THE QUANTITATIVE INVESTIGATION OF INDIAN MOUNDS

With Special Reference to the Relation of the Physical Components to the Probable Material Culture

BY

S. F. COOK AND A. E. TREGANZA

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The University of California, through the California Archaeological Survey, is compiling a state-wide record of archaeological sites. The Survey master file employs a system of site designations based upon county names. Since all future archaeological reports will use this new terminology, a concordance of site designations for the sites mentioned in this paper is given here.

RV 120	Men-120
RV 187	Men-187
RVF 255	Men-382
SB 16	SBa 16
SB 53	SBa-53
SB 81	SBa-81
C.6	Sac-6
C.56	SJo-56
C.66	Sac-66
C.68	SJo-68
C.142	SJo-142
S.1	Col-1
S.43	Sac-43
S.66	Sac-21
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Richmond 1	CCo-275
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P.1 (Petersen I)	Sol-1
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(Contribution from the Division of Physiology, School of Medicine, and the Department of Anthropology of the University of California, Berkeley)

INTRODUCTION

IN SEVERAL recent papers the present authors[1] discussed their attempts to develop analytical methods whereby certain physical components of archaeological sites could be utilized to gain information concerning ecological and cultural factors.[2] In this paper these methods have been applied to nineteen California sites, rather widely separated in space and time, in order to make such comparisons as possible.

The physical items analyzed were those employed in previous work: rock, together with baked or burned clay; mammal, bird, or fish bone; charcoal; shell; and chips of obsidian or, sometimes, other conchoidal silicates which we refer to collectively as flint. In all analyses the procedure was to take as many samples as could readily be obtained (or worked) from each site. The volume of the sample was measured, if possible. Each sample was brought to the laboratory, dried, weighed, and passed through a screen of 2-mm. mesh.[3] The residue held by the screen was then sorted by hand and each component weighed. The results could then be expressed as the percentage by weight of the original sample. For several of the sites the sample volumes were known and for these the densities were calculated directly.

It was desirable to have, in addition to these concrete items, some idea concerning the area, mass, volume, and probable population density of each mound. For this purpose indirect methods were employed, discussions of which will be found in conjunction with the descriptions below.

DESCRIPTION OF SITES

The sites studied may be classified in groups, according to location and age. They are listed briefly on the next page.

[1] The authors acknowledge with thanks a grant from the Committee on Research of the University of California which defrayed the cost of securing the samples from which these analyses were made.

[2] Cook, 1947; Cook and Treganza, 1947; Treganza and Cook, 1948.

[3] No attempt was made here, as previously, to differentiate between material held by the 7-mm. as opposed to the 2-mm. screen. To have done so would have nearly doubled the labor involved, without yielding data of commensurate importance. Furthermore, for comparative purposes we are primarily interested in the total quantities, not the size classification.

Central Valley and Delta Sites

LATE CULTURE PERIOD

P.1.—This is the site previously designated Petersen I, described in detail by Cook and Treganza (1947). It lies along the southern edge of Lindsey Slough, some ten miles north of Rio Vista, in Solano County. The surrounding country is flat and marshy, but the low elevations known as the Montezuma Hills lie only a few miles to the west.

P.3.—This site, designated Petersen III in the paper published recently (1948) by Treganza and Cook, is situated approximately half a mile east of P.1. It has been excavated completely, as described in that publication.

S.1.—This is known as the Miller mound. It is on the west bank of the Sacramento River seventeen miles north of Knights Landing in Colusa County. It represents an alluvial habitat, in the flat valley close to the river and many miles from the nearest hills. A brief description of the archaeology of the site has been given by Lillard, Heizer, and Fenenga (1939).

C.6.—This site, known as the Johnson mound, is near the Cosumnes River, seven or eight miles east of the Sacramento River and not far northeast of the town of Thornton. The surrounding area is typical valley plain although the first foothills of the Sierra Nevada begin a few miles to the east. It has been excavated by E. J. Dawson (Schenck and Dawson, 1929) and R. W. Newman (report in preparation).

S.104, upper stratum.—This site is on Tyler Island (whence its former designation, Tyler Island no. 3) in the delta region some four miles east of Isleton in Solano County. The site has been little studied but appears to consist of two clearly distinct strata. The upper layer is typical Late period material, loose, dark, and ashy; it sharply contrasts with the lower layer, primarily a consolidated sand but containing burials probably dating from the Middle period. The time interval between the two occupations must have been considerable. The adjacent soil is a highly organic peat. Typical delta plain surrounds the site on all sides for several miles. There are no hills for some distance.

MIDDLE CULTURE PERIOD

S.43.—The Brazil mound lies near the Sacramento River just north of Courtland, Sacramento County. It is a typical river habitat.

S.66.—The Morse mound lies on the north bank of the Mokelumne River, a few miles northwest of Thornton. Its excavation has been described by Lillard, Heizer, and Fenenga (1939).

S.99.—This site, also known as the Deterding site, lies on a bluff above the American River about ten miles northeast of Sacramento. It is just within the border of the Sierra foothills in gently rolling country and has been described by Lillard, Heizer, and Fenenga (1939, pp. 46–49).

S.104, lower stratum.—Although not much is known concerning the lower level of this site, except that it may derive from the Middle culture period, it seemed advisable to examine samples. The deposit lies on the southern end of Tyler Island in the delta region of Sacramento County.

EARLY CULTURE PERIOD

C.56, C.68, C.142.—These three sites all lie within the big bend of the Mokelumne River not far north and northeast of Thornton. Together with C.107 they constitute the entire known remnant of the Early culture in the Central Valley. The topographical and ecological conditions at the time of their inhabitation are not known with certainty, but it is reasonable to suppose that the river-marsh habitat was not essentially different from what it is today, save for a lesser degree of alluviation on the valley floor. All three mounds have been described in detail by Lillard, Heizer, and Fenenga (1939).

Southern Coastal Sites

The three southern coast localities studied are all situated along the Santa Barbara Channel, not far from the city of Santa Barbara. The antiquity and richness of cultural remains in this part of the coastal area have long interested cultural anthropologists and have presented several controversial aspects. The scientific reports on the region which have been published to date (Rogers, 1929; Olson, 1930; Carter, 1941; Orr, 1943) stand as an invitation to further research. We feel that any additional information which can be supplied will, in the long run, contribute to the solution of the problem of the prehistory of southern California. David B. Rogers (1929) has defined a sequence of three cultural periods, the Oak Grove, Hunting, and Canalino, which corresponds, at least roughly, to the Early, Middle, and Late horizons of the lower Sacramento Valley. In our short stay it was our purpose to obtain at least a few samples from each of the cultural period sites designated by Rogers.

SB 16.—This site, representing the Oak Grove culture, is at Ortega Hill, in the saddle of a ridge bordering the sea at the western edge of the suburb called Summerland, southeast of Santa Barbara. The site was originally described by D. B. Rogers (1929, p. 71) as lying at the crest of a knoll somewhat seaward from the place where our soil profiles were taken. Our point of investigation was suggested by P. C. Orr, who, several years earlier, had removed two extended burials from almost the exact spot from which we took our samples. Judging by the burials and the mano-metate association, here is a typical Oak Grove culture deposit. The occupation area of the deposit is of exceptional interest owing to its highly compact nature and its physiographic location in a saddle with several feet of sterile overburden.

SB 53.—This is a Hunting culture site, also known as Campbell no. 1. It lies west of Goleta Slough directly on Highway 101 (Rogers, 1929, p. 142).

SB 81.—This Canalino site, known as Las Llagas, is seventeen miles west of Santa Barbara near where the highway crosses Las Llagas Canyon. The midden is on the crest of a bluff directly overlooking the sea[4] (Rogers, 1929, p. 214).

[4] During our visit to the southern coastal area we were hospitably received by A. S. Coggeshall, Director of the Santa Barbara Museum of Natural History. Phil C. Orr, archaeologist for the same institution, also generously took time to show us sites and to aid in collecting field data.

Round Valley Sites

Our purpose in going to Round Valley, in Mendocino County, was to obtain samples from an area lying well within the mountainous, rather than the valley or coastal, habitats of the aboriginal population. Round Valley, it is well known, was densely populated at the time of the American occupation and the number of recognizable historic and prehistoric sites runs well into the hundreds. Although there is evidence of cultural stratigraphy, published data are lacking. Hence no attempt was made to secure a series based upon a temporal sequence. In fact, all the sites examined show evidence of historic contact (Treganza, Smith, Weymouth, in press).

RVF 255.—This is colloquially known as the Fort site since it lies just outside the ruins of Fort Wright, an Indian post of the 1850's. It is definitely established that the site was first occupied not much later than 1850, when the fort was built, and abandoned about twenty years later (F. B. Rogers, p. 221).

RV 120.—This site is in the northeastern section of Round Valley, just within the present limits of the Indian reservation. The presence of glass beads, abalone ornaments, and cremations suggests that this is an aboriginal site, perhaps Yuki, later occupied by Pomo Indians under the reservation control in force during the early Caucasian settlement of the Covelo district.

RV 187.—This deposit lies at the base of the western foothills of the valley about one-half mile north of the Weymouth ranch. Exploratory excavations have yielded historic material in the upper levels and precontact data from the lower strata. The skeletal material so far recovered suggests a Yuki physical type (Treganza, Smith, and Weymouth in press).[5]

San Francisco Bay Region Sites

Richmond 1.—The data from this site have already been reported on (Cook and Treganza, 1947), but it seems desirable to include them here since they appear to be fairly typical of the San Francisco Bay shell mounds. The site is on the northern boundary of the city of Richmond, Contra Costa County (site 275 of Nelson's San Francisco Bay Survey).

Monument site.—This site was discovered only two years ago and is still the subject of investigation. It lies about four miles north of Walnut Creek, near the town of Concord, Contra Costa County, at the head of what may once have been an arm of Suisun Bay. Its temporal position has not yet been finally determined, although it clearly is older than the recent culture period. The samples were taken at the time of its original excavation.

MASS AND POPULATION

Total Mass

In order to evaluate the significance of the total mass of the various mound constituents in terms of human ecology, it is first necessary to derive some

[5] For assistance in locating and sampling the Round Valley sites we are much indebted to W. D. Weymouth, whose family also kindly extended to us the hospitality of their home during our visit.

estimate of two factors, total mass of the site and average population. The problem of obtaining such estimates has been discussed in the papers previously mentioned, and it has been pointed out that an absolutely precise determination is probably impossible. With respect to total mass, however, the excavation of a complete site has shown (Treganza and Cook, 1948) that the use of the small-sample method plus the application of simple geometrical formulas permit reasonably close approximations. Thus for the site Petersen III, the mass as determined by actual weight was 48,631 kg. and the volume 31.57 cu. m. The volume as calculated on the basis of a segment of a sphere was 41.45 cu. m. and on the basis of a cone was 27.36 cu. m. In the first calculation the error was +31.98 per cent, and in the second −13.35 per cent. Hence, although it would be unwise to insist upon any specific figure, we may say that for any site the anticipated error of the volume calculated by geometrical methods will be of the order of plus or minus 25 per cent. An error of this magnitude is unsatisfactory but cannot be decreased without extensive dissection of the site itself, a procedure in most instances quite impracticable. Nevertheless, a rough approximation is better than none, and at least we know the limits of tolerance of the method. The calculation of population can also be carried out only approximately, but that it is possible to arrive at rational values will be set forth below.

Since the exact procedure for calculating mass and volume varies from site to site, it will be advisable to discuss each site separately. As a summary the final results are given in table 1. The data for the Richmond mound and the two Petersen mounds are taken directly from previous papers.

LATE PERIOD CENTRAL VALLEY SITES

S.1.—As a first step the area must be computed. In the field the outline of the periphery of the mound was determined and plotted to scale. The limits were fixed, not by mere visual inspection, but by a series of test borings with an auger and careful measurement with a steel tape. The resulting outline was a broad and slightly irregular oval. In order to test various methods the area was calculated by three different procedures. (1) Several measurements of the diameter were made from the scale outline drawing and the mean diameter was determined. The area, πr^2 was 2,570 sq. m. (2) The outline was considered an ellipse and the major and minor half axes were obtained by measurement from the scale drawing. Then, by the formula for the area of an ellipse, πab, the area was found to be 2,706 sq. m. (3) The scale outline drawing was transferred to finely subdivided coördinate paper and the area estimated by counting the squares, or graphic projection. The area was 2,661 sq. m.

The three results are quite close, differing by a maximum of approximately 5 per cent. Of the three methods, the graphic projection is probably the most accurate, and therefore 2,661 sq. m. was accepted as the best figure.

The cross section of the site, obtained by plotting the values from pits and test borings, approached most closely the form of a sphere, with a maximum altitude of 2.54 m. Since the site was not perfectly circular in outline, we calculated the radius of the base by finding the radius of a circle with an area

equal to the graphically computed area of the site, 2,661 sq. m. This procedure introduced a small but not serious error. Then the formula was applied for finding the volume of a segment of a sphere: $\frac{1}{6}\pi h(h^2 + 3a^2)$, where a is the radius of the base and h is the altitude (or maximum depth of the mound). The result was 3,388 cu. m.

The mass is the product of the volume by the density. The density value was calculated directly from approximately thirty samples taken from pits and borings. The volume of the samples was measured at the time they were taken from the ground. They were subsequently air dried in the laboratory for several months and then weighed. This procedure gave actually the gross or apparent density, as pointed out in the publication on the excavation of the site Petersen III (Treganza and Cook, 1948), but the data can be used for present purposes without reservation. The mean density of all the samples was 1.210 and the mass, therefore, 4,099 metric tons. The error in computation was probably not greater than plus or minus 10 per cent.

C.6.—This large and important site lies on the bank of an old channel of the Cosumnes River. It is irregularly oval in outline, roughly 200 m. in its longest dimension. Since the graphic projection method gives most accurate approximation, it was used for area computation. The value obtained was 22,781 sq. m.

For volume we first calculated the radius of a circle having the same area as that calculated by graphic projection. Then a reconstruction, based upon nine pits and auger borings, was made of the cross section. The auger borings showed that the top of the mound was flat, with a fairly uniform down slope, beginning approximately 20 m. in from the periphery. The mean depth indicated by the excavations was 1.42 m. Hence the volume may be calculated by considering that the mound has the form of a truncated cone, using the formula:

$$\text{Volume} = \pi/3 \; h(r_1^2 + r_1 r_2 + r_2^2)$$

The value obtained was 25,376 cu. m.

MIDDLE PERIOD CENTRAL VALLEY SITES

S.43.—This is the first of three Middle period sites. Its area was computed by four methods. Since the outline was rather evenly pear-shaped, it could be treated as a circle, an ellipse, or as a double right triangle with the hypotenuses congruent. The fourth method used was graphic projection. The results respectively were 861, 903, 791, and 841 sq. m. The mean was 849 sq. m., again indicating that on the whole, provided a good scale map of the site can be made, the graphic projection method is the best approximation. A series of three pits and nine borings showed that the cross section was close to a segment of a circle and that the volume could best be computed by the formula for a segment of a sphere. The maximum depth was 1.27 m.; the volume, 531 cu. m.

C.66.—A good part of this site is buried under a recent alluvial deposit from the near-by Mokelumne River but by means of three pits and eleven auger borings it was possible to reconstruct the form of the cross section. The outline

was roughly circular but the graphic projection method was considered to give a more accurate estimate of area, 5,780 sq. m.; the estimated volume was 4,198 cu. m. As in all the foregoing estimates, the mass was calculated directly from the mean apparent densities derived from samples.

S.99.—The estimate of the physical dimensions of this site presented a good deal of difficulty, and certain assumptions had to be made in order to achieve even an approximation. The outline of the mound was a nearly regular oval. However, the site is at the summit of a 30-foot bluff overlooking the American River (some 10 miles east of Sacramento) and the river has undercut the bluff, causing part of the site to be lost. The major part of the truncated oval remained and could be measured, but the measurements for the missing minor portion had to be filled in by conjecture on the scale drawing of the site. This necessitated the assumption that the lost part of the mound actually did complete the oval, an assumption made merely because no other more reasonably fitted the apparent circumstances. The area, computed by the formula for the area of an ellipse, was 973 sq. m.; determined by graphic projection it was 1,023 sq. m. Of the two figures, although their difference is not great, the last is probably preferable. The maximum depth, as determined by pits and borings, appeared to lie not far from the present edge of the bluff but, since the land has been cultivated for a long time, it was impossible to be certain whether the slope toward the periphery of the mound was originally straight or curved, that is, whether we should regard the site as a segment of a sphere or as a cone. In default of more conclusive evidence we arbitrarily employed the formula for a sphere. The volume, then, became 584 cu. m., a value probably subject to considerable error.

EARLY PERIOD CENTRAL VALLEY SITES

C.68.—Here we consider the first of three Early sites. Since it is perhaps the latest within this cultural period, or for other reasons, it has been conserved in essentially its pristine form—a recognizable mound. The peripheral part was covered with three or four feet of alluvial clay deposit but, by borings, the true outline and depth was ascertained. The outline was an irregular circle. Considered as a circle, the area of the site was 5,205 sq. m.; as an ellipse, the area was 5,080 sq. m.; by graphic projection, it was 4,725 sq. m., probably the most accurate estimate of the three. In three dimensions the mound most closely approached a segment of a sphere, with a maximum depth of 2.01 m. The volume was then 5,165 cu.m. and the mass 6,466 metric tons.

C.142.—This site is very old and all vestige of an actual mound has been lost, even if we assume that the site ever possessed the form of a mound. Consequently we relied exclusively on a series of three pits and twenty-seven auger borings, which were carefully taken with particular reference to determining the peripheral limits of the site by means of a hydrochloric acid test on the soil. The form of the mound mass was irregular. In surface outline it most closely resembled a broad, irregular oval. With respect to depth the entire surface is now nearly level with the surrounding ground. (The site lies in a large field which has been plowed for many years.) Auger borings showed that

the southern half of the mound has a fairly uniform average depth of 1.06 m. and the northern half of 0.508 m. In each half the limits of the plateau, as it were, could be ascertained from the detailed borings and thus could be plotted fairly accurately. Treating each half separately, we estimated by graphic projection the total area and, reasonably closely, that of the plateau. The volume of that part of the site under the plateau was, of course, given as the product of the area and the average depth. The peripheral portion was considered in cross section as a right triangle, one limb of which formed the average depth at the edge of the interior plateau, the other limb the mean distance from the edge of the plateau to that of the mound proper. The volume was then the product of the area of this triangle and the circumference, which was taken as the mean of the circumference of the interior plateau and the circumference of the site as a whole. The total area was 6,117 sq. m. and the volume was 4,613 cu. m. The error involved was probably considerable.

C.56.—The area of this site was computed according to the graphic projection method based upon three pits and thirteen borings. The depth was taken first as the mean of the three pits. However, it is known that during the past ten years this site has been leveled for agricultural purposes and that, as a result, the apparent depth has been reduced. Our mean was 1.48 m., but the data given by Lillard, Heizer, and Fenenga (1939) showed that at least 35 cm. ought to have been added to reach the original maximum depth, 1.83 m. (or 72 in.). The mound was considered a segment of a sphere, and the area set at 2,647 sq. m., the volume at 2,420 cu. m.

SOUTHERN COASTAL SITES

SB 16.—This is the earliest of the Santa Barbara sites. It lies completely buried under a later alluvial deposit and, moreover, has been almost entirely destroyed by a road cut directly through the center of the mound. Only one pit could be excavated. There are, then, no data from which even an approximate estimate of size can be based. (Rogers, 1929, pp. 71–72.)

SB 53.—This site was oval in outline and pits and borings showed that it was flat at the top with a consistent mean depth of 1.22 m. Areas were determined by graphic projection and the volume calculated by means of the formula for a segment of a cone. (Rogers, 1929, p. 143, map no. 18.)

SB 81.—Neither the dimensions nor the outline of this site were measured exactly. Nevertheless the site had a roughly circular outline with a radius of approximately 47 m. The deepest boring was 1.09 m. The formula for a segment of a sphere was used for computing volume. The error of the values shown in table 1 was between 25 and 30 per cent of the estimate. (Rogers, 1929, p. 215, map no. 26.)

ROUND VALLEY SITES, MENDOCINO COUNTY

RVF 255, RV 120, RV 187.—These are all small sites and quite recent in time. The methods for computation employed for size did not differ from those previously described and need not be recapitulated in detail. The errors involved were, appproximately, plus or minus 25 per cent of the estimate.

OTHER SITES

Monument.—This site is deeply buried beneath later soil deposits and, indeed, has never been completely excavated. Our samples were very few in number and were all taken from one pit. Hence any estimate of mound size would be worthless.

S.104, upper (Late) and lower (Middle) strata.—This compound site was revealed through excavation of a large sand pit and has been partly destroyed. We excavated no archaeological pits and took no borings. Our samples, therefore, had to be taken from the vertical bank of the sand pit. There was no possibility of estimating the dimensions of the site.

POPULATION

For the estimate of the number of inhabitants living on a prehistoric site there are no concrete data whatever. We have to depend upon our knowledge of habitation methods, family number, and many purely subjective criteria. Nevertheless, there is no good reason to suppose that guesses of this sort are seriously in error when they are supported by a careful study of a specific site and an adequate background in general ethnology.

We have four sites in Central California which have been subjected to minute scrutiny. The first is the Ellis Landing shell mound, investigated by Nelson in 1910. The second and third are the Richmond shell mound and the Petersen site (Petersen I) recently described (Cook and Treganza, 1947). The fourth site is Petersen III, also described in a recent paper (Treganza and Cook, 1948).

For all four sites the surface area is known or has been calculated. These values, together with the pertinent estimates of average population are shown in the following table.

Site	Area in square meters	Estimated mean population
Ellis Landing	8,230.0	100
Richmond	3,142.0	50
Petersen I (P.1)	531.0	25
Petersen III (P.3)	89.3	10

We believed that there might be some functional relationship between surface area and population, hence we plotted these values in various ways. Only one method brought to light anything of significance. When the logarithm of the area was plotted against the logarithm of the estimated population, the four points fell very close to a straight line (see fig. 1, circles). This implied a relationship of the type:

$$\log \text{population} = \text{constant} \times \log \text{area}$$

Why such an empirical equation should hold is not readily explained. It was perhaps because the inhabitants of these sites actually lived on top of the

mound, leaving vacant the slope toward the periphery. If so, and if the average density in the livable area itself were constant, then as the size of this area increased, the population would increase in direct proportion to the extension of the inhabitable upper surface rather than to the total area of the mound. Meanwhile the ratio of the upper surface to the total area would not remain constant but would tend to increase. Hence the ratio of population to total area would likewise increase.

Regardless of explanation, however, this mathematical relationship becomes of considerable empirical value if it is sufficiently accurate to permit the calculation of the population of new or other sites merely by linear interpolation,

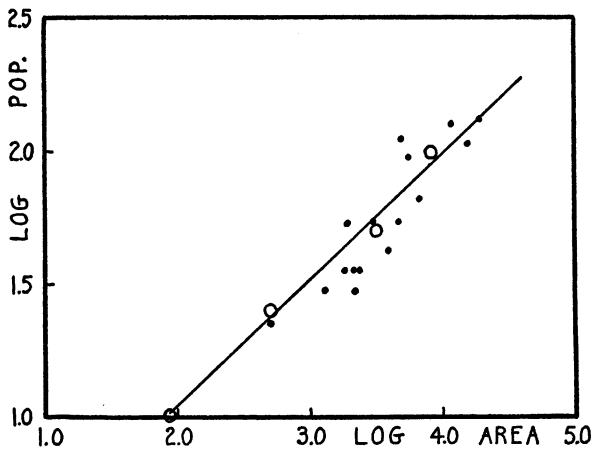

Fig. 1. Estimate of population from area by linear interpolation. Ordinate: logarithm of population. Abscissa: logarithm of area. Circles, four Central California sites. Dots, sixteen Yurok villages (after Waterman, 1920).

if the area is known. Despite the closeness of fit of the line connecting these four points, there are only four points, a very small number in the statistical sense. It would add much to the validity of the method if the same relationship could be found to hold with another series of sites outside the area we have considered.

Fortunately such a series is available from the territory of the Yurok described by Waterman (1920), who shows scale drawings of sixteen towns with houses and house pits. We drew the probable outline of each village as a line carried peripherally to the outlying houses and calculated the area graphically from the given scale of linear distance. The population was computed by multiplying the number of houses and house pits by six, the most likely value for the mean number of inhabitants per house. The results are set forth in table 1. The appropriate logarithms were then plotted on the same graph with those from the four Central Californian sites (see fig. 1, solid dots). The coincidence is striking.

The correlation coefficients for the two series were then calculated. That for the four first sites was +0.856, a high value even considering the very small

number of sites. For the sixteen Yurok villages, the correlation coefficient was +0.896, a highly significant value. It was clear, therefore, that the two series were governed by the same type of relationship, although the regions are separated by about 250 miles. Quantitatively there was a slight difference. The best fitting straight line was determined for the two sets of values and the slope of the line computed by the method of least squares. The result for the central group was +0.361; for the northern group, +0.567. This difference can no doubt be ascribed to variation between the two regions in mode of

TABLE 1

POPULATION OF YUROK VILLAGES

Village	Area (in sq. mi.)	No. of houses	Population
Omen	766	4	24
Rekwoi	19,314	22	132
Woxero	2,251	6	36
Woxtek	3,942	7	42
Qootep	4,896	19	114
Pekwan	5,690	16	96
Meta	2,223	5	30
Murek	16,002	18	108
Saa	4,719	9	54
Kepel	3,068	9	54
Qenek	1,802	6	36
Wahsek	2,132	9	54
Weitspus	11,589	21	126
RLrgr	1,338	5	30
Pekwutul	2,174	6	36
Tsurai	6,349	11	66

Source: T. T. Waterman, Yurok Geography, 1920, UC–PAAE 16:177–314.

living, type of dwelling construction, and the like, as well as to the fact that the inhabited places of the Yurok are not true mounds.[6] Irrespective of minor quantitative differences, however, it is evident that the graph of the four central sites may be used for estimating population from area by linear interpolation with a relatively high degree of safety. This has accordingly been done and the results have been incorporated in table 2.

PHYSICAL COMPONENTS OF THE MOUND MASS

The final data for the analyses of physical components in the sites previously described are presented in table 3, pp. 236–237. The results are expressed in terms of percentage of total weight, together with the standard errors. These data require considerable explanation and discussion, particularly from the ecological standpoint.

[6] If we possessed the requisite data, it would be of interest to investigate other, more widely separated, areas in order to determine whether the log-log relationship has general or universal validity. Moreover, the constants of the slopes might provide a simple means for comparing various types of village construction and living conditions.

Rock and Clay

We may consider first the quantities of rock and clay found in the various mounds, beginning with the central group of Late sites, Richmond, Petersen I, Petersen III, S.1, and C.6.

The Richmond site contained 17.15 per cent rock. The value would have been very much higher, had not the mound mass been heavily diluted by accumula-

TABLE 2

Summary of Data on Mass, Volume, and Population

Site	Area (in sq. mi.)	Volume (in cu. m.)	Apparent density	Mass (in m.t.)	Estimated population
Central Valley					
S.1	2,661	3,388	1.210	4,099	52
C.6	22,781	22,376	1.181	29,969	228
P.1	531	234	1.3 (est.)	304	25
P.3	89	30	1.625	49	10
S.104 (upper)	....	....	....	....	..
S.43	841	531	1.343	713	30
C.66	5,780	4,198	1.329	5,579	94
S.99	1,023	584	1.216	710	34
C.56	2,647	2,420	1.352	3,272	54
C.68	4,725	5,165	1.252	6,466	69
C.142	6,117	4,613	1.688	7,787	78
S.104 (lower)	....	....	....	....	..
Southern coastal					
SB 16	....	....	....	....	..
SB 53	9,516	7,954	1.804	14,349	96
SB 81	6,362	3,469	1.735	6,019	48
Round Valley					
RVF 255	165	50	1.333	67	14
RV 120	2,277	1,162	2.098	2,438	48
RV 187	565	521	1.740	906	24
San Francisco Bay					
Richmond 1	3,142	3,114	1.3 (est.)	4,048	50
Monument	....	....	....	....	..

tion of shell. In fact, if we compute rock on the basis of the mound matrix minus shell, the relative quantity reaches 37.3 per cent. To acquire this large quantity, however, was a simple matter for the inhabitants because the site, although situated at the tide line of the bay, is less than a mile from the rocky hills northwest of Richmond. Since there is no rock actually in the soil upon which the mound was built and hence all rock had to be deliberately imported, the value for this site gave an indication of the total quantity used when free access to a good supply was close at hand and no particular economy was necessary.

The Miller mound, site S.1, presents a very different aspect. Lying roughly half a mile from the Sacramento River in the middle of an extensive alluvial plain, it is at least fifteen miles distant from the nearest hills and rock outcrops. Hence for the inhabitants to carry in stones meant a long and arduous journey. Correspondingly, we found a rock content for the site of only 4.88 per cent, much of which, furthermore, consisted of relatively small pebbles, with large, rough fragments notably absent. It appears that the natives depended to a considerable extent upon detritus washed down the river in time of flood rather than upon pieces dug from the soil in a hilly or stony region. If so, then the value of approximately 4 or 5 per cent must represent the minimum rock supply regarded as necessary for domestic purposes, mainly cooking.

The Johnson mound, site C.6, according to our findings, contained 14.66 per cent rock and clay but at least 10 per cent of that was clay, leaving only about as much actual rock as was found in site S.1. This result is in harmony with the location of site C.6, which is near the lower Cosumnes River in the plain at the edge of the main valley floor, far removed from any natural rock outcrop.

The presence of clay, estimated at 10 per cent by weight, is consistent with the long-recognized fact that the Johnson mound was the largest "baked clay" producing site in the valley.[7] There seems little doubt that here we are dealing with a real manufacturing industry for local use and for export. The purpose of an industry of this kind was partly to provide various types of clay artifacts, but most of the material went into the fabrication of balls or masses which could serve as cooking stones, sinkers, and other objects; that is, the clay was a substitute for natural rock. The market was no doubt provided by numerous small villages situated along the lower Sacramento and San Joaquin rivers, which possessed no good local source of rock or clay deposits.

Some notion of the labor involved in the industry can be obtained from the data now available. The mound mass was calculated as nearly 30,000 metric tons (table 1), exclusive of an unknown quantity of baked-clay artifacts that were probably exported. Hence there must be a minimum of 3,000 metric tons or 3,000,000 kg. of burned or baked-clay refuse now in the mound, not counting the clay powder of size too small to catch in a 2-mm. sieve. It would not be inappropriate to add 50 per cent to account for this fraction, making in all 4,500,000 kg. There was no clay at the site; it had to be brought in from some outside source. It then had to be worked, modeled into artifacts, and baked. How many complete artifacts this represents there is no way of telling, but the number must have reached the hundreds of thousands. If only one-tenth of the raw clay reached final form—and this would be a pure guess—and if each artifact weighed on the average 250 g. or half a pound, there would have been manufactured 1,800,000 artifacts. The estimated average population of the site was 228 persons. If we exclude the active men, the infants, and the infirm, there might have been 100 individuals participating in the industry at any specific time. If we were to allow one man hour to produce one artifact (including obtaining the material, processing, and firing the clay), then the

[7] For a discussion of this point with respect to the Johnson mound, reference may be made to the analysis by Heizer (1936).

TABLE 3

Physical Components of the Mound Mass

Site	Rock and Clay			Bone			Shell		
	Percentage*	S. E.	S. E. as percentage of mean	Percentage*	S. E.	S. E. as percentage of mean	Percentage*	S. E.	S. E. as percentage of mean
Central Valley									
S.1	4.88	0.41	8.40	0.239	0.078	14.41	0.482	0.074	15.35
C.6	14.66	1.11	7.84	0.287	0.0338	11.78	0.0204	0.0035	17.16
P.1	25.18	2.15	8.54	0.366	0.125	34.15	0.009	0.0023	25.56
P.3	40.28	....	....	0.239	.....	.....	0.0072	.....	.....
S.104 (upper)	4.89	0.42	8.59	0.831	.....	32.16	0.1292	0.0388	30.02
S.43	5.68	0.36	6.34	0.539	0.058	10.75	0.108	0.023	21.30
C.66	8.34	0.85	10.20	0.619	0.097	15.66	0.0513	0.0077	15.00
S.99	13.13	1.63	12.41	0.086	0.0095	11.05	0.0169	0.0054	31.95
C.56	5.12	0.59	11.50	0.190	0.0336	17.68	0.0208	0.00619	29.75
C.68	20.16	2.23	11.06	0.216	0.037	1.72	0.0094	0.0019	20.21
C.142	3.84	0.38	9.95	0.025	0.0036	14.40	0.00092	0.00056	60.85
S.104 (lower)	2.07	0.51	24.64	0.2322	0.1145	49.25	0.00	0.00	0.00
Southern coastal									
SB 16	1.02	0.12	11.76	0.00	0.00	0.00	0.00	0.00	0.00
SB 53	1.12	0.44	39.31	0.0251	0.0067	26.69	12.87	2.266	17.60
SB 81	6.25	1.36	21.76	0.256	0.0565	22.01	3.036	0.939	31.92
Round Valley									
RVF 255	52.16	0.93	1.78	0.0013	0.00127	97.60	0.00	0.00	0.00
RV 120	48.22	2.86	5.83	0.0168	0.0075	44.65	0.00	0.00	0.00
RV 187	40.61	1.27	4.01	0.0098	0.00254	25.94	0.00	0.00	0.00
San Francisco Bay									
Richmond 1	17.15	2.07	12.05	0.064	0.038	.....	45.90	1.310	2.85
Monument	2.90	0.96	33.10	0.0198	0.0037	.....	0.1388	0.0785	56.50

* Percentage of weight of total mound mass.

TABLE 3—*Continued*

Site	Charcoal			Obsidian			Flint		
	Percentage*	S. E.	S. E. as percentage of mean	Percentage*	S. E.	S. E. as percentage of mean	Percentage*	S. E.	S. E. as percentage of mean
Central Valley									
S.1	0.181	0.024	13.25	0.0011	0.00079	7.18	.....	.....	.....
C.6	0.1886	0.02075	11.12	0.00681	0.00165	24.23	.....	.....	.....
P.1	0.109	0.050	45.85	0.0033	0.0012	36.35	.....	.....	.....
P.3	0.0796	.....	.....	0.00593	.....	.....	.....	.....	.....
S.104 (upper)	0.475	0.135	28.42	0.00950	0.00780	82.10	.....	.....	.....
S.43	0.0056	0.002	35.70	0.00025	0.00011	44.00	.....	.....	.....
C.66	0.00419	0.00089	21.22	0.00230	0.00119	51.82	.....	.....	.....
S.99	0.07965	0.01205	15.05	0.00069	0.00023	30.00	.....	.....	.....
C.56	0.00107	0.00071	66.35	0.00035	0.00014	38.80	.....	.....	.....
C.68	0.00236	0.00193	81.77	0.00030	0.00017	57.33	.....	.....	.....
C.142	0.00	0.00	0.00	0.00	0.00	0.00	.....	.....	.....
S.104 (lower)	0.00	0.00	0.00	0.00	0.0	0.00	.....	.....	.....
Southern coastal									
SB 16	0.00	0.00	0.00	0.00	0.00	0.00	.....	.....	.....
SB 53	0.00015	0.00001	6.67	0.00	0.00	0.00	0.00132	0.00006	4.54
SB 81	0.00897	0.00361	40.25	0.00024	0.00011	45.85	0.00756	0.00260	34.40
Round Valley									
RVF 255	0.1083	0.0279	25.75	0.00	0.00	0.00	.....	.....	.....
RV 120	0.1903	0.0442	23.22	0.00	0.00	0.00	.....	.....	.....
RV 187	0.3492	0.0913	26.11	0.00	0.00	0.00	.....	.....	.....
San Francisco Bay									
Richmond 1	0.072	0.017	23.60	0.00	0.00	0.00	.....	.....	.....
Monument	0.00130	0.00045	34.60	0.00	0.00	0.00	.....	.....	.....

* Percentage of weight of total mound mass.

labor cost would have been 1,800,000 man hours or, with 100 people working, 18,000 village hours. If each person actually worked at the job one hour a day every day in the year, the gross production period would have amounted to fifty years. In fact it probably covered a span of several centuries. We do not claim precise validity for these figures; they are presented only to give some idea of the magnitude of the primitive clay artifact industry carried on at site C.6.

Petersen I (P.1) and Petersen III (P.3) showed respectively 25.18 and 40.28 per cent rock and clay. This is a very high percentage by comparison with other sites in the same general area, although it is quite comparable with that found in the Richmond mound. The material in Petersen I was almost exclusively rock, whereas that in Petersen III included a great deal of burned and baked clay. The content in rock alone is probably very similar in the two sites. Since they are about half a mile apart, there is no reason why this should not be so. Both are on the bank of a slough, surrounded by low and marshy ground with no surface rock whatever. Nevertheless, some three or four miles to the west are the low and rolling Montezuma Hills. We may assume, therefore, that the inhabitants of both sites carried in from the hills a variety of stone needed for hearths, cooking stones, implements, and other uses, the short distance affording no serious obstacle to transport.

With respect to the additional clay found in Petersen III (probably nearly 15 per cent by weight) certain puzzling problems arise. It is to be noted at the outset that this site is immediately adjacent to the much larger mound, Petersen II, which also contained a considerable amount of burned clay. Indeed, these two sites may have operated as a single economic unit during the period of their growth. The clay baked or burned here could not have been necessary for domestic use as a replacement for rock since the supply of rock, as already shown, was copious and of a suitable nature for stone baking. An alternative hypothesis is that the inhabitants operated here a clay industry for export, similar to that which characterized the Johnson mound.

Such a hypothesis, however, is open to serious objection. First, most of the fired clay is unmodeled and thus of no value, since its form cannot be altered. Second, no evidence remains to show that artifacts were made and fired on the site before export as useful finished pieces. In our complete excavation of the mound we found only five modeled clay artifacts (Treganza and Cook, 1948, p. 296), as contrasted with thousands to be seen in the matrix of the Johnson mound.

If the clay was not used and was not exported in the form of finished artifacts, then its presence must have been incidental to other domestic activities. At the beginning of the occupation of Petersen III the area was probably low and swampy; especially wet in winter. We have already shown (Treganza and Cook, 1948) evidence of artificial mound building at this site and this may perhaps also hold for Petersen II. The entire lower third of the mound appears to be a fill, consisting predominantly of small, irregularly shaped masses of hardened clay. Thus if clay had been brought in as raw material to build up a base, then much of it would have been heated and burned by the repeated

building of fires on its surface. Furthermore, we also have some evidence that the base of the houses may have been coated with clay and that house floors may have been of packed clay construction. Such clay would be irregularly fired when, as often happened, the house burned down. A certain amount would also be contributed by cooking fires built upon the floors. Since, however, the vast majority of the clay fragments are derived from the lower third, the constructed base, and since clay house floors occur at other sites, it is reasonable to conclude that the high clay content of this site may be attributed primarily to the manner of construction of the site and not to any artifact industry.

If we concede the conclusion formulated in the paragraph above, then we must consider that the clay in Petersen III, other than that which formed the artificial base, was purely adventitious. What we might regard as the functional rock would then amount to approximately 25 per cent, or nearly the same percentage as that found in Petersen I, a site in which there was no appreciable amount of clay.

The three Middle period sites in the Central Valley, S.43, C.66, and S.99, may be considered together. They were approximately contemporaneous and were built perhaps 1,500 to 3,000 years before those of the Late culture. During this interval there was probably no profound change in the climate and vegetation of the region. Moreover, since most rock does not change while lying in the mound, its present quantity is a true index to the amount actually deposited by the inhabitants.

Site S.43, close to the existing channel of the Sacramento River, resembles in its surroundings C.66, which is near the banks of the lower Mokelumne. Both are long distances from any hills or outcrops of native rock and in this respect are similar to S.1 and C.6. Site S.43 contained 5.68 per cent and C.66 contained 8.34 per cent rock by weight. These values for the rock content (exclusive of clay) are within the general range characteristic of the two recent sites, although C.66 appeared to contain a little more rock than the other three. Furthermore, the rock itself consists of rather small stones and pebbles, some of which are waterworn, suggesting that the stones were collected, as at S.1, from local watercourses rather than outcrops.

Site S.99 contained 13.13 per cent rock, a definitely larger quantity. The nature of the rock, however, is somewhat different from that encountered at the other Middle period sites. The mound, as previously mentioned, is situated on a bluff directly overlooking the American River. The surrounding terrain is composed principally of an unconsolidated conglomerate in which are loosely embedded vast numbers of waterworn rocks of all sizes. Moreover, the river bed is paved with smooth cobbles of a similar appearance. The mound itself consisted of a fine black sandy soil in which were included a great many rocks of this sort. This feature was noted by Fenenga (Lillard, Heizer, and Fenenga, 1939, p. 47), who described the mound mass as being "a slightly indurated midden deposit differing from other Transitional deposits in that there was a great quantity of stream cobblestones throughout the mound mass." He also noted two burials with a platform of these stones above and

below. We also discovered a similar burial. It is quite clear, therefore, that this type of rock was so plentiful that the inhabitants were able to utilize it very liberally for ceremonial as well as for domestic purposes.

In our samples it was noteworthy that the rock occurred only as large fragments, with few or no pieces of intermediate or small size. Moreover, contrary to Fenenga's description and our own observation, a number of these were not of the smooth, stream-worn variety, but were rough or angular pieces, as if derived directly from more or less undisturbed bedrock. It is consequently possible that the natives may have obtained stones from more than one source, although the evidence of field observation renders it almost certain that the predominant supply came from the river bed and the adjacent deposit of conglomerate. It is possible that in the process of stone boiling some cobbles were fractured from the heat, resulting in angular fragments.

The consistently large size of the stones, irrespective of type, may have disturbed the accuracy of our sampling. If so, it is quite possible that the percentage by weight found on analysis was too low. Such an error, if present, is not serious since it can be compensated for by the recorded field observations. Evidently the location of S.99 was extremely favorable to a supply of rock, and the inhabitants made use of the commodity in a variety of ways, well beyond the minimal domestic need. It may be added that the mound seemed to be totally devoid of clay.

The three Early period sites, C.56, C.68, and C.142, all lie within a small area in the bend of the lower Mokelumne River near sites S.43 and C.6. Their age may be estimated as 3,000 to 7,000 years and they have undergone considerable alteration, as evidenced by the presence of a thick calcareous hardpan. So far as soil-rock relations are concerned, it is highly probable that the area has not changed materially during this time interval except for the steady addition of alluvial deposit brought down by the rivers. If the physiographic features were thus essentially the same during the occupancy of these sites as they are today, the rock content would be expected to match that of the later sites. The percentage of rock was 5.12 for C.56 and 3.84 for C.142. The percentage for C.68 was 20.16, a very much higher value; higher even than at S.99, where native rock is abundant. The apparent discrepancy can probably be explained by the conditions under which the sites were excavated. In the summer of 1946 site C.68 was relatively untouched by archaeologists. The samples of matrix included great masses of hardpan, through which pits and borings had to be sunk. In working over the samples for analysis it was impossible to grind up and pulverize for sifting these lumps of tough, concrete-like material without destroying the bone, shell, and charcoal we wished to recover. As a result, much hardpan was retained, rendering the value for the percentage of "rock" fictitiously high. Visual inspection during the cleaning and sifting operations indicated that there was very little true rock or stone present. It is safe to assume, therefore, that site C.68 is on a par with the other two early sites in true rock content, thus conforming to the general principle that the rock content of mounds in the alluvial valley floor is relatively meager. It is known that C.142 and C.56 were also originally covered with a heavy

hardpan. Indeed, Lillard, Heizer, and Fenenga (1939) report that at the time of their excavation the mound C.56 still had a calcareous cap. But by 1946 both these sites had been broken up and their surfaces had been thoroughly plowed. Our samples, therefore, contained little, if any, of the unbroken hardpan and little error in computing rock content was introduced by its presence.

In considering these Early sites one other factor must not be neglected. It is assumed that the rock fragments found in the Late and Middle period sites were imported mainly for domestic purposes, although much of the finer material doubtless came in attached to plants, shellfish, and sticks of wood. The primary domestic use was for the construction of hearths and for artifact manufacture. Now it is perhaps possible that the Early people employed a different method for cooking and processing food and may not have built as many fires as the later peoples or may have done so in a different manner. If so, then we might not expect to find many or any large rock fragments. Such a possibility is suggested by the almost complete absence of anything but very small pieces of stone, particularly in sites C.68 and C.142.

The three Santa Barbara sites are all within a short distance of the seashore. Although the soil of the immediate environs consists mainly of alluvial soils, there is an almost unlimited supply of rock both from conglomerate outcrops along the coastal terraces and from the high hills to the north. Nevertheless, the rock content of the three sites studied was relatively low: 1.02 per cent for SB 16, 1.12 for SB 53, and 6.25 for SB 81.

The oldest site, Ortega Hill or SB 16, represents the Oak Grove culture, which is somewhat analogous culturally to the Early sites of the Central Valley and may perhaps coincide with them in age. We found that its remnant (for the bulk of the mound was destroyed) consisted of little more than a thick layer of highly compacted and partly metamorphosed ash. When the ash was freed from the coarser particles, there remained only a few tiny rock fragments such as might have been brought in at random by wind, by water washing, or even inadvertently by the inhabitants. The underlying subsoil could have contributed nothing but very fine sand or clay. There was no evidence whatever of the utilization of rock for domestic or other cultural purposes. If we assume that Ortega Hill was a habitation site, we are forced to conclude, on the basis of what our samples yielded, that despite a favorable environment the people of this period made no hearths and used no stone for domestic purposes. That they had fire and depended extensively upon cooked food was attested not only by the huge ash deposit but also by the tremendous number of metates and manos found in the vicinity, artifacts which, we understand, had been formerly plowed from the original site. The Early Central Valley sites did not give evidence of much reliance upon rock as a necessary cultural adjunct, but the Oak Grove site studied here indicated no reliance on rock at all beyond its use for manos and metates.

These conclusions are so much at variance with what might be expected that we must question our sampling. The accounts of D. B. Rogers (1929, pp. 345–350) indicated that most Oak Grove sites produced standard midden deposit with considerable rock included. This fact was confirmed by our own

observations and leads us to doubt whether the limited area and stratum we sampled at Ortega Hill can be regarded as providing typical Oak Grove material at all. A greater number of samples over an expanded area would no doubt produce quantitative results more in line with what has been reported for the Oak Grove culture.

When we examined SB 53 (Campbell no. 1) we found the same type of difference in stone persisting. This site resembles the San Francisco Bay mounds in the vast amounts of shell content. Yet, in contrast to the Bay mounds, SB 53 had an exceedingly low rock content. The Richmond mound contained 17.15 per cent rock in contrast to 45.90 per cent shell (see table 3). The mound at SB 53, on the other hand, contained only 1.12 per cent rock and 12.87 per cent shell. At the same time the physiographical environment of the two sites is very similar. The fine material in both is almost the same in appearance and texture: fine, black, "greasy," and ashy, indicating intense and long occupation. The explanation of the difference in rock content of the two sites must lie, therefore, in the cultural tradition rather than in the environment.

The Las Llagas site (SB 81) conformed more closely to the Late culture sites of the Central Valley, since it contained 6.25 per cent rock. Many of the fragments were of reasonably large size and indicated domestic use for fires. However, in the close propinquity to the mound of extensive reserves of free native rock the external conditions resembled more closely those found near site S.99 than at S.1, C.6, S.43, and C.66. But the rock content of S.99 was twice as great as that of SB 81.

Taking all three cultural periods into consideration, we must conclude that certain cultural trends, apparent in the Santa Barbara Channel region but not evident in the Central Valley, are due only in part to the environment. Although stones and rock were readily available in the former region, they were not employed so extensively nor probably in the same manner as in the latter area.

The three Round Valley sites are all representative of the Early historic culture period, for they all contained Caucasian material in their upper levels. Their ecological status was highly uniform. RV 120 and RV 187 are situated at the edge of the valley just at the first rise of the hills. RVF 255 lies perhaps a mile from the hills but on a very low knoll where there is almost no topsoil overlying bedrock. All three had a very high rock content, the percentage values were 48.22, 40.61, and 52.16 for RV 120, RV 187, and RVF 255, respectively. A large fraction of this rock is unavoidably present and would inevitably accumulate from the adjacent slopes during human occupation, irrespective of the type of culture characterizing the human group.[8]

[8] A somewhat similar state of affairs was seen in a group of recent mounds in the low hills near Suscol, some four or five miles south of Napa. On the slopes above these sites may be found a continuous zone of weathered basaltic lava. During the course of time the mass wasting of this stratum and the creep of talus have caused a gradual downward movement of rock debris. Parallel with this process at a lower elevation, the accumulation of human refuse on the habitation sites was gradually building up. The interaction of these two phenomena resulted in a deposit exceptionally heavy in rock content, in fact, so heavy that excavation with a shovel was very difficult.

The influence of these local soil conditions was particularly obvious in site RVF 255. This little mound was occupied, during historic times, for no more than twenty years and had scarcely evolved beyond the initial stage of surface occupation of the ground. The mound matrix as it now exists is little more than the original soil mixed with masses of loose rock carried up from below. Recent geological work in Round Valley indicates that the greater part of the area was subjected in recent times to rather rapid alluviation, which covered the bedrock with coarse detrital sediments consisting in large part of rough rock fragments. Our observations on site survey in the valley floor confirmed this. Many sites lie on surfaces ranging from coarse gravel to boulders, resulting in a primary admixture of mound debris and rock. In the initial phases of mound construction rock would naturally predominate. Another factor of importance here is the work of ground squirrels and other burrowing rodents, which bring up debris from lower levels to the surface. These factors are particularly evident in a very young mound such as RVF 255. The other two mounds, RV 120 and RV 187, very likely started in the same manner. However, they were occupied for a considerably longer period; hence the organic and cultural detritus is of relatively greater quantitative importance.

In contrast with Santa Barbara, the Round Valley area showed indisputably the influence of external environmental factors. On the other hand, it is likely that the Round Valley culture pattern included much greater utilization of the existing rock and stone resources than the pattern characteristic of the Santa Barbara region. One important factor to consider is that in the later phases of Santa Barbara cultural history much cooking was done in steatite vessels, whereas in Round Valley, as in the Sacramento Valley, cooking was done in baskets by means of stone boiling. In this use of stone the Round Valley culture more closely resembles that found in the Napa Valley, the Richmond site, the Petersen sites, and S.99.

At S.104 (Tyler Island), the upper (Late) stratum, with 4.89 per cent rock, conformed quite closely to the general picture of the valley habitat. This mound is several miles removed from any natural rock supply save for the little that may have been provided by the river itself. The lower (Middle period) stratum, with 2.07 per cent rock, was composed almost entirely of a fluvial sand deposit and in many respects was aberrant. As was also true of the Monument, or Concord, site, not enough is yet known of the cultural features to warrant much discussion of the significance of the rock contained in the mounds.

In summary, we may state that the analyses showed a consistent use of rock and stone for utilitarian purposes in the central hill and valley sections of the state. This supply was provided up to the limit of probable domestic necessity (apparently at the level of approximately 4 to 6 per cent by weight of the mound matrix) by whatever means were at the disposal of the inhabitants. In the marshes and alluvial plains of the valley and delta a few stones were gathered from stream beds (S.43, C.66); however, the bulk of the lithic material was of direct import (Heizer and Treganza, 1944, p. 299), and in the Central California Valley a substitution was made by the baking of clay arti-

TABLE 4

BONE AND MEAT CONTENT

Site	Percentage of bone*	Percentage of bone: corrected value	Total bone (in kg.)	Total edible flesh (in kg.)	Assumed duration of occupancy (in years)	Edible flesh per inhabitants per day (in g.)
Central Valley						
S.1	0.541	0.569	22,176	887,040	2,000	23.3
C.6	0.287	0.335	86,011	3,440,440	1,200	34.4
P.1	0.366	0.489	1,113	44,520	400	9.2
P.3	0.239	0.481	117	4,680	200	6.4
S.104 (upper)	0.831	0.873	.....	.....	.....	....
S.43	0.539	0.571	3,843	153,720	400	35.1
C.66	0.619	0.676	34,534	1,381,360	800	50.3
S.99	0.086	0.099	611	24,440	300	6.6
C.56	0.190	0.198	6,217	248,680	.....	21.0
C.68	0.216	0.271	13,967	558,680	1,000	22.2
C.142	0.025	0.026	1,947	77,880	1,000	2.7
S.104 (lower)	0.232	0.236	.....	.....	.....	....
Southern coastal						
SB 16	0.00	0.00	.....	.....	.....	0.0
SB 53	0.0251	0.0292	3,602	144,080	800	5.1
SB 81	0.256	0.282	15,408	616,320	600	58.6
Round Valley						
RVF 255	0.0013	0.0027	1	40	20	0.4
RV 120	0.0168	0.0325	410	16,400	300	3.1
RV 187	0.0098	0.0155	89	3,560	200	2.0
San Francisco Bay						
Richmond 1	0.064	0.173	2,591	103,640	700	8.1
Monument	0.0198	0.0202	.....	.....	.....	....

* Percentage of total sample, by weight.

facts, as exemplified at site C.6. Where native rock deposits were reasonably close at hand, the supply reached and exceeded the apparent limiting value of 4 to 6 per cent (Petersen I, Richmond, S.99) and in certain places, where the inhabitants virtually dwelt on bedrock, this commodity passed any conceivable limits of necessity (RV 120, RV 187, RVF 255). Deviations were seen in the Santa Barbara sites; near them there was an abundant supply of rock, which seemingly was never utilized on an appreciable scale. This distinction was probably due to cultural variation rather than to environmental pressure, like the practice mentioned earlier of cooking in steatite vessels instead of stone boiling in baskets.

Bone

The bone content of a prehistoric mound, together with the shell, if any, constitutes a fair index to the type and quantity of animal food available to the inhabitants, since only these nonorganic materials persist over a period of centuries. The greater part of the diet of aboriginal peoples in California consisted undoubtedly of plant food, all of which has long since decomposed, leaving no visible trace. From the samples obtained at the sites all bone scraps which were held by the 2-mm. screen were separated. No attempt was made, however, to segregate the bone according to specific animal source, although a rough tally was kept of general categories, such as mammal, bird, and fish bone. The results are expressed in the usual manner, percentage by weight of the entire sample (see table 3 and table 4, col. 1). This may be designated as the gross value for the percentage of bone. At the same time it may be somewhat more exact to consider the quantity present after deducting the other major mound components, rock, clay, and shell, for the three sites. A mound grew by accretion or accumulation; the amount of a material like rock or clay may be quite independent of such a constituent as bone. The fundamental point of reference was the fine matrix or soil rather than the aggregate of all components, large and small. Hence we arrived at the corrected percentage of bone, shown in the third column of table 4. To compute this value we determined the percentage of bone in the total mass minus the percentage of rock and clay in all samples. Shell was deducted for the three sites (SB 53, SB 81, Richmond) in which it constituted more than 1 per cent of the total weight.

In order to estimate dietary value it was necessary to have some idea of the total weight of bone as well as of its concentration. In previous calculations of this kind we took the ratio of dry, dead bone to original fresh weight of an animal as 6 : 100. Many sites in this series, however, contained considerable quantities of fishbone, of which the relative weight is less than for mammal and bird bone. Consequently, it was desirable to reduce the ratio slightly, say 5 : 100. Therefore, the total weight of dry bone from each site was calculated from the gross percentage (table 3) and the total mound mass (table 2) and expressed in kilograms (see table 4, col. 4). To compute the total fresh weight of the carcasses this value was first multiplied by 20 (according to the ratio above). Recognition was then taken of the high probability that the bone actually recovered from the mound or from samples thereof represented only a portion of the animal food actually brought to the site by the inhabitants

and consumed. The rest of the bones could have been used for industrial purposes, thrown away at random, or carried off by animals. Lacking the slightest concrete data concerning this point, we made the pure assumption that the lost bone was equal in quantity to the recoverable bone. Hence the factor of 20 was increased to 40, and the total edible flesh was taken as the kilograms of dry bone multiplied by 40 (table 4, col. 5). It was legitimate to regard dry bone as edible material, since we knew from many accounts that the California aborigines were accustomed to consume as food the viscera, membranes, brain, bone marrow, and occasionally pulverized bone—indeed, sometimes everything except the skin.

Even though we had a crude estimate of the total amount of edible flesh brought to any given site, we still wished to get some idea, however subject to error, of the average amount of this material normally consumed per person. This purpose required a rational estimate of (1) the population density and (2) the time involved. For the first factor we had the figures already cited (table 1) for the mean number of inhabitants to be expected at each site. For the second, our recourse was a reasonable guess. This guess was based upon our general knowledge of the duration of the principal culture periods (in turn derived from archaeological study, chemical analyses, etc.), as well as from the gross appearance, mass, and depth of the individual sites. The sixth column, table 4, contains such guesses. For certain sites there were contributory bits of evidence. For example, it is known that site C.6 persisted throughout the entire Late culture period; this period probably lasted at least 1,000 years or longer. Therefore, the hypothesis of 1,200 years for the duration of C.6 was not likely to be seriously incorrect. The upper half of site S.1 derived from the Late period and the lower half probably from the Middle period. The latter period, *in toto*, probably exceeded the former in length. Hence the mound must have been inhabited for approximately 2,000 years. The dates of origin and abandonment are definitely known for RVF 255. The mound was inhabited for very close to twenty years. All the values for assumed occupation time are given in table 4, column 6. The corresponding values for average daily intake of animal flesh per person, expressed in grams, were computed and entered in table 4, last column.

The Central Valley Late and Middle culture sites constituted a more or less uniform and natural ecological group. They include S.1, S.43, C.6, C.66, and the two Petersen sites. They all lie along rivers or sloughs in the flat, marshy plain of the lower Sacramento and its tributaries where the mammalian, bird, and fish fauna has for many centuries been very prolific. The bone density, as shown in the third column of table 4, within the limits of our method, was remarkably consistent, with an average value of approximately 0.52 per cent. There were, however, some qualitative differences. The four upriver sites (S.1, S.43, C.6, C.66) contained relatively large amounts of fish remains with correspondingly little mammal and bird, whereas the Petersen mounds contained almost exclusively mammal and bird bone. This distinction can probably be attributed to the fact that S.1 and S.43 are very close to the main channel of the Sacramento River and C.6 and C.66 are on the banks of the

Cosumnes and the Mokelumne, whereas the Petersen mounds are alongside the narrow and stagnant Lindsey Slough, into which only a few fish penetrate. Enormous quantities of water birds, however, once inhabited and nested in the marshy "tulares" of the delta country.

For the four sites east and north of the delta the calculated daily mean of flesh consumption per person was likewise consistent with the values 23.3, 34.4, 35.1, and 50.3 g. for sites S.1, C.6, S.43, and C.66, respectively. In order not to insist upon too exact a figure we put the quantity at somewhere between 20 and 40 g. This, it should be noted, means roughly an ounce of this food a day, a satisfactory, although by no means a liberal, level of animal protein intake. The corresponding values for the two Petersen sites were 9.2 g. (P.1) and 6.4 g. (P.3). Considering the high percentage of animal bone in the mounds and the known extensive food resources of this type, we are inclined to believe that the calculated result was in error, owing perhaps to faulty assumptions of the duration of habitation. Probably the consumption of animal food approached that indicated for the other four sites (S.1, S.43, C.6, and C.66).

The Early period valley sites C.68 and C.56 had a somewhat lower bone concentration than the contiguous Late and Middle sites, together with a correspondingly lower intake of animal food per person (22.2 and 21.0 grams respectively). Nevertheless, considering the numerous possible sources of error, the results implied no very different style of life during the Early period. There is no reason to suppose that the topography and ecology of the Central Valley has undergone any profound change within the past few thousand years or that the natives were any less able to obtain game during the Early culture period than later. Indeed, in physical appearance the bone scraps found in our samples from C.56 and C.68 were identical with those from the Middle and Late period sites. It is, therefore, reasonable to conclude that both qualitatively and quantitatively the sources and utilization of animal food remained constant in the lower valley and delta region since the arrival of the first known human beings.

Other sites present special problems. C.142, the third Early horizon Central Valley site, contained remarkably little bone, 0.026 per cent. This is less than 3 grams of flesh per person per day, an utterly inadequate quantity. The difficulty was apparently in the assumption that the figure for the mean population derived from the surface area—which was satisfactory as far as it went—represented a continuous occupation of the mound. Archaeologists who have studied the site observed that there was a marked scarcity of ash, little indication of hearths or house floors, and few artifacts other than those associated with burials. Hence, it is quite probable that this site was used intermittently for camping and perhaps ceremonial purposes, for there numerous burials were uncovered. If this is true, then relatively little animal bone would be expected and no conclusions concerning the real diet of the people are warranted.

The rather low value for the corrected percentage of bone at the Richmond site was explicable on the basis of the exceedingly high shell content. The major portion of the animal food consisted of shellfish; hence it was unnecessary for the inhabitants to expend much energy in obtaining vertebrates. For this site,

therefore, the daily ration of 8.1 g. of vertebrate flesh per person was probably a reasonably close estimate. On a basis of percentage of mound mass the Ellis Landing site, also on the Bay, produced a similar relationship, with 0.077 per cent mammal bone as compared with 0.064 per cent for the Richmond site.

Site S.99 is a mystery. This mound is on a bluff overlooking the American River in its lower reaches, just within the foothills. It must have been the habitat of fish, particularly trout and salmon. Yet the samples showed no trace whatever of fishbone. Mammals and birds no doubt were abundant. Yet the density of this type of bone in the samples was low (0.099 per cent). Possibly the inhabitants secured principally large mammals like elk and deer and the bones, being of considerable size, were simply not picked up in our small sample series. Whether or not this is true, it was evident that the vertebrate fauna near S.99 was quite distinct from that of the valley and plains sites. The former could not depend upon the prolific aquatic and avian resources which in great part supported the latter. It would be desirable to check this apparent difference by examining more sites in the lower foothills of the Sierra Nevada.

We found that the Ortega Hill site, in the Santa Barbara group, contained no bone whatever. This peculiarity of the mound was in line with its other characteristics and will be discussed subsequently. SB 53, the Hunting culture site, as defined by D. B. Rogers, carried a small volume of bone (0.0292 per cent) which represents a daily intake per person of perhaps 5 grams of vertebrate flesh. However, this site also contained a great deal of shell, in this respect resembling closely the Richmond site. In SB 81, the Late, or Canalino, mound, there was 0.282 per cent bone, a value comparable to that found in some of the Central Valley sites. There was also a considerable amount of shell, but much less than in SB 53. Apparently the Canalino people depended much less on shellfish and much more on vertebrate food than did those of the Hunting culture. Though we lack ethnographic details concerning the Hunting culture economy, it is apparent, at least, that the later coastal groups were essentially a maritime group, hence dependent upon larger sea mammals. Indeed, the daily intake of animal material per person at SB 81 seems to have equaled that of the Central Valley sites.

All three Round Valley sites showed an extraordinarily low bone content. At the Fort site (RVF 255) there was probably an obvious reason for this, since the mound was occupied entirely during historic times and was near a fort held by soldiers. The few miserable Indians no doubt depended almost exclusively upon the charity of the whites for sustenance and consumed very little wild game or other whole animals. The other two sites, however, antedated the American occupation of the valley and should constitute a fair index to the local aboriginal economy. But data for RV 120 and RV 187 showed only 0.0325 and 0.0155 per cent bone content and approximately 3.1 and 2.0 g. animal flesh per person per day. These results bear close resemblance to those obtained from S.99, the site near the Sierra foothills. Moreover, the topographic and biotic environment of the two regions is more or less similar. Both are in or near extensive ranges of hills, although the Mendocino County

terrain is definitely more rugged. In neither is there any extensive reserve of water birds or fish, although a fair supply of trout and salmon is to be found in both the American River and the creeks flowing through Round Valley. Presumably the chief source of animal food was medium and big game, particularly deer and rabbit, which were abundant in these localities, and still are. Moreover, ethnographic studies have shown that all the California Indian tribes made snares, traps, and so on with which to capture these animals and did, indeed, take numbers of them.

However, it is quite possible that the emphasis of Indian economy was directed toward fishing and, particularly, seed gathering. Early Caucasian observers are unanimous in identifying the acorn, from the great oak forests of the coast ranges and Sierra foothills, as the predominant food of the natives. If this was so, then perhaps the consumption of animals was smaller than we anticipated. Nevertheless, we are forced to question the sampling methods used in this study and to inquire whether they were wholly suitable for the problem of assessing the density of large animal bone.

At each large Central Valley and coastal site we took 30 to 40 samples, or even more, by means of two to four pits and two to five auger borings. At S.99 we took 25 samples from three pits and one boring. At RVF 255 there were 4 samples from one pit, a wholly inadequate number, but circumstances of terrain and time made it impossible to secure more. At RV 120 we took 10 samples from two borings and at RV 187 the same.

It is well known to all who have excavated habitation sites that mammal bones, even from animals as small as the rabbit, do not become comminuted and do not reach such a fine state of subdivision in the mound matrix as the more fragile bird bone, nor do they separate into a mass of minute fragments as does fishbone. Most frequently mammal bones, even after having been cooked and smashed to obtain the marrow, still persist as large pieces. Let us assume that we are dealing with a rib, a hip joint, a cannon bone, or a femur which may weigh 500 g. or more. Let us also assume that the density of such bones in a site is high, say ten such pieces weighing a total of 5 kg. in each cubic meter of site. Then, if the specific gravity of the mound is 1.3, the percentage of bone by weight will be 0.385. If, for illustrative purposes, the volume of the mound is 5,000 cu. m. and the probable average population 70 persons, the total animal flesh represented will be 1,000,000 kg. If, finally, we assume that the mound was inhabited for a thousand years, the daily intake of animal flesh per person amounts to about 39 g., an entirely adequate level. This intake, moreover, would not include the small amount of nutrient obtained from various invertebrates.

In the hypothetical case just outlined it was assumed that each cubic meter of the mound contained ten 500-gram pieces of bone. If the distribution were perfectly random, then one piece should appear in each 100,000 cc. Our samples contained on the average 2,000 cc. Hence one piece should appear in every fiftieth sample. However, if we took only a total of 25 samples, then the chance of getting one piece would be only one in two, and if we took 10 samples, the chance would be one in five. To express it in another way, we may say that the

probability that we secured an adequate sampling of the large mammalian bone at sites S.99, RV 120 and RV 187 is considerably less than unity. Just how much less is impossible to determine, since we do not know the actual density of this type of bone in these sites. To get a satisfactory estimate it would be necessary to take either a far larger number of samples of the same size or the same number of samples, each of much greater size. In passing, it may also be noted that similar considerations also apply to any other class of relatively large objects, such as artifacts or burials, which tend to occur only sporadically in a mound.

This critique of our sampling method warrants the conclusion that the supply of food derived from large animals at site S.99 and the Round Valley sites may have been greater than is here indicated; that it may indeed have approached in magnitude the amount apparently characteristic of the river and delta sites.

Of the two sites, Monument and S.104 (lower and upper strata), we know only that S.104, both upper and lower strata, contained bone in approximately the same percentage as other sites in the same general region. Since we had no information concerning the original size of the deposit, no estimates of food intake could be made. Nor could we give an estimate for the Monument site, although here the bone content appeared to be very low.

Shell

All the Central Valley sites contained a little shell—predominantly, if not exclusively, river mussel—ranging from 0.00092 per cent at C.142 to 0.482 per cent at S.1. Although it is clear from these results that the natives made consistent use of shellfish as a source of food, in the quantitative sense this probably had relatively little significance. At S.1, with a total mass of 4,099 metric tons, the shell in the aggregate weighed 198,000 kg. For the San Francisco Bay mussel the ratio of shell weight to flesh weight (Cook, 1947) was 2.35 : 1 and there was no reason to suppose that the river mussel showed a materially different ratio. Thus the total available meat at S.1 was 84,300 kg. With a mean population of 52 and a probable duration of 2,000 years the daily supply per person was approximately 2.2 g. For all the other sites the equivalent value was less than 1 g. It is probable that the inhabitants of this area utilized this source of food to the maximum extent possible but that the total supply was not very great.

The Richmond site is a true "shell mound," in which the quantity of this material reached extremely high proportions, 45.90 per cent by weight, a figure approaching that of the Ellis Landing site which contained 69.43 per cent. Using the ratio of dry shell to meat, as above, we calculated that the total mass of food available was about 791,000 kg., and that the daily ration per person amounted to about 62 g. As pointed out in a previous discussion (Cook, 1947), this intake, plus that obtained from vertebrate sources, represented an adquate level of animal protein.

Of the sites in the Santa Barbara region the Oak Grove site, Ortega Hill (SB 16), contained no shell whatever, although casual examination of other

Oak Grove sites showed the presence of small amounts of molluscan remains. The Hunting culture mound, SB 53, on the other hand, had a shell percentage of 12.87, not so high as that of the Richmond mound and other San Francisco Bay mounds but still considerable. However, the animal here utilized was not the mussel but the Pismo clam. The extraordinarily heavy shell of this mollusc made the ratio of shell to meat much higher than for the mussel. Clams from San Francisco Bay have been found to have a shell-to-meat ratio of 3.5 : 1; that of clams from the south coast is even higher, at least 5 : 1. This means 369,200 kg. of meat or approximately 13.2 g. per person per day for the Richmond site. Hence the intake of animal protein from shellfish at Santa Barbara was significant in the dietary sense but not of such great relative importance as among the mussel-eating people to the north. The Late site, SB 81, contained notably less shell, 3.036 per cent. This means 36,600 kg. of meat and a daily intake of 3.5 g. per person. Clearly shellfish were a distinctly secondary item of diet at this time and place and were probably replaced by deep-sea fish and mammals.

These findings raise an interesting problem with respect to the presence and utilization of the Pismo clam on the Santa Barbara coast. The complete absence of shell at the Ortega Hill site, and our failure to find bone, together with the generally aberrant nature of the mound, does not preclude the existence of shellfish on the near-by beaches. These factors merely demonstrated that for some reason the inhabitants brought very little, if any, shellfish to the locale of the mound. During the period of the Hunting culture there was an abundance of the species and the inhabitants of site SB 53 made use of it to a marked extent. The later Canalino people at SB 81, however, depended upon it relatively slightly. Whether this lesser use was due to a depletion of the clam along the shore or to altered food habits induced by cultural changes cannot be decided with certainty. However, the ease with which the clam was obtained, together with the evidence of the great quantities taken by the people of the preceding culture period, incline us to favor the latter hypothesis.

At the Round Valley sites there was no trace of food shell in our sampling, although occasionally shell artifacts occurred in the mound debris. Such a finding was entirely to be expected upon purely ecological grounds, since there is neither tidewater nor a permanent fresh-water stream in the valley. The nearest habitat of shellfish is on the coast fifty miles across the hills, much too great a distance for the inhabitants to travel in the ordinary course of food gathering.

Shell was found at the Monument site and in the Late horizon level at Tyler Island (S.104, upper), although none at all was present in the Middle horizon deposit (lower stratum) at this site. Both these mounds are close to the lower Sacramento River and the upper Bay. Hence mussels must have been numerous and within easy reach of the inhabitants. The entire absence of molluscan remains in the Middle culture stratum at Tyler Island is hard to explain since they occur in the upper or Late stratum and in several Middle period sites not far distant. However, there is still some question whether this

lower stratum represents a zone of true or continued occupancy. Possibly we are here dealing with conditions of intermittent occupation somewhat the same as noted for site C.142.

Charcoal

Charcoal, as the term is used here, means lumps and pieces of carbonized wood sufficiently large to be held by the 2-mm. screen. It does not and cannot include the finely powdered material which is scattered, almost in the form of dust, throughout the mound matrix. Consequently no claim can be made that our quantitative estimates represented the total volume of free carbon in a site; to determine this volume, chemical methods of analysis are necessary. What we obtained by physical analysis thus merely indicates the general order of carbon content and must always be a serious underestimate.

Inspection of table 3 shows two sites (in addition to S.104, lower) from which no discrete particles of charcoal were secured. These are C.142 and SB 16, probably the oldest sites of any we excavated, both characterized, moreover, by other aberrant features. The other two Early period sites in the Central Valley (C.56 and C.68) yielded respectively 0.00107 and 0.00236 per cent charcoal, or an average of 0.00171 per cent. The Middle period sites S.43, C.66, S.99 in the valley plus their equivalents in other areas, SB 53 and the Richmond site, showed an average of 0.03232 per cent. The comparable value for the recent or Late sites (S.1, C.6, SB 81, RVF 255, RV 120, RV 187, P.1, P.3, and S.104, upper), is 0.18777 per cent. Clearly the charcoal content diminishes with age because of the slow breakup and disintegration of the relatively large fragments of carbon under slow pressures and shifts of material within the mound. Indeed it has been demonstrated (Setzer, diss., Univ. Calif., 1947) that in some Early sites (e.g., C.68) a considerable amount of the original charcoal has been gradually compressed and reworked until it is now in the colloidal state, hence entirely impossible to measure except by chemical methods.

If allowance is made for the slow comminution of carbon fragments with time, it is likely that all the sites except C.142, SB 16, and S.104 (lower stratum) actually contain roughly equivalent amounts of charcoal. The value may be tentatively set at the average found for the best preserved sites, that is, approximately 0.2 per cent by weight. Of the three exceptions, it has already been suggested that C.142 was not a true habitation site, hence would not be expected to contain much, if any, charcoal. Moreover, any small quantity which it once may have held has probably, in view of the great age of the mound, long since disintegrated into particles impossible to detect by our methods. The Ortega Hill site (SB 16) and the lower stratum of Tyler Island (S.104) presented special problems which are subsequently discussed.

The value of 0.2 per cent indicated above means 2 g. per kilogram or 2 kg. per metric ton of mound matrix. At least an equal quantity must be added to account for free but already powdered carbon. To cite a specific example, S.1 contained a total of 4,099 tons, of which (using the rounded value of 0.2 per cent) 16,396 kg. was charcoal. How much fresh wood this represented cannot be stated with accuracy, since the charcoal was the random residue of uncon-

sumed wood. From common and empirical experience we might be justified in maintaining that the carbon was less than 1 per cent by weight of the original wood. The weight, then, must have been more than 1,639,600 kg. The annual average, assuming an active life of 2,000 years for the mound, would then exceed 820 kg., or nearly 100 kg. per family per year, or approximately a pound a day. Obviously this would be an inadequate supply; however, the figure is in terms of the irreducible minimum, not the probable actual quantity.

Even with such a drastic underestimate it is evident that at all these sites there was sufficient wood to keep the domestic fires burning and perform primitive cookery. This fact, in turn, poses the question: where was the firewood obtained? At the Round Valley sites, at Santa Barbara, at S.99, and at the Bay shell mounds there was no problem; in all these areas there were abundant stands of oak and other trees within easy reach. In the Central Valley and along the lower Sacramento the arboreal vegetation was and is much less prolific. However, there is considerable brush and shrubbery together with some willows on the banks of the rivers and sloughs and it is possible that before the advent of the white man the drier plains supported a fair stand of oak. Moreover, the river, especially during winter high water, provides a good deal of driftwood. It is hard to visualize the valley natives traveling one or more days to the foothills of the Sierra Nevada or the Coast Range in order to transport bulky loads of firewood. We conclude, then, that local resources, although perhaps not abundant, were at least adequate. Hence environmental circumstances proved no serious deterrent to the development of a food economy based upon the campfire and some type of cooking.

Obsidian and Flint

These materials remain in the various sites in the form of completed artifacts and, as such, are of primary interest to the cultural anthropologist and archaeologist. Their occurrence in a mound may be more or less random but may also be contingent upon the customs of the people. Large concentrations are likely to accompany burials and thus escape the method of small samples as employed by us. However, if a stone industry existed which provided numerous artifacts for local use or for export, lithic residues are likely to be distributed in a more or less haphazard fashion throughout the mound substance. The raw material may have been imported as such or crude blanks may have been acquired, from which the final product could be finished with a minimum of labor. In either case, chips and fragments would remain. The presence of these, therefore, even in minute amounts, indicates some industrial activity.

In samples from about half the sites investigated we found obsidian chips, although only in traces. The greatest quantity was in S.104 (Tyler Island), Late horizon. Nearly as much was found at C.6, where the obsidian represented 0.00681 per cent of the total weight. This mound was calculated to have a mass of 29,969 metric tons; hence the probable total of obsidian residues was 2,000 kg. The least amount was found at S.43, with a probable total of about 2 kg. These are absolute values and, when the results are placed on a relative basis, the discrepancy is not so great: 66.7 g. per ton of mound for C.6 and

2.8 grams for S.43. Sites S.1, C.66, S.99, C.68, C.56, the Petersen sites, and SB 81, all showed intermediate values. None at all was found at C.142, SB 16, SB 53, the Richmond site, or the Round Valley sites. On the basis of the sites examined it would seem evident that the obsidian-working industry, at least on a material scale, was centered in the region of the Central Valley and the delta. However, had we sampled sites in Napa Valley or the Clear Lake region, the center of highest frequency would undoubtedly have shifted to these areas, for here is found the greatest natural occurrence, the largest number of aboriginal quarries, and the most intensive use of obsidian of any place in California (Heizer and Treganza, 1944, pp. 303–306, map 1, figs. 5A–5B, 6, 7). Our samples indicated that there existed in aboriginal times a rather active obsidian trade, most of which was flowing into the Central Valley. The presence of numerous chips from C.56 and C.68 indicates a trade relationship as far back in time as the Early period. It is difficult to understand why obsidian chips were absent from the Richmond and Round Valley sites, especially from the latter region, where the mythology of the Yuki placed so much emphasis upon obsidian and the Yuki-Kato wars were fought over possession of this commodity (Kroeber, 1928, p. 396). Nevertheless, a surface survey of some 450 sites in Mendocino County showed obsidian to be of rare occurrence. It is possible that Franciscan chert, a very adequate substitute, was employed, since the region provides an abundant supply of this material.

Flint chips were found in recognizable form only at the two later Santa Barbara sites, indicating persistence of this type of material in this region after it had been substantially superseded by obsidian in the north. There was a little obsidian in SB 81, but both there and at SB 53 flint predominated.

CONCLUSION

Excluding the Monument site and S.104 (Tyler Island), we analyzed seventeen habitation mounds. These fall within four broad ecological provinces: (1) the Central Valley and delta, (2) San Francisco Bay, (3) Mendocino County coast ranges (Round Valley), and (4) southern sites of the Santa Barbara Channel coast. The last three were internally homogeneous; the first, not entirely so. With respect to certain cultural components, we found general uniformity; with respect to other components, there were both quantitative and qualitative differences that in turn were referred to environmental variation.

The Central Valley province is characterized physiographically by extensive alluvial plains traversed by numerous slowly flowing rivers, crisscrossed by relatively stagnant sloughs, and subject to periodic flooding. The habitation sites occur consistently near one of these watercourses, a situation which satisfied the primary need of a permanent supply of water for domestic purposes in the face of a long annual drouth, a basic necessity which determined the location of settlements throughout California history and prehistory. The riverbank also provided for various other important needs of primitive man. First, it furnished food, as may be seen from the large quantities of fishbone and appreciable amounts of shell found in all sites near the rivers. Second, it supported a type of vegetation readily adaptable to human use. Numerous spe-

cies of trees and shrubs flourish in areas where permanent water is reached by the roots. In turn, this vegetation provided food and wood. The food derived from the plants themselves, as leaves, fruit, and roots, and from the fauna supported by the vegetation, particularly birds, the bones of which were second only to those of fish in the mound residues. Wood was used for three important purposes, houses, implements, and fuel. Its use as fuel was manifest in the universal presence of material quantities of carbonized material and powdered charcoal.

In addition to the semiaquatic vegetation there was available a probably not copious but still very significant food contribution from the dry plain stretching throughout the interfluvial areas. Here grew predominantly the oaks and the grasses. It is likely that the bulk of the carbohydrate and much of the protein in the aboriginal diet were derived from the numerous types of seed available plus the great nutritional staple, the acorn. Thus the riverbank and the plain supplemented each other beautifully in the dietary sense, providing sustenance for the really extensive populations which apparently inhabited the area for many centuries.

This otherwise very favorable environment was deficient in one important constituent, rock, a material essential for the construction of hearths, for stone boiling, and for artifacts. In most of the sites studied the rock amounted to approximately 4 per cent of the total weight. Hence this figure represents the minimum quantity necessary to support the local economy. To secure the rock the natives could not rely upon the adjacent land surface, since this is, and for a long time has been, composed of purely alluvial deposits of clay and sand. Therefore they resorted to secondary expedients. Among these were the utilization of small fragments and pebbles from the stream beds, and importation of native rock from somewhat distant but attainable outcrops such as the Montezuma Hills, Coast Range, and outliers of the Sierra Nevada. Where such sources were too distant or inadquate, it was necessary to manufacture artificial rock by burning clay (Heizer, 1936). Fortunately the valley floor did provide adequate reserves of this substance. Some baked clay was found in most observed locations but it appeared in high concentrations at a few sites, particularly C.6 and the Petersen mounds. From this distribution it may be inferred that the clay industry was localized in a relatively few places, these no doubt being determined by the accessibility of the proper type of soil. The quantity found at C.6 was much greater than necessary for local use. Hence this site probably represented a center of export to other less favored villages.

The crude, unmodeled masses and fragments of incinerated clay found at Petersen III are probably a by-product of the mound construction and do not indicate an export industry in artifacts. Such an industry, moreover, was unnecessary in view of the adequate supply of native rock near by.

In the Central Valley the rock, bone, and charcoal content was substantially similar in all sites, regardless of age. No distinction at all can be drawn between the Late and Middle culture periods. If we allow for secondary changes induced by such soil alterations as compaction and hardpan formation, we must include the two Early period mounds, C.56 and C.68, with the rest. C.142 was

so deficient in these constituents that we must conclude either (1) that C.142 is so much older than C.56 and C.68 that a profound ecological change occurred between the periods of their habitation or (2) that C.142 was used not for continuous, intensive habitation but for sporadic, casual occupation. Since there is no external evidence for any material climatic change in the valley since the late Pleistocene, the second alternative seems to be indicated.

The San Francisco Bay province, the "shell mounds" of which are typified by our Richmond site, differs from the Central Valley primarily in its situation on salt rather than fresh water. This in turn is reflected in the different littoral and aquatic biota. The marginal vegetation is somewhat scantier, although the surrounding hills maintain an oak and grass flora closely similar to that of the valley. The firewood supply and the seed and acorn crops were, therefore, fully as plentiful as in the valley. However, except for rather extensive tule swamps at the upper and lower extremities of the Bay, there was less opportunity for the congregation of water fowl. But this deficiency was more than compensated for by the presence of vast beds of mussels. So huge and inexhaustible were these beds that the area supported scores of villages from the Middle culture period well into historic times. From the masses of shell fragments found within the mounds we have calculated that this source alone furnished an adequate amount of animal food.

The Santa Barbara coast presents a definitely different picture. Although the hinterland carries the same oak-grass complex as the Central Valley plain and the San Francisco Bay hills, the Channel sites front upon the open sea. The Spanish accounts, as well as ethnographic data, make it abundantly clear that the Late, or Chumash (Canalino), culture was relatively highly developed and heavily dependent upon deep-sea fishing. Evidence of this activity was found in the soil from site SB 81 in the form of numerous vertebrae and other fragments of fishbone. At the same time there was a considerable amount of shell of the Pismo clam, indicating that the littoral fauna was likewise utilized. With respect to rock and charcoal there was no essential difference between this site and those in the central part of the state. The Hunting culture site, SB 53, contained remarkably little rock, relatively little bone and charcoal, but very much more shell than SB 81. It is difficult to say whether these differences are referable to a change in environment or culture pattern or to merely fortuitous local variation. Before advocating the first alternative, it would be necessary to examine several more sites from each culture age to determine whether the same pattern persisted throughout each group. As matters stand, it would be premature to dogmatize concerning the apparent differences between the sites.

If the Ortega Hill mound, site SB 16, is a typical representative of the most ancient culture, Oak Grove, then a number of obscure points need elucidation. The great numbers of metates and manos found in the vicinity suggest a well-developed seed-grinding culture. The 15-inch-thick stratum of almost pure, highly compacted white ash, which constitutes the mound proper, certainly indicates fires and cooking. The complete absence of discrete particles of charcoal might be accounted for on the basis of slow disintegration of

carbonized wood with age. But since such material was found in appreciable, although not very large, quantities at C.68 and C.56 in the valley, its total absence at Ortega Hill would mean that Ortega Hill is much older than the two other sites—that it is, indeed, many thousands of years old.

The undoubted deposit of ash is difficult to reconcile with the entire absence of rock or its substitute, baked clay, particularly since rock is everywhere easily available. If we predicate that rock fragments were employed at most sites for hearths and fireplaces, then we have to envisage at Ortega Hill a culinary culture which built fires and cooked or roasted food on the open ground, or, once the site was established, on a great area of ash. This might be conceded but, if so, the inhabitants must have lived, slept, and carried on their other occupations elsewhere, and what we call the site must have been little more than an ashpit.

If the site was actually an ashpit used only for preparing food, then how account for the complete lack of either bone or shell? These materials resist even hardpan formation in the Central Valley and would inevitably still be visible here if they had ever been present. Bone and shell, moreover, represent the two primary sources of animal food—vertebrates and molluscs—found in the region. It is hard to imagine a population near Santa Barbara which existed upon plant material alone, and still more difficult to imagine that such a population utterly neglected or overlooked the magnificent food resources provided by these animals.

The conclusion is, therefore, almost mandatory that our limited sampling failed to give a true picture of the Oak Grove culture, although burials were discovered in the immediate vicinity. The investigations of D. B. Rogers, as well as our own observations elsewhere, demonstrated that the Oak Grove people left as residues huge numbers of manos, large rock cairns, burned rock, charcoal, house pits, mammal bone, and small quantities of shell (cf. D. B. Rogers, 1929, pp. 55, 167, 179). These remains all indicate what might be termed a "normal" midden deposit, one which would conform to the ethnographic and ecological probabilities. The spot from which we took our samples must be, then, distinctly aberrant and atypical. More samples from other sites are needed before the Oak Grove culture can be properly evaluated by physical analysis.

Round Valley is a purely hill habitat. The water resources are limited to a few small creeks and springs and, indeed, we noted in our survey a good correlation between springs and sites. For plant food the natives depended upon acorns from the extensive oak forests which covered the hillsides and spread over the valley floor, supplemented by various berries, seeds, greens, and roots in season. There were no molluscs. Waterfowl were available in small numbers, if at all. The inhabitants were forced to rely for animal food upon fish, large game (principally deer), rabbits, rodents, reptiles, and insects.

It is likely that our sampling methods with respect to mammals gave an inaccurate and too low value, as suggested previously. Nevertheless, even allowing for considerably more bone than we found in the samples, the general amount was definitely less than at the Central Valley sites.

The importance of fish as a dietary item seems doubtful. On the one hand, the impression from ethnographic sources is that fish food was important to the Yuki economy. That the winter run of salmon and steelhead is large is a widely known fact. Our site survey showed a concentration of habitations along the streams. Indeed, in Hull's Valley, just to the north of Round Valley, survey showed an abnormally small number of sites, a phenomenon which may be accounted for by the assumption that a waterfall between the two valleys prevents the entrance of the salmon. It is a matter of record that the Yuki caught and ate these fish (Kroeber, *Handbook*, 1925, p. 174).

On the other hand, in the sites examined, all of recent origin, there was no trace of fishbone. Several explanations of this absence may be offered. Perhaps because of random distribution of these remains, we simply failed to find them. However, fishbones are very small, chiefly vertebral, and if their concentration here were in any way comparable with that in other sites, at least a few pieces could scarcely have escaped observation. It might also be claimed that fishbone was not preserved. But the preservation of fishbone was perfect in many other sites of vastly greater age. The pulverizing of dried fish might also be an explanation. Were the bones removed by the Yuki dogs? Some depletion in number was certainly possible in this way but it would have been far more difficult for dogs to remove fine fishbone than coarse mammal bone. Yet we found the latter but not the former. There is no clear physical reason why, if fish were consumed more than very casually at the sites, some trace of their bones should not be found in 25 samples. Another explanation, although a poor one, might be that the fish were consumed, or at least prepared, at some point removed from the site itself. If this explanation is not acceptable, then there is no choice save to conclude that the consumption of fish, in the aggregate, was much smaller than the ethnographic data would lead us to suppose.

On the whole it appears that, with no molluscs, few birds, a doubtful supply of fish, and no overabundance of mammals, the inhabitants of Round Valley existed upon a definitely marginal diet of animal food and that the Coast Range habitat had a less adequate supply of animal food than the Central Valley, San Francisco Bay, and the Santa Barbara coast. And yet the sum total of food must have been great. Otherwise it is impossible to account for the 300-odd sites within the 36 sq. mi. of Round Valley and the many historical accounts implying a huge population. The explanation must lie in plant resources.

As previously mentioned, the region furnishes an abundance of acorns, buckeye nuts, berries, roots, and small seeds. Most of these materials require long cooking. That cookery was practiced on a large scale is directly attested by the tremendous residues of charcoal found in the sites. Almost unlimited fires were possible because of the large wood supply. Oak, manzanita, and many shrubs cover the hills and mountains for miles around and originally probably extended well into the valley. The final necessity, rock, was furnished in enormous quantities by the subsoil itself. Hence all natural conditions favored the emphasis upon and plentiful utilization of wild plant food. The economy,

moreover, was nutritionally sound; a possible deficiency in animal protein could be compensated for by a very liberal allowance of plant protein, even though the latter had a lower biological value.

With the Round Valley sites must be reckoned S.99. This mound, lying just at the border of the Sierra Nevada foothills, lacked bone but contained a great deal of charcoal and small amounts of shell. Bird bone and fishbone were present in much smaller quantities than in the sites along the lower river courses. There was an abundance of rock, but no baked clay. The surrounding country is rough and hilly, bearing a large stand of oaks. It may be presumed, therefore, that the inhabitants were oriented toward a hill rather than a valley environment.

Very little is known of the culture of S.104 (lower stratum), Middle horizon, and the Monument site. Nevertheless a few ideas about the life of the inhabitants may be derived from the present study. It should be noted first that both sites contained very little rock (2–3 per cent) and even this was in the form of small pebbles rather than large pieces. There was no trace of baked clay. At S.104, Tyler Island, there was no charcoal, and at Monument, the merest trace. It might be concluded that the dwellers at the Monument site, in comparison with the inhabitants of all the other Late and Middle period mounds of the region, used fire very sparingly. In this connection it has been suggested, for S.104 at any rate, that the spot, like C.142, was possibly used for burials and rare encampments. But that there was some habitation is attested by the very considerable quantity of bone found at S.104 and of shell at Monument. Conceding that shellfish and birds or mammals were consumed, we must grant that there was at least occasional domestic occupation. This, however, may well have been of a semitransient nature which did not involve much cooking in the preparation of food or more than temporary campfires.

The distribution of shell was also significant. Its total absence at S.104, lower (Middle horizon), was very difficult to reconcile, not only with its universal presence in all other river sites, but also with its presence in quantity in the Late horizon of the same site, unless we adopt the theory of casual or transitory occupation. If we adopt this hypothesis, we need not maintain either that the river, for some curious reason, was devoid of mussels during the Middle period, or that permanent inhabitants failed to make use of an available supply. Transient campers would probably not find and gather any appreciable amount of the molluscs.

Monument site is now four or five miles from the nearest tidewater, the intervening land being entirely filled in. From the quantity of shell in the midden it is very easy to deduce that at the time of occupation an arm of Suisun Bay reached inland to the vicinity of the mound. Since that time an environmental change has occurred sufficient to alter an essentially riparian or semiaquatic habitat into one more closely approaching that of the interior coast ranges or Sierra foothills.

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UC	University of California
-AR	Anthropological Records
-PAAE	Publications in American Archaeology and Ethnology

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