THE PHYSICAL ANALYSIS OF NINE INDIAN MOUNDS OF THE LOWER SACRAMENTO VALLEY

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S. F. COOK and R. F. HEIZER

With the collaboration of Martin Baumhoff, Thomas Bolt, Albert Elsasser, Gordon Grosscup, and James Robson

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MAPS

Abbreviations

AA	American Anthropologist
A Ant	American Antiquity
UC	University of California Publications
–PAAE	American Archaeology and Ethnology
–AR	Anthropological Records
UCAS	University of California Archaeological Survey
–R	Reports
USGS	United States Geological Survey

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INTRODUCTION

DURING the past few years a group of faculty members and their students at the University of California, Berkeley, have been interested in physical and chemical analysis as a tool for the investigation of problems in archaeology.* The first premise upon which we have proceeded has been that to reconstruct the life of extinct peoples it is necessary to utilize all material residues derived from their activity—not only pottery, buildings, and works of art but also bones, soil, dirt, and refuse of any description. Our second premise has been that no tangible material is too crude or too insignificant to tell us something concerning the conditions under which aboriginal populations carried on their existence.

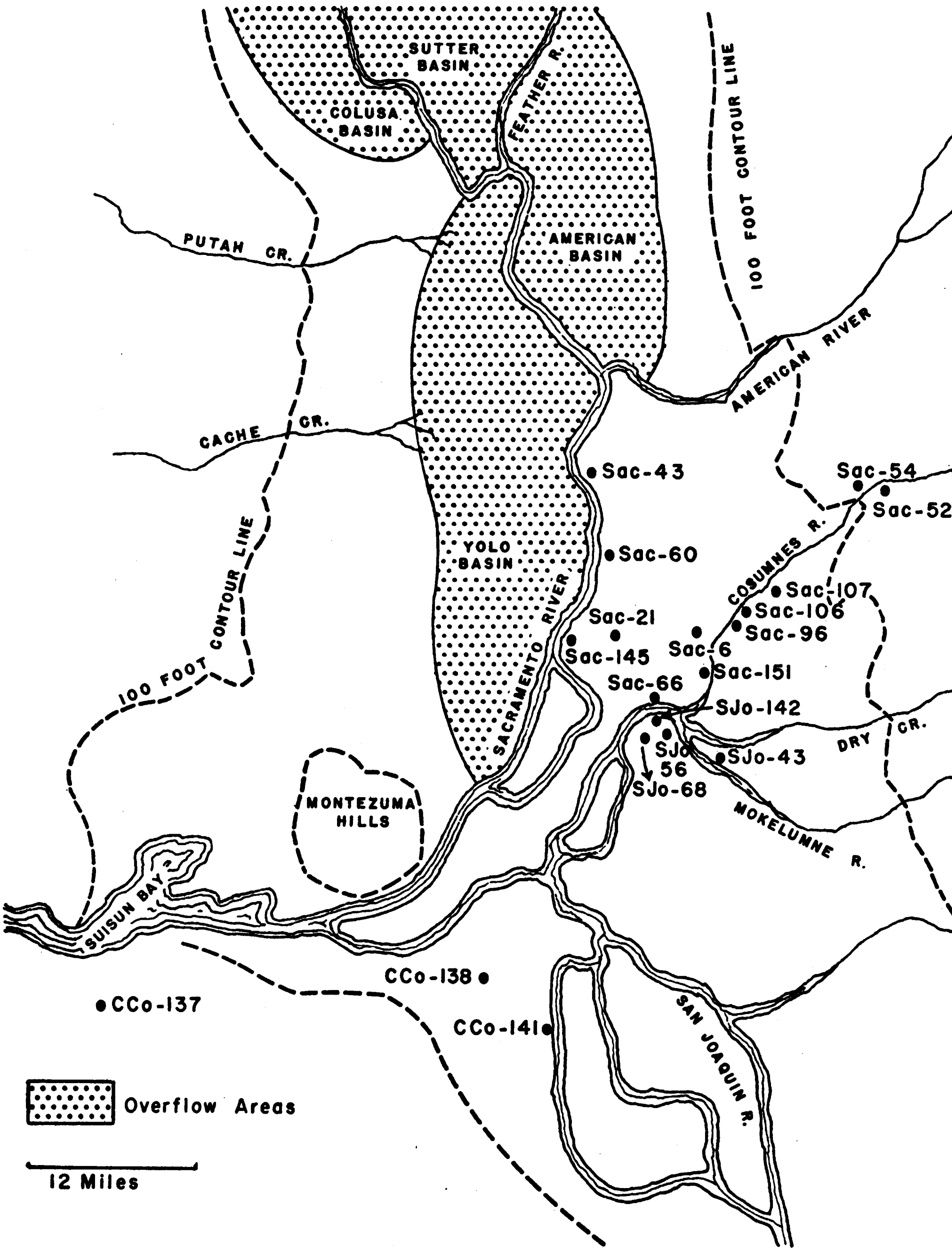
To establish our methods we started with the literal dissection, or complete excavation, of a single small habitation site from which every cubic foot of earth was weighed and every artifact and bone counted. This enabled us to lay down a general formula for the sampling of other sites which would assure an adequate statistical treatment of the content but at the same time would reduce the manual labor to a feasible amount.[1]

Subsequently, a series of sites was sampled—a series embracing several of the important archaeological areas in California. It was then possible to point out how these areas differed, both qualitatively and quantitatively, in certain aspects of material culture and to correlate these differences with variations in the physiography and ecology of the corresponding regions. In this particular instance many of our conclusions could have been reached equally well by the use of ethnographic data. However, our results demonstrated that physical analysis leads to essentially correct deductions even in the total absence of any ethnographic knowledge. It is therefore particularly well adapted to the investigation of those aboriginal populations concerning which there is no written or verbal record whatever.

In the present paper we proceed along the lines already laid down and present the results of a number of different but interrelated investigations that have been

* The authors acknowledge with thanks the financial assistance, in this investigation, of the Viking Fund, Inc., of New York, and of the Committee on Research, University of California.

[1] S. F. Cook, A Reconsideration of Shellmounds with Respect to Population and Nutrition, AA, 12:51–52, 1947; S. F. Cook and A. E. Treganza, The Quantitative Investigation of Aboriginal Sites: Comparative Physical and Chemical Analysis of Two California Indian Mounds, A Ant 13:135–141, 1947; A. E. Treganza and S. F. Cook, The Quantitative Investigation of Aboriginal Sites: Complete Excavation with Physical and Archaeological Analysis of a Single Mound, A Ant 13:287–297, 1948; S. F. Cook and A. E. Treganza, The Quantitative Investigation of Indian Mounds with Special Reference to the Relation of the Physical Components to the Probable Material Culture, UC–PAAE, 40:223–262, 1950.



Map 1. Sites in Lower Sacramento Valley

carried on during the past year and a half. In doing so we indicate new applications of the general method and suggest certain new problems.[2]

By the methods described in previous publications it has been possible to compare numerous habitation sites on the basis of relatively indestructible components, particularly rock, shell, bone, and charcoal. In all these sites, however, little if any trace now remains of the vegetable and nonosseous animal residues they must once have contained. The loss is due to the many decades that have elapsed since the sites were occupied, with the consequent disappearance of plant material through organic decomposition. Open sites are exposed to rain and to soil moisture which make possible rapid action by microörganisms and promote oxidation.

AMADOR-3: THE STUDY OF A DRY CAVE DEPOSIT

We have been fortunate recently in discovering a cave site (Ama-3) containing a single extensive deposit, part of which was exposed to the weather, part protected by the overhanging roof (pl. 23, *a, b*). A direct comparison of the deposit in the two parts, one wet and the other dry, is therefore within the scope of physical analysis.

The cave lies in Amador County, in T. 4N, R. 10E, about ten miles northeast of Clements, San Joaquin County. In recent times this spot was close to the boundary between the Northern and Plains Miwok.[3] A dry cave deposit in Miwok territory is of particular interest because we have an excellent published analysis of the Miwok material culture that can be used for comparison with the older cave finds.[4] The cave is in a vertical exposure of andesitic tuff (Mehrten formation), which has weathered out to form a level-floored area 190 ft. long and from 20 to 80 ft. wide. The entrance is about 10 ft. high and the roof drops toward the back so that in the rear the cave is only about 2 ft. high.

Inside the cave the occupation midden has been preserved in a dry and undisturbed condition so that even the most delicate plant tissues, like leaves and grass, though thoroughly desiccated have undergone no other apparent physical or chemical alteration. The deposit, however, extends in an unbroken horizon out past the mouth of the cave and beyond any shelter to a region fully exposed to winter rains. In this peripheral area the matrix appears to consist principally of rock and dark soil, thus resembling that of most open sites.

We were able to secure four samples of the material inside the cave (interior or dry deposit) and two samples from well outside (exterior or wet deposit). Although

[2] This report is definitive in one sense, however, for most of the data upon which it is based are derived from a specific program of field work carried out in the summer of 1949. The University of California Summer Session class in archaeology, in which eleven students participated, spent the six weeks from June 18 to August 1 in the Cosumnes Valley and lower Sacramento Valley screening 5 × 5 ft. test pits and collecting column samples of deposit from the vertical walls of these pits. The careful control of stratigraphic measurement, the close inspection of the screenings—which were washed, dried, and sorted for bone, shell, stone, artifacts, etc.—and the continual attention devoted to the problem of interpretation of refuse deposits was a valuable experience for everyone concerned. The results reported here are largely due to the labors of this student group. Those students listed on the title page as collaborators were among the group and should properly be considered co-authors.

[3] A. I. Kroeber, Handbook of the Indians of California, BAE–B 78, pl. 37, 1925.

[4] S. A. Barrett and E. W. Gifford, Miwok Material Culture, Bulletin of the Public Museum of the City of Milwaukee, 2:117–276, 1933. A paper on the archaeology of site Ama-3 will be published by A. E. Treganza and R. F. Heizer.

TABLE 1

ANALYSIS OF SIX SAMPLES FROM SITE AMA-3

Components	Composition of samples (Percentage of total weight)[a]							
	From wet part of site			From dry part of site				
	1 (11,030 gm.)	6 (10,505 gm.)	Mean	2 (9,000 gm.)	3 (8,853 gm.)	4 (8,965 gm.)	5 (7,718 gm.)	Mean
Rock								
Total	20.00	18.38	19.19	12.62	14.32	18.46	14.35	14.80
Imported	14.03	16.33	15.18	9.46	10.35	9.73	8.16	9.42
Wood								
Charcoal; carbonized	0.666	0.660	0.663	0.605	0.465	0.607	0.509	0.546
Scraps	0.0	0.0	0.0	0.2288	0.3028	0.2678	0.3122	0.2779
Bone	0.0746	0.0733	0.0740	0.0417	0.0316	0.1177	0.0833	0.0685
Shell and seed hulls								
Mussel	0.0079	0.0250	0.0165	0.0024	0.0022	0.0878	0.0037	0.0240
Acorn and buckeye	0.0189	0.0	0.0094	0.5910	1.1690	1.6620	0.7630	1.0460
Leaves	0.0	0.0	0.0	0.0189	0.0949	0.0357	0.0195	0.0422
Grass, straw, seeds, undetermined plant fragments	0.0182	0.0	0.0091	2.8490	3.3580	3.1320	3.1920	3.1330

[a] The very fine residue (dirt) which was not segregated brings the total of each column to 100 per cent.

the small number of samples precludes any rigid statistical analysis, nevertheless certain differences between the two areas show very clearly. The data are presented in table 1, in which the individual components are expressed in terms of percentage of total weight of the samples.

It is evident that the stable materials—rock, bone, charcoal, and shell (fresh-water mussel)—appear at substantially the same level of concentration in both the wet and dry parts of the deposit, as would be expected in a homogeneous accumulation. The rock found in the samples is derived from two distinct sources. One is the cave itself, the walls of which consist of a soft friable sandstone possessing some cohesive strength but poorly adapted for hearths or stone boiling. Hence the occupants were forced to bring in rocks of greater density and tougher consistency. Accordingly we find this denser and tougher rock comprising from 8 to 16 per cent of the total weight. On the whole, if we allow for the small number of samples, we may conclude that no significant change takes place in the relative quantity of inorganic constituents of a habitation midden during exposure for one or two centuries to the normal outdoor climate of Central California.

The perishable matter makes up approximately 4.5 per cent of the weight of the dry deposit. Careful separation of the component pieces reveals that the bulk of the material consists of grass, straw, seeds, and very numerous minute vegetal fragments the nature of which could be determined only with a microscope. The remainder is composed largely of whole or broken hulls of acorn and buckeyes, nuts which seem to have been an important dietary staple. There is also a considerable quantity of wood scraps, most of them in a perfectly preserved condition. Finally, there are many dried oak leaves. Collectively these objects form exactly the type of refuse and debris which we should expect the former occupants to derive from the neighboring vegetation (pl. 24, *a*), the debris being scattered at random throughout the interior of the cave.

Of the two samples (nos. 1 and 6 in table 1) from the wet deposit, one contains no indication whatever of the organic debris found in such profusion in the dry deposit. The other shows small traces (approximately 0.04 per cent) of acorn hull and grass. The grass may have blown in from the adjacent fields during recent times. This almost complete disappearance of plant residues from the wet, exposed deposit is definite evidence that whatever material of this nature the wet part of the site originally contained has been entirely decomposed within a period of not much more than one hundred years.[5] It is also reasonable to deduce that at the time of occupation many, if not all, of the open sites of the Central Valley and near-by foothills resembled in texture and composition the dry deposit now found in the Amador cave. This deduction is discussed further in the following section.

With respect to the life of the cave inhabitants we may conclude that the natives brought in large amounts of grass and straw, probably to sleep on. Small twigs and leaves were scattered about in profusion. Larger pieces of wood were used either for fires or for other purposes, since many of the scraps appear to have been worked on by human hands. The many worked wood artifacts include digging sticks, arrow-shaft fragments, and other implements. Local acorns and buckeye nuts

[5] The cave appears to have been last occupied in late prehistoric and early historic time, probably 1800–1850. Presumably, earlier use of the cave extends into the full prehistoric period.

were gathered and hulled inside the cave; otherwise no such mass of hulls could have accumulated. From the relative frequency of the two kinds of husk it may be inferred that both types of nut were consumed in roughly equal quantities. The high level of charcoal, furthermore, indicates many fires, which blackened the walls of the cave, if one may judge by smoke-blackened walls and roof and the loose fragments of cave rock covered with a soot layer. Intense application to cooking is indicated also by the high percentage of imported rock, which could have been used only for hearths and boiling stones. This inference is further corroborated by the discovery of several fist-sized boulders still covered by a dried film of flour mush, probably derived from acorn flour. The picture thus emerges of intensive human activity, directed principally toward gathering and preparing foodstuffs: bulbs, acorns, buckeye nuts (indicated by husks), meat (indicated by numerous mammal and bird bones) and shellfish—freshwater mussels from the river a few miles away. These activities must have been concentrated in relatively short periods of time during which the cave provided shelter and piles of grass served as bedding.

This theory of the cave as a transitory home for food-gathering expeditions is supported by the huge numbers of rat and mouse pellets in all the dry samples, amounting to approximately 1 per cent of the total mass. The pellets are not found primarily on the surface or in pockets, as they would be if these rodents had been active *since* the last occupation, but are distributed uniformly throughout the mixture. Hence it may be argued that *during* the occupation era there were frequent periods long enough for rats and mice to enter the cave, burrow through the refuse, and perhaps even go through a breeding cycle. Any cave exhibits strong evidence of rodent habitation but the enormous quantity of fecal material in this particular cavern postulates some special attraction for the animals. The fresh residues from extensive culinary operations would be just such an attraction.

RECONSTRUCTION OF AN OPEN SITE

From the appearance and composition of the dry deposit found in the Amador cave, it may be possible to draw certain inferences concerning the surface, or active, habitation layer of other sites during the time of actual occupancy. As a concrete example we may consider the Johnson mound, site Sac-6, which lies about seven miles northeast of Thornton.

The probable composition of the surface layer, say the uppermost six inches, may be computed directly from the data derived from Ama-3. If we assume, as is reasonable, that the living conditions and the plant and animal environment were quite similar at both sites, then the relative differences between the wet and dry parts of the Amador deposit may be considered to hold for Sac-6 without much modification. Specifically, the deposit in the wet part of the cave has undergone the same changes that produced the present-day mound matrix at Sac-6, whereas the dry deposit may be regarded as simulating what the fresh, unaltered surface of Sac-6 was during the period of inhabitation. Applying the Amador cave data directly to the analyses of column samples for Sac-6, given in table 3, we get the following comparison. (All figures are per cent of total sample weight.)

	Present soil of Sac-6	*Aboriginal surface layer of Sac-6 at time of occupation (calculated)*
Rock and clay	11.47	7.12
Bone	0.63	0.58
Shell	0.06	0.08
Charcoal	0.30	0.25
Total organic matter	...	4.50
Acorn hulls	...	1.05
Wood scraps	...	0.28
Leaves	...	0.04
Grass, straw, seeds, and other plant fragments	...	3.13
Soil, powdered clay, etc.	87.55	87.47

The soil and the imperishable materials in the aboriginal surface layer appear in almost the same amounts as in the weathered deposit of today. The primary difference is the presence of 4–5 per cent organic matter in the aboriginal surface layer. It would be erroneous to assume, however, that the physical appearance and consistency of the Sac-6 surface was identical with what we now find inside the Amador cave.

The Amador cave material was laid down continuously on a surface which, being always dry, was preserved from decomposition during occupancy as well as throughout the time elapsed since abandonment of the site. The Sac-6 midden material was deposited continuously on a surface that was dry in summer but wet in winter. Hence animal and plant residues were subject to decomposition during the wet season only. We may visualize the condition at Sac-6 somewhat as follows.

In May and June the ground dries out and becomes dusty from great quantities of fine soil and clay. The inhabitants bring in grass and straw for beds, and brush and twigs from firewood are scattered about. Acorn hulls and small animal bones are distributed over the surface, as well as household rubbish of all descriptions, and these particles are trampled into the upper layer of dust which begins to take on the consistency of the dry Amador deposit. As the long dry season continues, the surface layer resembles more closely the dry deposit at Ama-3, but when the late autumn rains begin, the dry dust becomes a sea of mud, incorporating within it all the refuse deposited during the summer. Now, with the advent of moisture, the fecal material and bits of dried animal flesh rapidly decay and, under the influence of molds and bacteria, such lighter plant fragments as leaves and grass stems begin to decompose. To be sure, new deposits are laid down, but in these decomposition also proceeds with rapidity. By March or April, when the ground begins to dry out, most of this material has probably disintegrated, leaving intact only such hard and indurated substances as the fiber of leaves and grasses and the woody parts, together with the bones of the animals. By June, therefore, the previous summer's increment has largely disappeared. The cycle then repeats itself.

It is thus apparent that the deep dry deposit of the type found in the Amador cave never got a chance to accumulate in an open site and that exposed deposits remained always in the incipient stage of formation, best developed in late summer and fall, retrogressing in winter and spring. The inhabitants thus lived half the year upon a dusty surface partly covered with grass, sticks, leaves, acorn hulls, cast-off domestic refuse, and both human and animal fecal matter, whereas winter turned the surface into a muddy mass within which all these materials slowly rotted. The extent of the putrifactive process is graphically indicated by the amount of the organic component preserved in the Amador cave deposit.

THE CONTENT OF ASH ACCUMULATIONS

The extensive excavation of mound Sac-6 on the Cosumnes River disclosed a number of large ash lenses. These appeared to be masses of fine white ash plus partly burned refuse that had accumulated near the site of a hearth or fireplace. Indeed, the observations in the field make it clear that these white ash accumulations represent materials taken from fireplaces in the houses and disposed of somewhere in the village area.

If the composition of such lenses differs significantly from that of the unspecialized mound soil, then the random sampling of the latter by our usual methods may be subject to certain error. To investigate this point eight samples of ash, taken from seven different pits and trenches, were examined in the customary manner. The results could then be compared with random soil samples obtained on an unselected basis from the mound as a whole. The mean values of the components of the ash samples are presented in table 2, together with those for thirty-seven random pit column samples.

Without attempting to compute the statistical significance of the differences between the ash and soil samples we may conclude from a simple inspection of the data that:

1. There is no important difference in the percentages of rock, shell, or obsidian.
2. There is approximately four times as much total bone and charcoal per unit weight of deposit in the ash as in the mound generally.
3. The ratio of fish bone to total bone is very much higher in the ash.

These conclusions merit further examination with reference to two distinct aspects, statistical, and ethnographic or ecological.

VALIDITY OF SAMPLING

The presence of ash lenses does not disturb the values for rock, shell, and obsidian obtained by random sampling of pits and trenches. For bone and charcoal, however, too low or too high values may be obtained if the ash lenses do not occur at normal frequency in the walls of the pits or trenches actually sampled. The determination of the normal frequency of ash lenses in a specific site would require the almost complete excavation of the site, a procedure impracticable under actual field conditions. Therefore, in the present paper, it must be assumed that some error is introduced in this way, but it appears that the error is not great enough to invalidate the conclusions.

The mathematical evaluation of the disturbing effect of ash lenses necessitates a number of simplifying assumptions. Because we do not have the required information concerning any actual existing site, let us consider a purely hypothetical mound. The soil of this mound, apart from ash lenses, contains 0.1 per cent charcoal by weight, a figure within the range of values given in table 3 for column samples.

In addition, we will postulate, first, that the mound is square, 200 ft. on a side, and everywhere exactly 10 ft. deep; second, that within each 10 ft. cube of soil there is an ash lens 5 ft. long, 5 ft. wide, and just 1 ft. thick, the depth at which each lens occurs being random and immaterial. Every lens contains charcoal in a concentration of 0.4 per cent by weight, or four times the value for the normal, or nonashy, deposit. We are allowed to take three columns or drive three borings in such a way as to yield thirty samples, each 1 ft. thick. The location of the pits or borings in relation to the surface exposure is determined solely by chance. We wish to know how much our final mean value for charcoal is distorted by the random penetration of ash lenses and hence by the inclusion of ash in the samples.

TABLE 2

MEAN VALUES OF CERTAIN COMPONENTS IN ASH SAMPLES FROM SITE SAC-6

Components	Percentage of total weight[a]	
	Ash samples (8)	Random soil samples (37)
Rock and clay	13.86	11.47
Bone	2.549	0.624
Fish bone	2.114	0.176
Shell	0.064	0.058
Charcoal	1.257	0.298
Obsidian	0.0198	0.0107

[a] The very fine residue which was not segregated brings the total of each column to 100 per cent.

The total volume of the site is 200 × 200 × 10 ft. or 400,000 cu. ft. Since there is one ash lens under every 100 sq. ft. of surface there are 400 lenses in all, with a total volume of 400 × 25 ft. or 10,000 cu. ft. Thus 10,000 cu. ft. contain 0.4 per cent charcoal, whereas the other 390,000 contain 0.1 per cent, and the mean content for the entire site is 0.1075 per cent.

The probability that any single column or boring will pass through an ash lens is 1 : 4, and of its *not* encountering one is 3 : 4. With three tries (or columns) the probability of missing an ash lens in all three is $(3:4)^3$ or 27 : 64 or 0.422; the probability of striking one lens is 0.422, that of striking two lenses is 0.141, and that of striking three lenses (one in each column) is 0.015. Now, with no ash, the mean value of charcoal in the samples would be 0.1 per cent. If ash was contained in one sample, the mean value would be 0.11 per cent; if in two samples, 0.12 per cent; and if in three samples, 0.13 per cent. The error in the first value is minus 7.5 per cent, in the second plus 2.5, in the third plus 12.5, and in the fourth 22.5. But it has been shown that under the assumed conditions the probability of getting either no ash or one sample with ash is 0.844. Hence there are better than four chances in five that the error introduced by ash will not exceed 7.5 per cent. There is one chance in twelve that it will be 12.5 per cent and about one chance in sixty-seven that it will reach 22.5 per cent. Since the sampling error itself, irrespective of ash, will always amount to fully 10 per cent, the probability, with only thirty samples, of a serious disturbance of the data because of the presence of lenses is very slight.

Although the discussion above is based on a purely imaginary site, it nevertheless approximates known field conditions and situations closely enough to warrant the belief that ash lenses do not seriously impair the validity of the results obtained.

ETHNOGRAPHIC INFERENCES

In the summer of 1949 the expedition camp was situated on the edge of Sac-6, and this mound was more completely excavated than any other during the season. The site, a prominent elevation in the flat alluvial plain, may be described as a refuse midden which caps an original red-clay subsoil knoll. The surface of the site stands 8 ft. above the present surrounding land level, and the thickness of the midden cap varies from 2.5 ft. to 8 ft. At some time in the last forty years a low swampy area containing a shallow, marshy lake, fed by a meander channel of the Cosumnes River, lay just north of the site. From the waters of this lake must have come the fresh-water mussels, fish, and waterfowl, whose remains are so abundant in the midden layers of the village site. The lake borders no doubt produced an abundance of tule, swamp rushes, and the like, from which thatched house coverings, matting, baskets, and similar items were manufactured. Evidences of such industry (carbonized specimens) have been recovered from the site.[6] The borders of local streams bear a heavy growth of willow and cottonwood. Oaks form a parkland in the neighborhood. Charcoal from the midden, when its components can be identified, is usually of willow or oak. There were large numbers of tule elk which were an important article of the meat diet. Furthermore, their bones were much used for implements since they are large, dense, and heavy.

The absence of stone in the alluvial plain made it necessary to import rocks for the stone-boiling of foods or to find a substitute for them. The people may alternatively have given up basket-boiling in favor of boiling in clay-lined pits, using wooden bowls or pottery vessels. The presence in the area since ancient times[7] of hand-molded, baked clay objects offered an easier solution to this problem, and until the historic period clay cooking stones were manufactured as a stone surrogate. It is clear that there are more cooking stones in the midden than could reasonably have been used by the population of Sac-6 alone[8] and it is highly probable that this village was a manufacturing and distributing center for clay cooking balls. This would explain in part the abundance of ash deposits and the amazing quantities of fired clay objects. Our evidence indicates that the clay balls were fired in the houses; it is therefore probable that the clay industry was operated on a family basis. At the southwest edge of the midden is a large depression, which has been studied by Dr. Hans Jenny, of the Division of Soils of the University of California, who concludes that it is a borrow pit from which red clay was dug, presumably for making clay balls.

The very high proportion of fish bone in the ash, as contrasted with bird and mammal bone, is noteworthy. We may infer that the Indians used the fireplace

[6] W. E. Schenck and E. J. Dawson, Archaeology of the Northern San Joaquin Valley, UC-PAAE 25:289–413, 1929. Note pp. 395 ff.

[7] In the Early Horizon, whose antiquity is known to be at least 4,000 years, such objects were made. See discussion in a recent paper by R. F. Heizer, The Archaeology of Central California, I: The Early Horizon, UC-AR 12:1, 1949.

[8] For a discussion of the magnitude of the baked clay industry at site Sac-6 see the paper by Cook and Treganza, UC-PAAE, 40:223–262, 1950.

as a garbage dump, into which they threw the residues of fish and other small objects for incineration, whereas they threw the bones of larger animals casually on the surface of the mound. The larger bones may also have been scattered by dogs although few bones show clear signs of gnawing.

On the other hand, the surfaces of the house floors exposed at site Sac-6 are composed of thin laminae of earth which contain an abundance of unburned fish bone. Now the fact that many of the fish bones (mostly ribs and vertebrae) in the ash pits are unburned, even though enclosed in a matrix of fine, powdery, white wood ash resulting from complete combustion of wood, leads us to suppose that these unburned bones come from floor sweepings of the houses rather than from incineration. If this is so, we have inferential evidence of a domestic custom, evidence which, unimportant per se, illustrates the sort of reconstruction of prehistoric activity made possible by the physical analysis of mound remains.

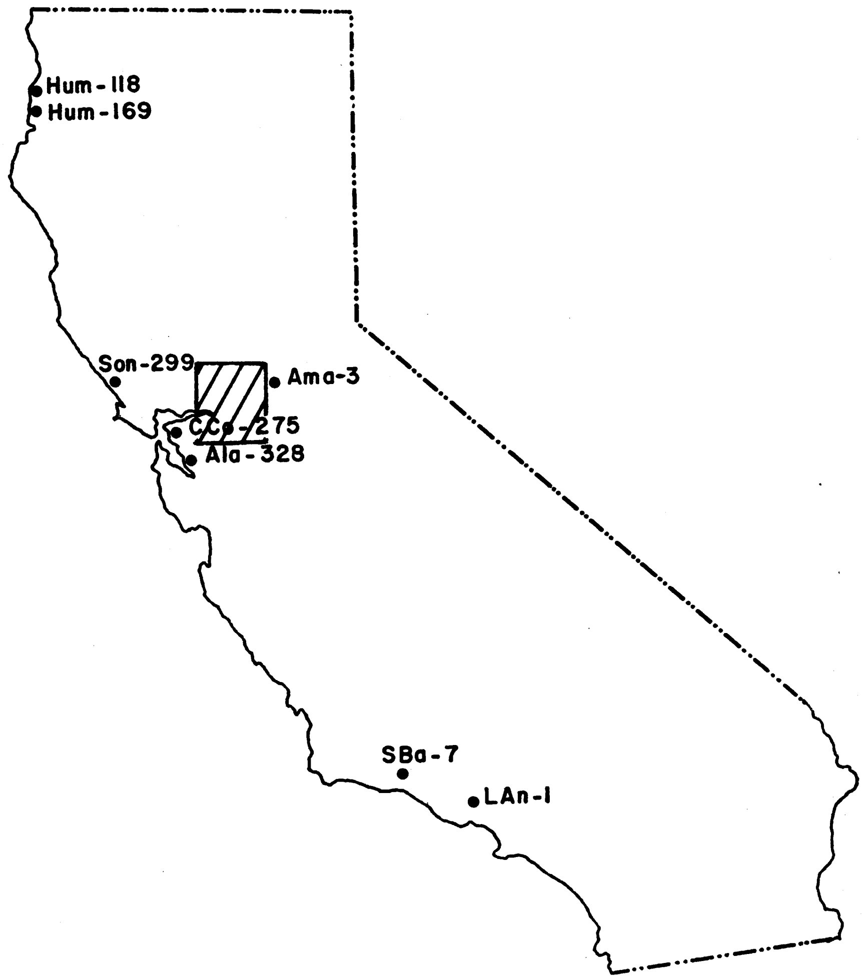
The small obsidian chips in the ash pits suggest that the men practiced their art of arrow-point flaking in the houses as well as outdoors.

FIELD VERSUS COLUMN SAMPLING

The standard procedure for physical analysis which we evolved in the preliminary tests described elsewhere entails the taking of a series of column samples. Each sample is then brought to the laboratory and passed through a 1/8-in. or 2-mm. screen. Comparisons are then based upon the material retained by the screen. Since this technique is relatively laborious and time-consuming, it was suggested that we modify the method so that most of the work could be done in the field at the time of excavation. In particular, it was proposed to sink pits 5 ft. square. Each successive foot in depth would then be considered one sample, with a volume of 25 cu. ft. All the soil in this 1-ft. stratum would then be passed through a 1/2-in. (12–13-mm.) screen and the coarse material held by the screen would be analyzed.

To repeat, any given volume of mound deposit, say one cubic foot, will contain particles falling within three size categories: less than 1/8 in. in average diameter, between 1/8 in. and 1/2 in., and greater than 1/2 in. The first category is disregarded as impossible to analyze without a prohibitive amount of labor and expense. Hence the material usually examined falls within the second and third categories. The proposal is therefore to determine the third category alone and from it calculate the second. Now this is an acceptable method if, and only if, the relation between the particles held by the 1/2-in. screen and those held by the 1/8-in. screen is consistently the same; in other words, if the ratio between the quantities in the two size ranges is reasonably constant. In practice, however, the nature and the numerical value of this relationship can be determined only empirically, that is, through the analysis of the same mound material by the two methods, field and laboratory.

An experiment of this character was performed in the summer of 1949. Nine earth mounds in the Central Valley (see map 1) and one shellmound in Sonoma County were excavated. At each site two or more pits, 5×5 ft., were dug and the soil was sifted through a screen of 1/2-in. mesh. The material retained was washed, dried, and sorted (see pl. 24, *b*), after which each component—rock, bone, etc.—was weighed. The weight of the entire mass put through the screen was subsequently calculated from density determinations made on small samples in the laboratory.



Map 2. Sites outside Lower Sacramento Valley. The hachured area is given in map 1.

The quantity of each component could then be expressed on a percentage basis. The small samples, derived from a column cut in a wall of each pit, were used for laboratory analysis. This analysis involved sifting through a 1/8-in. screen, followed by the segregation of the individual components. In tables 3 and 4 both sets of results are given as the mean percentages for each of the ten sites. To recapitulate: in table 3, under "Field or pit samples" are shown the percentage values by weight for each component when the data refer to pieces of rock, bone, etc., with a mean diameter greater than 1/2 in. Under "Column samples" are shown similar values, when the particles were all of sizes greater than 1/8 in. in mean diameter. In table 4 the values for pit samples of baked clay and bone and for column samples of fish bone are given in specific detail.

We may now examine the internal consistency of the data. Let us take as an example the total rock and clay content of site Sac-6. For this component there are thirty-four pairs of values and for each the following ratio has been computed:

$$\frac{\text{per cent rock and clay over } 1/8\text{-in. diam. in column sample}}{\text{per cent rock and clay over } 1/2\text{-in. diam. in field sample}}$$

The numerical value of the mean of the ratios for the thirty-four sample pairs is 1.92. The standard error of estimate is 0.168, or 8.75 per cent of the mean. This result may be interpreted to signify that, had we known in advance the mean value of the ratio (1.92) and had we taken only field samples, we could have estimated the percentage of rock and clay in a corresponding series of column samples within plus or minus approximately 10 per cent. Such an error, though not critical, is nevertheless appreciable and should be avoided if possible.

The greatest objection to the method, however, is precisely that we do *not* know the value of the ratio in advance. We must perform both sampling operations in their entirety to discover it and thus we automatically nullify the results anticipated from the field samples. This objection would be met, however, and field sampling would be established as a useful procedure if we could assume that the same mean ratio for column and field samples holds for all sites within the same general geographic area. This hypothesis can be tested directly by computing the corresponding ratios for rock and clay for the other nine sites excavated. When we do this, we discover that the average ratio for the ten sites is not 1.92 but 4.40. The coefficient of variation between the sites is 47.9. This means that within the area included in these ten sites the probability is 0.667 that a set of field samples from any particular site will not vary by more than 47.9 per cent from the corresponding set of column samples. Conversely, the probability is 0.333 that it will so vary. One may argue that under certain circumstances such a wide variance would not render completely useless a study of the site; at the same time he will be forced to admit that the field sampling method is less satisfactory and dependable than column sampling.

A similar calculation for bone gives a coefficient of variation between sites of the order of 125. Sampling bone by the field method is thus shown to be much less reliable than sampling rock. The results are even worse with shell, and with charcoal the data cannot even be computed because, owing to its finely divided state in the

TABLE 3

COMPOSITION OF SAMPLES FROM NINE VALLEY SITES AND ONE COASTAL SITE (SON–299)
(Percentage of total weight)[a]

Components	Sac–6	Sac–106	Sac–107	Sac–151	Sac–96	SJo–43	Sac–52	Sac–145	Sac–54	Son–299
	Field or pit samples									
Baked clay	5.407	0.759	1.107	0.972	0.891	3.440	0.0	0.236	0.010	0.0
Rock	0.237	0.454	0.878	0.332	0.404	0.481	1.652	0.011	1.946	1.245
Bone	0.0634	0.0102	0.0177	0.0254	0.0192	0.0724	0.0038	0.0038	0.0065	0.0522
Shell	0.0087	0.0022	0.0013	0.0016	0.0017	0.0586	0.0	0.0005	0.0	1.3140
Obsidian	0.0017	0.0003	0.0002	0.0	0.0002	0.0008	0.0	0.0	0.0	0.0
	Column samples									
Rock and clay	11.47	4.67	7.77	5.61	7.09	7.76	15.72	1.18	8.86	4.69
Bone	0.6238	0.2486	0.2313	0.2020	0.2954	0.5715	0.1149	0.3519	0.0475	0.1088
Shell	0.0577	0.0192	0.0247	0.0220	0.0341	0.5300	0.0102	0.0120	0.0043	27.1500
Obsidian	0.0107	0.0006	0.0016	0.0	0.0170	0.0038	0.0004	0.0004	0.0010	0.0004
Charcoal	0.2982	0.0389	0.0584	0.0258	0.0871	0.0392	0.0632	0.0123	0.0192	0.0080

[a] The very fine residue which was not segregated brings the total of each column to 100 per cent.

ground and the rough treatment it experiences, no charcoal is retained by the ½-in. screen.

The conclusion therefore seems warranted that any mound component occurring in pieces or particles smaller than ½ in. in diameter should be sampled by the column method or its equivalent, with the single exception of artifacts which are discussed in the following section.

THE PROBLEM OF ARTIFACTS

Artifacts not associated directly with burials are often found distributed at random throughout the site mass. It is sometimes of interest in connection with cultural studies to obtain some idea of their total number. Hence a sampling procedure would be appropriate.

Most artifacts, but not all, are of moderately large size and tend to be scattered at rather infrequent intervals throughout the mound substance. One would therefore anticipate the use of a screen and the taking of relatively large samples. A ⅛-in. screen would certainly retain all artifacts, but to pass great masses of soil through such a small mesh would be impracticable either in the field or the laboratory. Hence, a screen of ½-in. mesh is mandatory. A mesh of this size, however, is likely not to catch the smallest objects, such as glass or shell beads, or tiny obsidian points. Consequently we need some data on the proportion of artifacts held by the ½-in. screen. Fortunately a study of this sort has been made recently by Clement A. Meighan, reported by the University of California Archaeological Survey.[9] Mr. Meighan tested the matrix of site Mrn-232 and computed the recovery of thirteen types of artifacts. His procedure was to turn over the material with a shovel during the excavation of a pit and to remove by hand all artifacts found. The same soil was then passed through a ½-in. screen. He found that 75 per cent of the total items recovered were removed by hand and 25 per cent were thereafter caught by the screen. Mr. Meighan believes that all or substantially all would have been retained by the screen even if the manual inspection had been omitted. It is likely therefore that recovery by screening will be almost 100 per cent complete.

The samples must be reasonably large. An ordinary column sample 3 × 3 × 12 in. contains 108 cu. in., whereas a field sample 5 × 5 × 1 ft. contains 43,200 cu. in. Hence if we assume, for example, that there is one artifact in the field sample, the probability of its turning up in the corresponding column sample is exactly 1 in 400. Column samples are thus much too small unless a tremendous number are taken. On the other hand, the entire pit constitutes too large a sample; at least ten pits would have to be dug and screened in order to compute the artifact content of an entire mound.

A test case is furnished by site Sac-6. In 1949 seven pits were dug, which produced forty samples one foot in depth. The soil was completely screened and the artifacts were counted. If we disregard those made from clay, the mean number of artifacts was 4.8 per cu. m. (Meighan's unit of measure is cu. yds.). If we use forty field samples, the standard error of estimate is 18.35 per cent of the mean, whereas if we use the pits themselves as samples, the standard error is 15.15 per cent. The

[9] C. A. Meighan, Observations on the Efficiency of Shovel Archaeology, UCAS–R 7, 1950.

TABLE 4

Clay and Bone from Nine Valley Sites and One Coastal Site
(Percentage of total clay or bone)

Components	Sac-6	Sac-106	Sac-107	Sac-151	Sac-96	SJo-43	Sac-52	Sac-145	Sac-54	Son-299
Baked clay (pit samples)										
Worked	41.3	11.7	....	10.2	17.4	57.0	....	....	....	....
Unworked	58.7	88.3	....	89.8	82.6	43.0	....	....	....	....
Bone (pit samples)										
Mammal	84.5	93.4	88.4	97.7	90.6	90.4	96.1	60.2	98.0	84.4
Bird	8.38	1.46	2.17	1.20	3.85	5.91	1.41	4.44	0.0	11.03
Fish	1.29	0.32	0.33	0.0	1.50	1.00	0.68	25.94	0.0	2.53
Unidentifiable residue	.83	4.82	9.10	1.10	4.05	2.69	1.81	9.47	2.0	2.04
Bone (column samples)										
Fish	28.26	5.22	2.65	....	17.72	25.60	....	19.60	....	50.20

TABLE 5

Artifacts from Sites Excavated in 1949
(Average number per cu. m. of mound)

Type	Sac-6	Sac-106	Sac-107	Sac-151	Sac-96	SJo-43	Sac-52	Sac-145	Sac-54	Son-299
Obsidian	1.190	0.0	0.470	0.0	0.0	1.553	0.0	1.382	0.0	0.0
Bone	0.595	0.0	0.313	0.0	0.544	1.978	0.0	0.922	0.0	0.811
Pigment	0.372	0.0	0.157	0.0	0.0	0.281	0.0	0.0	0.470	0.0
Stone	1.600	3.085	0.784	0.403	1.452	2.965	0.0	0.0	0.0	7.840
Glass, etc.	0.119	0.906	0.0	0.403	0.906	0.563	0.0	0.0	0.0	4.050
Clay	18.710	2.176	1.882	6.850	0.0	7.770	0.0	2.304	0.0	0.0
Total	22.586	6.167	3.606	7.656	2.902	15.110	0.0	4.608	0.470	12.701

improvement in accuracy obtained by using few but very large samples (i.e., pits) is negligible. We may therefore conclude that a greater number of samples of intermediate size, say about 25 cu. ft. of mound soil, represents the optimum for field conditions. This means in practice digging two to several pits, the exact number depending on the depth of the mound.[10]

The other nine sites excavated in 1949 were treated in a similar manner. The complete data for the ten sites are presented in table 5. At five of these sites (Sac-52, Sac-96, Sac-145, Sac-54, Son-299) too few field samples were taken to justify any statistical treatment. The number of samples taken at the other five were: 40 (Sac-6), 8 (Sac-106), 10 (Sac-107), 8 (Sac-151), and 12 (SJo-43). In these five mounds the mean number of artifacts (including clay artifacts) per cubic meter was respectively 23.1, 6.3, 3.8, 7.7, and 15.4; the standard errors of estimate, expressed as per cent of the corresponding mean, were 18.5, 39.7, 34.0, 38.8, and 25.0. It is evident that, if the number of samples at the other four sites had approached that of Sac-6 (i.e., 40), the standard errors would have been of the same order of magnitude. At best, therefore, the artifact content of a mound can be estimated with no less than approximately 20 per cent error.

Accepting the error, we can still learn a good deal about the occurrence of artifacts. For example, let us consider our best site, Sac-6. From table 5 it appears that there are 18.7 clay artifacts per cubic meter and 4.4 nonclay artifacts per cubic meter. In another publication the total volume of this mound is given as approximately 22,376 cu. m. Hence we are justified in stating that the total of clay artifacts left in the mound by the inhabitants reaches 418,312 plus or minus 20 per cent. From the artifacts recovered in 1949 it was determined that the average weight of a clay artifact is 33 gm. Hence the total weight of the artifacts at site Sac-6 would be nearly 14,000 kg., a figure which gives us a fair notion of the clay industry at that site. It should be remembered, of course, that this number does not include the artifacts specifically associated with burials. In a similar manner it can be computed that the mound contains the following artifacts (exclusive of those found with burials): 26,627 obsidian points, 13,313 bone implements, 35,801 stone and 11,635 shell artifacts, all these totals within an error of approximately plus or minus 20 per cent.

It is thus evident that many of the statistical results based on artifacts recovered from the 1949 excavations must be taken with reservations. Particularly, those from Sac-96, Son-299, Sac-52, Sac-145, and Sac-54 are no doubt quite inaccurate in detail. Nevertheless, certain points merit comment.

1. The very heavy incidence of clay artifacts at Sac-6 is not due to any error in sampling. The moderately heavy incidence at Sac-151 and SJo-43 is also definitely established. Some, but relatively little, baking of clay may have been carried on at Sac-106, Sac-107, and Sac-145. It is almost certain that no clay was baked at the remaining four sites.

In the floodplain sites (Sac-6, Sac-151, SJo-43, Sac-106, and Sac-145) excellent

[10] There should be no misunderstanding that what we are dealing with here is total *number* of artifacts. The range of *types* of artifacts cannot be estimated from such limited sampling. Extensive excavation alone can yield sufficient numbers of artifacts of different categories to enable the analyst to assign the site to its cultural position and to identify and define the culture complex of that site.

pottery clay is readily available, so differences in quantity at the respective sites represent differences in manufacture or use of the baked clay balls. There can be little doubt that the Sac-6 village fabricated these pieces for export, for they occur here in excessive numbers. At near-by Sac-151, a smaller village, the people either made their own cooking stones of clay or obtained limited numbers, sufficient for their needs, by trade from a near-by village, probably Sac-6. The different quantities in baked clay balls found at the various sites may also, we realize, reflect the mode of the baked clay art. Time distinctions between sites may be detected by determining the sequence of types from stratigraphic sampling in order to fit the sites into temporal series.[11]

2. The absence of any artifacts of consequence at Sac-52 and Sac-54 looks suspicious. Six field samples were taken at each of these. Even if the average number of artifacts per cubic meter is only three, the probability that two, one, or no artifacts would turn up in six samples is very small. On the other hand, it is also improbable that the sites actually contained no obsidian, bone, stone, shell, or clay artifacts.

Some of the actual probabilities involved in the determination of artifacts at site Sac-52 may be of interest. At this site no artifacts whatever were found in the screening of six field samples. From all the other nine sites (with which Sac-52 may legitimately be compared) an aggregate of 96 samples was taken. Of these, 68 disclosed at least one artifact, leaving 28 samples in which none was discovered. If we take this value as an empirical basis, the probability of finding no artifact at all in a sample in this area is $(28:96)^6$ or 1:1631 or 0.00061. In other words, if Sac-52 has the same cultural characteristics as the other sites and if the distribution of artifacts is determined solely by random chance, then the probability of finding at least one artifact in at least one sample at Sac-52 is 0.99939. This overwhelming probability leads us to wonder whether Sac-52 does not really differ either physically or culturally from the other sites. Similar considerations apply to Sac-54, where only a few scraps of pigment were found and none of the other common types of artifacts.[12]

3. The high incidence of nonclay items in SJo-43 requires explanation, for the mean number per cubic meter is 7.6 as contrasted with 4.4 per cubic meter in Sac-6.

4. At site Son-299 the high incidence of stone and shell artifacts, together with complete absence of clay, is consistent with its coastal location, but the absence of obsidian is puzzling. It should be noted, however, that the sampling was inadequate, since only five 1-ft. levels were tested. Thirty or forty such samples might give a different result.[13]

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[11] This study is being concluded by Donald Lathrap, Assistant Archaeologist, UCAS.

[12] In the course of digging the Sac-52 stratipits a flexed burial was encountered at the edge of one pit. Accompanying this burial were several large flaked stone blades, which are almost certainly of Middle Horizon type. The site may therefore be provisionally classed as a Middle Horizon settlement.

This footnote is by Heizer; the text statement was written earlier and independently by Cook. Our evidence in general is that Middle Horizon sites in Central California do produce fewer dissociated artifacts in the mound mass than Late Horizon middens.

[13] If the Son-299 sample were somewhat more extensive and obsidian chips were still lacking, this would constitute pretty clear evidence that raw obsidian was not imported to the site and there reduced to finished implements. The Son-299 burials were commonly accompanied by well-flaked obsidian points and blades, and these may have been obtained in finished form from neighboring tribes to the north and east in whose territories there are obsidian quarries.

5. The appearance of glass, iron, etc., in six of the ten sites leads to the important question of distribution, specifically of vertical distribution, for if it can be shown that a certain type of artifact appears only in some particular horizon, a clue is thereby obtained to the cultural history of the inhabitants. A very obvious instance of such layering is that of the historic materials mentioned above, for these materials are found only in the uppermost level. They constitute an index to the extent of occupancy by the natives subsequent to the advent of the white man.

A satisfactory analysis of the vertical distribution of native artifacts found in the course of sampling is naturally limited by the small numbers in which they are usually found. Moreover, a relatively large number of pits would be necessary in order to compare the same horizon at different locations within the site. None of the 1949 data are sufficient for this purpose with the single exception of clay artifacts in Sac-6. If we tabulate these according to their occurrence in 1-ft. horizons, we find that their respective frequency is as follows:

Depth of horizon below surface (in ft.)	*Average number of clay artifacts per field sample (5 × 5 × 1 ft.)*
0–1	11.2
1–2	18.5
2–3	10.5
3–4	16.0
4–5	17.5
5–6	0.5
6–7	6.0
7–8	0.5
8–9	0.0

The average number remains essentially constant down to a depth of 60 inches, below which clay artifacts are very rare or almost entirely absent. One might therefore deduce that the clay-baking technique, at least as an industry, came into quite sudden vogue and that it subsequently continued as a major occupation until the site was abandoned. Further development of such a thesis depends upon knowledge derived from the full study of the cultural history of the site.

THE COMPARATIVE ECOLOGY OF NINE CENTRAL VALLEY SITES

The nine valley sites excavated in the summer of 1949 all lie within a circle, the diameter of which is not more than thirty miles (map 1). The periphery of the area on the west touches the Sacramento River above Walnut Grove and on the east falls just short of the Sierra Nevada foothills above Sloughhouse. In a north and south direction the area includes parts of the valleys of the Cosumnes and Mokelumne rivers. Ecologically the province is quite uniform, consisting of flat valley land becoming slightly rolling to hilly in the easterly part and intersected by many rivers, creeks, and sloughs. Profound differences are therefore not to be expected between the sites.[14]

[14] The local geography and biotic environment are treated in the following publications: E. W. Schenck and E. J. Dawson, Archaeology of the Northern San Joaquin Valley, UC–PAAE 25: 296–305,1929; J. B. Lillard and W. K. Purves, The Archeology of the Deer Creek–Cosumnes Area, Sacramento County, California, Sacramento Junior College, Dept. Anthro., Bull. 1, pp. 4–7, 1936; W. Weir, Soils of Sacramento County, California, Univ. Calif. Coll. of Agric. Exper. Sta., Berkeley, 1950; A. M. Piper, H. S. Gale, H. E. Thomas, and T. W. Robinson, Geology and Ground-Water Hydrology of the Mokelumne Area, California, USGS, Water Supply Paper No. 780, 1939.

The following is a brief résumé of local conditions as they exist today.

Sac-6. 7 mi. NE of Thornton, in the NW ¼ of sec. 36, T. 6N, R. 5E. On the bank of a former channel of the Cosumnes River. Surrounding terrain flat. Soil deep alluvium. Vegetation grass and, formerly, a parklike growth of valley oak, with remnants still present.

Sac-96. 3 mi. E. of Sac-6 in the NE ¼ of sec. 29, T. 6N, R. 6E, on the bank of an overflow channel of the Cosumnes River, the main channel now being ⅛ mi. to the northwest. To the north of the site is river bottom land covered with willow and oak. To the south is oak parkland. The terrain is flat alluvium.

Sac-106. 1 mi. upstream from Sac-96 in NW ¼ of sec. 28, T. 6N, R. 6E. The terrain and vegetation are the same. (Pl. 25, *a*, *b*.)

Sac-107. 3.5 mi. SE of Elk Grove. In the floodplain of the Cosumnes River. Local vegetation willow, cottonwood, and oak. Oak parkland in the vicinity.

SJo-43. 4 mi. NW of Woodbridge, in SW ¼ of sec. 9, T. 4N, R. 6E. On the bank of the Mokelumne River (pl. 25, *c*, *d*) with oak parkland to the east and southeast and the bed of former freshwater lake, Tracy Lake, ½ mi. to the N and NW. Terrain slightly rolling.

Sac-151. 2 mi. S of Sac-6 in NE ¼ of sec. 12, T. 5N, R. 5E. On the left bank of the Cosumnes in an overflow bottom. Surrounded by oak parkland, bordered on west by overflow bottom vegetation of oak, wild rose, wild grape, cottonwood, and willow.

Sac-145. On the left bank of the Sacramento River 6 mi. W of site Sac-6. Two hundred yds. to the east is the border of former Stone Lake. The site occupies a natural rise in the tule swamp bordering the lake. Oak parkland obtains to the E and riverbank vegetation along the shore of the Sacramento.

Sac-54. Near Sloughhouse on the right bank of the Cosumnes River, 10 mi. above site Sac-96 and 2 mi. W of Bridgehouse. The surrounding terrain is moderately rolling with rises 50 to 100 ft. in elevation. Many rock outcrops occur within one or two miles. River bed filled with cobbles. The knolls are grassland but the river bottom has a prolific growth of willow, oak, and cottonwood.

Sac-52. On a bluff 50 ft. above the Cosumnes River, ¾ mi. above site Sac-54. Valley narrow. Surrounding land consists of low knolls and hills. Valley bottom ½ to 1 mi. wide with willow and oak. A great deal of gravel and frequent outcrops of rock near by.

As we progress eastward from the lower Cosumnes and Mokelumne toward the upper courses of these rivers we can observe a progressive change in mound content which corresponds, with numerous minor exceptions, to the trend away from the floodplain-marsh habitat to the slightly higher, gently rolling, more poorly watered area just below the line of the first true foothills of the Sierra. This shift in mound content with the gradual alteration of the terrain may be recognized quite clearly if we reorganize the data from table 3 so as to arrange the sites as closely as possible with reference to their location on the two rivers (table 6). The most westward site, Sac-145, is on the Sacramento River itself and, since it appears to possess a highly distinctive character, should be considered apart from the others. Sites Sac-6, Sac-151, and SJo-43 are almost identical in locality and river ecology, as are Sac-106 and Sac-96. Sac-107 stands by itself farther upstream than the preceding pair, and of course Sac-54 and Sac-52 are separated from the others by a considerable distance.

The single site, Sac-145, was situated on the bank of the main Sacramento River not far from a small freshwater lake. The very small amount of clay, rock, and charcoal here are good evidence that habitation of the site was not long continued or intensive. However, the very high proportion of fish bone, especially of bones from such large fish as salmon and sturgeon, indicates that the place was used as a fishing station. Numbers of birds were also taken as well as a small amount of shell.

The birds may have gathered at the lake, and the big river was certainly a source of salmon and other sizable fish. Hence this site must have specialized in a particular type of food-gathering. Since the relative absence of rock precludes intensive habitation, it may be conjectured that much of the animal food secured was prepared or at least consumed elsewhere.

The remaining eight sites were continuously inhabited. They may be discussed with reference to the following specific components.

Clay.—The decrease of baked clay observed as one moves from west to east is consistent with the concentration of workable clay deposits at the lower elevations toward the main axis of the Central Valley. By "worked" clay we mean whole or fragmentary objects which have been hand-fashioned, smoothed, and fired. Unworked baked clay takes the form of unshaped pieces, which may have been accidentally burned or may have come from the clay linings of fireplaces or the plastering of smokeholes of houses. However, the extent to which baked clay was used depended largely on the local economic and cultural pattern of the mound dwellers. Thus, as previously pointed out, there was a huge clay artifact industry at Sac-6, and the manufacture of baked clay articles may also have been a major program at SJo-43. (Note in table 4 that 41.3 per cent of the clay objects included in the field samples were worked at Sac-6 and 57.0 per cent at SJo-43.) The other sites on the lower Cosumnes and Mokelumne rivers yield much less baked or burned clay and a much smaller proportion of it has been worked. At Sac-52 and Sac-54, where no clay deposits are readily available, baked clay artifacts disappear completely from the samples.

Rock.—The steady increase in the rock content of site deposits as we go up the rivers is very striking. Since rock was an essential item, its use increased toward the foothills, where the outcrops of exposed bedrock and the gravelly, instead of muddy, bottoms of the streams make it more available. Downstream, where there was almost no rock on the alluvial plain, it tended to be replaced by baked clay. The shift from artificial to natural rock is thus clearly apparent as one goes towards the foothills.

Shell.—The river mussel tends to be most abundant in the lower part of the rivers. Hence, as one might expect, the amount of river mussel shell in the site deposits decreases progressively as one travels upstream.

Fish.—Fish, like mollusks, are less abundant in the upper reaches of the rivers. However, the column samples show a greater and more consistent decrease in the proportion of fish bone than the field samples. The latter catch the bones of large fish only, whereas the former include the remains of fish of all sizes. It may therefore be deduced that large fish, perhaps principally salmon, were taken throughout the length of the streams on which these sites were situated. Even as far upstream as Sac-52 the component of large fish bone was considerable. On the other hand, by the time Sac-52 is reached the small fish bone almost disappears. These smaller fish were evidently native to the sluggish, semistagnant marshes and sloughs of the level plain through which coursed the lower Cosumnes and Mokelumne rivers; hence they were available only to the lower-river dwellers. As an article of diet the fish must have been of considerable importance to the inhabitants of such sites as Sac-6, Sac-96, and SJo-43. This inference is supported by the greater amount and diversity of fishing apparatus found in the lowland sites. At Sac-6 straight (gorge), curved (C-shaped) bone fishhooks, fish spears,[15] carbonized fish nets and net sinkers abundantly attest the importance of fishing gear in the material culture.

Bird.—The amount of bird bone decreases upstream in a manner closely paralleling that of small fish remains. This is understandable, since the avian fauna consists primarily of marsh and waterfowl of which there were formerly vast numbers along the Sacramento and San Joaquin rivers and the lower courses of their affluents. Ten or twenty miles to the eastward, where the lateral valleys are constricted, there are almost no marshes, and birds must have been relatively scarce and difficult to secure.

Total bone.—The data show an unequivocal decrease in the total amount of bone found in the samples as we progress upstream. This might be taken as indicating a corresponding decrease in the total animal material consumed by the natives. On the other hand, it might be due to a combination of cultural factors, together with a sampling error. In a previous study[16] the same problem was discussed with respect to sites in the Sierra foothills and the coast ranges of Mendocino County. Cook and Treganza were more or less of the opinion that the Indians inhabiting these areas depended very heavily upon acorns and other vegetable food sources. However, they pointed out that the column sampling method, which they used exclusively, might give too low results for large objects such as whole mammal bones or fragments of them. But in the present sampling of upstream sites there is no significant difference in the decrease of the total bone found in the field samples and in the column samples. Since the field sampling method we used is quite adequate for determining the frequency of mammal bone, it follows that the smaller bone content in the upper sites is a real phenomenon and cannot be ascribed to faulty sampling.

Part, but by no means all, of the decrease can be ascribed to a smaller supply of fish and birds, as discussed above, since these two types of animal contributed at best no more than 25 per cent of the total bone. We are forced to consider two alternatives: (1) the inhabitants of the upper sites actually consumed much less animal food and relied more heavily on plant resources than those of the lower sites; or (2) in the region approaching the foothills either large game was slaughtered at a distance from the site and only the meat was carried home or else the bones were disposed of at some spot other than the site itself.

Both these possibilities may be true at the same time. The tule elk was common in the lowland marshy areas, whereas deer was more abundant in the rolling foothill country. The greater numbers of elk and their larger individual size would probably result in more meat being available to the occupants of Sac-6 in the marshy area than of Sac-54 near the foothills. Deer could be obtained by both groups, but the people of Sac-54 would rely on it more heavily, the elk being absent or very rare. Deer are often hunted far afield in the foothills, and only the best parts would be carried home; thus less bone would be found in the refuse heaps. Also, a higher percentage of the bones thus brought (probably limb bones) would be manufactured into tools at Sac-54 than by the occupants of Sac-6, who had more

[15] J. Bennyhoff, Californian Fish Spears and Harpoons, UC-AR 9:312–316, 1950.

[16] Cook and Treganza, UC-PAAE, 40:223–262, 1950.

bone than they could use. This surplus is evident in the occurrence in the deposit of many unworked elk and deer cannon bones. Elsewhere one finds only rarely an unmodified cannon bone, since these bones, split lengthwise and ground to a point, are favorite pieces for use as awls in making coiled basketry.

Charcoal.—Because the domestic economy of all the natives here considered depended upon fire for the preparation of food, no great differences in the charcoal residue found at the various sites should be anticipated. Nor, with one exception, are there notable differences. Sac-6 has from three to five times the charcoal content of any other site, a fact that can be explained, not on the basis of any difference in the ordinary domestic or culinary custom, but by the baked clay industry, which must have required enormous quantities of wood.

TABLE 6

COMPOSITION OF SAMPLES FROM NINE CENTRAL VALLEY SITES
(Percentage of total weight)

Components[b]	Sac-145	Sac-6[a] Sac-151 SJo-43	Sac-96[a] Sac-106	Sac-107	Sac-54[a] Sac-52
Clay (F)	2.096	3.273	0.825	1.107	0.005
Rock (F)	0.4642	0.3501	0.4294	0.8780	1.7990
Shell (F)	0.0005	0.0238	0.0020	0.0013	0.0
Shell (C)	0.0120	0.2032	0.0266	0.0247	0.0072
Fish (F)[c]	25.940	0.76	0.91	0.33	0.34
Fish (C)[c]	19.60	17.62	11.47	2.65	0.0
Bird (F)[c]	4.44	5.16	2.65	2.17	0.71
Total bone (F)	0.0038	0.0537	0.0147	0.0177	0.0052
Total bone (C)	0.3519	0.4658	0.2718	0.2313	0.0812
Charcoal (C)	0.0123	0.1211	0.0630	0.0584	0.0412

[a] Values in this column are averages for sites listed in heading.
[b] F, field sample; C, column sample.
[c] Percentage of total bone.

The origin of the extensive white ash lenses may also be the fires used in baking clay artifacts. The evidence for the source of these ash dumps from house fireplaces has been presented above. We may therefore further suppose that the great quantities of baked clay artifacts are the product of individual household activity and that this industrial specialization was village wide.

SHELLMOUNDS

We have available data from four sites which, from the huge quantities of molluscan remains that they contain, are commonly called shellmounds. These are: CCo-275, in Richmond on the northeastern shore of San Francisco Bay[17] (the data for this site are taken from a previous paper), Ala-328 toward the southern end of the same bay, Son-299 on the western shore of Bodega Bay, and Hum-169 at Trinidad Bay some 200 miles to the north (map 2).

The salient feature of these sites is of course the presence of great masses of shell, which testifies to the heavy reliance by the inhabitants on mollusks as a source of

[17] Data for this site are taken from Treganza and Cook, A Ant 13:135–141, 1947.

food. The dietary aspect has been discussed elsewhere.[18] What concerns us here is the possibility of demonstrating significant differences in the content of mounds of this type from various localities. The data are summarized in table 6.

It is apparent that there are some differences in the values for shell itself, since the shell percentage of total mound weight varies from 17.45 to 45.90. These two extremes are both from San Francisco Bay sites, the intermediate values, 27.15 and 31.23, being derived from the sites on the outer coast. It is therefore clear at the outset that, so far as these four sites can furnish evidence, there was no significant variation between the two ecological provinces in the quantity of shellfish or in the

TABLE 7

ANALYSES OF COLUMN SAMPLES FROM FOUR SHELLMOUNDS

(Percentage of total weight)[a]

Components	CCo-275 (14 samples)	Ala-328 (28 samples)	Son-299 (5 samples)	Hum-169 (17 samples)
Rock	9.24	17.47	4.69	15.59
Bone	0.0640	0.1600	0.1088	0.2038
Shell	45.90	17.45	27.15	31.23
Obsidian	0.0	0.0005	0.0004	0.0003
Charcoal	0.0720	0.1474	0.0080	0.4841

[a] The very fine residue which was not segregated brings the total of each column to 100 per cent.

gathering and eating habits of the inhabitants. Indeed, differences between the sites on San Francisco Bay seem to have been greater than those between the Bay sites and those of the exposed coast.

Within the Bay, the Richmond site (CCo-275) contains more than twice as much shell as the Newark site (Ala-328), and in this connection it is worth noting that Gifford in 1916 showed that the Ellis Landing site (CCo-295) contained 69.43 per cent of shell by weight, a figure greater even than that found at Richmond. The northern end of the Bay, near San Pablo Strait, is surrounded by low hills and relatively rocky shores, whereas the southeastern shore is flat and marshy. The common mussel, *Mytilus edulis,* is a rock-dwelling form; hence it was doubtless more abundant in the north.

If the quantity of shell in the mounds is a criterion, then it follows that the inhabitants of San Francisco Bay, and probably of other coastal areas as well, depended for their food on extremely local sources. If there had been an extensive interchange of commodities up and down the shores of the Bay, one would expect inequalities of local shell deposits to cancel out, either because of trade from place to place or short expeditions of not more than twenty-five or fifty miles to tap the richer deposits. If this had been so, one would expect substantial equality in the percentage of shell found in the sites along the eastern shore of the Bay, regardless of latitude.

Turning now to the other mound components, we must point out that the data for Son-299 are based on only five samples. The analyses given for this site in table

[18] S. F. Cook, A Ant, 12:51–52, 1947; E. W. Gifford, The Composition of California Shellmounds, UC–PAAE 12:1–29, 1916.

6 consequently cannot be regarded as very significant. In fact, the safest procedure probably is to disregard the figures for this site entirely, except for shell.

Of the two San Francisco Bay sites, Ala-328 has the higher content of rock, bone, and charcoal, a fact quite consistent with its lower percentage of shell. For if the inhabitants, through necessity or choice, depended less on shellfish as a food staple, they would tend to compensate by eating more seeds and vertebrates. There was unquestionably an adequate supply of the latter: fish in the Bay and estuaries, birds in the marshes, and mammals behind the shoreline. Even if we assume that the inhabitants of the site would secure mussels when convenient, other forms of animal food would fairly easily replace the mollusks as a food staple when necessary. There was probably, therefore, a sort of labile equilibrium, considered in geographic terms, which represented a balance between availability and convenience of food sources and which could be readily shifted in either direction depending upon relatively small changes in the character of the environment.

A trend toward the use of vertebrate food, such as there seems to have been toward the southerly part of the Bay, would, it seems to us, carry with it an increased use of rock for fireplaces and cooking, and would result in larger deposits of charcoal. The picture presented by the two Bay mounds is thus fully consistent.

The site at Trinidad Bay, Hum-169, contains a quantity of shell intermediate between the amounts found at the two San Francisco Bay sites. There is, however, nearly as much rock as at Ala-328, and more bone. The charcoal content of Hum-169 is much higher. One may consequently deduce that although the natives drew heavily upon the molluscan reserves of Trinidad Bay, they actively hunted vertebrates, which, because of the location of the site, must have been derived primarily from the ocean—deep sea fish and large marine mammals. The preparation of such animals for eating would require large fires and hence account for the very high percentage of charcoal found in the samples.

SUMMARY

In the foregoing pages we have described several applications of the physical analysis of residual mound or site material according to the small-sample technique discussed in previous papers.

1. The well-preserved remains found within a dry cave (Ama-3) make possible a reasonably exact reconstruction of the economic life of the prehistoric occupants. Comparison of this deposit with similar material which, lying just outside the cave, has been exposed to weathering permits us to deduce the probable former conditions at an open site, such as Sac-6.

2. A statistical analysis of the content of ash lenses at site Sac-6 enables us to make several inferences concerning the domestic habits of the former inhabitants, particularly with reference to their dietary and housekeeping customs.

3. Using site Sac-6 as a test case we made a study of the relative effectiveness of field sampling (taking a few samples of large size) as compared with column sampling (taking a large number of smaller samples). The results show that any mound component occurring in particles less than ½ in. in diameter should be sampled by the column method.

4. In the sampling of artifacts, particularly if a segregation of types is desired,

a large number of large samples is necessary. When properly handled, this method is capable of yielding information on the occurrence and distribution of artifacts within a single site as well on the differences between sites. Data concerning cultural distinctions may thus be obtained.

5. A brief study based on the sampling method was made of the comparative ecology of nine sites in the Central Valley. It was shown that many of the dietary habits and domestic customs of the inhabitants could be correlated with the local physiography and fauna and that minor differences in the environment were reflected in corresponding cultural distinctions.

6. A similar study was made of four coastal shellmounds, within which the same sort of correlation was evident.

PLATES

EXPLANATION OF PLATES

Plate 23

Site Ama-3. *a*. Cave from the west. *b*. Interior of cave looking west.

Plate 24

a. Looking south across the Mokelumne River plain from the mouth of cave at site Ama-3. *b*. Sorting screened pit samples at site Sac-6, July, 1949.

Plate 25

Central Valley sites. *a*. Looking upstream along edge of site Sac-106. Note oak and brush border of bank which marks the south edge of the wide Cosumnes River overflow channel. *b*. Site Sac-97, one mile west of Sac-106 on edge of swamp. Original willow thicket and oak vegetation is still preserved. *c*. Looking down Mokelumne River toward site SJo-43. *d*. Large oaks on southeast edge of site SJo-43.

a

b

SITE AMA-3

a

b

A View from Ama-3 Cave; Sorting Pit Samples at Site Sac-6

a

b

c

d

CENTRAL VALLEY SITES