, the latter distance would be reduced to about 60 km. Some possible evidence for the extension of the gulf to the basin as late as the A.D. 1600s is noted below.)

Explanations for the occurrence of shell bead manufacturing at the Elmore Site might relate this activity to the circumstances of the site's occupation. One hypothesis would be to posit a desire to make use of a potential labor source. If the main economic activity which was based at the site was the hunting of waterfowl, and if this was primarily a male activity, women may have had few specific tasks to accomplish when at the site. The value of their labor, if devoted to bead manufacturing, would have been stored and would have been retrievable later through the exchange of finished beads. Raw materials for shell bead manufacturing, although coming from a considerable distance, would have been relatively easy to carry during wide-ranging seasonal rounds; or they might have been obtained through exchange with groups based nearer to the source areas. Alternatively (or additionally), shell bead manufacturing may have been a preparation for a period of anticipated stress which would result from the impending loss of Lake Cahuilla's lacustrine resources. The wealth represented by finished shell beads may have been an element used by occupants of the Elmore Site to cushion their transition into the post-lake period, for instance by purchasing subsistence resources or by making gifts to cement social bonds which would be useful in a time of territorial readjustments.

An alternative explanation of shell bead manufacturing at the site is suggested by the subsequently-discovered mourning anniversary feature, which contained approximately 330 burnt *Olivella biplicata* and *O. dama* spire-removed beads, one burnt *Glycymeris* sp. ornament, and one fragment of unmodified *Laevicardium elatum* shell. The shell artifacts found elsewhere at the site may represent "items that broke during manufacture, were lost during manufacturing, were part of some ancillary symbolic behavior related to the ceremony, or were deemed for whatever reason not appropriate to include in the ceremony" (Jerry Schaefer and Martin D. Rosen, personal communication, 1997).

Bone

A total of 17,602 vertebrate faunal specimens were recovered at the Elmore Site. Of these, 2,445 (13.9%) were identified to species, to genus, or to a higher grouping below the class level. The identified mammal and reptile remains are notable for being very limited in quantity (Table 13). Large mammals (deer), medium mammals (coyote/dog, fox), small mammals (lagomorph, rodent), and lizards are all represented. Bird bone is by far the most abundant faunal type at the Elmore Site (Table 14). A total of 2,353 specimens were identified, and at least 12 species are represented. American coot (*Fulica americana*) predominates, accounting for about 73% of the identified specimens. Also fairly abundant are pochards and their allies (*Aythya* spp.) with 17%, and western or Clark's grebes (*Aechmophorus* sp.) with 7% of the identified specimens. Freshwater fish remains include 407 bones and scales. Of these, 64 specimens were identified to three species: razorback sucker (*Xyrauchen texanus*), bonytail (*Gila elegans*), and machete (*Elops affinis*) (Table 15). Razorback sucker strongly predominates.

The vertebrate faunal assemblage from the Elmore Site clearly attests to the lacustrine associations of the site. The predominance of aquatic birds requiring open expanses of water to become airborne is indicative of this, as is the presence of freshwater fish species which are characteristic of the lower Colorado River and of its sometime outlet, Lake Cahuilla. The mammalian and reptilian remains are not specifically lacustrine.

Table 13. Identified mammal and reptile remains.

Taxon	Common Name	Number of Specimens
Mammals		
Ammospermophilus leucurus	white-tailed antelope squirrel	1
Canis sp.	coyote or dog	1
cf. *Dama henionus*	cf. mule deer	1
Lepus californicus	black-tailed jackrabbit	3
cf. *Lepus californicus*	cf. black-tailed jackrabbit	1
Sylvilagus audubonii	desert cottontail	10
Thomomys umbrinus	southern pocket gopher	1
Vulpes velox	kit fox	1
Total		19
Reptiles		
Dipsosaurus dorsalis	desert iguana	1
Iguanidae	iguanid lizards	3
Phrynosoma platyrhinos	southern desert horned lizard	2
cf. *Phrynosoma platyrhinos*	cf. southern desert horned lizard	2
Sceloporus magister	yellow-backed spiny lizard	1
Total		9

Procurement methods may be inferable in the case of waterfowl, as discussed by Beezley (1995; Laylander 1994:Attachment). It is likely that these prey were caught in nets stretched across the water. Also provocative is Beezley's suggestion that there is a bias toward female coots and grebes in the assemblage and that, in the case of the coots, this bias may be attributable to the time of day during which the birds were hunted, as related to differential diurnal nesting responsibilities for the two sexes. It should be noted, however, that the apparent ratio of females to males in the assemblage is only about 1.5 : 1 and that, when considered in terms of minimum numbers of individuals defined within the site as a whole or within the major excavation block areas, the contrast is not statistically significant.

Table 14. Identified bird remains.

Taxon	Common Name	Testing Phase		Data Recovery Phase	
		NISP	MNI	NISP	MNI
Aechmophorus sp.	western / Clark's grebe	2	2	154	12
Anas crecca	green-winged teal	-	-	3	2
Anatinae	ducks, geese, swans	2	-	8	-
Aythya affinis	lesser scaup	2	1	192	15
Aythya cf. *affinis*	cf. lesser scaup	1	-	3	-
cf. *Aythya affinis*	cf. lesser scaup	-	-	3	-
Aythya americana	redhead	-	-	10	4
Aythya cf. *americana*	cf. redhead	1	-	2	-
Aythya marila	greater scaup	-	-	39	7
Aythya cf. *marila*	cf. greater scaup	-	-	3	-
Aythya valisineria	canvasback	-	-	110	12
cf. *Aythya valisineria*	canvasback	-	-	2	-
Aythya sp.	pochards and allies	-	-	28	-
cf. *Aythya* sp.	cf. pochards and allies	-	-	8	-
Catoptrophorus semipalmatus	willet	-	-	2	1
Fulica americana	American coot	54	7	1657	76
cf. *Fulica americana*	American coot	3	-	11	-
Limnodromus scolopaceus	long-billed dowitcher	-	-	2	1
Oxyura jamaicensus	ruddy duck	2	1	33	5
cf. *Oxyura jamaicensus*	ruddy duck	2	-	-	-
Passeriformes	perching birds	-	-	1	-
Pelecanus cf. erythrorhynchos	American white pelican	-	-	1	1
Podiceps nigricollis	eared grebe	-	-	12	3
Total		69	11	2284	139

Possible seasonality indicators in the vertebrate faunal remains were noted by Beezley. Three bones from young cottontails (*Sylvilagus audubonii*) may indicate an occupation at the site during a season other than winter. The presence or absence of a seasonal hiatus in lagomorph births in southern California, however, has been disputed (Laylander 1993b). The lizards which are represented at the site would have been most accessible during seasons other than winter, when they hibernate. Greater scaup (*Aythya marila*) would apparently have been absent in spring and summer, and lesser scaup (*Aythya affinis*) and canvasback (*Aythya valisineria*) would have been absent in summer. In sum, the available evidence is compatible with an occupation confined to a single season of the year. Fall would be the most probable such season. However, the evidence also does not rule out an occupation of several seasons, or even on a year-round basis.

Table 15. Identified fish remains.

Taxon	Common Name	Number of Specimens
Catostomidae	sucker family	19
Cyprinidae	carp and minnow family	1
Catostomidae / Cyprinidae	sucker or minnow family	4
Elops affinis	machete	1
Gila elegans	bonytail	4
Xyrauchen texanus	razorback sucker	35
Total		64

Radiocarbon Dating

Ten radiocarbon dates have been obtained for the Elmore Site. All are based on charcoal which was collected from the main cultural deposit, Stratum 2 (Table 16). The estimates for the ten radiocarbon dates from the Elmore Site, in calibrated real-calendar years (Stuiver and Reimer 1993), range between A.D. 1488 and the present. For each of the dates except one, the one-sigma error range (68% probability range) falls entirely within the post-A.D. 1500 period; for all except two of the dates, the error range falls entirely after A.D. 1600. This seems fairly convincing evidence that occupation of the site occurred after the initial European probes into the general region by Alarcón and Díaz in 1540 (as discussed below).

Stratigraphic evidence, discussed earlier, suggests that the Elmore site represents a single, relatively short, occupation episode. This would imply that the radiocarbon dates all refer to essentially the same point in time. Such an assumption for a suite of radiocarbon dates can be tested, using an equation cited by Aitken (1990:95-98, 111-112):

$$T = \frac{(Y_1 - Y_m)^2}{S_1^2} + \frac{(Y_2 - Y_m)^2}{S_2^2} + \cdots$$

in which Y_1 , Y_2, etc., are radiocarbon dates; S_1, S_2, etc., are one-sigma error ranges, and Y_m is the weighted mean radiocarbon date, calculated as:

$$Y_m = \frac{Y_1 / S_1^2 + Y_2 / S_2^2 + \cdots}{1 / S_1^2 + 1 / S_2^2 + \cdots}$$

Table 16. Radiocarbon dates.

Lab No.	Unit	Depth (cm)	^{14}C Age	Age	^{13}C-Adjusted Date	Best-Estimate One-Sigma Range
Beta-42011	5	30-40	110 ± 60	110 ± 60	A.D. 1710, etc.	A.D. 1680-1753, etc.
Beta-42012	8	40-50	330 ± 80	370 ± 80	A.D. 1488, 1609, 1611	A.D. 1443-1644
Beta-53003	15	60-70	250 ± 50	260 ± 50	A.D. 1654	A.D. 1638-1669, etc.
Beta-53004	21	30-40	130 ± 70	150 ± 70	A.D. 1686, 1738, etc.	post A.D. 1666
Beta-53005	27	10-20	200 ± 50	250 ± 50	A.D. 1657	A.D. 1641-1672, etc.
Beta-53006	29	10-20	30 ± 70	30 ± 70	modern	modern
Beta-53007	31	60-70	220 ± 70	240 ± 70	A.D. 1660	A.D. 1638-1680, etc.
Beta-53008	34	str.2	100 ± 50	110 ± 50	A.D. 1710, etc.	A.D. 1683-1745, etc.
Beta-53009	36	10-20	190 ± 60	230 ± 60	A.D. 1663	A.D. 1644-1680, etc.
Beta-53010	37	10-20	260 ± 50	290 ± 50	A.D. 1644	A.D. 1520-1569, 1627-1660

The calculated value for T can then be evaluated by using Table 17. If the obtained value of T exceeds the figure in the table, the implication is that the initial assumption--that all of the dates are coeval--can be rejected, and the possibility of several episodes of occupation at the site is raised. If the obtained value of T does not exceed the table figure, the radiocarbon measurements may all be coeval.

Table 17. Test values *T* for evaluating contemporaneity of a suite of radiocarbon dates (after Aitken 1990).

Number of Samples	2	3	4	5	6	7	8	9	10	11
T (95% confidence)	3.8	6.0	7.8	9.5	11.1	12.6	14.1	15.5	16.9	18.3

When all ten radiocarbon dates from the Elmore Site are considered in this way, the value for *T* is found to be 22.6, which exceeds the test standard of 16.9, and the hypothesis that all ten are coeval must be rejected with 95% confidence. The radiocarbon evidence, in itself, therefore does not provide support for the hypothesis of a single, short-term occupation. However, it may be worth considering whether the more extreme of the dates represent anomalies rather than true estimations of periods of site occupation. Such anomalies could perhaps be caused by modern contamination of the charcoal samples and by the prehistoric use of old wood. If the two extreme dates, 30 +/- 70 and 370 +/- 80 years, are discarded as outliers, then the remaining eight dates give a value for *T* of 12.0, which is lower than the test standard of 14.1. The contemporaneity of these eight dates is plausible.

An advantage gained from working with the hypothesis that the suite of eight dates may represent essentially a single point in time is that, collectively, they provide a more precise estimate of that point than any of the dates could provide individually. This estimate consists of the weighted mean, according to the formula introduced above, and a new one-sigma error limit:

$$S = \left(\frac{1}{1/S_1^2 + 1/S_2^2 + \cdots} \right)^{1/2}$$

Using these two equations, the suite of eight dates may be consolidated into a single date, 210 +/- 20 radiocarbon years B.P. Calibrated, this corresponds to A.D. 1669, as well as to 1789 and later dates. The one-sigma range encompasses A.D. 1663-1675, 1776-1798, and 1943-1954. The two-sigma range (with a 95% probability of encompassing the "real" date) covers A.D. 1657-1681, 1751-1804, and 1936-1954. It is unlikely that a substantial stand of Lake Cahuilla occurred as late as the late eighteenth century. Therefore, the radiocarbon evidence suggests that the Elmore Site was occupied sometime in the second half of the seventeenth century, perhaps between A.D. 1660 and 1680. Some of the broader regional implications of this dating of the site are explored in a later section.

Interpretations For Regional Prehistory

Models of Lake Cahuilla

The construction of a model for the physical conditions of the rise and fall of Lake Cahuilla can provide a useful context within which to interpret archaeological evidence associated with the lake. It is not to be expected that any such model will precisely match the circumstances which actually occurred during the lake's rise and fall, but the model may be able to suggest a plausible scenario and to identify some limits within which the actual events are likely to have been confined.

Key parameters relating to the lake's rise and fall include the volume of the lake basin, the rate of water input into the basin, the rate of water loss through evaporation, and the salinity of the inflowing water. Variables which can be derived from these key parameters include the time required for the lake's rise to various levels, the time required for its fall, and the salinity of the lake during the successive stages of its recession. Previous physical models of Lake Cahuilla were offered by David L. Weide (1976), Philip J. Wilke (1978), and Michael R. Waters (1980, 1983). Each of these previous models discussed only certain of the relevant parameters and derived variables mentioned above.

Two other physical factors concerning the lake will also be considered briefly. The first is the depositional rate for lacustrine sediments, used as an index of the duration of lake stands. The second concerns expectable chronological patterns in the shifts of the Colorado River's course into and away from the Salton Basin.

Lake Volume

Estimation of the volume of Lake Cahuilla at various levels is essential for estimating the rate at which the lake rose. Volume is also a key parameter for estimating lake salinity under conditions of recession. Previous models of Lake Cahuilla have not discussed the lake basin's volume. The estimates of volume which are used in this discussion are derived from estimates of the area of the Salton Basin at 20-foot intervals, from the lowest portion of the basin to the +40 foot contour (Fig. 16). For consistency and simplicity, English-system units of measurement rather than metric ones are used throughout the following discussions. For the portion of the basin within the United States, the area estimates are based upon USGS topographic maps, and were made by counting the sections (one-mile-square areas) which have at least half of their surface area lying below the successive 20-foot contours. Somewhat rougher estimates were used for the portion of the basin in Baja California, because the available topographic mapping for that area is less detailed. Table 18 (Appendix) summarizes the estimated basin area at various contours.

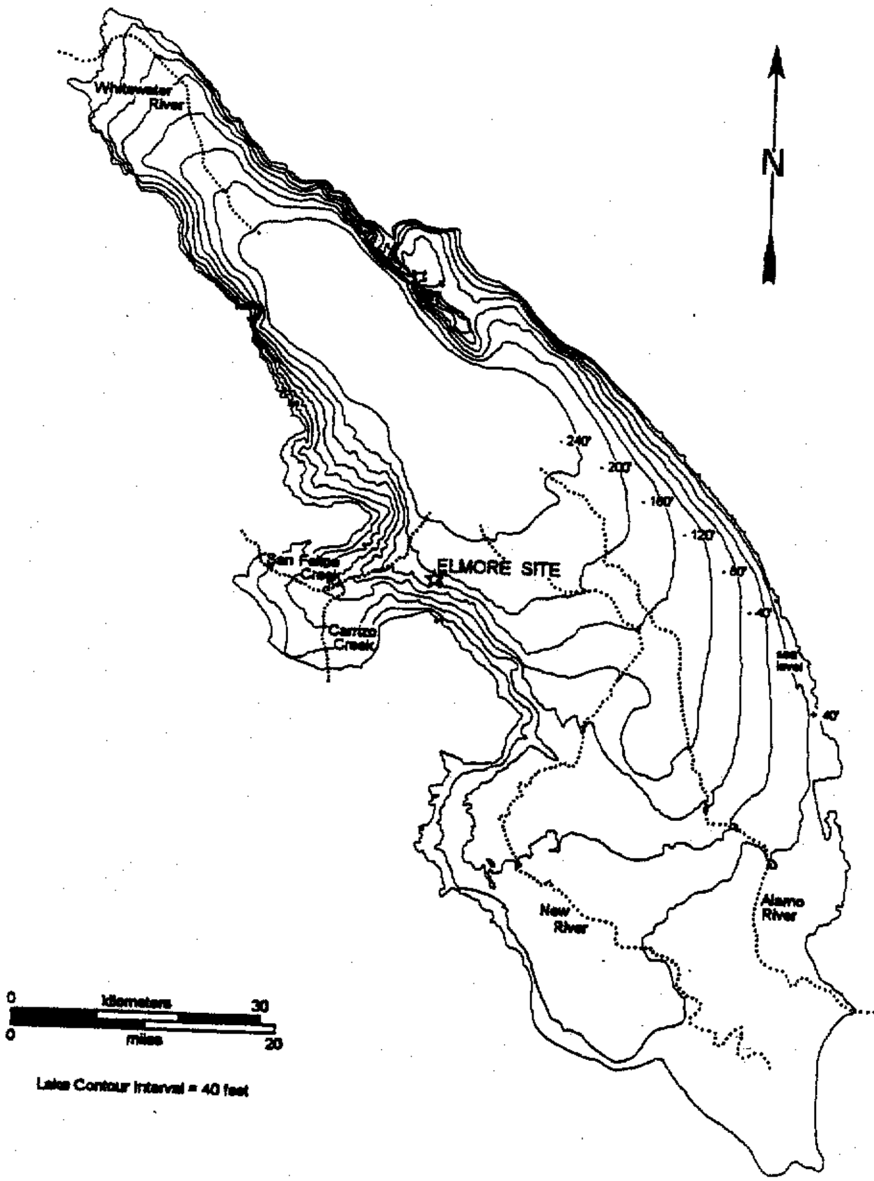

Fig.16. Contour map of the Lake Cahuilla basin.

To convert the surface areas to volume estimates, the following equation was used:

$$V_n = \frac{20 * (A_n + A_{n+1} + (A_n * A_{n+1})^{1/2})}{3}$$

in which V_n is the volume of the nth 20-foot increment above the -280 foot elevation, and A_n is the estimated area of the lake at the elevation of ((20 * n) - 280) feet. The volume of the lake at a given level is the sum of the increments lying below that level.

Potential sources of error in the volume estimates include imprecision in the area estimates and changes in the basin configuration subsequent to the presence of the lake. The section-counting method of calculating area provides an estimate which is probably less crude than most of the other key parameters in the lake model. Changes in the basin configuration could have resulted from tectonic uplift or subsidence in the region or from natural filling of the basin with sediment. It seems reasonable to assume here that such changes have not been major, at least for the most recent stand of the lake.

Water Input

Water entered the prehistoric Salton Basin from four sources: surface flow from the Colorado River, surface flow from other rivers and drainages, groundwater seepage, and direct precipitation. The volume of surface flow from the Colorado River into the Lake Cahuilla basin is the primary water input factor. It is also the element of the hydrologic model which is most difficult to deal with in a satisfactory way. The figures used here (Table 19) are based on the U.S. Reclamation Service statistics for the average monthly flow of the Colorado River at Yuma between 1903 and 1934 (Kelly 1977:19). Two main problems should be noted. First, the amount of precipitation within the Colorado River drainage system may have varied significantly over the centuries. Second, it is not assured that the river's flow went entirely into the basin or entirely away from it at any given period; there may have been partial or very temporary diversions, complicating the picture of the lake's rises and falls. As a first approximation, an all-or-none model of the river's course into or away from the basin seems justifiable, although the potential for substantial departures from it in the actual history of the lake needs to be borne in mind.

Weide (1976) concluded that surface flow from rivers and creeks other than the Colorado River, such as the Whitewater River and San Felipe Creek, was essentially negligible. No specific estimates of the magnitude of this factor were offered, but the conclusion seems reasonable. Such surface flow has not been factored into the calculations of the present hydrologic model. According to Weide (1976:12, citing Hely et al. 1966:8), groundwater seepage into the basin prior to the development of irrigation systems was also negligible. This factor has also not been included in the present model.

Modern precipitation in the Lake Cahuilla basin averages about 3 inches per year. Conditions in the past may have differed, but it is unlikely that direct precipitation was ever a major factor in the Lake Cahuilla hydrologic budget. For the present model, the mean of the modern monthly precipitation averages for Indio, Brawley, and Calexico has been used (Felton 1965:95, 98).

Table 19. Monthly averages for hydrologic budget factors: Colorado River flow, direct precipitation, and evaporation.

Month	River Flow $x10^6$ acre-feet	Precipitation inches	Evaporation inches
January	0.51	0.49	1.88
February	0.64	0.41	2.73
March	0.88	0.24	4.38
April	1.24	0.10	6.32
May	2.49	0.04	9.16
June	3.99	0.02	7.72
July	2.24	0.07	8.65
August	1.04	0.34	9.37
September	0.69	0.25	8.44
October	0.62	0.21	6.92
November	0.48	0.19	4.12
December	0.48	0.54	2.12
Total for Year	15.30	2.90	71.81

Sources: Felton 1965; Hely et al. 1966; Kelly 1977.

Water Loss

Water loss from the Lake Cahuilla basin would have been essentially limited to two factors: evaporation and surface outflow. Evaporation is related to air temperature, humidity, and lake surface area. As a working approximation, the monthly evaporation rates for the model of prehistoric Lake Cahuilla have been taken as equal to the average evaporation rates calculated for the Salton Sea during the years 1961 and 1962 (Hely et al. 1966:C15). The Salton Sea figures show considerable variation, both between the results from the several different methods used in their calculation and between the two years involved in the study.

If the use of these figures in modeling Lake Cahuilla's evaporation rate errs, it seems most likely that the error would be in the direction of an overestimation of the evaporation rate, for the period during which the Elmore Site was occupied. If regional paleoclimatic conditions were significantly different at that time, it seems most likely that the difference would have been in the direction of cooler temperatures and therefore a lower evaporation rate in the seventeenth century, which at least in Europe was a climax of the *Little Ice Age*. It is also possible that a high lake stand might have exerted an influence on its own immediate climate, moderating temperatures and increasing humidity. These changes would also have worked to lower the evaporation rate.

Surface overflow would have occurred when the lake reached the height of its lip. At present, the elevation of the lip is approximately 40 feet above sea level, and it is assumed to have remained essentially constant during at least the last millennium. This assumption is supported by the high water markers left by the lake around its basin, which conform to this elevation. When water continued to flow into the basin after an elevation of +40 feet had been reached, any water exceeding the amount evaporated would have passed to the lower delta of the Colorado River in Baja California. Outflow probably took place at an outlet point near Cerro Prieto and into the present channel of the Hardy River. Because surface outflow would have been fully determined by water input minus evaporation, this factor can be considered a dependent variable in the model.

Salinity

Estimating the salinity of Lake Cahuilla at various points in its history may be important in projecting the plant and animal resources which were likely to have been associated with it and in evaluating its suitability as a source of drinking water for prehistoric peoples. To model changes in the salinity, historic salinity figures for the Colorado River have been used. MacDougal (1907:3) reported the total soluble solids in the Colorado River at its summer flood stage (May 1 to June 29, 1900) as 322 parts per million. Salinity was up to 200% higher in other seasons. (Salinity of sea water is about 35,000 parts per million.) In the model, it is assumed that the salinity of the lake during overflow conditions was the same as that of the Colorado River and that salts were progressively concentrated, without subtraction, during the evaporation of the lake's waters.

The realism of the model is made problematical by a number of factors. First, the mineral load of the inflowing Colorado River may have been different in the past, for instance because of higher or lower rates of erosion in various portions of its catchment. Second, during full lake stands, a horizontal salinity gradient may have existed, reflecting incomplete flushing of salts because the lake's inlet and its outlet were both located at the southern end of the lake. The salinity of the water at the northern end of the lake may have been greater than that of the Colorado River. Third, a vertical salinity gradient may have existed in the waters of the lake. This would probably have made the equilibrium salinity of the full lake different from the salinity of the Colorado River. It might also make total lake salinity a misleading index for the compatibility of particular portions of the water column with particular floral, faunal, and human uses. Fourth, the salinity of the lake during a transgression might have been significantly increased by the redissolving of salts which had been precipitated during a previous recession of the lake. Fifth, the salinity of the lake during a recession might have been lessened by withdrawal of salts from the system through localized precipitation and isolation. Sixth, the salinity of the lake at particular levels during a recession might have been temporarily lessened but ultimately increased as a result of partial or temporary natural diversions of the river's waters into the basin. Partial diversions happened several times during the nineteenth century, and Schaefer (1986) presented archaeological evidence for a partial prehistoric diversion.

Transgression Scenario

Previous archaeological estimates for the filling time of Lake Cahuilla have apparently not been based on any detailed modelling. Weide (1976:15) estimated that, under modern hydrologic and climatic conditions and with full diversion of the Colorado River into the basin, it would have taken "more than four or five years". Waters variously cited Wilke (1978) as suggesting that filling of the lake would have taken "about 10 years or less" (Waters 1980:44) or "about 12 to 20 [years]" (Waters 1983:375).

For the present model, a computer program was developed which calculated the level of the lake during filling on a month-by-month basis. Arbitrarily, filling is taken as beginning in June, the month when the Colorado River's flood normally crests. Parameters used in the calculations included:

> the month's volume of water which would have entered the basin with a full diversion of the Colorado River (calculated from the historic-period measured flow volume);
>
> the elevation which the surface of the lake would have reached with that increment of water volume, interpolated on the basis of the 20-foot-contour areas for the lake basin;
>
> the rise in elevation produced by direct precipitation, according to the modern monthly average; and
>
> the drop in elevation produced by evaporation, according to the modern monthly average.

Table 18 (Appendix) indicates the results of this calculation. According to the model, Lake Cahuilla would have reached the +40-foot level about 18 years after initial diversion of the river into the basin. The lake would have reached the Elmore Site, at an elevation of -180 feet, in one year and three months. As it approached the site, the lake would have been rising at a rate of about 20 to 30 feet per year, or stretching out its shoreline at a rate of perhaps 1 mile per year.

For comparison, filling rates were also calculated on the basis of assumptions that the inflow from the Colorado River amounted to 120, 110, 90, and 80 percent of its historic volume. Total filling under these circumstances would have taken about 14, 16, 21, and 26 years, respectively.

Recession Scenario

O'Connell (1971:178) suggested that desiccation of Lake Cahuilla, under conditions similar to modern ones, would have taken place "within a relatively short period of time, certainly no more than 100 years". Wilke (1978) estimated about 60 years as the time required for complete disappearance of the lake, on a similar basis to the model used here.

In the model, rediversion of the river away from the Lake Cahuilla basin has been assumed to have occurred in June and thereafter to have been total. Starting at an elevation of +40 feet, the new elevation has been calculated monthly by subtracting the lowering caused by evaporation and adding the rise from direct precipitation. The model suggests that it would have taken about 56 years for the lake to completely disappear. The top of Obsidian Butte, more than 120 feet below sea level, would have been exposed after about 28 years. The Elmore Site, at -180 feet, would have been uncovered after about 38 years. The base of Obsidian Butte, at -230 feet, would have been joined to the mainland after about 47 years.

For comparison, models have also been considered which involve only partial diversion of the Colorado River away from the basin, with 10 and 20% of the flow still entering the receding lake. A scenario involving a consistent but partial flow into the basin is physically improbable, but it may illustrate the magnitude of the effects which might have resulted from more erratic partial inflows. With 10% of the river's volume continuing to enter the basin, it would have taken about 70 years for the Elmore Site location to be exposed, and the lake would have stabilized at a level of 216 feet below sea level after about 140 years. After a similar period of time, with 20% of the river's volume flowing into the basin, the lake would have stabilized at about 120 feet below sea level.

An illustration of the potential oversimplification involved in the model's assumption of uninterrupted recession is provided by site CA-IMP-5204, located on a recessional beach line at sea level (Schaefer 1986). Faunal materials recovered from the site include remains from small and medium-sized individuals of *Mugil cephalus* (striped mullet). This species lives both in the oceans and in the Colorado River, but it apparently only spawns in the ocean. If the lake had reached sea level by uninterrupted recession from the +40-foot shoreline, it would have taken about seven years to do so at modern rates of evaporation. Had that scenario been correct, only large mullets should have been present in the lake. The recovery of bones from small and medium- sized mullets probably indicates that fish entered the receding lake through some partial or temporary diversion of the Colorado River into the basin during recession.

Salinity projections are more problematical than projections for rises and falls of the lake. The recession salinity figures in Table 18 (Appendix) are based on the assumptions that, at the beginning of the recession, the salinity of lake waters was equal to that of the modern Colorado River at its modern flood stage and that salts were progressively concentrated, without precipitation or other forms of withdrawal, in the lake's diminishing waters.

The model suggests that, when the Elmore Site was exposed, the salinity of the lake would have been almost nine times the salinity of the Colorado River and about 1/12 the typical salinity of sea water. A salinity equal to that of sea water would have been reached when the level of the lake was down to about 250 feet below sea level, lower than the present level of the Salton Sea.

Some general plausibility to the recessional salinity model is suggested by Van de Kamp's observations on faunal remains associated with lake deposits in various parts of the basin. According to Van de Camp (1973:841-843):

> Saltwater fossils are found in the lowest parts of the basin, generally below the -200-ft (-61-m) contours. Fossils indicating brackish water are found below -150-ft (-45-m) elevation, and freshwater fauna are found to the exclusion of others between -100-ft (-30-m) and +40-ft (+12-m)

Sedimentation Rate

Waters' (1983) chronology for Lake Cahuilla was based in part on a projected sedimentation rate for the lake. The locality which was used to develop the rate was a stratigraphic exposure a few feet below sea level near the northwestern end of the lake. A stratum of lacustrine deposits was exposed between two fluvial strata, and it was bracketed chronologically by two radiocarbon dates (^{13}C-corrected) based on culturally-deposited charcoal in the fluvial strata which underlie and overlie the lacustral stratum. Waters proposed a sedimentation rate of 0.3 cm per year at this locality as reasonable, based on this evidence.

Several problems may be noted with accepting this sedimentation rate as a basis for a chronology of the lake. First, there is no assurance that the sedimentation rate of Lake Cahuilla was approximately constant, either within a particular lacustral interval or between different lacustral intervals. As Waters reported, the stratigraphic sequences which he studied are marked by numerous unconformities (erosional gaps in the stratigraphic record). Particular lacustrine strata are entirely missing or very unequal in thickness at different localities. The stratum which was used to estimate the sedimentation rate was overlain by an observed unconformity, which indicated that at least some erosional loss of lacustrine sediments had occurred. Such losses in this stratum may have been minor, but the available evidence provides no basis for deciding whether or not this was the case. If they were major, the losses may have resulted in a large underestimation of the sedimentation rate.

There is no assurance that the radiocarbon dates closely bracket the lacustral interval. If they are accepted as otherwise valid, the dates can provide maximum limits beyond which the lacustral interval could not have extended, but they provide no minimum estimate for that interval.

The radiocarbon evidence is not sufficiently precise to provide any but very general time limits for the lacustral interval. The two bracketing dates are 1150 +/- 100 radiocarbon years B.P. and 1265 +/- 100 B.P. According to the statistical test discussed above, these dates could be essentially identical ($T = 0.66$, as against a test value of 3.8); that is, they suggest no minimum limit for the length of the period which they bracket. To get a maximum estimate for the length of the bracketed period, one may take the two-sigma (95% probability) range for each date, which gives a total span of 515 years (950-1465 B.P.). Waters also reported three radiocarbon dates from what were presumed to be exposures of the same lacustral stratum at three different localities. These three dates (1200 +/- 100 B.P.; 1280 +/- 100 B.P.; and 1340 +/- 100 B.P.) could all be statistically equivalent ($T = 1.0$, as against a test value of 6.0), again suggesting no minimal duration for the interval. Waters' estimate for the length of the lacustral interval was about 200 years, which is possible, but the evidence for it is not compelling.

Regularities in the Colorado River's Shifts

A final aspect of lake modeling which is worth considering relates to the physical mechanisms responsible for the lake's rises and falls. The immediate causes, of course, were shifts in the course of the lower Colorado River into or away from the Salton Basin. In general, the shifting of a river's course within its delta would tend to be an irregularly-timed phenomenon, varying according to the specific physiographic characteristics of a particular course as well as with year-to-year fluctuations in the inputs of water and sediment. The point of interest in the present context is whether there would have been specific physical constraints which would have given some measure of patterning to the Colorado River's behavior.

Waters' (1983) chronology for Lake Cahuilla during the late Holocene will be discussed in more detail in a later section. It will be suggested there that Waters' scenario for the lake's rises and falls offers more precision than the available radiocarbon and geological evidence warrants. Nonetheless, it is worth considering the physical likelihood of that scenario. In particular, three characteristics of Waters' scenario merit attention here: incomplete recessions are proposed, but incomplete fillings are not; in two instances (ca. A.D. 940 and A.D. 1210), the lake is proposed to have begun to refill as soon as its preceding recession was complete; and full lake stands are proposed to have lasted for periods of a century or more.

On the first point (incomplete recessions, but no incomplete fillings), Waters' scenario seems entirely reasonable. The initiation of diversion of the river northward into the Salton Basin seems essentially unpredictable, and might well have occurred again before the recession from a previous filling had been completed. On the other hand, once a substantial portion of the Colorado River's flow was diverted northward, there is reason to think that the filling of the lake would have continued without interruption. From a point south of Pilot Knob, where the river's two potential routes, either directly to the gulf or into the Salton Basin, diverged, the maximum gradient southward to the head of the Gulf of California would have averaged about 1.7 feet per mile (0.32 m/km). The maximum gradient from the same point to the lower portion of the Salton Basin would have been nearly three times as steep, or about 4.6 feet per mile (0.87 m/km). It seems likely that the river would have entrenched itself into the soft lacustrine sediments and maintained its northward flow. This apparently would have occurred after the river's accidental diversion to create the Salton Sea in 1905, had engineering efforts on an epic scale not been expended to prevent it.

As to the second point (initiation of filling immediately after completion of recession), there seems no plausible mechanism which would tend to produce such a pattern. Of course, this still might have happened in two or more instances, merely as a coincidence.

On the third point (long full lake stands), a contrary pattern can be suggested. Although, as just noted, there seems to be no plausible mechanism to have caused filling to begin upon completion of recession, there is a plausible mechanism which might have tended to cause recession to begin very soon after completion of filling. When the level of the lake rose to 40 feet above sea level, most of the gradient advantage of flow into the lake was lost. From south of Pilot Knob to the shoreline, the maximum average gradient would have been about 2.3 feet per mile (0.44 m/km). Much of the Colorado River's great load of silt would have settled out in the still waters of the lake's inlet, clogging that inlet and tending to force the river to shift to a new channel, such as the one leading directly to the gulf. If this view is correct, one should expect, contrary to Waters' chronology, that full stands of the lake would have tended to be relatively brief.

Regional Chronology -- Historic Evidence

The testimony of early European observers constitutes an important source of evidence concerning the lower course of the Colorado River and the presence or absence of a large body of water in the Salton Basin during the last 500 years. However, this evidence is not always easy to evaluate. The problems which must be taken into account include difficulties in reconstructing vaguely-reported travel routes, the recasting of unwritten firsthand travel reports by later narrators, and the collection by travellers of misleading or misunderstood information from local Native Americans.

From 1539 until the 1770s, only about a half dozen parties of Europeans reached the portion of the Colorado River between its junction with the Gila River and its mouth. Few of the pre-1770 travelers set foot in Imperial or Coachella Valley or looked out over the Salton Basin. Nonetheless, their reports concerning the lower course of the river, as well as in the information on regional geography which they received from the local people they met, are relevant to the story of Lake Cahuilla. For the period from the 1770s onward, direct testimony on the condition of the Salton Basin is generally available, at least intermittently.

Ulloa, Alarcón, and Díaz: 1539-1540

Francisco de Ulloa was the first European to reach the head of the Gulf of California by sea. Ulloa's trip is documented by narratives written by himself (Wagner 1929:12-46) and by Francisco Preciado (Hakluyt 1903-1905:206-278) and through maps which were based on Ulloa's information. After following the Sonoran coast northward, Ulloa reached the head of the gulf, which he named *Ancón de San Andrés*, in late September 1539. As that area was approached, the gulf's water was observed to be "white, like river water", and later, shallow, muddy, and reddish in color (Wagner 1929:20). Ulloa's ships could go no farther, although the tide was observed to ebb and flow through a channel northward from San Andrés. (This was perhaps the Colorado River's tidal bore.) Preciado reported that the explorers speculated as to whether the channel might lead to lakes or to a great river. However, no contacts were made with the aboriginal inhabitants of the region, so this was probably pure speculation. Maps based on Ulloa's voyage, such as the Sebastian Cabot map of 1544, show narrowing, estuary-like openings at the head of the gulf, or undefined gaps in the coastline, but these maps show neither lakes nor any northward continuation of the gulf beyond a strait.

The comments concerning red, muddy water and white water in this area indicate that the Colorado River, in its September low stage, was draining into the gulf, rather than expending its waters in filling Lake Cahuilla. This testimony probably also indicates that the river was flowing directly to the gulf, rather than by way of a full Lake Cahuilla, since most of the river's silt and clay would probably have settled out in the lake, if it had passed through that body.

George F. Carter (1964), considering the commentary by Henry R. Wagner (1925) on Ulloa's account, noted the use of the term *ancón* to describe the northern limit reached by the expedition. In sixteenth-century usage, according to Wagner (1925:22), the term generally denoted "a tidal channel connecting one body of water--the sea, for example--with another body of water." This might suggest that Ulloa had some evidence indicating that there was a large body of water north of the head of the gulf. Carter (1964:77) found the term "suggestive, if no more" concerning the possible existence of Lake Cahuilla at that period. However, even if *ancón* was intended by Ulloa to have such a connotation, the implied connection north of the gulf might have been to Laguna Macuata (Laguna Salada) in the Pattie Basin of northern Baja California, rather than to Lake Cahuilla. Moreover, the explorers evidently had no basis beyond pure speculation for positing a body of water at the distance of Lake Cahuilla.

A second sea expedition reached the head of the Gulf of California in the following year. Hernando de Alarcón ascended the Colorado River twice during August and September 1540. Some disagreement exists as to how far up the Colorado River Alarcón travelled, but there is a consensus that he went at least as far as the Pilot Knob-Yuma area (Elsasser 1979; Forbes 1958, 1965; Hammond and Rey 1940; Wagner 1929). He later wrote a detailed account of his journey, in a letter. Subsequent maps by Domingo de Castillo and Diego de Homem also reflect the expedition's experiences.

Alarcón's narrative makes clear that the Colorado River, or at least the portion of it which he followed, did not pass through any great freshwater lake. Alarcón elicited a fair amount of geographical information from the Colorado River Indians through native interpreters, but he evidently got no report of a lake, except for one rather cryptic note which is discussed below. Nor did his conversations with the inhabitants reveal any indications that there had been recent major shifts in the river's course. In an interview with Alarcón (Elsasser 1979:25), an old man who was living on the lower Colorado River related that

> in a certain lake dwelt an old woman, who was much honored and worshipped of them [the natives]. She remained in a little house which was there, and she never did eat anything. It was there that they made things which did sound [i.e., bells, presumably of metal--*annotation by Elsasser*], and that many mantles, feathers, and maize were given her. I asked what her name was, and he told me that she was called Guatazaca, that thereabout were many chiefs who in their life and death used the like orders which they of *Cevola* [i.e., Zuñi] did. They had their dwellings in the summer with painted mantles; in winter dwelt in houses of wood, two or three lofts high. He had seen all these things, except the old woman.

In another conversation, the same informant, without mentioning a lake, had responded to Alarcón's inquiries about gold and silver by indicating that his people brought metal "from a certain mountain, where an old woman dwelt" (Elsasser 1979:24).

It is possible (although far from certain) that this story had some relation to Lake Cahuilla. Elsasser (1979:35) suggested that the reference was entirely mythical. The associations linking an old woman to an island, an island to metal, and a lake to metal, would be repeated in later traveller's accounts. Alarcón reported nothing concerning the direction of the supposed lake, its distance from the river, or its size. Two islands were associated with Lake Cahuilla. When the lake was full, Bat Cave Buttes was a large island, becoming attached to the mainland only when the water level dropped to about 100 feet below sea level. A much smaller (but perhaps economically more important) island was Obsidian Butte, which began to be exposed when the water level had dropped to 130 feet below sea level and ceased to be an island when it dropped to 230 feet below sea level. There is no evidence that metal was ever procured or used by the prehistoric inhabitants of the Lake Cahuilla area. Speculatively, it might be suggested that the "ring" of obsidian glass and the special value attached to it as a material might have seemed to Alarcón's native informant to establish a correspondence between that material and the metal bells of the Spanish.

Wagner (1926:14, 24) read further hints concerning the early geography of the Colorado River delta in the accounts of the Alarcón expedition:

> Evidently while Alarcon was away...one of the vessels...made a reconnaissance of the California coast.... This expedition discovered the channel which connects at high water the delta of the Colorado with [Laguna Macuata], as appears from the name "Brazo de la Laguna" [on early maps].... It seems certain that [Alarcón] heard of Volcano Lake [near Cerro Prieto] and probably also of the Salton Sea, which may have been filled with water at the time

Wagner assumed that a body of water in the Pattie Basin would have represented the remnants of a natural diversion of the Colorado River around the southern end of the Cocopa Mountains. Another possibility is that sedimentation in the delta had not yet separated the basin from the Gulf of California.

Also in 1540, Melchior Díaz travelled overland from Sonora to the lower Colorado River, attempting to meet Alarcón. Díaz arrived too late to contact Alarcón directly, but he did recover a note which the latter had left. On his return toward Sonora, Díaz was accidentally killed; perhaps in part for this reason, the written records of his expedition are rather confused. Forbes (1958, 1965) summarized the sources of information, none of which is first-hand. It is not certain whether Díaz first reached the Colorado River at its mouth or farther up. It is known that he travelled for some distance along the river, crossed it, and then made an extended trip to the west. Those travels brought him in contact with high sand dunes and with a volcanically active area. On the basis of descriptions of the travels west of the river, the most commonly-accepted interpretation is that Díaz crossed the Mexicali Valley from around Pilot Knob to the vicinity of Cerro Prieto (Ives 1973; Sykes 1937). An alternative scenario is that he travelled west from the vicinity of Blythe or Parker on the Colorado River to near Niland in the Salton Basin, and then south to the river again (Forbes 1958). If either of these itineraries is correct, the presence of a substantial stand of Lake Cahuilla at that date seems to be ruled out by the lack of any reference to it in the accounts which have survived.

Taken together, the reports of the Ulloa, Alarcón, and Díaz expeditions seem to seriously undermine the plausibility of the suggestion by Waters (1983) that the Lake Cahuilla's recession from a full stand began as late as 1530.

Oñate: 1604-1605

A key episode in the early history of the lower Colorado River was the expedition overland from New Mexico led by that colony's governor, Juan de Oñate, in 1604-1605. The Oñate expedition was probably the only Euramerican penetration to the region between Díaz in 1540 and Kino in 1700. Information on the Oñate expedition was transmitted to posterity through at least four channels. The most detailed is an eyewitness account by a Franciscan missionary, Francisco de Escobar, which was written in Mexico City in the same year as the expedition (Hammond and Rey 1953:1012-1031; Colahan and Rodríguez 1986). A shorter first-hand report, often overlooked by later historians, was written by one of Oñate's captains, Gerónimo Marqués. This report was incorporated into an account of the Vizcaíno expedition along the California coast which was written by a Carmelite Friar, Antonio de la Ascensión (Wagner 1929:266-267). A detailed secondary narration, probably based in part on Escobar's account but with substantial differences from it, was composed in 1626 by a Franciscan historian, Gerónimo Zárate Salmerón (Bolton 1908:268-280). Finally, some additional second-hand comments were recorded in 1632 by Nicolás de Cardona, an explorer of the Gulf of California, on the basis of communications from Marqués and others. The Oñate accounts are a curious blend of factual reporting and medieval fantasies about monstrous races of men.

Oñate's party of 30 soldiers and two Franciscans crossed through previously-reconnoitered Zuñi and Hopi territories in New Mexico and Arizona and reached the Colorado River by way of the Bill Williams Fork. They passed down the river, from the territory of the Mohave Indians to the river's mouth. The descriptions of the river establish that its outlet at that time was the Gulf of California and not Lake Cahuilla. However, there are elements in the reports which raise some further issues. Oñate's party reported observing at first hand that the gulf continued for an unknown distance farther to the northwest from the river's mouth, behind some mountains. This probably refers to an extension into the Pattie Basin, behind the Sierra Cucapá. The Pattie Basin may still have been part of the gulf at that period, or Laguna Macuata may have received tidal waters or river overflow, as it has more recently. Oñate's party also understood native informants to say that the gulf continued on indefinitely, first to the northwest, then north, then northeast, then east. This report seems to have been the primary source for the general belief of European geographers, during the seventeenth century and even later, that California was an island rather than a peninsula (Polk 1991). The mistake of the Oñate accounts on this point may have derived largely from wishful thinking concerning the much- sought Strait of Anian (the Northwest Passage linking the Atlantic and Pacific Oceans). It is also possible that the presence of a partial stand of Lake Cahuilla, or a memory of the full lake among native informants, may have played a role in the confusion.

Another contribution of the Oñate party to mythical seventeenth-century geography was the Lago de Oro, or Lake of Gold (Fig. 17). This lake also may have had some sort of relationship to Lake Cahuilla. Although the Oñate reports put the Lago de Oro on the maps, the notion of such a lake was not original to them. Vague accounts which reached Alarcón concerning a lake have already been mentioned. Two decades before Oñate's expedition, Antonio de Espejo had led a reconnaissance of New Mexico and surrounding regions in 1583. At Zuñi, Espejo received reports that, at a distance of 60 days' march, there was a large lake with many towns, where the people wore bracelets and earrings of gold (Bolton 1908:184; Hammond and Rey 1966:225). The story of the lake was repeated to Espejo in the Hopi country. Oñate heard reports from a Bahaçecha (possibly a Quechan) informant, on the

Colorado River above the Gila junction, that "near here, nine or ten day's travel, there was a lake on whose shores lived people who wore on their wrists bands or bracelets of a yellow metal" (Hammond and Rey 1953:1019). The lake was said to lie between west and northwest.

The stories of the Lago de Oro heard by Espejo and Oñate may be another instance of the Spanish optimistically putting words into the mouths of native informants. The association of rich treasure with a large lake may be an echo of Tenochtitlán and the lakes of the Basin of Mexico, whose discovery the explorers hoped to duplicate in the far north. However, it also seems possible that the accounts from native informants may bear a relation to a past or present stand of Lake Cahuilla.

From Kino (1701-1702) to the Nineteenth Century

Eusebio Francisco Kino, a noted Jesuit missionary and cosmographer, made numerous pioneering journeys in Baja California, Sonora, and southern Arizona. Two of his trips took him to portions of the Colorado River below its junction with the Gila River (Burrus 1971). In November 1701, Kino followed the east bank of the Colorado from the Gila junction to a point more than halfway to the river's mouth in the Gulf of California. He then crossed the river and returned the way he had come. In March 1702 he followed a similar route but this time travelled as far as the river's mouth. Kino's objectives in these trips were, to a large extent, geographical; in particular, he aimed to resolve the matter of whether California was an island or a peninsula. The reports of these expeditions are not rich in geographical or ethnographic detail, but they are supplemented by the regional maps which Kino prepared and which were widely copied by subsequent cartographers (Burrus 1965; León-Portilla 1989). It seems implausible either that Kino would have failed to hear of a large lake close to his route, had there been one, or that, hearing of it, he would have failed to report the fact. The evidence indicates that the Colorado River was flowing directly into the gulf and that no substantial lake was present at this period.

In the decades after Kino, other Jesuit missionaries probed the margins of the Colorado River delta. Juan de Ugarte, one of the first Jesuit missionaries in southern Baja California, made a reconnaissance by sea of the head of the gulf in 1721 (Ramos 1958:15-50). He found the river entering the gulf rather than filling the Salton Basin. Fernando Consag, another Baja California missionary, reached the Colorado River by sea in July 1746 (Venegas 1943:III:91-120; Barco 1973:368-375). He explored the river's mouth but did not ascend it. The force of the river's flow and the potability of its water establish that the Colorado River was flowing into the gulf at that period. A Sonoran Jesuit, Jacob Sedelmayr, made two visits in the period 1748-1750 to the portion of the Colorado River below the junction with the Gila (Venegas 1943:II:346; Donohue 1969:123; Dunne 1955:55). Information on Sedelmayr's travels is scanty, but evidently he found nothing to upset the established notions concerning the river's lower course.

Based on a 1656 map of Nicholas Sampson, reproduced in León-Portilla 1989:94. Note the island of California, the Gulf of California ("Mar Vermejo"), the Colorado River ("R. de Tecon"), and the "Lago de Oro".

Fig.17. Seventeenth century map of western North America.

The Salton Basin entered a fully historical era in the 1770s. A Sonoran Franciscan, Francisco Garcés, made a reconnaissance from the lower Colorado River westward as far as the northern end of the Sierra Cucapá in 1771 (Coues 1900). A soldier based in San Diego, Pedro Fages, crossed the Peninsular range east of San Diego in 1772 and travelled along the western margin of the Colorado Desert (Bolton 1931). In 1774, Juan Bautista de Anza pioneered a route across the Salton Basin linking Sonora to the California coast, and he repeated the trip in 1775-1776 (Bolton 1930). Anza's well-documented expeditions establish definitively the absence of any lake in the Salton Basin during that period.

Subsequent Spanish parties followed similar routes until the Quechan revolted in 1781, killing Spanish settlers and travellers on the lower Colorado River. The revolt was followed by several expeditions aiming to rescue survivors and exact reprisals. Because the overland connection between California and Sonora was severed by the Quechan revolt, the subsequent decades are relatively obscure. Nonetheless, sporadic accounts of the region were still made. For instance, José Joaquín Arrillaga went into the western basin in 1796 (Arrillaga 1969). José Romero entered the Coachella Valley and reestablished the link with Yuma in 1822-1825 (Bean and Mason 1962). After Romero, there are no gaps of more than a few years in the record of travels into and across the Colorado Desert.

Although no substantial fillings of the Salton Basin occurred in the period between 1822 and 1904, ephemeral stands, probably produced by spilling of a portion of the Colorado River's flood waters into the basin, were frequent. Wilke (1978:7), following MacDougal (1914), listed seven years in the nineteenth century during which ephemeral lakes formed at the bottom of the basin: 1828, 1840, 1849, 1852, 1862, 1867, and 1891. The listing is probably incomplete.

In summary, the written historical record provides no unambiguous evidence for any full or substantial partial stand of Lake Cahuilla since the earliest contact period (1539). A fair body of evidence indicates that the lake was not present in 1539-1540. In 1604-1605, the Colorado River was still--or again--flowing directly into the Gulf of California, but there are a few uncertain hints at the presence of a partial lake stand. If the lake was entirely absent in 1605, the hydrologic model discussed above suggests that it could have refilled by the middle 1620s and then receded to the level of the Elmore Site by the middle 1660s. In 1701-1702, the river was again flowing directly into the gulf, and there are no indications of a partial lake stand. The historical record makes it highly improbable that any refilling of the lake occurred in the very early eighteenth century. Historical evidence and the hydrologic model seem to rule out any full stand of the lake after about 1720.

Regional Chronology -- Radiocarbon Dating

Radiocarbon dating provides the most widely-used and generally-acceptable method for defining the chronology of Lake Cahuilla. A considerable corpus of radiocarbon dates bearing on the history of the lake has been accumulated during the last 35 years. The present discussion is limited to dates which relate to the chronology of the period since about A.D. 1000 and which have some plausible link to the presence or absence of Lake Cahuilla. Eighty-five radiocarbon dates are summarized in Table 20 (Appendix, and see also Fig. 18).

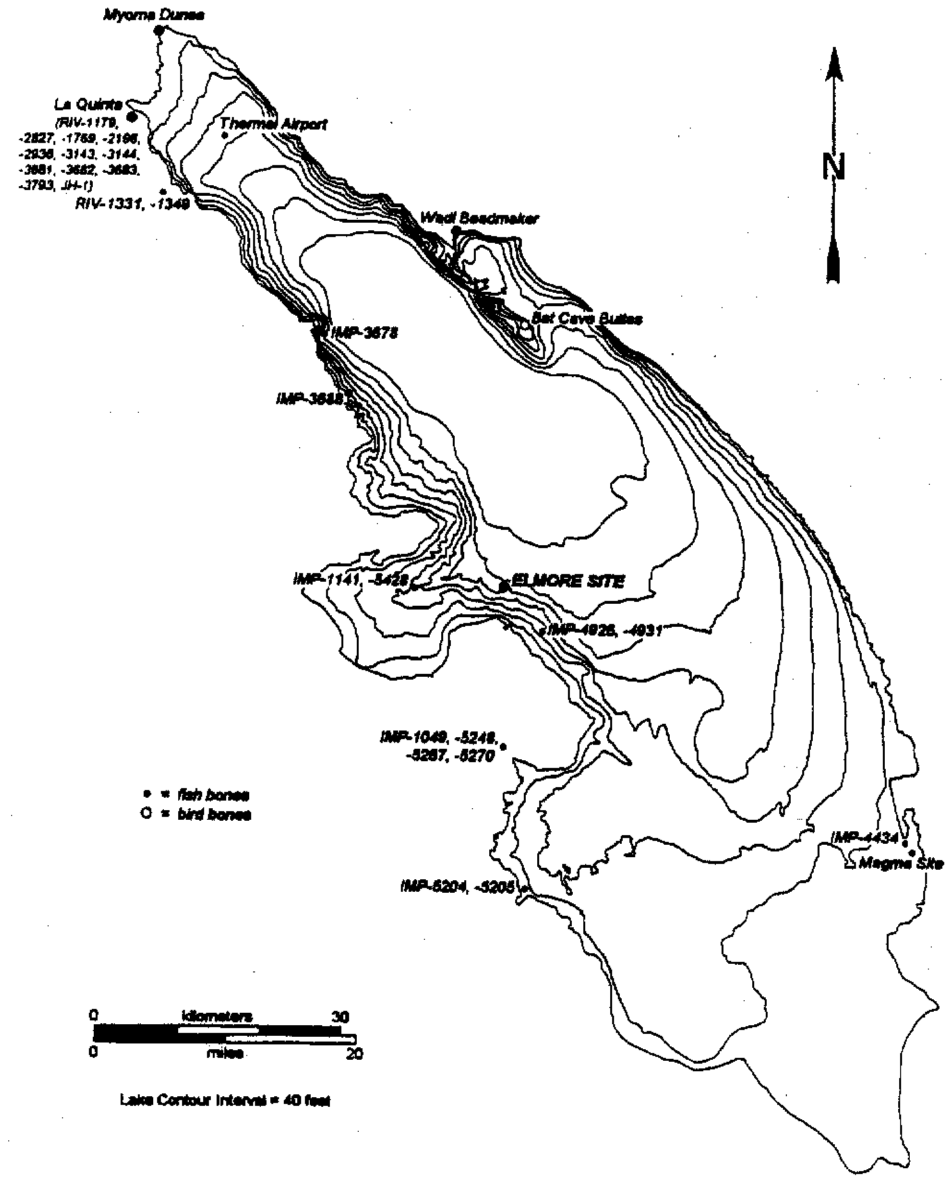

Fig. 18 . Map of Lake Cahuilla sites with radiocarbon dates.

Previous interpretations of available Lake Cahuilla radiocarbon dates were offered by Philip J. Wilke (1978) and Michael R. Waters (1983) (Fig. 19). Although both of these interpretations draw substantially on forms of evidence other than radiocarbon dates, it may be useful to reexamine them critically here.

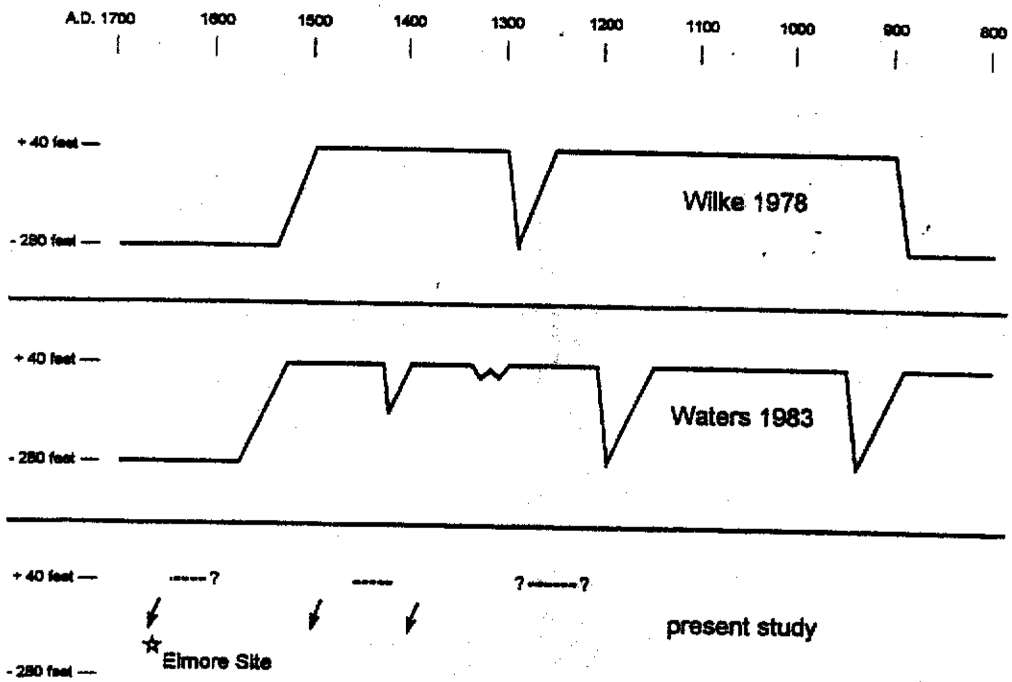

Fig. 19. Proposed chronologies for Lake Cahuilla

In the radiocarbon dates which were available to him, Wilke perceived clustering which suggested the presence of at least three lacustral intervals during the last 2,000 years. The first interval predated A.D. 1000, and it therefore lies outside of the scope of the present discussion. He proposed that a second lacustral interval occurred between about A.D. 900 and 1250, and the third, between about A.D. 1300 and 1500. Wilke's second and third lacustral intervals correspond roughly with the first and third clusters of radiocarbon dates which will be discussed in this section. Wilke's evidence that an episode of desiccation of the lake separated the second and third intervals came from the Peppertree Site (CA-RIV-463), near Perris Reservoir in western Riverside County. At that site, substantial amounts of obsidian, some of it assigned to the Obsidian Butte source, were found in deposits with radiocarbon ages of 870 +/- 80 and 215 +/- 60 years (not ^{13}C- adjusted; uncalibrated). In evaluating the Peppertree Site evidence, questions might be raised concerning the association between the obsidian and the radiocarbon dates. Another problematic factor is that scavenging of previously-worked obsidian may have occurred during periods when the Obsidian Butte source itself was inaccessible.

Waters (1983) proposed another chronology for the lake during the last 1,300 years. This proposal was based primarily on stratigraphic observations and radiocarbon dates from three localities which are located just below sea level in the northern Salton Basin. Waters' interpretation was similar to Wilke's in its broad pattern but was different in many details. A first lacustral interval, between about A.D. 700 and 900, is not germane here. The second full stand was thought to date between A.D. 940 and 1210, as evidenced by a stratum of lacustrine sediments at one location (without any directly-associated radiocarbon dates). Complete desiccation of the lake appeared to have occurred in the late twelfth to early thirteenth century, followed promptly by a third full lake stand; for this, too, the evidence was primarily stratigraphic. The full stand of Lake Cahuilla after A.D. 1250 was interrupted twice. Around A.D. 1300, there occurred one or more partial recessions to about sea level, as indicated by radiocarbon dates and lenses of fluvial sediments at that elevation. A deeper but still incomplete recession was proposed for the early fifteenth century, on the basis of a major fluvial stratum. The final recession was proposed as having begun in the early sixteenth century. The two main reasons for choosing that date were (a) the presence of an estimated 100 years of lacustral sedimentation (ca. A.D. 1430-1530) (discussed in a previous section) and (b) the historic-period evidence that the Colorado River emptied directly into the Gulf of California at the time of Ulloa, Alarcón, and Díaz. Subsequently, Waters and others (Dominici 1987:13; Schaefer 1986:11; Sieh 1981) suggested the possibility that a later, historic-period lake stand occurred, perhaps in the seventeenth century.

One observation to be made is that the chronological precision with which previous scenarios for Lake Cahuilla have been formulated is considerably greater than the precision of the radiocarbon evidence upon which they are primarily based. Individual radiocarbon dates have one-sigma error factors of 50 years to 200 years. A single date can at best define an event to within a range of a couple of centuries. On such a basis, it can be argued that a chronology is compatible with the available empirical evidence, but not that it is mandated by the evidence.

As an alternative approach, the radiocarbon data can be interpreted somewhat more conservatively. This is done by focusing on two questions: What chronological models are *not* compatible with the available evidence? What is the *simplest* chronological model which will encompass the available evidence?

Each radiocarbon date is a probabilistically-defined time range within which certain conditions may have existed. For the present discussion, those conditions can be reduced to essentially two states: the presence of a full stand of Lake Cahuilla, and the presence of a partial stand. A cluster of dates which individually have similar implications concerning the status of the lake may be considered, conservatively, as estimations of a single "event" even though in reality an extended span of time may be involved. In so far as the evidence for such events (full or partial lake stands) is compelling, and in so far as their chronological placements are firm, plausible chronological scenarios for the lake's prehistory will be constrained by them.

A minimum of six clusters of radiocarbon dates seem to be sufficient to subsume most of the available evidence (Fig. 20). The first cluster was cited by Wilke as evidence for his second lacustral interval (ca. A.D. 900-1250). It originally consisted of six radiocarbon dates, four of which were based on charcoal and two on freshwater shell, none of them corrected for isotopic fractionation (LJ-7, LJ-99, LJ- 106, LJ-960, LJ-965, and LJ-GAP-57). Two additional dates, UCR-2084 and UCR-2085, collected more recently, also seem to belong with this group. All eight dates seem plausibly associated with a full lake stand. If the dates are considered to refer to a single event, the weighted mean estimate for that event, with its one-sigma range, is 786 +/- 35 radiocarbon years B.P. The calibrated equivalents are a best-estimate date of A.D. 1269 and a range between A.D. 1228 and 1283. According to the statistical test of contemporaneity discussed above, the value for T is 9.4, which indicates that the suggestion that all eight dates relate to a single event is not contradicted. One implication of the single-event test is that this set of radiocarbon dates does not provide any basis for defining the duration of the lacustral interval. (It must also be borne in mind that none of the dates were corrected for isotopic fractionation and that both charcoal and shell dates are included.)

Six other dates (Beta-17949, Beta-37534, Beta-37900, Beta-37901, UCR-993, and UCR-998), for which isotopic fractionation corrections are available, seem to belong in the first cluster, with the previously-mentioned eight. Considered by themselves as estimates of a single event, these six dates give a pooled age estimate of 810 +/- 26 radiocarbon years B.P., calibrated to A.D. 1245, with a one-sigma range between A.D. 1222 and 1276, and with an acceptable T value of 5.2. If both ^{13}C-corrected and uncorrected dates are pooled, the age estimate is 801 +/- 21 radiocarbon years B.P. (calibrated, A.D. 1253; range, A.D. 1228-1277; $T = 14.9$). This cluster of dates makes a strong case for the presence of a full stand of Lake Cahuilla around the middle of the thirteenth century. It does not indicate the duration of that stand, nor whether or not there may have been other stands during the period ca. A.D. 1000-1300.

The second cluster includes six ^{13}C-adjusted radiocarbon dates (Beta-14194, Beta-17947, Beta-42010, UCR-992, UCR-994, and UCR-995). Each date is based on charcoal from a site at or below sea level. Most have clear associations with lacustrine resources, indicating that a partial lake stand, rising or receding, was present. Although, in some cases, the "old wood" problem was invoked to explain away these dates, they seem to suggest a reasonably clear picture of an episode of lake recession. The lower-elevation dates are generally later in time, as would be expected, but for present purposes the dates can perhaps be considered to refer to a single "event" in time. The value for T (2.4) is acceptable, and the pooled age is 581 +/- 30 radiocarbon years B.P., which is calibrated to a best-estimate date of A.D. 1400, and a range of A.D. 1320-1342 and 1392-1408). This cluster argues for a major recession of the lake at some time during the fourteenth or early fifteenth century. The simplest model would be that this recession was the aftermath of the full stand represented by the first cluster noted above.

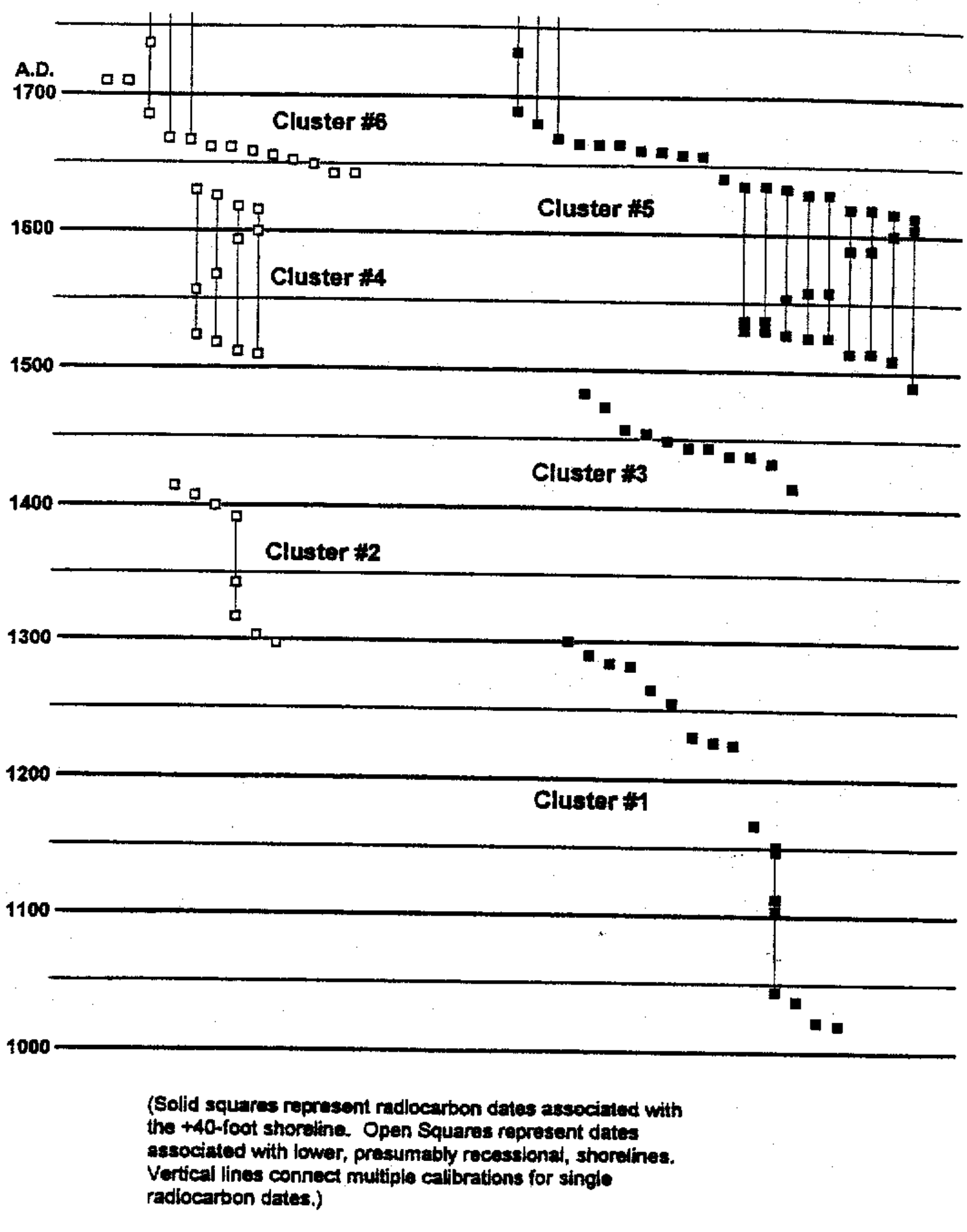

Fig. 20. Clusters of radiocarbon dates associated with Lake Cahuilla.

The third cluster includes four ^{13}C-adjusted dates (Beta-37905, Beta-37909, UCR-986, and UCR-997). Two of the dates are based on freshwater *Anodonta* sp. shell. The samples were recovered from slightly below sea level, but evidently not in archaeological contexts, so they date the presence of the lake at least to sea level and quite possibly in a full stand. The other two are charcoal samples from sites above the maximum shoreline. The four could represent a single point in time ($T = 1.2$, as against a standard of 7.8), which is estimated as 415 +/- 35 radiocarbon years B.P. (A.D. 1457; range A.D. 1443-1483). Linked with this cluster are seven other radiocarbon dates, all of which are apparently well-associated with a full lake stand, but which were not corrected for isotopic fractionation (Beta-13232, Beta-36960, Beta-36961, LJ-GAP-58, LJ-GAP- 59, M-596, UCR-380). If the 11 dates are pooled ($T = 5.7$), the estimated age is 446 +/- 23 radiocarbon years (A.D. 1445; range A.D. 1438-1453). These dates seem to suggest solidly another full stand of the lake some time in the fifteenth century, subsequent to the recession indicated by the second cluster.

To define the fourth and subsequent clusters, it may be useful to introduce into the model the constraints imposed by the evidence of historic-period records. The radiocarbon evidence, by itself, would be compatible with a simpler model involving merely a continued full stand of the lake until its final recession in the seventeenth century. However, as discussed in a previous section, there is evidence that a full lake stand was absent both in A.D. 1539-1540 and in 1604-1605. This suggests that, minimally, the model should include one cycle of recession and transgression between the fifteenth and the seventeenth centuries.

With this proviso in mind, a fourth cluster may be defined on the basis of four radiocarbon dates (none corrected for isotopic fractionation) relating to recessional conditions (A-6672, A- 6673, Beta-14195, and UGa-4650). These give a pooled age of 347 +/- 30 years ($T = 0.16$). Calibrated, this suggests a best-estimate of A.D. 1517, 1585, or 1623 (range A.D. 1483-1636). Although rather vague, this may be interpretable as evidence of the late-fifteenth- or early-sixteenth-century recession of the lake prior to the arrival of Alarcón and Díaz.

A fifth cluster of dates may similarly be distinguished as the final full stand of the lake. Included in this cluster are seven radiocarbon measurements which have been corrected for isotopic fractionation (Beta-37902, Beta-37904, Beta-37911, Beta-37912, Beta-37913, Beta-57863, and one unnumbered date), which give a pooled age of 291 +/- 21 radiocarbon years, calibrated to A.D. 1644 (range A.D. 1637-1651; $T = 5.2$). Another thirteen measurements (Beta-54874, Beta- 54875, Beta-54876, Beta-54877, LJ-102, UCR-124, UCR-152, UCR-153, UCR-2083, UCR- 2093, UGa-1470, UGa-1471, and UGa-1472) which may be assignable to this cluster lack that correction. These 20 dates have a pooled radiocarbon age of 275 +/- 14 years, calibrated to A.D. 1649 (range, A.D. 1644-1654; $T = 23.4$).

Additionally, Jerry Schaefer (1994) reported that a series of radiocarbon dates have been collected for non-cultural but lacustrine peat deposits associated with the +40-foot shoreline of Lake Cahuilla, and that these dates also indicate the presence of a full stand of the lake around the middle of the seventeenth century.

Perhaps some or all of another group of dates (Beta-37906, Beta-37907, Beta-57860, Beta-57861, M-597, M-598, UCR-125, UCR-163, UCR-319, UCR-348, UCR-349, and UCR-350), which are all apparently associated with the full shoreline but which are rated as less than 150 years old, also belong to this cluster. If so, the anomaly of their low apparent ages remains unexplained. As noted in a previous section, the historical record seems to be incompatible with a full stand of the lake having occurred as late as the eighteenth century.

The sixth and final cluster of dates is the one which includes the Elmore Site occupation and which relates to the final recession of the lake. In addition to the eight radiocarbon dates from the Elmore Site (with two outliers excluded, as discussed above), the cluster includes two other ^{13}C-adjusted dates (Beta-17475 and Beta-42009). This cluster shows the poorest internal consistency ($T = 13.6$, as against a test value of 16.9), but this diversity is basically caused by the diversity of readings obtained from the single deposit at the Elmore Site. The ten dates give a pooled "event" age of 217 +/- 18 radiocarbon years (A.D. 1667 or 1789; range A.D. 1661-1672, 1780-1796, etc.). The sixth, recessional cluster of radiocarbon dates is virtually indistinguishable chronologically from the fifth cluster, which was associated with a full lake stand. This reflects the limited precision available with radiocarbon dates, and perhaps also the brevity of the final full stand.

Three other non-^{13}C-adjusted dates with recessional associations seem to belong to the final cluster (A-6674, Beta-5955, and UCLA-192). Combined with the ten ^{13}C-adjusted dates, the resulting cluster has a radiocarbon age of 222 +/- 16 years (A.D. 1665; range A.D. 1660-1670; 1784-1794).

In summary, the radiocarbon evidence supports the existence of at least two full stands of Lake Cahuilla during the last 1,000 years. When the evidence from early historical records is added, the minimum number of stands is raised to three. The simplest scenario compatible with both lines of evidence would propose that Lake Cahuilla:

was full in the thirteenth century;
receded in the late fourteenth or early fifteenth century;
had filled again by the fifteenth century;
receded again in the late fifteenth or early sixteenth century;
filled again in the early seventeenth century; and
receded for the final time in the late seventeenth century.

Regional Chronology -- Obsidian Studies

Obsidian hydration measurement is a chronometric method which has come to be widely employed in some regions. However, its usefulness is limited by major uncertainties concerning source-specific calibrations and their precision and reliability. Such problems severely limit the ability of the method, at present, to help resolve issues concerning regional chronology in the Colorado Desert. On the other hand, a significant contribution may be possible in the opposite direction, through the use of independent information concerning the chronology of the Elmore Site to help resolve issues in the interpretation of obsidian hydration results.

Obsidian Butte, the evident source for the obsidian at the Elmore Site, is located about 17 km northeast of the site, near the present shoreline of the Salton Sea. The peak of Obsidian Butte is about 130 feet below sea level, and its base is about 230 feet below sea level. When Lake Cahuilla was full, this obsidian source was entirely inaccessible to prehistoric inhabitants of the region. When the receding water level of Lake Cahuilla first exposed the peak, the nearest shoreline would have been about 14 km to the northeast of Obsidian Butte. When the water level had sunk to 180 feet below sea level (the elevation of the Elmore Site), the peak of Obsidian Butte would still have been exposed as an island, with about 12 km of open water still separating the island from the nearest shoreline. According to the hydrologic model, another eight or nine years of uninterrupted evaporation from the lake would have passed before the lake level had dropped to -230 feet and Obsidian Butte was linked by dry land with the surrounding region. By that time, the Elmore Site would have been 3 km away from the nearest lake shoreline.

Archaeological evidence from coastal and montane portions of southern California suggests that obsidian from Obsidian Butte was rarely if ever used in that region prior to the Late Prehistoric period (e.g., Hughes and True 1985; Laylander 1993b; Shackley 1981:46). The small amounts of obsidian which were used in the western region during earlier periods came primarily from Coso Volcanic Fields in the northern Mojave Desert, while lesser amounts may have been derived from a source near San Felipe in northeastern Baja California (Laylander 1993b). During the Late Prehistoric period, Obsidian Butte was the primary source of obsidian for southernmost California. Visual sourcing, supported by x-ray fluorescence analysis of a sample of specimens, indicates that most or all of the obsidian recovered at the Elmore Site came from Obsidian Butte.

Obsidian hydration analysis is based on the fact that, when an obsidian surface is freshly exposed by flaking, a microscopically-visible rind begins to form as a result of the absorption of water into the glass. The rind becomes progressively thicker, and therefore its thickness in some fashion marks the passage of time. Complicating factors include:

variability between the hydration rates for obsidian from different sources with different physical or chemical characteristics;

in at least some cases, possible variability with differences in the character of obsidian from a single geological source;

variation of hydration rate with ambient temperature;

possible variation with humidity and/or soil chemistry; and

possible unsuitability of the hydration process for simple mathematical modeling.

Theoretical and empirical considerations have suggested different models for the relationship between time and hydration thickness. The two most frequently adopted models are a linear one, according to which elapsed time is directly proportional to hydration thickness (cf. Meighan 1983), and a "diffusion" model, according to which elapsed time is directly proportional to the square of hydration thickness (cf. Friedman and Trembour 1983). A variety of other models have also been suggested, although not specifically with respect to Obsidian Butte material (e.g., Bettinger 1989; Ericson 1977; Koerper et al. 1986). With a sufficient number of independent calibration points, the choice of a formula type for the particular obsidian source can be made empirically. However, in general the choice has been based on a-priori preferences derived from other obsidian studies or from theoretical physical considerations.

Given a linear or diffusion formula type, a second constant which defines the hydration formula, the coefficient, has generally been derived in one of two ways. The first is the correlation of particular hydration readings with particular radiocarbon dates. The second is the correlation of frequencies of readings with certain events, usually an historic-period decline in aboriginal obsidian use. It must be noted that the associations between hydration readings and radiocarbon dates are generally far from secure, and knowledge of historic-period changes in obsidian use is sketchy at best. At least six different calibration formulas for Obsidian Butte obsidian have been suggested (Table 21). In evaluating these formulas, it is important to bear in mind the various ways in which they were derived.

Paul G. Chace's linear rate was based in part on 18 readings from the Nelson Site (CA-SDI- 5680) in western San Diego County and in part on a collection of 540 readings "from 34 different sites in or near San Diego County" (Chace 1980:9). Chace's readings were on unsourced obsidian; it was assumed that most of the obsidian came from Obsidian Butte, with perhaps some of the larger hydration readings being attributable to material from the Coso Volcanic Fields source or to geologically-exposed surfaces on Obsidian Butte material. Christenson and Russell (1981) criticized the use of unsourced readings. However, subsequent studies in the region using x-ray fluorescence sourcing support the likelihood that most of Chace's readings were correctly attributed to Obsidian Butte material. Chace suggested that four fixed calibration points could be used to define a hydration curve for Obsidian Butte:

> (1) Zero hydration would correspond to the time of measurement (i.e., A.D. 1980). Such an assumption is common to most, although not quite all (cf. Bettinger 1989; Ericson 1977), hydration calibrations.
>
> (2) Hydration readings of 1.4 microns would correspond to 120 years of elapsed time (A.D. 1860, in Chace's study). This hydration value was the lower limit of the readings from the Nelson Site, which contained one aboriginal historic-period item, a projectile point made from artificial glass. The reading of 1.4 microns also corresponded to one tail of Chace's regional hydration-reading frequency curve and was taken as marking the time of the final disruption of the aboriginal obsidian trade.
>
> (3) Hydration readings of 2.0 microns would correspond to 200 years (A.D. 1780). These readings fall at or slightly after the peak of the regional hydration-reading frequency curve. Chace proposed that the obsidian trade had been continuously growing until it began to be disrupted by Spanish missionization, which began in San Diego in 1769.
>
> (4) Hydration readings of 3.8 microns would correspond to 380 years (A.D. 1600).

Table 21. Hydration formulas proposed for obsidian from the Obsidian Butte source.

Formula [1]	Reference	Elmore Site mean 2.2 microns =	One-Σ Range 2.2 ± 0.36 microns
T = 78.16 * d	Dominici 1984	A.D. 1820	A.D. 1792 - 1848
T = 95 * d	Chace 1980	A.D. 1783	A.D. 1749 - 1817
T = 47 * d^2	O'Neil 1984	A.D. 1765	A.D. 1684 - 1833
T = 110 * d	Koerper et al. 1986	A.D. 1750	A.D. 1710 - 1790
T = 314 * d	Townsend 1986b	A.D. 1302	A.D. 1188 - 1414
T = 200 * d2	Friedman and Obradovich 1981	A.D. 1025	A.D. 681 - 1315
T = 147 * d	present study	A.D. 1669	A.D. 1608 - 1716
T = 99 * $d^{1.5}$	present study	A.D. 1669	A.D. 1578 - 1740
T = 67 * d^2	present study	A.D. 1668	A.D. 1546 - 1762

1 T is the age of the hydrated surface, in years before the time of measurement; d is the thickness of the hydration rim, in microns; * indicates multiplication

These readings lie near the other tail of the hydration-reading frequency curve and were taken to correspond to the initial accessibility of the Obsidian Butte source after the recession of Lake Cahuilla. Chace estimated the latter event at A.D. 1600. If these calibration points are accepted, the result is strong support for a linear hydration curve and for Chace's calibration constant. However, the dates suggested for the three earlier correlation points (the initiation of the obsidian trade, its peak, and its end) and the correspondences of the respective hydration values (1.4, 2.0, and 3.8 microns) are all subject to question.

Irving Friedman and John Obradovich (1981) proposed a diffusion formula based on matching an index for Obsidian Butte's major-element chemical composition (silicon, calcium, magnesium, and water) and the mean annual soil temperature (at Brawley) with experimentally-derived hydration curves. No archaeological calibration was involved in Friedman and Obradovich's proposal. When tested against the regional corpus of Obsidian Butte hydration readings, the Friedman and Obradovich model seems to be far too slow to merit acceptance.

Following the approach used by Chace, Debra A. Dominici (1984) based her rate primarily on independent estimates of events relating to the presence or absence of Lake Cahuilla and the historic-period end of obsidian use, matched against the regional patterns in hydration measurement frequencies. The frequency patterns were considered to be more compatible with a linear hydration curve than with any of the other curve forms suggested by Ericson (1977). Given the linear form, Dominici used three relatively large hydration readings to derive the hydration constant. First, a reading of 9.7 microns from site CA-SDI-813 in Anza-Borrego Desert State Park was considered to coincide with A.D. 1210, which had been suggested by Michael R. Waters (1983) as a hiatus between two stands of Lake Cahuilla. This correlation gave a hydration constant of 79.79 years per micron. Second, a reading of 6.7 microns from site CA-SDI-674 in western San Diego County was considered to coincide with A.D. 1420, which had been suggested by Waters as another hiatus between two lake stands. (However, in Waters' model, this recession was partial, and would have stopped just short of exposing the top of Obsidian Butte.) Matching 6.7 microns with A.D. 1420 gave an hydration constant of 84.18 years per micron. Third, a reading of 5.8 microns on a utilized flake (apparently unsourced) from site SDM-C-89 was the largest reading on a sample of specimens from the San Diego Museum of Man. This was considered by Dominici to coincide with A.D. 1575, which was taken to mark the final recession of Lake Cahuilla. This correlation would give a hydration constant of 70.52 years per micron. Dominici averaged the three estimates to derive her final hydration constant of 78.16 years per micron. Some problems have already been noted concerning Waters' lake chronology and the potential problem of scavenged obsidian.

Henry C. Koerper, Jonathon E. Ericson, Christopher E. Drover, and Paul E. Langenwalter II (1986) proposed a linear formula, $T = 110\,d$. The proposal was based on 19 hydration readings on sourced obsidian specimens recovered from an Orange County site, CA-ORA-855. The specimens had a maximum hydration reading of 2.0 microns, a mean reading of about 1.64 microns, and a standard deviation of 0.25 micron. The radiocarbon dates at the site seemed to point to an eighteenth-century occupation. According to the proponents, "Obsidian Butte material at CA-ORA-855 would have been exploited perhaps no earlier than a late 17th century A.D. [Lake Cahuilla] water drawdown" (Koerper et al. 1986:53).

Chace also proposed a diffusion equation, $T = 47\ d^2$ (O'Neil 1984), and Elizabeth Coughlin and Jonathon E. Ericson proposed a linear equation, $T = 314\ d$ (Townsend 1986b). The researchers did not discuss the basis for these proposals.

The Elmore Site offers some important advantages for Obsidian Butte hydration studies. The site appears to represent a single, fairly brief occupation, dating from around A.D. 1670. A moderate quantity of obsidian has been recovered from the site. Although flaked obsidian tools, such as projectile points, might represent scavenged materials which were produced during earlier periods, it seems reasonable to assume that the obsidian wastes represent flaking which occurred at the site during the brief period of its occupation. The mean hydration thickness, matched with the mean radiocarbon date, would therefore provide one fairly secure point on a hydration rate curve (for the physical conditions which have prevailed at the site since its abandonment). As a bonus, the scatter of hydration readings around the mean provide a basis for estimating the "noise" involved in hydration dating.

An initial problem to be considered is the possible effects of different postdepositional environments on hydration rate. In particular, it has been suggested by some investigators that specimens on the ground surface (particularly in open, desert settings) may show notably higher hydration values than specimens which have been buried for the same length of time (Bouscaren and Wilke 1987; Layton 1973; Wilke 1986b; but for a contrary conclusion see also Hall and Jackson 1989).

The results from the Elmore Site support the view that surface specimens hydrate significantly faster, at least under some circumstances. The 23 readings on 22 subsurface specimens from the Elmore Site have a mean value of 2.2 microns. Ten readings on eight surface specimens have a mean value of 4.1 microns. If only the lower value for each of the two surface specimens with multiple hydration bands is considered, the eight surface readings have a mean value of 3.4 microns. Because of this contrast in hydration values between surface and subsurface specimens, the two sets of readings will be considered separately here.

For the subsurface specimens, if the radiocarbon dating of the Elmore Site and its characterization as the residue of a short-term occupation are accepted, then one relatively firm calibration point for the hydration rate of Obsidian Butte material is established: 2.2 microns would correspond to an elapsed time of about 324 years. Three of the possible calibration formulas based on this correspondence are $T = 147\ d$, $T = 67\ d^2$, and $T = 99\ d^{1.5}$. The first formula is a linear rate, and the second is a diffusion rate. The third formula is an intermediate type, of a sort which some empirical studies suggest may be appropriate (cf. Hall and Jackson 1989; Laylander 1987). No empirical basis for testing the relative merits of these and other formula types is provided by the single calibration point from the Elmore Site.

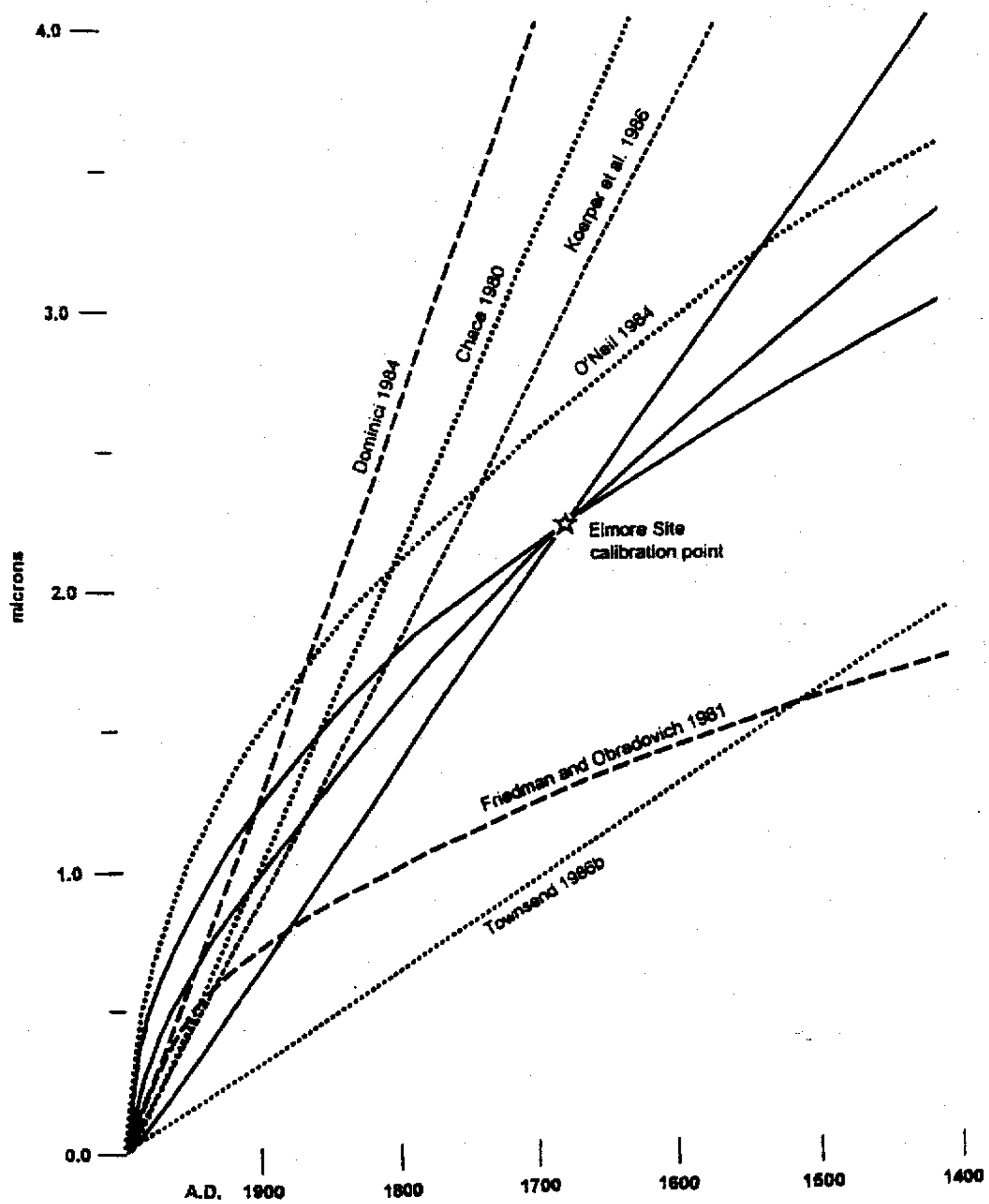

Fig. 21. Calibration curves for the hydration of obsidian from Obsidian Butte.

It will be noted that these formulas indicate significantly slower rates of hydration than were proposed by Chace, Dominici, and Koerper et al., but substantially faster rates than those proposed by Friedman and Obradovich and by Coughlin and Ericson (Fig. 21). As the third and fourth columns in Table 21 suggest, none of the previously-proposed formulas provide satisfactory dates for the obsidian at the Elmore Site.

The degree of clustering in the hydration readings on subsurface obsidian specimens is also of interest. If the interpretation is accepted that the readings represent essentially a single point in time, the scatter of their values represents a measurement of the degree of chronological precision which is available in the hydration method, at least under the particular conditions of the Elmore Site. The sample standard deviation for the 23 readings is 0.36 micron. This can be interpreted as an error factor which subsumes (a) reading error, (b) such microenvironmental variation in subsurface temperature, humidity, and soil chemistry as may be present in the Elmore Site deposit, (c) such physical and chemical variability as may be present in the obsidian, and (d) such random error as may be inherent in the physical process of hydration.

It is not clear whether such an error factor should be considered as an absolute amount (constant for large and small hydration readings), as proportional to the amount of hydration, or as a complex blending of the two. If the error factor is absolute, the suggested error factor represents, in a linear formula, a one-sigma range of plus or minus about 50 years. If the error factor is proportional, it represents a one-sigma range of about 16%. The error is larger than the usually-reported reading error alone of 0.1 or 0.2 micron. However, it is small enough to suggest that, under favorable conditions, hydration measurement may be an effective chronometric tool.

As has been noted, the specimens recovered from the site's surface were found to have a mean hydration measurement of 4.1 microns, or 3.4 microns if the higher value for each of two double-band specimens is excluded. The standard deviations are, respectively, 1.58 microns and 0.68 micron. Because the surface specimens are believed to have been produced by the same flaking events which produced the subsurface specimens, the higher readings for surface specimens confirm previous suggestions that, at least in open desert settings, surface specimens tend to hydrate at significantly faster rates than subsurface specimens.

There is also considerably more inconsistency in the readings from the surface specimens, as reflected in the higher standard deviation. Two ways to interpret this observation can be suggested. The first is that hydration is substantially more erratic on surface specimens, and consequently that hydration is a substantially less accurate chronometric tool to use on specimens from surface contexts. A second interpretation is that the exposure and erosion of portions of the cultural stratum at the Elmore Site has been a gradual, ongoing process. The variability in the hydration values of surface specimens might then reflect the variable proportions of the specimens' individual postdepositional histories which were spent in subsurface contexts. If the latter interpretation is correct, the higher hydration values would more nearly reflect the true surface-condition hydration rate. Hydration of surface specimens would evidently have to be at least 75% faster than that of subsurface specimens. The data from the Elmore Site are not capable of resolving this question, because the postdepositional histories of individual surface specimens are not known.

Regional Chronology -- Lithic, Ceramic, and Shell Artifacts

Lithic, ceramic, and shell artifacts have been widely used in the region as chronological indicators. However, the generally accepted time discriminations are rather broad. fFor instance, Archaic dart points vs. Late Prehistoric arrow points, or preceramic Archaic vs. ceramic Late Prehistoric assemblages. As discussed below, finer discriminations have also been suggested, but still with limited precision and with uncertain reliability. The proposed lithic, ceramic, and shell artifact chronologies do not appear to be sufficiently well-established to be capable of shedding substantial light on the dating of the Elmore Site. However, as in the case of obsidian hydration, the unusually firm dating of this site by other methods provides an opportunity to test the chronological values which have been proposed for some lithic, ceramic, and shell traits.

Projectile Points

Large projectile points, such as Elko series points, have generally been considered to be dart points and to have been in use prior to the availability of bow-and-arrow technology, which is represented by small projectile points. The transition from the use of large to small points has usually been dated to around A.D. 300-700, although the use of the large points may have persisted for some time after the introduction of the small ones. No large points were recovered at the Elmore Site, suggesting that the bow and arrow had entirely replaced the atlatl and dart by ca. A.D. 1670.

Among small projectile points, four types have been suggested as having some chronological significance in southern California. These types are Rose Spring/Eastgate, Dos Cabezas Serrated, Cottonwood Triangular, and Desert Side-Notched points.

Rose Spring/Eastgate points, which are typically corner-notched or stemmed in form, have often been considered diagnostic of the early portion of the Late Prehistoric period (pre-ca. A.D. 1300) in the Great Basin and Mojave Desert (e.g., Bettinger and Taylor 1974; Warren 1984; Warren and Crabtree 1986). At Indian Hill Rockshelter in southeastern San Diego County, the absence of Rose Spring/Eastgate points, or their near-absence (cf. McDonald 1992:191; Wallace et al. 1962), was suggested as indicating a hiatus in the use of the site prior to about A.D. 1300 (Wilke 1986a:161). However, in regions where Rose Spring/Eastgate points do occur, there is some evidence that their production continued as late as the historic period (Yohe 1992). Moreover, Rose Spring/Eastgate points seem to be generally absent from mountain and coastal areas west of the Colorado Desert, where it is less plausible to posit that there was an occupational hiatus. The absence of Rose Spring/Eastgate points in the Elmore Site assemblage may indicate that the use of this form did not continue as late as the seventeenth century, but more likely it merely reflects the fact that this form was never adopted in the region.

The Dos Cabezas Serrated type was defined at Indian Hill Rockshelter by Philip J. Wilke and Meg McDonald (1986; McDonald 1992). Its chronological range has been little explored, as yet. McDonald et al. (1994) suggested that Dos Cabezas Serrated points may tend to date from the latest portion of the Late Prehistoric period. The presence of one serrated point in the Elmore Site assemblage would be compatible with this suggestion.

Cottonwood Triangular and Desert Side-Notched points have generally been assigned time ranges extending from around A.D. 1000 up to the historic period. Some scholars have proposed that the Cottonwood Triangular type appeared first (e.g., Rogers 1939; Warren 1984; Warren and Crabtree 1986), while others have proposed the opposite (e.g., Jennings 1986:117). Contrasts in the apparent sequence of the two types may reflect regional differences; in any event, the data from the Elmore Site cannot address the question. The Elmore Site assemblage does establish that both forms were in use in the later seventeenth century. It probably also establishes that both types were used at the same time by members of a single small community. This coexistence of the two types may reflect differences between them in intended function, in the methods and materials used to attach points to arrow shafts, or in individual skills and preferences.

Whether there is chronological significance to the proportions of Cottonwood and Desert Side-Notched points within assemblages is an issue which has not yet been seriously explored. For a sample of Colorado Desert sites (Table 22), the contrasts in relative frequencies are moderate. However, much of this variability seems to be patterned geographically. Southern sites, in ethnographic Kumeyaay-Diegueño territory, tend to have higher proportions of Desert Side-Notched points than do northern sites, in ethnographic Cahuilla territory. A similar contrast between southern Yuman sites with frequent Desert Side-Notched points and northern Takic sites with few side-notched specimens was reported by D. L. True (1966, 1970) for the mountain region of San Diego County.

Ceramic Wares and Types

In some regions, ceramic typologies have proven to be uniquely valuable for defining relatively tight chronological sequences. That success has most commonly been based on the study of decorative motifs. However, the ceramics of the Colorado Desert are mostly unpainted, as well as being relatively simple in vessel form. Nonetheless, a variety of approaches to the problem of ceramic typology in the region have been proposed by (May 1978b; Rogers 1936, 1945; Schroeder 1958; Van Camp 1979; Waters 1982a, 1982b, 1982c).

Table 22. Small projectile points from selected Colorado Desert sites.

Project	Reference	Cottonwood Triangular Count	Cottonwood Triangular Percentage	Desert Side-Notched Count	Desert Side-Notched Percentage	Dos Cabezas Serrated Count	Dos Cabezas Serrated Percentage
Indian Hill Rockshelter	McDonald 1992	64	32.2%	92	46.2%	43	21.6%
Dry Lake	Eighmey and Cheever 1992	-	0.0	2	100.0	-	0.0
Superstition Mountains	Schaefer 1988	8	33.3	13	54.2	3	12.5
Elmore Site	present report	6	28.6	14	66.7	1	4.8
Truckhaven	Rosen 1988	3	100.0	-	0.0	-	0.0
Toro Canyon	Schaefer and Pallette 1993	2	28.6	5	71.4	-	0.0
RIV-86	Dominici 1987	16	76.2	5	23.8	-	0.0
La Quinta	Sutton 1988b	10	90.9	1	9.1	-	0.0

Michael R. Waters published the most detailed discussion of Lower Colorado Buff ware ceramics to date, and his typology is the one most widely followed by subsequent investigators. He proposed chronologically diagnostic ceramic types within a three-phase scheme of Patayan I, II, and III, which was directly based on Malcolm J. Rogers' scheme of Yuman I, II, and III phases. Selected body sherd characteristics of Waters' types are summarized in Table 23, and the proposed chronological and geographical ranges are summarized in Table 24. In principal, Waters accorded taxonomic priority to vessel form and surface treatment, although it is evident that most of the materials which he classified were nondiagnostic in these respects, as were most of the materials subsequently classified according to his scheme by other analysts. His type definitions were polythetic, and the priorities or weights to be assigned to the various attributes were not explicitly stated. Such factors as these make the replicability of type assignments under Water's typology highly problematical.

Problems concerning the chronological and geographical ranges which were proposed by Waters for his Lower Colorado Buff ware types have been reported by several analysts:

Janet E. Townsend (1985) noted discrepancies between the ways in which the Lower Colorado Buff ware type names were applied by Rogers and by Waters. Examining the ceramic type collections of Rogers and Waters, she suggested that Rogers' Carrizo I type corresponded to Waters' Colorado Buff type and that Rogers' Carrizo II type corresponded to Waters' Tumco Buff type. She also noted that the collection from Waters' Colorado Buff type site, near the Colorado River, did not include Colorado Buff sherds. Townsend suggested that this type "is not common in the Colorado River Valley area. In fact, [it] seems to be a western Lake Cahuilla phenomenon with at least one focus in the San Sebastian Marsh area [a short distance west of the Elmore Site]" (Townsend 1986a:200).

Table 23. Selected body sherd characteristics for plain Lower Colorado Buff ware types*.

	Temper / Inclusions				Clay
Type	Quantity	Types [1]	Form	Frags	Fracture
Black Mesa Buff	very scarce	Q, F, L, Sl	rounded	yes	medium-hard
Colorado Beige	5 - 55%	Q, F, L, Mc, Sl	rounded-subangular	no	soft-medium
Salton Buff	15 - 50%	Q, F, C, Sl	well-rounded	no	very hard
Topoc Buff	30 - 50%	Q, F, H, Mc	subrounded-subangular	no	medium-hard
Tumco Buff	very scarce	Q, F, L, Sl	rounded	yes	medium-hard
Palomas Buff	10 - 35%	F, Q, L, Mc	rounded	no	very soft
Parker Buff	medium-abundant	F, Q, H	rounded-angular	no	medium
Colorado Buff	1 - 10%	Q, F, Sl	subrounded-subangular	no	medium-hard

1 C = cryptocrystalline silica; F = feldspar; H = hornblende; L = lithics; Mc = mica; Q = quartz; Sl = freshwater snail shell
*Waters (1982b).

Martin D. Rosen (1985a:43-45) noted the close association of sherds typed by Waters as Salton Buff, Tumco Buff, and Colorado Buff, at a site which was well below the Lake Cahuilla shoreline. The site was interpreted as postdating the final full stand of the lake.

Debra A. Dominici (1987) reported ceramic assemblages, typed by Waters, from sites in the Coachella Valley, well below sea level. The assemblages were dominated by Salton Buff sherds, with lesser amounts of Tumco Buff and some Colorado Buff. The location of the sites, together with radiocarbon dates, obsidian hydration measurements, and several historic-period artifacts, suggested a later date for the sites than the ceramic types seemed to indicate.

Philip S. Wilke and Mark Q. Sutton (1988) recovered Colorado Buff sherds, along with more numerous Salton Buff sherds, from CA-RIV-1179, in association with the +40 foot shoreline of Lake Cahuilla at La Quinta. They suggested that the Colorado Buff type must have appeared earlier than had previously been supposed. Brooke S. Arkush (1989), reviewing the monograph by Sutton and Wilke (1988), suggested that Colorado Buff was produced in the Salton Basin as early as A.D. 1000.

James D. Eighmey and Dayle M. Cheever (1992) reported ceramic assemblages with Tumco Buff and Salton Buff, but no Colorado Buff, from three sites on the +40 foot shoreline. As discussed above, the radiocarbon dates obtained from two of these sites seem to belong to a cluster which postdates the conventional end for the Patayan II phase.

Table 24. Chronological and geographical ranges for plain Lower Colorado Buff ware types.

Type	Chronological Range	Portion of Geographical Range Nearest to Elmore Site
Black Mesa Buff	A.D. 700 - 1000	eastern Lake Cahuilla shoreline, with rare sherds in western Imperial County and eastern San Diego County
Colorado Beige	A.D. 700 - 1050	Colorado River, with occasional sherds on eastern Lake Cahuilla shoreline and rare ones in eastern San Diego County
Salton Buff	A.D. 950 - 1500	western Lake Cahuilla shoreline, with occasional sherds in and around study area
Topoc Buff	A.D. 1000 - 1400	rare sherds in eastern San Diego County
Tumco Buff	A.D. 1000 - 1500	occasional sherds on western Lake Cahuilla shoreline and rare ones on lake bed
Palomas Buff	A.D. 1000 - post 1900	western Arizona
Parker Buff	A.D. 1000 - post 1900	Colorado River and rare sherds in Chuckwalla Mountains east of Lake Cahuilla
Colorado Buff	A.D. 1500 - 1900	in and around study area

after Waters (1982b, 1982c).

C. William Clewlow, Jr., Theresa A. Clewlow, and Hazel Wald (1992) noted the association of Tumco Buff with Colorado Buff sherds at CA-IMP-5959, a site considered to postdate Lake Cahuilla. They suggested that, locally, Tumco Buff was produced well after the end of the Patayan II phase. (But see also the discussion of radiocarbon dates, which suggests that this site contains remains from both the final recession of Lake Cahuilla and an earlier, fifteenth-century recession.)

Jerry Schaefer took Waters' Lower Colorado Buff ware typology as his starting point but proposed a number of alterations and elaborations. In the Dunaway Road project (Schaefer 1986), at sites around sea level in western Imperial County, the buffware assemblage was found to be dominated by Tumco Buff, with minor amounts of Colorado Buff and Salton Buff also present. Because the Dunaway Road sites were interpreted as being associated with the final recession of Lake Cahuilla, the ceramics were seen as evidence that Colorado Buff "did not come into widespread use until after A.D. 1700" (Schaefer 1986:45). (In an earlier section of the present study, the radiocarbon dates from the Dunaway Road sites study are assigned to earlier recessions of the lake.) In studies at San Sebastian, which Schaefer considered to postdate the lake, Colorado Buff was dominant. "Tumco Buff" represented 19% of a sample from San Sebastian, but Schaefer suggested that the sherds classified as Tumco Buff contained sherd temper rather than the unpulverized clay fragments of the Patayan II Tumco Buff type, and that they therefore constituted a new (unnamed) Patayan III ceramic type. Salton Buff was also included in the San Sebastian sample, in small amounts, as were Parker Buff and Ocotillo Buff (cf. May 1978b). Near Superstition Mountain in western Imperial County, Schaefer (1988) reported that, in a pre-Patayan III assemblage dominated by Tumco Buff, some of the specimens appeared to contain sherd temper, undermining the Patayan III age proposed for this trait at San Sebastian. In a recent summary, Schaefer (1994) proposed that Tumco Buff was manufactured in the western Salton Basin until around A.D. 1700; that Colorado Buff, which was perhaps "descended" from Tumco Buff, began to be made somewhat before that date; and that the chronological dividing line between Patayan II and Patayan III should be moved from A.D. 1500 to around A.D. 1700.

The assemblage from the Elmore Site provides a basis for testing some of the chronological proposals concerning ceramic types. Two key assumptions in this discussion are that the Elmore Site ceramics date from the late seventeenth century A.D., and that the ceramic types used in the Elmore Site analysis correspond reasonably well to the types defined by Waters. Bearing these assumptions in mind, two main points are worth noting concerning the evidence from the Elmore Site:

The predominant ceramic type in the Elmore Site assemblage is type C, or Colorado Buff. This agrees with previous conclusions that Colorado Buff is a Patayan III type, postdating A.D. 1500. It tends to contradict Schaefer's suggestion that this type flourished only after A.D. 1700. (It does not either contradict or support the suggestion by Arkush (1989) that Colorado Buff also occurs in Patayan II contexts.) The association of Colorado Buff with a final recessional phase of Lake Cahuilla is also possible under Waters' ceramic and lacustrine chronologies.

Smaller amounts of type BT and type S are present in the Elmore Site assemblage. Type BT (probably Tumco Buff) and type S (Salton Buff) should be confined to Patayan II contexts, according to Waters' chronology. The Elmore Site assemblage gives strong additional support to Schaefer's suggestion that Tumco Buff, or something very similar to it, extends into the post-A.D. 1500 period as well.

Other Ceramic Traits

In addition to ware/type analyses, chronological values for particular ceramic traits have been suggested. The views of Rogers (1945) on specific traits and their chronological significance were more fully developed than his views on ceramic typology. He recognized Yuman I, II, and III phases, corresponding to Waters' Patayan I, II, and III phases, but

Rogers' phases were intended to apply primarily to the Yuman "core area" in the lower Colorado River valley. According to Rogers, only the Yuman II and III phases are represented in the Salton Basin. Table 25 summarizes ceramic traits which were considered to be chronologically diagnostic for the Yuman I and Yuman III phases in the Yuman core area. No traits unique to the Yuman II phase were identified. Rogers observed that earlier, "residual" traits were present at later times in geographically peripheral areas. If valid, this observation would tend to eliminate any diagnostic value for Yuman I traits in the Salton Basin. Waters (1982a) adopted Rogers' scheme, with some modifications, and evidently intended that it apply to the whole of the Patayan region.

Table 25. Chronologically diagnostic traits in Lower Colorado Buff ware.

Rogers (1945)	Waters (1982a)
Traits Exclusive to Patayan I / Yuman I	
basket molding	basket molding
small-mouth ollas	
direct (rather than recurved) walls on ollas, canteens, jars, and bowls	direct (rather than recurved) walls on jars
pipes	
rounded (rather than flat) lips	
lug handles	lug handles
loop handles	loop handles
absence of stucco finish	absence of stucco finish
"Colorado shoulder"	"Colorado shoulder"
rim notching	lip notching
incised decoration	incised decoration
absence of reinforcing rim band	
burnishing	burnishing
red slip	red slip
absence of black-on-buff and red-on-red decoration	absence of black-on-buff and black-on-red decoration
	absence of effigy head scoops
	hemispherical molding
Traits Exclusive to Patayan / Yuman III	
recurved walls on seed jars	
absence of cylindrical neck coils	absence of unobliterated neck coils
black-on-red decoration	
absence of zoic design elements	absence of zoic design elements
	reinforced rim band
	absence of rounded (rather than flat) lips

Several of Rogers' and Waters' proposals concerning chronologically diagnostic ceramic traits can be evaluated with evidence from the Elmore Site:

Rim Recurvature. Rogers suggested that direct (rather than recurved) walls on ollas, canteens, jars, and bowls were a trait confined to the Yuman I period. Waters made the more restricted proposal that direct walls on jars were confined to Patayan I. The Elmore Site, dating from the Yuman / Patayan III period, contained rim sherds from both the bowl and jar classes which are considered to be direct rather than recurved.

Ceramic Pipes. According to Rogers, pipes were a Yuman I, not a Yuman II or III, trait. A ceramic pipe was recovered from the Elmore Site. However, the item appears to be Tizon Brown ware, rather than Lower Colorado Buff ware. Pipes occur with fair frequency in relatively late contexts in San Diego County, which may have been the principal area of Tizon Brown ware manufacturing. A pipe might also be more likely to have survived as a curated item than would a ceramic vessel. Nonetheless, the Elmore Site specimen supports a suggestion that the use of ceramic pipes, and probably their manufacture as well, continued after the Yuman / Patayan I period.

Lip Shape. Rogers considered rounded vessel lips to be a Yuman I trait, and flat lips to be a Yuman II / III trait. Waters included both rounded and flattened lips as Patayan I and II traits, but only flattened lips as Patayan III. The Elmore Site assemblage includes 18 rounded lip sherds, which indicate that lip flattening was not universal in the post-A.D. 1500 period.

Handles. Both Rogers and Waters considered lug handles and loop handles to be traits which were confined to the Yuman / Patayan I period. No ceramic handles were found in the Elmore Site collection, which therefore supports that view.

Lip Incising. Rogers recorded "rim notching" and "incised decorations" as traits which were present in Yuman I but absent in Yuman II and Yuman III ceramics. Waters similarly recorded the traits as being absent from Patayan II and Patayan III ceramics. However, Waters (1982b:569) noted, in his discussion of Colorado Buff, a Patayan III type, that "techniques such as rim notching...are rare in the desert regions of California". He reported notched lips on sherds which were assigned to post-Patayan I dates on the basis of ceramic type or context. In a study involving 201 rim sherds, Waters (1982d:A-1) reported one Patayan III notched rim sherd, "which is rare for Colorado Buff but does occur". In another study, Waters (1986:B-3, B-5, B-8) reported seven bowl rim sherds and one jar rim with notching (out of a total of 134 rim sherds); three of the notched bowl rims were classified as Tumco Buff, and the other notched rims were classified as Salton Buff, both of them Patayan II types. In a third study, Waters (1985:185) reported one notched Salton Buff rim sherd from a small collection at a site which he assigned to the sixteenth century. A fourth study (Waters 1987) included incised rim sherds typed as Salton Buff (27 cases), Tumco Buff (3 cases), and Colorado Buff (1 case). Schaefer (1986:45) reported two incised rims (out of 37 rim sherds) on specimens classified as Tumco Buff and "obviously Patayan II-III bowl types".

The Elmore Site assemblage includes three incised rim sherds, out of at total of 67 rim sherds recovered. On the basis of vessel form and wall thickness, it is clear that the three sherds represent three different vessels. All three sherds are classified as type C (cf. Colorado Buff type). Such evidence indicates that rim incising was practiced well after A.D. 1000. The suggestion that incising was relatively rare during the later periods cannot be effectively evaluated without adequate quantified data for comparison.

Burnishing. Rogers and Waters considered burnishing as a Yuman / Patayan I trait. No burnished specimens were recovered from the Elmore Site, which therefore supports that view.

Stucco Finish. Rogers (1945:188) listed stucco finish as absent from Yuman I but present for Yuman II and III. Similarly, Waters (1982a:282) listed it as absent from Patayan I but "common" for

Patayan II and III. To test the validity of these generalizations in the Salton Basin, it is necessary to look for cases in which either ceramics considered to have been manufactured prior to A.D. 1000 (on the basis of radiocarbon dating, or by typological classification) have stucco finishes, or ceramic assemblages postdating A.D. 1000 have a significant absence of stucco finish.

It would be difficult, at present, to address the first of these cases. Substantial assemblages in the Salton Basin which would be classified as Yuman / Patayan I seem to be lacking. Rogers (1945:184) excluded the basin from the maximum area for the Yuman I phase. Waters (1982a:286; 1982c), on the contrary, identified a substantial number of sites, primarily on or near the eastern Lake Cahuilla shoreline, which he considered to have Patayan I ceramics. However, in none of these sites, as reported by Waters, were the ceramics exclusively, or even in majority, assigned to Patayan I types. Waters did not report statistics, by ceramic type, for the occurrence of stucco finish, although his type descriptions listed the stucco trait for all of the Patayan II and III types and for none of the Patayan I types.

The main problem with the second test is to determine what level of occurrence would make the trait "common" and what sample size would be needed to document a significant absence. At two sites on the eastern shoreline of Lake Cahuilla (CA-IMP-4434 and CA-IMP-5167), Waters (1986) reported that 100 out of 878 Salton Buff sherds (11%), 29 out of 372 Tumco Buff sherds (8%), and 1 out of 57 untyped sherds (2%) had stucco finishes. At CA-IMP-5204, near the western shoreline, 13% of the 228 Tumco Buff sherds which were recovered had stucco finishes (Schaefer 1986). The collections from the Elmore Site and several other sites in the vicinity (Laylander 1991a, present study), which may be assignable to both Patayan II and III periods, contain no examples of stucco finish, out of 1,046 sherds.

The frequency of occurrence of stucco finishing may have some diagnostic significance in the Lake Cahuilla basin. Contrasts may exist between assemblages in which stucco-finished items account for less than 1% of the sherds and assemblages with about 10% stucco-finished sherds. It is not clear whether this contrast, if it exists, is to be interpreted as chronological (Patayan II vs. Patayan III), geographical (eastern vs. western areas), or functional (sites with substantial emphasis on cooking vs. sites with storage/transport ceramics).

Some Conclusions on Ceramics

An accumulating body of evidence appears to argue that many of the ceramic types and traits which have been proposed as discriminating chronological phases within the Late Prehistoric period in the Colorado Desert do not have the diagnostic value suggested for them. However, before the chronological value of ceramics is written off entirely, some qualifying factors merit consideration:

Types and traits which are not valid as chronological indicators on a presence/absence basis may be valid on a relative-frequency basis. For example, assemblages with a predominance of Salton Buff and Tumco Buff sherds may be distinguishable as earlier than ones in which Colorado Buff predominates, even though all three types may be present in all of the assemblages. To test such possibilities, more thorough and consistent reporting, larger samples, and better independent chronological controls are necessary.

It may be possible to select and define ceramic types and traits which will be more effective as chronological diagnostics than the ones which are commonly in use at present.

The variability in the ways in which ceramic types were discriminated by Rogers, Schroeder, May, Waters, and others indicates that "natural", intuitively obvious divisions are probably not present within Lower Colorado Buff ware. An element in the chronological effectiveness of types and traits is likely to lie in the clarity, rigor, and replicability of their definitions. Apparent chronological anomalies with existing types may be caused, in part, by noise from a lack of comparability in different analyses. On the other hand, apparent patterns may be exaggerated and given a false solidity if vague definitions cause the location of an assemblage or its presumed dating, rather than merely the characteristics of the specimens, to be used in making type assignments.

Chronological periods may be redefined in ways which isolate changes in ceramic technology, preferences, and practices more effectively than do the conventionally assigned dates for Yuman I / II / III or Patayan I / II / III. The emerging picture of the complexity of Lake Cahuilla's history, extending later in time than previously thought and interrupted by several recessions, makes it unlikely that the old three-phase chronology of before, during, and after the lake is optimal.

Shell Beads

Rosen (1995; Laylander 1994:Attachment) has discussed the relation between the shell beads recovered from the Elmore Site and the bead chronologies developed by King (1981) and others for coastal California. The principal bead types found at the Elmore Site, *Olivella* sp. barrel beads and *Olivella* sp. spire-removed beads-, have not been considered chronologically diagnostic on a presence/absence basis. However, in the Santa Barbara Channel area, these two types are most common in assemblages datable to relatively early periods (ca. 6000 to 800 B.C.) and are rare in later ones. Their predominance within the Elmore Site assemblage indicates an inconsistency in the patterns of shell bead manufacture and use in different portions of southern California. Because of this, the application of a coastal bead chronology to sites in the Colorado Desert region (e.g., King 1988; McDonald 1992:288) is probably not advisable.

Bead chronologies specific to the Colorado Desert have not yet been developed. It is noteworthy that the Elmore Site bead assemblage is dissimilar to the one reported for a Lake Cahuilla site near La Quinta (King 1988). This suggests that considerable variability may exist among Colorado Desert sites as well as between the latter and sites in adjacent regions.

Exploitation of Lacustrine Resources

Lake Cahuilla nourished a special set of plant and animal resources which were, for the most part, not otherwise available to aboriginal peoples in the Colorado Desert. These include waterfowl, freshwater fish, freshwater mollusks, and plants adapted to freshwater marsh conditions. Some archaeological evidence is available concerning the roles these resources played in lakeshore subsistence and the timing and sequence in which they ceased to be available as the lake receded.

Floral Resources

A distinctive freshwater marsh plant community can be inferred for the Lake Cahuilla shoreline, in so far as the shoreline was stable enough for such a community to establish itself. Philip J. Wilke (1978:39) suggested the presence of "vast stands of cattail (*Typha*), tule or bulrush (*Scirpus*), and reed (*Phragmites australis*), as well as other economically important plants." These plants may also have been available at springs and along river courses.

The direct evidence for prehistoric exploitation of these resources is fairly limited, but convincing. Wilke (1978) studied human coprolites at the Myoma Dunes area, near the +40-foot shoreline in Coachella Valley, and found evidence for dietary use of bulrush (*Scirpus acutus*, *S. californicus*, and *S. validus*) seeds and of cattail (*Typha* sp.) seeds and pollen. These wetland resources, although commonly represented in the Myoma Dunes coprolites, were not clearly dominant. About 20 non-lacustrine plant resources were also represented, and several of them (goosefoot, witchgrass, pinyon nut, screwbean, purslane, and *Decoria*) were common in the coprolites. At sites CA-RIV-1179 and CA-RIV-2827 in La Quinta, Nancy Farrell (1988) reported human coprolites with cattail and bulrush remains. Karen K. Swope (1988) reported the recovery by flotation of remains from several wetland resources, including bulrush, cattail, and spikerush (*Juncus* sp.), at CA-RIV-1179. (See also Sutton 1993.)

It would be of interest to know the extent to which shoreline plant resources continued to be available as the lake receded from its maximum shoreline. No floral residues were identified at the Elmore Site which would directly clarify this matter. (It is evident that the absence of such evidence should not be taken to imply that floral materials were not being processed and consumed at the site.) The abundant waterfowl remains recovered from the site provide indirect testimony on floral conditions. Wilke (1978:113) suggested:

> With the drying of the lake, species common to marshy habitats were immediately affected. These included the mudhen [American coot] (*Fulica americana*), the remains of which were so common at the Myoma Dunes, as well as the various ducks and geese that feed on the seeds of bulrush, cattail, and other marsh plants....The disrupted ecological balance of the ever-diminishing lake no doubt had a devastating effect on the food chains of many species. It seems logical to assume that the focus of activity on the Pacific flyway simply shifted to the nearby Colorado River Delta.

The Elmore Site faunal assemblage, with its abundant remains from coots, ducks, and other aquatic birds, seems to establish that no such ecological devastation occurred before the final demise of the lake.

Mollusks

One species of freshwater mollusk in Lake Cahuilla, *Anodonta dejecta*, was exploited. Wilke (1978:40) reported the presence of middens, up to 1 foot thick, of *Anodonta* shells mixed with charcoal, ceramics, and other cultural material, above the northwestern shoreline of the lake. Subsequent studies have confirmed the presence of such shells in various archaeological deposits. For example, Robert M. Yohe, II, Roy A. Salls, Murray Smith, and Barry R. Neiditch (1986) reported 72 pieces of *Anodonta* shell from Indian Hill Rockshelter, on the western margin of the Colorado Desert in southeastern San Diego County. Mark Q. Sutton and Yohe (1988) reported 129 pieces (19.1 g) of *Anodonta* shell from site CA-RIV-1179 in La Quinta. Jerry Schaefer (1988:168) reported "small amounts" of *Anodonta* shell from sites near Superstition Mountain. Yohe (1990) reported 341 pieces (22.3 g) of *Anodonta* shell from CA-RIV-3682, near La Quinta. Schaefer and Drew Pallette (1993) reported 263 pieces (35.2 g) of *Anodonta* shell from CA-RIV-1331 and CA-RIV-1349 in Toro Canyon. Still unexplored are the nutritional value of this resource, its relative importance within aboriginal diets, and the methods used for processing it.

The extent to which *Anodonta* continued to be an exploitable resource as the lake level dropped is uncertain. According to J. Richard Bowersox (1973), the salinity of the receding lake would have been too high to sustain *Anodonta* below an elevation of about -20 feet. (At that elevation, according to the model discussed above, the salinity would have been about 1.6 times the salinity of the full lake.) Payen (cited in Wilke 1978:110) suggested that habitat change may have been more important than salinity in eliminating *Anodonta* populations. As has been discussed above, there is some indirect evidence from the Elmore Site that habitat changes in the falling lake were not as drastic as has sometimes been suggested. At any rate, the absence of evidence for *Anodonta* exploitation at the Elmore Site tends to support the conclusion that this species was scarce or locally extinct by the time the lake was as low as -180 feet.

Fish

At least five species of fish have been reported in archaeological assemblages associated with Lake Cahuilla (Table 26 Appendix; Fig. 22). Two species--bonytail (*Gila elegans*) and razorback sucker (*Xyrauchen texanus*)--account for most of the identified remains. Three other species (machete, *Elops affinis;* striped mullet, *Mugil cephalus;* and Colorado squawfish, *Ptychocheilus lucius*) are represented by very small quantities of bone. Remains from additional species may also be present, but unrecognized, in the assemblages (Gobalet 1992).

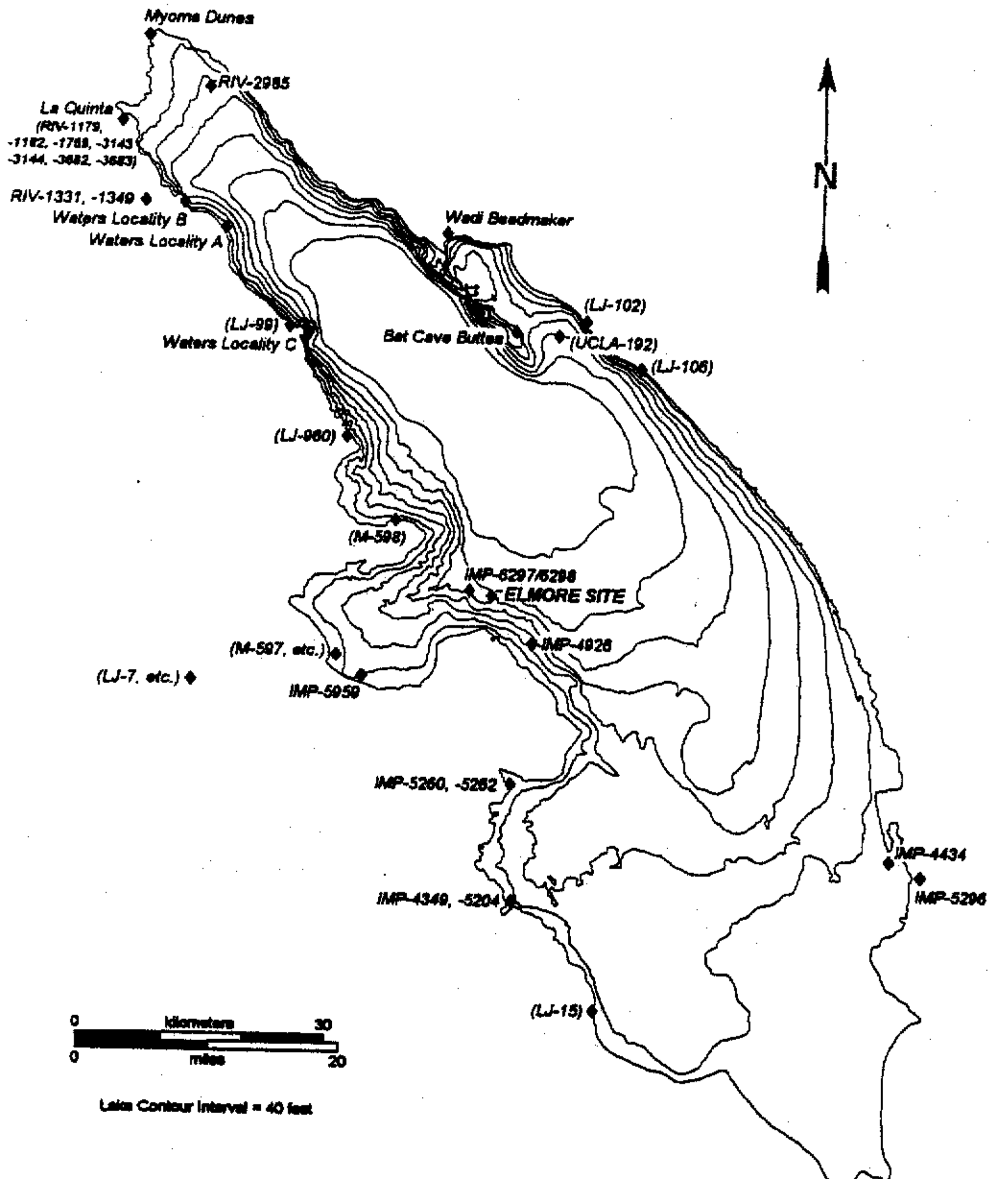

Fig. 22. Map of Lake Cahuilla sites with lacustrine faunal remains.

Procurement of lake fish was apparently done, at least in part, by the use of weirs. Numerous V-shaped rock features which have been interpreted as fish weirs have been reported from below the maximum western shoreline of the lake (e.g., Treganza 1945; Wilke 1978). As was the case with *Anodonta*, it is likely that the increasing salinity of the lake as it receded eventually eliminated the fish resources. Wilke (1988:8-9), noting the distribution of fish weirs near Travertine Point, commented, "the remarkable thing about these weirs is that it is possible to say with a certain degree of certainty that they were built...from about the 13th through the 28th year of the recession cycle of Lake Cahuilla. After that time, it is believed, the fish succumbed as a result of the rising salinity of the water as the lake shrank."

According to the model discussed above, the 28th year of recession would have brought the lake to about 120 feet below sea level. Elsewhere, Wilke (1978:110) reported that no weirs had been found below an elevation of -100 feet. Table 26 indicates that freshwater fish remains have been reported from sites at elevations of around -120 feet. The Elmore Site assemblage testifies that fish were exploited when the lake was below -180 feet. It is not known whether weirs at lower elevations have not been preserved, whether they were constructed in a different manner, or whether the basic techniques used to catch fish changed as the lake receded (cf. Gifford 1931:25- 26).

Beyond the question of a general extinction of fish, it is possible that the relative frequencies of particular fish species present in the lake or procured by aboriginal peoples may have changed. Of the two main species, bonytail tends to be less common in relation to razorback sucker at sites below sea level than is the case at some of the higher-elevation sites. However, some higher-elevation sites also have low proportions of bonytail. Colorado squawfish is not reported at sites below sea level, but its occurrence is rare in any case. The meaning of these patterns, if they are genuine patterns, is uncertain.

Birds

Aquatic birds were another important faunal resource associated with Lake Cahuilla. Unlike fish and shellfish, birds would probably have continued to use the lake even when its salinity level was high, if suitable floral or faunal resources were available to them. Table 27 summarizes the avian faunal remains reported from the Elmore Site and from several maximum-shoreline sites in Riverside County. The Elmore Site assemblage is the largest of these. One shared characteristic of the assemblages is a predominance of American coot (*Fulica americana*). In the largest collections, those from the Elmore Site and from Myoma Dunes, the pochards and allies (*Aythya* spp.) are also well-represented.

Aquatic bird remains from Myoma Dunes include five genera which were not found at the Elmore Site (great blue heron, bufflehead, Canada goose, black-crowned night-heron, and double-breasted cormorant), while the larger Elmore Site assemblage includes remains from only four genera not represented in the collection from Myoma Dunes (willet, long-billed dowitcher, ruddy duck, and American white pelican). This line of evidence, although certainly not compelling, offers a hint that the avian diversity was lower in the receding lake, or perhaps that hunting became more focused on particular species. In general, the Elmore Site assemblage establishes the existence of a previously-undocumented adaptive focus, at least for a time, on the hunting of aquatic birds, probably through the use of nets, during the last stages of Lake Cahuilla's final recession.

Table 27. Avian faunal remains identified from Lake Cahuilla sites.

Species	Myoma Dunes copro-lites [1]	Myoma Dunes other (MNI)	Wadi Bead-maker (MNI)	Bat Caves Butte (MNI)	CA-RIV-1179 (NISP)	Elmore Site (MNI)	Elmore Site (NISP)
Aquatic Birds							
Aechmophorus sp. (western/Clark's grebe)	-	-	-	-	-	12*	154
Aechmophorus occidentalis (western grebe)	-	1	-	-	-	-	-
Anas acuta (northern pintail)	-	3	1*	-	-	-	-
Anas crecca (green-winged teal)	-	-	-	-	-	2	3
cf. *Anas cyanoptera* (cinnamon teal)	-	2	-	-	-	-	-
Anas platyrhynchos (mallard)	-	3	-	-	-	-	-
Anas sp.	-	-	-	-	1	-	-
Anatidae (ducks, geese, swans)	-	-	-	-	-	-	8
Ardea herodias (great blue heron)	-	1*	-	11*	-	-	-
Aythya affinis (lesser scaup)	-	1*	-	-	-	15	192
cf. *Aythya affinis*	-	-	-	-	-	-	6
Aythya americana (redhead)	-	7	-	-	-	4*	10
cf. *Aythya americana*	-	-	-	-	-	-	2
Aythya marila (greater scaup)	-	-	-	-	-	7*	39
cf. *Aythya marila*	-	-	-	-	-	-	3
Aythya valisineria (canvasback)	-	1	-	-	-	12*	110
cf. *Aythya valisineria*	-	-	-	-	-	-	2
Aythya sp. (pochards and allies)	-	-	-	-	-	-*	28
cf. *Aythya* sp.	-	-	-	-	-	-	8
Bucephala albeola (bufflehead)	-	1	-	-	-	-	-
Branta canadensis (Canada goose)	-	1	-	-	-	-	-
Catoptrophorus semipalmatus (willet)	-	-	-	-	-	1	2
Cygnus columbianus (tundra swan)	-	-	1	-	-	-	-
Fulica americana (American coot)	11	48*	1	1*	4	76*	1657
cf. *Fulica americana*	-	-	-	-	-	-	11
Limnodromus scolopaceus (long-billed dowitcher)	-	-	-	-	-	1	2
Nycticorax nycticorax (black-crowned night-heron)	-	1	*	-	2*	—	-
Oxyura jamaicensis (ruddy duck)	-	-	-	-	-	5	33
Pelecanus cf. *erythrorhynchos* (American white pelican)	-	-	-	-	1	1	1
Phalacrocorax auritus (double-crested cormorant)	-	1	-	-	-	-	-
cf. *Podiceps grisegena* (red-necked grebe)	-	-	-	-	2	-	-
TOTAL	12	80	6	14	8	139	2284

* - includes subadult individuals

1 - counts are number of coprolites with bone from species

Sources: Wilke (1978); Sutton and Yohe (1988); present report

The Return of Non-Lacustrine Resources

The people occupying sites on Lake Cahuilla's maximum shoreline had access to a full range of non-lacustrine resources in the adjacent deserts and mountains. Coprolite analyses at Myoma Dunes and La Quinta, and faunal assemblages from various sites, confirm that these resources were exploited. What is less certain is the rapidity with which non-lacustrine floral and faunal communities were able to recolonize the lakebed as the waters receded. Wilke (1978:119-120) noted this uncertainty. Schaefer et al. (1987:22) suggested that it may have taken more than half a century for mesquite groves to establish themselves. The question has not yet been resolved by direct evidence, but the terrestrial faunal assemblage from the Elmore Site provides some clues. The site is located about 4.5 km from the nearest portion of the +40-foot shoreline. Faunal resources could have been procured above the shoreline and brought to the site, but local procurement is perhaps more likely. The Elmore Site's terrestrial faunal assemblage, although meagre, includes deer, kit fox, jackrabbit, cottontail, antelope squirrel, and three species of lizard. It appears likely that these animals, and the plants upon which they subsisted, had recolonized portions of the lakebed at the time when the Elmore Site was occupied.

Exchange and Travel

Clues to patterns in the prehistoric movement of peoples and goods are provided by the distribution of materials or manufactured items of nonlocal origin within archaeological assemblages from Colorado Desert sites. In some cases, the probable source areas and general directions of movement for the exotic items can be suggested, and preliminary inferences can be offered concerning the mechanisms involved. Several classes of exotic or possibly-exotic items were recovered from the Elmore Site. These include obsidian, other lithic materials, projectile points, ceramics, and marine shell.

Obsidian

Obsidian which was used at the Elmore Site came from the Obsidian Butte source, located about 17 km northeast of the site. Obsidian Butte accounts for a large majority of the obsidian found in Late Prehistoric sites in Imperial and San Diego counties. This source area is far closer to the Elmore Site than were the nearest known major alternative sources for obsidian, at Coso Volcanic Fields in the northern Mojave Desert and at a source near San Felipe in northeastern Baja California.

Several mechanisms might account for the presence of the obsidian at the Elmore Site. It may have been brought to the site as unworked raw material; as cores, blanks, or preforms; or as finished tools. At least some of the material evidently arrived at the site in an unfinished state, because the debitage includes moderately large flakes, as well as flakes with cortex on their dorsal and/or platform surfaces. The distance between the site and Obsidian Butte is greater than the 10 km daily foraging radius which is often suggested for hunter-gatherers.

The material may have been brought to the site as a product of special procurement trips, in the course of seasonal group movements, or as a result of intergroup exchange.

An aspect of obsidian procurement which is of particular interest is the likelihood that the people who travelled to the obsidian source did so by watercraft. If the shoreline of Lake Cahuilla was close to the Elmore Site when the site was occupied and when the obsidian was procured, Obsidian Butte would have been an island at the time, separated from the nearest shoreline by perhaps 10 km of open water. Prehistoric inhabitants of the western coast of southern California commonly made far longer trips across rougher waters to the Santa Barbara Channel Islands. However, it is unlikely that the prehistoric peoples of the Colorado Desert shared in the Chumash/Gabrielino seafaring tradition, or that they had watercraft more substantial than tule balsas. Under such circumstances, a trip to Obsidian Butte would have been a fairly adventurous undertaking. It may be speculated that the people made this trip not just to satisfy their individual needs for lithic material but also to obtain material which they could advantageously exchange to other individuals and other social groups. The Elmore Site occupants may themselves have been the ones to make the trip, or they may have been exchange partners of the obsidian procurers.

Other Lithic Materials

The probable sources for some of the other lithic materials used at the Elmore Site lie outside of the conventional one-day foraging radius around the site. The specific procurement areas which were involved are generally not known. It seems less likely that most of these materials were acquired through exchange, than they were procured directly, either on special quarrying trips or as a part of seasonal or other travels.

One rock type of particular interest in this context is the fine-grained material termed "wonderstone". Two major wonderstone quarries in the western Colorado Desert are known: Rainbow Rock, in northwestern Imperial County, and Cerro Colorado, in northern Baja California. The Rainbow Rock quarry is a little closer to the Elmore Site, in straight-line distance (about 40 km, as the crow flies, vs. about 50 km to Cerro Colorado). The trip to Rainbow Rock would also probably have been easier. The 180-foot Lake Cahuilla shoreline leads almost directly from the Elmore Site to the vicinity of the quarry, whereas reaching Cerro Colorado on a direct route would have required crossing the Yuha Desert west and southwest of the Superstition Mountains. However, if Andrew R. Pigniolo's observations concerning the lithic material at the two quarries and in the Elmore Site assemblage are correct, the Elmore Site material is attributable to Cerro Colorado. A possible explanation for this geographic anomaly is that other travel and/or trade connections apparently linked the Elmore Site with areas to the south. The use of shell from the Gulf of California at the site, as discussed below, supports this view. Another possible factor is that a prehistoric ethnic/linguistic boundary may have separated the Elmore Site from the Rainbow Rock quarry. A corresponding boundary, between the Kumeyaay-Diegueño and the Cahuilla, was recorded ethnographically, and seems to have been in place at least as early as the Anza visits of 1774-1776.

Projectile Points

The Elmore Site assemblage includes several projectile points with apical angles which are unusually small for the region. These long, narrow points are similar to some points reported from Arizona. Several different explanations might be proposed to account for the points: they may have been produced in another region and traded to the occupants of the Elmore Site; they may have been produced locally, in imitation of patterns observed through contacts outside of the local region, and possibly with the intention of being traded outside of the region; and they may have been locally produced to serve a specialized function which is otherwise not commonly represented at sites in the region. Based on present evidence, the choice between such explanations is not clear. One possible (but not decisive) argument against local production of the points is that Obsidian Butte obsidian is underrepresented among narrow points. Of 24 non-obsidian points, 9 (37.5%) have apical angles of 20° or less. Among seven obsidian points, only one (14.3%) falls in this class, with an apical angle of about 18°.

Ceramics

Ceramic types have potential value in identifying the regions of origin for archaeologically recovered sherds. However, the potential is seriously undermined by problems with the definition of types and with their interpretations, as was discussed above with regard to the potential chronological value of ceramic types.

The region in which a ceramic type was manufactured has most commonly been inferred from the relative prominence and centrality of that area within the type's distribution and from the relative importance which the type has within the assemblages from the region. This approach is not unreasonable, given certain qualifications. First, the type definition must be relatively clear, and its application must be consistent. The circularity which results from using geographical location as an element in deciding type assignments must be avoided. Second, the compared assemblages must be of sufficient size and sufficiently unbiased in their manner of collection so that contrasts in the relative frequencies of different types can be considered representative. Third, allowance must be made for the probability that at least some specimens of a given type were manufactured in widely dispersed locations rather than in the type's core manufacturing area. This might reflect the movement of individuals with different potting "templates" throughout the region, for instance as a result of intermarriage between groups.

As noted in above, several ceramic types may have been produced locally in the general region which includes the Elmore Site. In Ronald V. May's (1978a, 1978b) scheme for Lower Colorado Buff ware types, only Salton Buff (possibly corresponding to Waters' Salton Buff) was considered local in this area. Malcolm J. Rogers' notes, as published by Gena R. Van Camp (1979), assigned Carrizo Buff I (Waters' Colorado Buff?) and Carrizo Buff II

(Waters' Tumco Buff?), but not Salton Buff (Waters' Salton Buff?), to the west side of Lake Cahuilla. Michael R. Waters (1982b) assigned "foci" or manufacturing areas for Black Mesa Buff, Colorado Beige, Colorado Buff, Parker Buff, Topoc Buff, and Tumco Buff along the lower Colorado River; for Palomas Buff, on the Gila River; and for Salton Buff, on the entire maximum Lake Cahuilla shoreline. Janet E. Townsend (1985) suggested a focus for the Colorado Buff type at San Sebastian, near the Elmore Site, and Jerry Schaefer (1994) suggested that Tumco Buff was also produced in this region.

Applying these suggestions to the Elmore Site assemblage, there is some reason to suppose that sherds classified as types C (cf. Colorado Buff), BT (cf. Black Mesa Buff and Tumco Buff), and S (cf. Salton Buff) may have been locally produced. Taking Waters' typology and the modified version of it used here at face value, type CPPT sherds, which are moderately common in the Elmore Site assemblage, might seem to indicate a connection with the lower Colorado River valley. This interpretation is probably not justified. The typology used in the Elmore Site analysis seems to be particularly weak with respect to this category, which is something of a catchall for poorly fired sherds with considerable amounts of fairly poorly sorted inclusions. These sherds may be imported items, but it seems equally possible that they may represent a locally-made variant of one or more of the other types represented at the site.

Type Tz (cf. Tizon Brown ware) sherds from the Elmore Site are probably genuinely exotic items. These sherds seem to have been made with the residual clays of the mountain or foothill areas to the west of the Salton Basin. Schaefer (1994) suggested that such sherds reached the basin as a result of the seasonal transhumance of people between Lake Cahuilla and the western uplands.

The single painted sherd found at the Elmore Site remains an enigma. If this is indeed an Anasazi sherd from the Kayenta region, it testifies to a relatively far-flung system of trade connections. Two other sherds recovered from nearby archaeological sites (Laylander 1991a) have also been suggested as coming from the Southwest. One sherd from site CA-IMP-6297/6298 has a reddish clay matrix with buff slips and black painting on both surfaces. Larry Leach suggested probable Hohokam manufacture for this item, but, as with the Elmore Site sherd, other experienced observers have questioned this interpretation. A second sherd from CA-IMP- 6297/6298 is a grey rim sherd, with black vegetable paint. Formed by the coil-and-scrape method, with a narrow mouth and apparently pronounced shoulders, this sherd was considered by Leach to be eastern Anasazi. A local origin has not been suggested in this last case.

Marine Shell

Shell from both Gulf of California and Pacific Coast species was found at the Elmore Site. The minimum distance from the Elmore Site to the Pacific Coast is about 135 km. However, this figure understates the magnitude of a direct-route trip across the Peninsular Range. The distance from the site to the present head of the Gulf is about 185 km. As has been noted, the Gulf may have extended into the Pattie Basin in the seventeenth century, which would have reduced the distance to about 60 km. Both Pacific Coast and Gulf of California shell have also been reported from other Colorado Desert sites (e.g., Bennyhoff and Hughes 1987; King 1988; McDonald 1986, 1992).

More revealing than the mere presence of marine shell at the Elmore Site are the forms in which it was found. As noted above and discussed by Rosen (1995; Laylander 1994:Attachment), there is evidence that *Olivella biplicata* and *Olivella dama* beads were being manufactured at the site. Evidently, either through exchange or through extended collecting trips, the Elmore Site occupants acquired unworked *Olivella* shells as raw materials and brought them to the site, to be worked into beads.

Summary

The answers to the key questions relating to prehistoric Lake Cahuilla are still far from complete. Nonetheless, in working toward answers, progress has been made which would scarcely have been imaginable to a nineteenth century observer. Malcolm J. Rogers, Philip J. Wilke, Michael R. Waters, and many others ethnographers, geologists, historians, and geographers, as well as archaeologists, have made important contributions. Chronologies have been pieced together, using pottery, radiocarbon dating, obsidian hydration, and an assortment of other methods. Lifeways have been reconstructed on the basis of the living areas, tools, manufacturing debris, food wastes, and even the excrement of prehistoric people. Models have been developed which help to explain the changes in those lifeways, both in terms of the lake and in relation to other circumstances in the region.

The evidence from the Elmore Site (CA-IMP-6427) adds a few more pieces to the puzzle. The site is located on the western side of the Salton Basin, in an area of wind-blown sand, shallow washes, and irrigated croplands. At an elevation of about 180 feet below sea level, it sits some 220 feet below the level of Lake Cahuilla when the lake was full. The site location was probably selected because it is on the outer edge of a slight rise, which would have been relatively dry as the lake waters receded to the northeast. The site is moderately small in size, its artifact scatter extends over about 10,000 m^2, but the core area of intensive occupation was probably considerably less than a tenth of that.

Within the core area of the Elmore Site, a single charcoal-rich lens testifies to the prehistoric occupation. The site was apparently inhabited for no more than a brief period, between the time when it was uncovered by the waters of the receding lake and the time when the shoreline had receded too far to be conveniently accessible from it. According to soils studies, after the lake left, it never returned. Providentially, wind-blown sand from the drying lake bed covered the cultural deposit, apparently soon after its abandonment, preserving much of its charcoal and other remains for later archaeological discovery.

A broad range of material residues from the prehistoric occupation have been found at the site. The repertoire of stone tools and wastes is fairly complete: manos and metates, used for grinding tasks; finely-made projectile points, for arrows; bifaces, which may have been knives; small improvised edge tools, for cutting or scraping tasks; hammers and chopping tools, for a variety of jobs; and cores and debitage, left over from tool manufacturing. Ceramic sherds include vessel forms which would have been used in cooking and other food processing tasks, and other forms which were probably used to store or to transport food and water. Less utilitarian aspects of material culture are represented by a ceramic smoking pipe, by a range of shell beads and ornaments, and perhaps by some unusually narrow and delicate projectile points. Shell manufacturing debitage indicates that beads were being made at the site. Animal bone wastes identify a number of land mammal and reptile species which were hunted and brought to the site. Lake fish, particularly razorback sucker, were exploited. But the main hunting focus, to judge from the quantity of bone recovered, was on aquatic birds--primarily coots, but also grebes, scaups, canvasbacks, and other species. Fires at the site were probably used for cooking. The function (or functions) of a scattering of small excavated pits remains enigmatic: were they dug to acquire material, to support structures, or to store resources or process them?

A suite of radiocarbon dates tells us that the site was occupied some time around the second half of the seventeenth century, perhaps in the A.D. 1660s or 1670s. Chronologies which are based on ceramic types and vessel forms, obsidian hydration measurements, and projectile point styles seem to be much less precise or secure, but they do not seem to contradict the radiocarbon picture.

In human terms, what was happening at the Elmore Site? The occupants were probably a complete social group of men, women, and children, and not just a specialized task group, if we can judge by the range of activities represented there. The prehistoric people's main objective in coming to the site may have been to hunt and process aquatic birds. At any rate, the bones of such birds are the most conspicuous element in the material residues which have survived. However, as has been noted, various other resources were also being used, and other activities were taking place at the site.

The time of year when the people came and the length of their stay are not known with any certainty. The instability of the lake's shoreline at this elevation suggests that they stayed for a relatively short time, perhaps for less than a single full season. If they were at the site during only one season, the best guess, based on the birds and other animals which they hunted, would be that it was in the fall.

It is tempting to think that the people came to the site from the south or southeast. This conjecture is based on the presence at the site of shell from the Gulf of California, lithic material probably from Cerro Colorado in northern Baja California, and obsidian from Obsidian Butte (an island then, with its nearest approach to the mainland to the southeast of the Elmore Site). Possibly they had just harvested agricultural crops in the Colorado River delta. However, the site also contains shell from the Pacific Coast, as well as Tizon Brown ware pottery, which probably came from the west. If the occupation was in the fall, the next stage in the people's seasonal round may have been to go up into the western mountains, for the late fall acorn or pinyon harvest. The Laguna and Cuyamaca Mountains seem to have been seasonal meeting places for many groups from both the Colorado Desert and the western foothills and coastal plains. There, the people from the Elmore Site may have traded their obsidian, shell beads, buffware pottery, and lake resources such as dried bird or fish meat, for western products.

How would the Elmore Site people have viewed their way of life? A modern cliché is that the lifeways of premodern people, especially hunter-gatherers, were essentially timeless and unchanging--if not on a scale of millennia, then at least on the scale of the perceptions of the people who lived them. Whatever the merits of such a view in general, this surely cannot have been the perspective of the Elmore Site people.

Lake Cahuilla, which was apparently an important focus for at least a part of the Elmore Site people's lives, was visibly disappearing. Some of the older members of the group would probably have remembered when the lake was full, and when its area was more than three times as large as at present. They may have remembered collecting freshwater mussels, which were now gone, although their empty shells lay scattered about. They may have contrasted lake fishing in earlier times with its reduced present state. Possibly their parents told them about a still earlier period when there had been no lake at all, and about its rapid rise. It is not unreasonable to conjecture that the Elmore Site people were able to foresee the time, which was in reality less than a generation away, when the lake would again be gone. What would that awareness have meant for their way of life? Catastrophes are not uncommon for peoples living close to the natural world, but to most premodern peoples they have usually been sporadic and unpredictable. What would it have meant to the Elmore Site inhabitants' view of the world to be able to predict and prepare for such events, to know--as people in the twentieth century have known--that cultural change and environmental deterioration would be important elements in their lives and their children's lives?

Beyond this individual human perspective, cultures are also complex systems of beliefs and practices. As such, they perpetuate themselves by adapting to their natural and human environments, by competing with one another for survival, and by evolving in ways which serve to refine their adaptations or to meet changing circumstances. In the archaeological remains at the Elmore Site, and from other evidence, we can see (however dimly) a cultural system in operation. It gave to the Elmore Site people the technology and the accumulated lore which allowed them to exploit the lake's resources. It gave them a set of expectations about orderly behavior and the division of tasks, which would let them support themselves and their children efficiently and in peace. It drove them to forge and maintain links to a wider world, through seasonal travel, intergroup trading or gift-giving, and intermarriage--links which would be critical when access was needed to distant collecting areas, or when crises in the food supply arose, or when, the group's own resource base disappeared and they must merge into another group.

Our views of such prehistoric cultural systems are necessarily highly conjectural. However, increasingly, we can mine from the archaeological record the small, hard nuggets of fact, which permit us to test and refine our conjectures.

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Appendix

Table 3. Ethnographically-attested storage of food resources.

Resource	Before Storage, Dried	Before Storage, Cooked	Stored in Pit	Stored in Pot	Stored in Granary	Reference
Agave deserti (agave)	X	X		X		Barrows 1900; Bean and Saubel 1972; Hicks 1963
Amaranthus palmeri (amaranth)	X	X			X	Hicks 1963; Kelly 1977
Amelanchier pallida (service-berry)						Bean and Saubel 1972
Arctostaphylos spp. (manzanita)	X			X		Bean and Saubel 1972
Atriplex spp. (saltbush)						Bean and Saubel 1972; Gifford 1931; Hicks 1963
Cercidium spp. (paloverde)					X	Hicks 1963
Chenopodium spp. (goosefoot)		X			X	Barrows 1900; Bean and Saubel 1972; Hicks 1963
Citrullus vulgaris (watermelon)	X		X			Bean and Saubel 1972; Castetter and Bell 1951; Drucker 1937, 1941; Gifford 1933; Kelly 1977
Cucurbita moschata (pumpkin)	X		X	X	X	Bean and Saubel 1972; Castetter and Bell 1951; Drucker 1937, 1941; Hicks 1963; Kelly 1977
Echinocactus acanthodes (barrel cactus)	X	X		X		Bean and Saubel 1972; Hicks 1963
Juniperus californica (juniper)	X					Bean and Saubel 1972; Hicks 1963
Lycium spp. (wolfberry)	X	X		X		Castetter and Bell 1951; Hicks 1963
Olneya tesota (ironwood)						Hicks 1963
Opuntia spp. (cholla, beavertail, tuna etc.)	X			X		Barrows 1900; Bean and Saubel 1972; Hicks 1963
Panicum spp. (panic grass)				X		Hicks 1963
Phaseolus spp. (bean)	X	X		X	X	Castetter and Bell 1951; Drucker 1937; Gifford 1931, 1933; Hicks 1963; Kelly 1977

Table 3 continued	Before Storage,			Stored in		
Resource	Dried	Cooked	Pit	Pot	Granary	Reference
Pinus spp. (pine)		X	X	X	X	Bean 1972; Bean and Saubel 1972; Hicks 1963
Prosopis spp. (mesquite, screw bean)	X	X	X	X	X	Barrows 1900; Bean 1972; Bean and Saubel 1972; Castetter and Bell 1951;Drucker 1937; Gifford 1931, 1933; Hicks 1963;
Prunus ilicifolia (islaya)						Kelly 1977; Hicks 1963
Quercus spp. (oak)	X			X	X	Bean and Saubel 1972; Drucker 1941; Sparkman 1908; Hicks 1963;
Rubus spp. (blackberry, raspberry)	X					Spier 1923; Bean and Saubel 1972
Salvia columbariae (chia)	X	X		X		Barrows 1900; Bean and Saubel 1972; Hicks 1963
Sambucus mexicana (elderberry)	X			X		Barrows 1900; Bean and Saubel 1972; Hicks 1963
Typha spp. (cattail)	X			X		Castetter and Bell 1951
Vigna sinensis (black-eyed bean)				X	X	Castetter and Bell 1951; Gifford 1933; Kelly 1977
Washingtonia filifera (fan palm)	X			X		Bean 1972; Bean and Saubel 1972
Yucca spp. (yucca)	X	X		X	X	Bean 1972; Bean and Saubel 1972; Hicks 1963
Zea maize (corn)				X	X	Castetter and Bell 1951; Drucker 1941; Gifford 1931, 1933; Hicks 1963; Kelly 1977
various tubers and roots	X	X				Bean 1972
various greens	X					Bean and Shipek 1978
various fruits, blossoms, buds	X					Bean 1978
seeds of cultigens and semi-cultivated species, for planting						Castetter and Bell 1951
meat, fish	X	X				Bean 1972; Castetter and Bell 1951; Drucker 1937, 1941; Gifford 1933; Hicks 1963; Shipek 1991; Sparkman 1908
shellfish	X					Hicks 1963
Celerio lineata (lined sphinx moth)	X	X				Castetter and Bell 1951

Table 4. Obsidian hydration measurements.

UCLA Laboratory Number	Catalog Number	Provenience	Chemical Source Area [1]	Hydration Thickness (microns) [2]
13942	130	Surf. Coll. #84	--	NVH
13943	183-1	Surf. Coll. #103	--	3.0
13944	223	Surf. Coll. #119	--	2.5
13945	263-1	Surf. Coll. #134	--	2.9
13946	286	Surf. Coll. #146	--	3.0
13947	290	Surf. Coll. #147	--	2.8
13948	318	Surf. Coll. #161	--	3.4
13949	378-1	Unit #3, 0-10 cm	--	NVH
13950	382-2	Unit #3, 10-20 cm	--	3.2
13951	382-4	Unit #3, 10-20 cm	--	3.1
14584	592	Unit #19, 10-20 cm	--	2.2
14585	612	Unit #23, 0-10 cm	--	2.2
14586	715	Unit #35, 0-10 cm	--	2.3
14587	721	Unit #36, 0-10 cm	--	1.9
14588	736	Unit #38, 0-10 cm	--	2.7
14589	746	Unit #39, 0-10 cm	--	1.9
14590	546	Unit #14, 10-20 cm	--	2.4
14591	570	Unit #16, 10-20 cm	--	1.9
14592	606	Unit #22, 10-20 cm	Obsidian Butte	2.1
14593	622	Unit #24, 20-30 cm	--	1.9
14594	735	Unit #37, 10-20 cm	Obsidian Butte	2.0
14595	579	Unit #17, 20-30 cm	Obsidian Butte	2.1
14596	597	Unit #20, 20-30 cm	--	1.9

Table 4 continued

UCLA Laboratory Number	Catalog Number	Provenience	Chemical Source Area 1	Hydration Thickness (microns) 2
14597	729	Unit #36, 20-30 cm	--	2.0 / 2.4
14598	543	Unit #13, 30-40 cm	--	2.1
14599	583	Unit #18, 30-40 cm	Obsidian Butte	2.1
14600	672	Unit #31, 40-50 cm	--	1.9
14601	520	Unit #9, 50-60 cm	--	2.2
14602	587	Unit #18, 50-60 cm	--	2.1
14603	815	Unit #15, 90-100 cm	--	2.1
14640	185	Surf. Coll. #104	Obsidian Butte	3.4 (r)
14641	303	Surf. Coll. #152	Obsidian Butte	4.5 / 6.6 (r)
14642	332	Surf. Coll. #172	Obsidian Butte	2.6
14643	421	Surf. Coll. #206	Obsidian Butte	3.8 (r)
14644	450	Surf. Coll. #235	Obsidian Butte	3.5 (r)
14645	487	Surf. Coll. #266	Obsidian Butte	3.1 (r)
14646	497	Surf. Coll. #274	Obsidian Butte	2.4 (r)
14647	498	Surf. Coll. #275	Obsidian Butte	3.8 / 7.1 (r)

1 All specimens were visually sourced to Obsidian Butte

2 NVH = no visible hydration; (r) = hydration noted as "rough"

Table 10. Rim sherds.

Provenience	Type	Rim Angle	Rim Re-curved?	Rim Radius (cm)	Rim Length (cm)	General Vessel Form	Lip Form	Lip In-cised?	Lip Thick-ening
Surf. Coll. 9	CPPT	120^{0}	no	15	4.3	jar?	flattened	no	out
Surf. Coll. 20	C	20^{0}	no	15	7.8	bowl	flattened	no	both
Surf. Coll. 60	C	60^{0}	yes	7	6.2	jar	slightly flat	no	out
Surf. Coll. 70	BT	20^{0}	no	12	4.0	bowl	rounded	no	both
Surf. Coll. 74	C	110^{0}	yes	6	2.2	jar	rounded	no	out
Surf. Coll. 85	C	30^{0}	no	12	1.7	bowl	slightly flat	no	in
Surf. Coll. 92	C	70^{0}	no	6	5.0	bowl	flattened	no	out
Surf. Coll. 93	BT	120^{0}	no	7	2.5	jar	slightly flat	no	---
Surf. Coll. 97	C	110^{0}	yes	6	2.5	jar	rounded	no	out
Surf. Coll. 102	C	20^{0}	no	12	2.2	bowl	slightly flat	no	both
Surf. Coll. 103	C	60^{0}	no	15	3.7	bowl	flattened	no	out
Surf. Coll. 112	C	90^{0}	no	15	3.1	bowl	slightly flat	no	out
Surf. Coll. 123	C	?	no	>15	1.3	bowl	rounded	no	in?
Surf. Coll. 137	CPPT	70^{0}	yes	15	2.4	jar?	slightly flat	no	both
Surf. Coll. 174	C	90^{0}	no	12	2.6	bowl	slightly flat	no	in
Surf. Coll. 207	C	20^{0}	no	15	4.9	bowl	rounded	no	--
Surf. Coll. 229	BT	70^{0}	no	8	2.8	bowl	flattened	no	out
Surf. Coll. 238	C	30^{0}	no	4	1.8	bowl	slightly flat	no	--
Surf. Coll. 241	BT	60^{0}	no	15	3.1	bowl	rounded	no	--
Surf. Coll. 260	C	80^{0}	yes	10	1.6	jar?	slightly flat	no	--
Surf. Coll. 291	C	100^{0}	no	>15	1.6	bowl	slightly flat	no	out
#1, 0-10 cm	C	100^{0}	no	12	2.0	bowl	rounded	no	---
#5, 40-50 cm	C	50^{0}	yes	5	2.3	jar?	slightly flat	no	out
#9, 30-40 cm	C	130^{0}	no	8	1.5	jar	slightly flat	no	?
#9, 40-50 cm	C	120^{0}	no	10	1.2	jar	rounded	no	--

Table 10. Rim sherds. continued

Provenience	Type	Rim Angle	Rim Re-curved?	Rim Radius (cm)	Rim Length (cm)	General Vessel Form	Lip Lip Form	Lip In-cised?	Thick-ening
#9, 40-50 cm	C	20°	no	12	2.1	bowl	flattened	no	out
#9, 60-70 cm	C	60°	no	8	6.8	bowl	flattened	no	--
#9, 70-80 cm	C	80°	no	10	2.4	bowl	rounded	no	out
#12, 0-10 cm	C	90°	yes	13	1.6	bowl	slightly flat	no	out
#15, 60-70 cm	C	70°	no	7	3.9	bowl	slightly flat	no	both
#15, 60-70 cm	CPPT	?	yes	?	1.5	?	flattened	no	--
#16, 10-20 cm	C	?	no	?	1.6	?	flattened	no	--
#16, 10-20 cm	C	130°	no	5	2.2	jar	flattened	yes	out
#16, 10-20 cm	C	50°	no	12	9.0	bowl	slightly flat	no	out
#16, 10-20 cm	C	50°	no	12	14.8	bowl	slightly flat	no	out
#18, 30-40 cm	C	110°	yes	15	1.8	bowl	flattened	no	both
#19, 0-10 cm	CPPT	100°	yes	13	3.2	jar?	slightly flat	no	out
#19, 0-10 cm	C	100°	yes	15	2.7	jar	flattened	no	out
#19, 0-10 cm	C	100°	yes	15	2.1	jar	flattened	no	--
#19, 0-10 cm	C	90°	yes	3	2.2	jar	slightly flat	no	out
#19, 10-20 cm	C	110°	no	10	1.4	jar	slightly flat	no	--
#19, 30-40 cm	C	40°	yes	>15	10.6	bowl	slightly flat	no	out
#21, 20-30 cm	C	130°	no	11	2.3	jar	slightly flat	no	out
#21, 20-30 cm	C	100°	no	>15	2.7	bowl?	slightly flat	no	in
#21, 20-30 cm	C	40°	no	11	1.5	bowl	rounded	no	in
#22, 20-30 cm	C	80°	no	15	2.2	bowl	rounded	no	both
#23, 0-10	BT	110°	no	15	2.4	bowl	flattened	no	?
#24, 0-10 cm	C	20°	no	13	1.8	bowl	rounded	no	out
#24, 10-20 cm	C	?	no	?	0.7	?	rounded	yes	--
#25, 50-60 cm	C	80°	yes	11	4.3	jar	slightly flat	no	both

Table 10. Rim sherds continued.

Provenience	Type	Rim Angle	Rim Re-curved?	Rim Radius (cm)	Rim Length (cm)	General Vessel Form	Lip Lip Form	Lip In-cised?	Thick-ening
#26, 50-60 cm	C	70^0	no	4	1.9	bowl	rounded	no	--
#26, 50-60 cm	C	70^0	no	4	1.6	bowl	slightly flat	no	--
#26, 60-70 cm	C	70^0	no	4	1.2	bowl	rounded	no	--
#26, 60-70 cm	C	90^0	no	15	4.3	bowl	flattened	no	out
T#26, 70-80 cm	BT	80^0	no	13	2.2	bowl	slightly flat	no	both
#29, 10-20 cm	C	?	no	?	0.8	?	rounded	no	both
#29, 20-30 cm	C	100^0	yes	3	2.3	jar	slightly flat	no	--
#31, 60-70 cm	C	90^0	yes	10	3.6	bowl	slightly flat	no	out
#32, 10-20 cm	C	30^0	no	6	3.2	bowl	slightly flat	no	both
#32, 20-30 cm	C	80^0	no	>15	3.8	bowl	slightly flat	no	in
#34, stratum 2a	C	90^0	yes	6	4.8	jar	flattened	no	out
#35, 0-10 cm	C	50^0	no	>15	11.3	bowl	slightly flat	no	both
#35, 0-10 cm	C	90^0	yes	14	10.1	bowl	slightly flat	yes	out
#35, 0-10 cm	C	80^0	yes	11	3.4	bowl	flattened	no	out
#36, 0-10 cm	C	30^0	no	9	6.0	bowl	rounded	no	--
#38, 10-20 cm	C	70^0	no	15	2.5	bowl	rounded	no	both
#38, 20-30 cm	C	60^0	no	13	2.0	bowl	slightly flat	no	both

Table 18. Estimated surface areas, volumes, filling times, and recession times for Lake Cahuilla, at 20-foot contour intervals.

Elevation	Area	Volume	Filling Schedule		Recession Schedule		Recession Salinity
ft	mi^2	(10^9 ft^3)	yr	mo	yr	mo	(ppm)
+40	2113	8190	18	6	0	6	322
+20	1897	7073	15	4	3	9	373
+0	1656	6083	12	6	7	5	434
-20	1505	5202	10	6	10	9	507
-40	1314	4417	8	6	14	5	597
-60	1155	3729	7	5	17	9	707
-80	1044	3116	5	12	21	5	846
-100	943	2563	4	9	24	9	1029
-120	839	2066	3	11	28	4	1276
-140	719	1632	3	4	31	8	1616
-160	644	1252	2	6	35	4	2106
-180	560	916	1	9	39	8	2879
-200	486	624	1	6	42	4	4226
-220	402	371	0	11	45	8	7108
-240	302	169	0	6	49	3	15604
-260	185	34	0	6	52	8	77564
-280	0	0	0	6	56	3	--

Table 20. Radiocarbon dates relating to Lake Cahuilla after A.D. 1000.

Lab No.	^{14}C Age	^{13}C-Adjusted Age	Date	One-σ Range	Material	Reference
UCR-125	<100	–	–	–	coprolite	Taylor 1975; Wilke 1978
UCR-350	<100	–	–	–	charcoal	Wilke 1978
UCR-349	<100	–	–	–	charcoal	Wilke 1978
UCR-348	<150	–	–	–	charcoal	Wilke 1978
UCR-163	<150	–	–	–	charcoal	Taylor 1975; Wilke 1978
UCR-319	<150	–	–	–	charcoal	Wilke 1978
UCR-2094	<150	–	–	–	charcoal	Sutton 1988a
Beta-53006	30 ± 70	30 ± 70	modern	modern	charcoal	present study
Beta-37907	70 ± 60	50 ± 60	modern	A.D. 1710, 1822-1822, etc.	charcoal	Arkush 1990c
Beta-57861	120 ± 70	80 ± 70	modern	A.D. 1686-1739, etc.	charcoal	Schaefer and Pallette 1993
Beta-37906	110 ± 50	80 ± 50	modern	A.D. 1695-1725, etc.	charcoal	Arkush 1990c
Beta-57860	150 ± 80	110 ± 80	A.D. 1710	A.D. 1675-1777, etc..	charcoal	Schaefer and Pallette 1993
Beta-42011	110 ± 60	110 ± 60	A.D. 1710	A.D. 1680-1753, etc.	charcoal	Laylander 1991a
Beta-53008	100 ± 50	110 ± 50	A.D. 1710	A.D. 1683-1745, etc.	charcoal	present study
M-598	120 ±200	–	A.D. 1702, etc.	A.D. 1530-1537, post 1635	charcoal	Crane and Griffin 1958
M-597	130 ±200	–	A.D. 1695, 1695, etc.	A.D. 1525-1558, post 1631	charcoal	Crane and Griffin 1958
Beta-54877	140 ± 50	–	A.D. 1689, 1732, etc.	post A.D. 1675	charcoal	Eighmey and Cheever 1992
Beta-53004	130 ± 70	150 ± 70	A.D. 1686, 1738, etc.	post A.D. 1666	charcoal	present study
Beta-54875	170 ± 60	–	A.D. 1680, 1753, etc.	post A.D. 1663	charcoal	Eighmey and Cheever 1992
Beta-17475	230 ± 90	210 ± 90	A.D. 1669, 1786, etc.	A.D. 1641-1702, etc.	charcoal	Dominici 1987
Beta-37904	240 ± 50	210 ± 50	A.D. 1669, 1786, etc.	A.D. 1654-1683, 1744-1807, etc.	charcoal	Yohe 1990
A-6674	215 ± 55	–	A.D. 1668, 1788, etc.	A.D. 1651-1683, 1744-1807, etc.	charcoal	Clewlow et al. 1992
—	240 ± 70	220 ± 70	A.D. 1666	A.D. 1644-1686, 1738-1809, etc.	charcoal	Schaefer 1987
LJ-102	220 ±100	–	A.D. 1666	A.D. 1529-1537, 1634-1702, etc.	charred tule	Hubbs et al. 1960

Cluster	Site	Elevation	Comments
-	Myoma Dunes	> +40	See also UCR-124, UCR-152, UCR-153, and UCR-163. Freshwater marsh plant materials have been recovered from such coprolites, suggesting a lacustrine association for the date.
-	Wadi Beadmaker	> +40	See also UCR-348, UCR-349, UCR-380. A fishing station near the Lake Cahuilla shoreline.
-	Wadi Beadmaker	> +40	See also UCR-348, UCR-350, UCR-380. From a hearth.
-	Wadi Beadmaker	> +40	See also UCR-349, UCR-350, UCR-380. From the base of the midden
-	Myoma Dunes	> +40	See also UCR-125, UCR-125, UCR-152, and UCR-153. From a beam in a house adjacent to a Myoma Dunes coprolite bed. Interlaboratory check date of UCLA-1918 yielded an age of 100 ±60 years. The certainty of the association with Lake Cahuilla is not clear.
-	Bat Cave Buttes	> +40	From a hearth. Association with Lake Cahuilla may be uncertain.
-	RIV-1179	> +40	From the lower level of a cremation. See also UCR-2083, UCR-2084, UCR-2085, and UCR-2094. Although associated with fish bone, the date is discounted by its reporters as "apparently contaminated".
-	IMP-6427	-180	Discussed in present report.
-	RIV-1182	> +40	See also Beta-37906. Seems well associated with a full stand of the lake, but date is anomalously late.
-	RIV-1349	> +40	From a possible hearth at a site with freshwater fish bone and *Anodonta* shell. See also Beta-57860. Anomalously late for a full lake stand.
-	RIV-1182	> +40	See also Beta-37907. Seems well associated with a full stand of the lake, but date is anomalously late.
-	RIV-1349	> +40	From a possible hearth at a site with freshwater fish bone and *Anodonta* shell. See also Beta-57861. Anomalously late for a full lake stand.
6	IMP-6427	-180	Discussed in present report.
6	IMP-6427	-180	Discussed in present report.
-	—	> +40	Fish bone was also reported at the site. Association with a full stand of the lake appears to be fairly good.
-	—	> +40	From a subsurface occupation streak in a Lake Cahuilla shoreline sand-dune site. See also LJ-GAP-57, LJ-GAP-58, and LJ-GAP-59. This deposit was retested by date LJ-GAP-59; the result of the latter is perhaps more plausible.
5	IMP-5262	> +40	From a hearth. See also Beta-54874, Beta-54875, and Beta-54876. Relates to a full or near-full stand of Lake Cahuilla.
6	IMP-6427	-180	Discussed in present report.
5	IMP-5260	> +40	From an area of hearths and fish bone. See also Beta-54874, Beta-54876, and Beta-54877. Relates to a full or near-full stand of Lake Cahuilla.
6	RIV-2985	-49	See also Beta-17947 and Beta-17949. Interpreted as postdating the lake.
5	RIV-3682	> +40	See also Beta-37900, Beta-37901, Beta-37902, and Beta-37905. Regarded as suspect by reporter because of lateness. Seems well associated with a full lake stand.
6	IMP-5959	+ 0	From a site with two "seeds" from aquatic algae. See also A-6672 and A-6673. Interpreted as relating to a recessional shoreline.
5	IMP-5296	> +40	From a site with fish bone near the eastern shoreline. Seems to have a good association with a full stand of the lake.
5	—	> +40	From the eastern shoreline in Imperial County. Interpreted as having been produced by fires set to drive game. Association with the lake seems reasonable, unless the material is related to twentieth-century conditions.

Table 20. Radiocarbon dates relating to Lake Cahuilla after A.D. 1000 (continued).

Lab No.	^{14}C Age	^{13}C-Adjusted Age	Date	One-σ Range	Material	Reference
Beta-54876	220 ±120	–	A.D. 1666	A.D. 1520-1569, 1627-1889, etc.	charcoal	Eighmey and Cheever 1992
Beta-53009	190 ± 60	230 ± 60	A.D. 1663	A.D. 1644-1680, 1752-1804, etc.	charcoal	present study
Beta-5955	230 ± 50	–	A.D. 1663	A.D. 1647-1678, 1772-1801, etc.	tule charcoal	Shackley 1984
UCR-153	235 ±150	–	A.D. 1661	post A.D. 1480	bulrush seeds	Taylor 1975; Wilke 1978
Beta-53007	220 ± 70	240 ± 70	A.D. 1660	A.D. 1638-1680, etc. 1748-1799, etc.	charcoal	present study
UCR-152	240 ±150	–	A.D. 1660	post A.D. 1477	mesquite seed coats	Taylor 1975
UGa-1470	245 ± 60	–	A.D. 1658	A.D. 1639-1676, 1774-1800, etc.	charcoal	Brooks et al. 1977
Beta-53005	200 ± 50	250 ± 50	A.D. 1657	A.D. 1641-1672, etc.	charcoal	present study
Beta-54874	250 ± 50	–	A.D. 1657	A.D. 1641-1672, etc.	charcoal	Eighmey and Cheever 1992
Beta-53003	250 ± 50	260 ± 50	A.D. 1654	A.D. 1638-1669, etc.	charcoal	present study
UCLA-192	270 ± 60	–	A.D. 1651	A.D. 1525-1559, 1631-1669, etc.	charcoal	Fergusson and Libby 1963
Beta-42009	270 ± 60	290 ± 60	A.D. 1644	A.D. 1515-1591, 1621-1663	charcoal	Laylander 1991a
Beta-53010	260 ± 50	290 ± 50	A.D. 1644	A.D. 1520-1569, 1627-1660	charcoal	present study
LJ-15	300 ±100	–	A.D. 1641	A.D. 1472-1672, 1781-1795, etc.	charcoal	Hubbs et al. 1960
Beta-37911	350 ± 50	300 ± 50	A.D. 1641	A.D. 1515-1591, 1621-1657	charcoal	Arkush 1990c
Beta-37902	340 ± 60	320 ± 60	A.D. 1530, 1537, 1635	A.D. 1482-1654	charcoal	Yohe 1990
Beta-57863	380 ± 90	320 ± 90	A.D. 1530, 1537, 1635	A.D. 1460-1663	charcoal	Schaefer and Pallette 1993
UGa-1471	325 ± 75	–	A.D. 1527, 1553, 1633	A.D. 1472-1657	charcoal	Brooks et al. 1977
Beta-37912	350 ± 50	330 ± 50	A.D. 1525, 1558, 1631	A.D. 1482-1647	charcoal	Arkush 1990c
Beta-37913	380 ± 50	330 ± 50	A.D. 1525, 1558, 1631	A.D. 1482-1647	charcoal	Arkush 1990c
Beta-14195	280 ± 60	330 ± 60	A.D. 1525, 1558, 1631	A.D. 1477-1651	charcoal	Schaefer 1986
A-6672	340 ± 70	–	A.D. 1520, 1569, 1627	A.D. 1460-1651	charcoal	Clewlow et al. 1992
UCR-2083	350 ± 50	–	A.D. 1516, 1591, 1621	A.D. 1472-1641	charcoal	Sutton 1988a
UGa-1472	350 ± 55	–	A.D. 1516, 1591, 1621	A.D. 1468-1643	charcoal	Brooks et al. 1977

Cluster	Site	Elevation	Comments
5	IMP-5260	> +40	See also Beta-54874, Beta-54875, and Beta-54877. Relates to a full or near-full stand of Lake Cahuilla.
6	IMP-6427	-180	Discussed in present report.
6	IMP-4349	-10	From material underlying the cultural deposit of a site with fish bone. Apparently associated with early stage of lake recession.
5	Myoma Dunes	> +40	From a bed of decomposing human coprolites. See also UCR-124, UCR-125, UCR-152, and UCR-163.
6	IMP-6427	-180	Discussed in present report.
5	Myoma Dunes	> +40	From a bed of decomposing human coprolites. See also UCR-124, UCR-125, UCR-153, and UCR-163.
5	—	> +40	From "Lot 1", associated with fish bone, on the southern shore of Dry Lake. Relates to a full stand of Lake Cahuilla.
6	IMP-6427	-180	Discussed in present report.
5	IMP-5260	> +40	From a cremation. See also Beta-54875, Beta-54876, and Beta-54877. Relates to a full or near-full stand of Lake Cahuilla.
6	IMP-6427	-180	Discussed in present report.
6	—	-160	From hearths containing freshwater fish bones. Seems to be well associated with a low recessional (or possibly transgressional) shoreline.
6	IMP-6297/6298	-170	From a hearth. See also Beta-42010. Dates either a nonlacustrine period or a period in which the lake level was very low.
6	IMP-6427	-180	Discussed in present report.
-	—	> +40	From a site in Baja California just south of the international border. Interpreted by its reporters as reflecting a period of dense population related to the availability of water and fish from the lake, but the association with the lake does not seem to be compelling.
5	RIV-3144	> +40	See also Beta-37912 and Beta-37913. Seems well associated with a full lake stand.
5	RIV-3682	> +40	See also Beta-37900, Beta-37901, Beta-37904, and Beta-37905. Regarded as suspect by reporter because of lateness. Seems well associated with a full lake stand.
5	RIV-1331	> +40	From a hearth at a site with freshwater fish bone and *Anodonta* shell. Association with full lake stand appears good.
5	Hell's Half Acre	> +40	In association with fish bone, near the eastern shoreline. See also UGa-1472. Seems to be well associated with a full stand of the lake.
5	RIV-3144	> +40	See also Beta-37911 and Beta-37913. Seems to be well associated with a full stand of the lake.
5	RIV-3144	> +40	See also Beta-37911 and Beta-37912. Seems to be well associated with a full stand of the lake.
4	IMP-5204	+ 0	From several units in a site with freshwater fish bone. See also Beta-14194. Dates an early-stage recession of the lake.
4	IMP-5959	+ 0	From a site with two "seeds" from aquatic algae. See also A-6673 and A-6674. Interpreted as relating to a recessional shoreline.
5	RIV-1179	> +40	From a hearth associated with fish bone. See also UCR-2084, UCR-2085, UCR-2093, and UCR-2094. Seems to be well associated with a full stand of the lake.
5	Hell's Half Acre	> +40	See also UGa-1471. Seems to be well associated with a full stand of the lake.

Table 20. Radiocarbon dates relating to Lake Cahuilla after A.D. 1000 (continued).

Lab No.	^{14}C Age	^{13}C-Adjusted Age	Date	One-σ Range	Material	Reference
A-6673	355 ± 55	–	A.D. 1513, 1595, 1619	A.D. 1460-1641	charcoal	Clewlow et al. 1992
UGa-4650	360 ± 60	–	A.D. 1511, 1600, 1616	A.D. 1453-1641	charcoal	Phillips 1982
UCR-2093	360 ± 80	–	A.D. 1511, 1600, 1616	A.D. 1446-1647	charcoal	Sutton 1988a
UCR-124	365 ±140	–	A.D. 1490, 1605, 1613	A.D. 1428-1664	coprolite	Taylor 1975
Beta-42012	330 ± 80	370 ± 80	A.D. 1488, 1609, 1611	A.D. 1443-1644	charcoal	Laylander 1991a
Beta-37905	410 ± 50	380 ± 50	A.D. 1483	A.D. 1448-1525, 1558-1631	charcoal	Yohe 1990
Beta-36960	400 ± 60	–	A.D. 1473	A.D. 1441-1520, 1569-1627	charcoal	Arkush 1990b
UCR-380	415 ±140	–	A.D. 1457	A.D. 1406-1649	burnt fish bone	Wilke 1978
LJ-GAP-58	420 ±100	–	A.D. 1454	A.D. 1420-1530, 1536-1635	charcoal	Hubbs and Bien 1967
Beta-37909	350 ± 70	430 ± 70	A.D. 1449	A.D. 1430-1511, 1600-1616	charcoal	Arkush 1990c
M-596	450 ±200	–	A.D. 1444	A.D. 1305-1367, 1372-1657	charcoal	Crane and Griffin 1958
UCR-997	780 ±100	450 ±100	A.D. 1444	A.D. 1407-1516, 1591-1621	*Anodonta* shell	Waters 1983
LJ-GAP-59	470 ±100	–	A.D. 1438	A.D. 1403-1488, 1609-1611	charcoal	Hubbs and Bien 1967
Beta-13232	470 ± 70	–	A.D. 1438	A.D. 1410-1473	charcoal	Gallegos 1986
UCR-986	820 ±100	490 ±100	A.D. 1433	A.D. 1398-1478	*Anodonta* shell	Waters 1983
Beta-36961	530 ± 50	–	A.D. 1415	A.D. 1400-1436	charcoal	Arkush 1990b
Beta-17947	510 ± 80	530 ± 80	A.D. 1415	A.D. 1321-1340, 1393-1444	charcoal	Dominici 1987
Beta-42010	500 ± 50	550 ± 50	A.D. 1408	A.D. 1327-1333, 1395-1431	charcoal	Laylander 1991a
Beta-14194	400 ± 60	580 ± 60	A.D. 1400	A.D. 1307-1361, 1378-1421	charcoal	Schaefer 1986
UCR-994	700 ±100	615 ±100	A.D. 1318, 1343, 1392	A.D. 1289-1424	charcoal	Waters 1983

Cluster	Site	Elev-ation	Comments
4	IMP-5959	+ 0	From a site with two "seeds" from aquatic algae. See also A-6672 and A-6674. Interpreted as relating to a recessional shoreline.
4	IMP-4926	-100	From a hearth containing fish bone. Association seems to point to a late-stage recession of the lake.
5	RIV-1179	> +40	From the upper level of a cremation. See also UCR-2083, UCR-2084, UCR-2085, and UCR-2094. Associated with fish bone but also with an anomalous <150 B.P. date.
5	Myoma Dunes	> +40	From a human coprolite containing *Cucurbita pepo* seeds.
-	IMP-6427	-180	Discussed in present report. This date is anomalous when compared with others from the site.
3	RIV-3682	> +40	See also Beta-37900, Beta-37901, Beta-37902, and Beta-37904. Regarded as suspect by reporter because of lateness. Seems well associated with a full lake stand.
3	CA-RIV-1769	> +40	See also Beta-36961. Seems well associated with a full stand of the lake.
3	Wadi Beadmaker	> +40	See also UCR-348, UCR-349, and UCR-350. Seems to be fairly well associated with a full stand of the lake.
3	—	> +40	From a site near the mouth of Fish Creek Canyon. See also M-597, LJ-GAP-57, and LJ-GAP-59. The fact that the site is perhaps two miles from Fish Creek itself lends credence to the interpretation that the date relates to a full stand of Lake Cahuilla, although lacustrine resources in association with it are not specifically reported.
3	RIV-3143	> +40	Seems well associated with a full stand of the lake.
3	Wadi Beadmaker	> +40	From a subsurface level also containing fish bone. Date is plausibly associated with a full lake stand.
3	—	- 1	From Waters' Locality B, a lacustrine deposit separated by a fluvial stratum from the lacustrine deposit from which UCR-998 was collected. Date is plausibly interpreted as dating a lacustral interval.
3	—	> +40	From a subsurface occupation streak at the same site as LJ-GAP-58. This streak had been previously dated as M-597, the result of which was considered too recent to be plausible. It comes from a buried occupation streak in a sand-dune site, which also supports the proposed relation to a full stand of Lake Cahuilla.
3	IMP-4434	> +40	From a hearth in an excavation unit also producing fish bone and Patayan II ceramics. Date is plausibly associated with a full lake stand.
3	—	- 3	From Waters' Locality C in a lacustrine deposit. Date is plausibly interpreted as dating a lacustral interval.
3	RIV-1769	> +40	See also Beta-36960. Seems well associated with a full stand of the lake.
2	RIV-2985	-49	See also Beta-17475 and Beta-17949. Interpreted as possibly distorted by "old wood" problem from driftwood deposited by Whitewater River.
2	IMP-6297/6298	-180	From a hearth. See also Beta-42009. Dates either a nonlacustrine period or a period in which the lake level was very low.
2	IMP-5204	+ 0	From several excavation units in a site with fish bone. See also Beta-14195. Should date an early-stage recession of the lake. Schaefer suggested that the date is too early and most likely derives from wood which had died long before it was used.
2	—	- 3	From Waters' Locality A, in a hearth with burned fish bone and shell, in lacustrine deposits interbedded with fluvial deposits. See also UCR-992, UCR-993, and UCR-995. Date is interpreted as dating a lacustral interval (or perhaps more properly an episode of at least partial recession).

Table 20. Radiocarbon dates relating to Lake Cahuilla after A.D. 1000 (continued).

Lab No.	^{14}C Age	^{13}C-Adjusted Age	Date	One-σ Range	Material	Reference
UCR-992	770 ±100	655 ±100	A.D. 1304	A.D. 1280-1407	charcoal	Waters 1983
UCR-2084	670 ± 65	–	A.D. 1300	A.D. 1284-1325, 1336-1394	charcoal	Sutton 1988a
UCR-995	750 ±100	680 ±100	A.D. 1298	A.D. 1274-1400	charcoal	Waters 1983
LJ-GAP-57	720 ±100	–	A.D. 1288	A.D. 1229-1316, 1346-1391	charcoal	Hubbs and Bien 1967
Beta-37901	620 ± 50	750 ± 50	A.D. 1282	A.D. 1250-1293	charcoal	Yohe 1990
LJ-99	760 ±100	–	A.D. 1280	A.D. 1214-1303	charcoal (mostly tule)	Hubbs et al. 1960
Beta-37900	620 ± 50	790 ± 50	A.D. 1263	A.D. 1221-1284	charcoal	Yohe 1990
Beta-37534	770 ± 60	800 ± 60	A.D. 1253	A.D. 1213-1284	charcoal	Arkush 1990a
UCR-2085	820 ± 75	–	A.D. 1229	A.D. 1166-1283	charcoal	Sutton 1988a
LJ-965	830 ±140	–	A.D. 1225	A.D. 1032-1295	*Anodonta* shell	Hubbs et al. 1965
UCR-998	1190 ±100	835 ±100	A.D. 1223	A.D. 1048-1090, 1118-1142, 1154-1285	Anodontal shell	Waters 1983
Beta-17949	900 ± 70	900 ± 70	A.D. 1165	A.D. 1032-1226	charcoal	Dominici 1987
UCR-993	1295 ±100	945 ±100	A.D. 1044, 1104, 1112, 1147, 1151	A.D. 1008-1220	*Anodonta* shell	Waters 1983
LJ-106	960 ±100	–	A.D. 1037	A.D. 997-1214	charcoal	Hubbs et al. 1960
LJ-7	1000 ±200	–	A.D. 1022	A.D. 871-1254	charcoal	Hubbs et al. 1960
LJ-960	1010 ±200	–	A.D. 1020	A.D. 821-840, 860-1246	*Anodonta* shell	Hubbs et al. 1965
Beta-37533	1060 ± 60	1030 ±60	A.D. 1014	A.D. 978-1032	charcoal	Arkush 1990a

	Cluster	Site	Elevation	Comments
	2	—	-3	From Waters' Locality A, in a hearth with burned fish bone and shell, in lacustrine deposits interbedded with fluvial deposits. See also UCR-993, UCR-994, and UCR-995. Interpreted as dating a lacustral interval (or perhaps more properly an episode of at least partial recession).
	1	RIV-1179	> +40	From a hearth. See also UCR-2083, UCR-2085, UCR-2093, and UCR-2094. Date is apparently well associated with a full stand of Lake Cahuilla.
	2	—	-3	From Waters' Locality A, in a hearth with burned fish bone and shell, in lacustrine deposits interbedded with fluvial deposits. See also UCR-992, UCR-993, and UCR-994. Interpreted as dating a lacustral interval (or perhaps more properly an episode of at least partial recession).
1967	1	—	> +40	From the same site as LJ-GAP-58 and LJ-GAP-59 but from a stratigraphically-lower occupation streak.
	1	RIV-3682	> +40	See also Beta-37900, Beta-37902, Beta-37904, and Beta-37905. Appears well associated with a full stand of the lake.
	1	—	< +40	From a deposit of lake silt which is interbedded with beach gravels, near the western shoreline in Imperial County. Strata were interpreted as relating to cycles of inundation by the lake (probably relating to fluctuations in the lake level). Episodes of alluvial erosion might account for the gravels. Seems well associated with a full stand of the lake.
	1	RIV-3682	> +40	See Also Beta-37901, Beta-37902, Beta-37904, and Beta-37905. Appears well associated with a full stand of the lake.
	1	RIV-3683	> +40	See also Beta-37533. Appears to be well associated with a full lake stand.
	1	RIV-1179	> +40	From a hearth. See also UCR-2083, UCR-2084, UCR-2093, and UCR-2094. Apparently well associated with a full stand of the lake.
	1	—	+1200	From a hearth on Fish Creek in eastern San Diego County. The hearths contained numerous fish bones; the fish are thought to have run up Fish Creek from Lake Cahuilla for spawning. Be that as it may, the date seems to point to a period when the lake was present.
	1	—	-3	From Waters' Locality B, in a lacustrine deposit. Plausibly interpreted as dating a lacustral interval.
	1	RIV-2985	-49	See also Beta-17475 and Beta-17947. Interpreted as probably distorted by "old wood" problem from driftwood carried by Whitewater River.
	1	—	-3	From Waters' Locality A, in the same stratum as UCR-992, UCR-994, and UCR-995, containing lacustrine deposits interbedded with fluvial deposits. Plausibly interpreted as dating a lacustral interval.
	1	—	> +40	From a buried lens. Fish bone and a potsherd were associated. Correlation with a full lake stand seems reasonable.
	1	—	+1200	From the same location as LJ-965. Both dates seem firmly tied to a stand of Lake Cahuilla.
	1	—	> +40	Association with a full lake stand appears good.
	-	RIV-3683	> +40	See also Beta-37534. Association with a full lake stand appears good. Old wood problem considered probable by reporter because of discrepancy with Beta-37534.

Table 26. Fish remains identified from Lake Cahuilla sites.

Site	Elevation (ft. AMSL / BMSL)	*Elops affinis* (machete)	*Gila elegans* (bonytail)	*Mugil cephalus* (striped mullet)	*Ptycho-cheilus lucius* (Colorado squawfish)	*Xyrauchen texanus* (razorback sucker)	Unident-ified	Reference
Myoma Dunes coprolites [1]	> +40	-	19	1	-	7	46	Wilke 1978
Wadi Beadmaker coprolites [1]	> +40	-	2	-	-	2	6	Wilke 1978
CA-RIV-1179 / 2827 [2]	> +40	-	805	1	8	329	11,588	Follett 1988
CA-RIV-1331 / 1349 [2, 3]	> +40	1	360	-	13	38	10	Schaefer and Pallett 1993
CA-RIV-1769 [2]	> +40	-	469	-	17	431	-	Gobalet 1992
CA-RIV-2196 [2]	> +40	-	38	-	-	52	-	Gobalet 1992
CA-RIV-2936 [2]	> +40	-	2	1	-	3	-	Gobalet 1992
CA-RIV-3143 / 3144 [2]	> +40	-	13	-	-	12	-	Galet 1992
CA-RIV-3681 / 3682 / 3683 [2]	> +40	1	475	35	11	370	-	Gobalet 1992
CA-RIV-3793 [2]	> +40	-	1	1	4	78	-	Gobalet 1992
JM-1 [2]	> +40	1	295	18	-	48	-	Gobalet 1992
CA-IMP-4434 [4]	> +40	-	48.08	6.19	-	3.44	375.90	Gallegos 1986
CA-IMP-5205 [5]	> +40	-	+	+	-	-	-	Schaefer 1986
CA-IMP-5260 [2]	> +40	-	262	-	-	11	-	Eighmey and Cheever 1992
CA-IMP-5296 [2]	> +40	-	-	-	-	4	-	Schaefer 1987
Superstition alkali pans [2]	> +40	-	4	-	-	16	115	Schaefer 1988
Magma Site [6]	+31	-	2.36	2.85	-	248.53	-	von Werlhof et al. 1979
CA-IMP-5204 [7]	+0	2	171	4	2	14	-	Schaefer 1986
CA-IMP-3678 [2, 5]	-93	-	40	1	-	36	+	Follett 1985
CA-IMP-3688 [2]	-93	-	33	1	-	33	-	Rosen 1985b
house ruins [8]	-95	-	++	-	-	++	-	Wilke 1978
CA-IMP-4926 [5]	-100	-	-	-	-	+	-	Phillips 1982
Thermal airport [5]	-103	-	+	-	-	+	-	Wilke 1978
CA-IMP-4931 [5]	-120	-	-	-	-	+	-	Phillips 1982
San Sebastian [2]	-120	-	18	-	-	19	22	Schaefer et al. 1987
Elmore Site [2]	-180	1	4	-	-	35	30	Laylander 1991a

1 counts of number of coprolite samples with bone from species
2 counts of elements
3 bonytail, squawfish, and razorback sucker reported as *Gila sp.*, *Ptychocheilus* sp., and *Xyrauchen* sp. respectively
4 weights in grams
5 + = present
6 weights in grams; *Xyrauchen texanus* total includes 76.95 reported as "*Xyrauchen* (?) vertebrae"
7 minimum numbers of individuals
8 ++ = present in abundance