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MOLLUSCAN SPECIES IN CALIFORNIA SHELL MIDDENS

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INTRODUCTION[1]

A method of attacking the problem of the nature and extent of aboriginal man's exploitation of his environment is by quantitative analysis of refuse deposits. These deposits persist through time to a greater or lesser extent depending upon their nature and location. Primary concern here will be with those Californian middens, which due to their close proximity to waters rich in molluscan fauna, contain a large quantity of shellfish remains (Fig. 1A)[2]. Furthermore, only the shell components will be dealt with in detail, but references to other constituents will occasionally be made.

Ethnographical, historical and archaeological data suggest that California was relatively well populated aboriginally as compared to other areas exploited by similar hunting and gathering techniques. The archaeological data, with which we are primarily concerned, are to be found in the large number of occupation sites, as well as in the great quantities[3] of refuse accumulated at some of the middens. Considerable age of a number of these middens is indicated not only by the quantities of refuse but also by the fact that the bases of at least two of these middens on San Francisco Bay are over fifteen feet below high-tide level (Nelson, 1900, p. 354; 1910, p. 364 ff.).

Two methods have been employed in the quantitative analysis of Californian middens. Nelson (1909, 1910) essayed an estimate of the age and rate of accumulation of the Ellis Landing mound (CCo-295) based on the estimated volume of shell in the midden. Gifford (1916, pp. 12-14) used a different method wherein he computed the weight of various components in the course of analyzing samples from shellmounds of San Francisco Bay and elsewhere along the California coast. This type of research lay dormant until Cook (1946) reopened the problem in a stimulating paper[4] in which he refined and verified Gifford's method and demonstrated the technique of Nelson to be highly unreliable due to uncontrolled variables. This renewed interest in the physical composition of aboriginal sites coincided with the revitalization of California archaeology in the post-World-War II period.

Research by the present writer, while focused in particular on the shell content in sites, will serve to supplement similar data accumulated thus far. New calculations are added from six sites, five of which have not been sampled previously. The sixth, West Berkeley mound (Ala-307)[5], was sampled a second time as a result of the University of California Archaeological Survey excavation there during the summer of 1950.

The validity of results of investigations of this sort depend, in the first place, on the technique utilized in procuring the data. After exhaustive sampling and testing, which included the digging of an entire mound, Treganza and Cook offer the following suggestions to be used, "with appropriate local modification," for refuse mound sampling: "A component of the site which appears in large quantity and in a reasonably fine state of subdivision may be estimated with a fairly high degree of precision by the small sample technique. This usually would require samples of 1 to 5 pounds weight and from 15 to 30 in number. Mechanical separation of components, not chemical analysis, would be required. This method is applicable to rock, baked clay, small bone fragments, shell, etc." (Treganza and Cook, 1948, p. 292).

1. Numbers refer to "Notes" at end of this paper.

These suggestions were followed in collecting samples reported here. Certain modifications were necessary in view of the objective in mind and limitations of time involved. In every instance the writer's samples were taken by six or twelve inch levels in a vertical plane from top to bottom in the site. The number of separate samples thus obtained, varied with the depth of the site, from 3.5 feet at Mrn-307 to 17 feet at Ala-307. Volume was controlled by two different methods. Samples taken at Drake's Bay (Mrn-307), West Berkeley (Ala-307), El Sobrante (CCo-151) and from Bodega Bay (Son-299) were from columns four to twelve inches square, taken at the intervals mentioned above. A second sample from Son-299 and from another Bodega Bay site (Son-321) as well as one from a site on the edge of Elkhorn Slough (Mnt-229) were collected by taking a common cigar box full (approximately 90 cubic inches) of mound material from each one foot level. Therefore in all cases the criteria as to size of sample were followed. However, in only one, that from West Berkeley, does the number of samples fall within the 15 to 30 limit suggested.

For sorting the material, (which had been air dried) 500 to 1000 grams were weighed out from each one foot level. These were passed through a 1/8 inch (2 mm) screen, washed and again air dried. Material passing through the sieve consisted largely of soil. It also contained a considerable proportion of small fragments of shell together with other matter including ash and small bones. This was considered as residue. The preponderant species in residue samples was _Mytilus edulis_ or _Mytilus californianus_. For site CCo-151, six 10 g. samples were taken of the shell material passing through the 2 mm. screen and sifted through a sieve of 1 mm. mesh. Of components caught by the smaller screen, 83.5% proved to be fragments of _Mytilus edulis_. Besides residue, categories of components segregated included shell, sorted as to genus and/or species, bone, charcoal and stone which were segregated by one foot levels.

The shell species and other materials were then weighed and tabulated. From these tabulations, proportions were calculated, the results of which appear in Tables 1-16.

Cultural Significance of Shell Components

In discussing the shell content of archaeological sites it might be well to keep in mind a very significant statement made by Gifford, (1916, p. 7) "It may be taken as axiomatic that the species in a mound reflect the molluscan fauna of the vicinity, and hence the environment during the period of growth of the mound". In the opinion of the writer this statement could be extended to the effect that shellfish remains from mounds might be taken as _fairly sensitive indicators_ of the relative abundance of inter-tidal species. To this statement a qualification must be added, involving the amount of human effort spent in procuring a meal. This would involve size as well as habitat of the animal. Of the former, most species of _Acmaea_ (limpets), for example, though quite abundant would require a relatively greater amount of effort to gather enough to make a satisfactory meal than most other species found in sites. Another example cited to illustrate this point is that of the Horn shell (_Cerithidea californica_) which occurred in a proportion of 9% of the shell in the Castro mound (SCl-356, Gifford, 1916, pp. 8, 24) at the south end of San Francisco Bay. This appears to be substantially the case at another south bay mound (Ala-328).[6] The explanation of this relatively high proportion of a small snail seems to lay in the fact that people on these sites had difficult access to the more sizeable bay mollusks because of wide expanses of intervening salt marshes, and these snails (being a salt marsh species) were consequently resorted to more often. At the Emeryville and Ellis Landing mounds this form constituted less than one-tenth of 1% (Gifford, 1916, p. 24) of all the shell, as it did also at West Berkeley (cf. notes to tables). While it is true that the salt marshes which cut off the south bay sites are the most extensive in the bay area, it is also very likely true that the horn shell was somewhat more abundant in the marshes near the other sites than is evident in the site contents, but was less sought than the larger species as food.

Another example of how the ecological habits of a shellfish may be reflected by its presence or absence in a midden is that of the geoduck or gweduck (Panope generosa). This is the largest species of bivalve along the west coast of North America and is known to attain a weight of sixteen pounds (Ricketts and Calvin, 1948, p. 215). What is more remarkable is that the relationship of its shell to meat is much smaller than of most bivalves. The species occurs along the Californian coast at such places as Humboldt and Morro Bays (Bonnot, 1940, p. 247), as well as Tomales Bay (information from marine biologists at Pacific Marine Station, Dillon Beach). Yet, to the writer's knowledge this species has not occurred in any of the California middens examined to date.[7] The reason of course, is that the clam is found buried in approximately four feet of sand or muck, and thus was almost impossible for these Indians to procure with the tools they used. This clam is dug (with a great deal of effort) by present-day gatherers who use somewhat specialized equipment consisting of a narrow pointed shovel and an open right-angled "caisson" made of boards to keep the sides of the hole from caving in. The concave bladed digging sticks of the type used by the Lower Chinook (Ray, 1938, p. 112) and a couple of split wooden planks probably did the job quite as well for that people. This, incidentally, is a good example of how a slightly greater degree of cultural complexity opened a new food supply to the Lower Chinook and their neighbors, which was denied to the people with a similar but somewhat less elaborate material culture to the south.[8]

Composition of Three Large San Francisco Bay Mounds

At San Francisco Bay we now have two independent analyses of midden constituents of a major site. This site, the West Berkeley mound (Ala-307), situated at the mouth of Strawberry Creek was once quite extensive. Some excavation was performed on the site by University of California representatives in the first decade of the present century (date of Furlong and Peterson deposited in University of California Museum of Anthropology). From one of these digs a number of soil samples were taken, eight of which were analyzed by Gifford.[9] These ranged from two to twelve feet in depth from the surface, and the results of the analysis were published in 1916. Up to the spring of 1950 a fair size proportion of the mound was preserved, surrounded by industrial buildings. This remnant, about 200 feet long, 50 feet wide and standing 12 feet high above the present land surface was leveled for building purposes in the fall of 1950. Fortunately during the spring and summer an opportunity was afforded the University of California Archaeological Survey to excavate part of the remaining mound. A large and relatively adequate archaeological sample was obtained. In the course of excavation several soil samples were taken according to the procedure outlined above. One of these soil samples has been analyzed, the results of which appear in Tables 3 and 4.

There are certain rather striking differences between the results obtained from this sampling and those worked out for the 1916 report. Of the main components, Gifford found 52.5% shell, 42.3% residue (including ash) and 4.9% stone, while writer's analysis shows 23.1% shell, 69.0% residue and 7.8% stone. There are several possible explanations as to why such gross differences occur, the most probable one being in the method of taking the soil samples. For the earlier sampling, the weight of samples ranged from 31.5 to 832.9 grams with an average of 119.1 grams. Of them, the investigator says, "In each case the sample is typical of the mound at a particular level and does not merely represent the contents of a pocket of any kind, for example a fireplace" (Gifford, 1916, p. 2). Eight samples were taken by Peterson at depths of 2, 3.5, 4.5, 5, 6.5, 8, 10 and 12 feet. These intervals, while not as frequent as those obtained in the 1950 samples (1 foot intervals) are quite comparable to the latter ones down to the depth of twelve feet. Since the screening methods were practically identical to might try to compare results of a depth of twelve feet. The shell percentages reported by Gifford, (1916, p. 19) ranged from 28.1% at 12 feet to 72.8% at 4.5 feet. In the 1950 samples the shell was proportioned in a range of 19.5% at 8 feet to 33.2% at 6 feet. These differences are paralleled by the other main component, residue.

Since the residue is composed mostly of soil, that factor is obviously at the root of these differences but does not of course explain them.

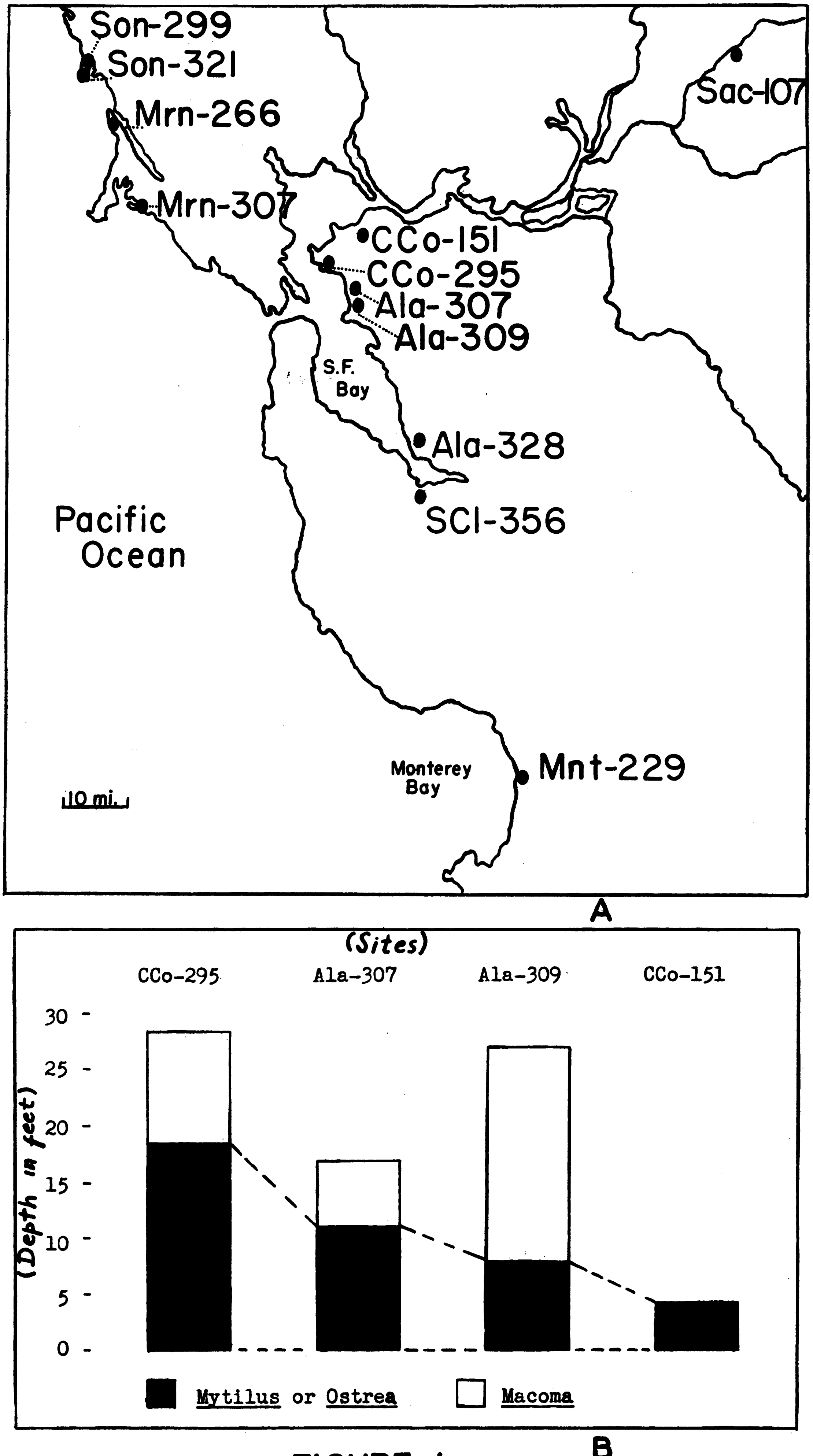
As far as method is concerned, all of the variables were less rigidly controlled in the earlier samples than in the most recent ones.

Another factor undoubtedly involved in the differences is that the samples were taken from two parts of the site. While it is not certain at just what part of the mound the earlier samples were taken (because of destructive inroads on the site since then), it is certain that they could not have been taken within an areal radius of 25 feet of the 1950 samples. These latter were taken from near the center of the 1950 excavation in a vertical plane apparently undisturbed and in an area which contained no unusual features.

With these differences in mind let us compare the proportions of species of shell in the two samplings as shown in Table 5.

From Table 5 we see that the most obvious difference is in the proportion of unidentified shell. This discrepancy can probably be explained by the fact that the particles of shell in the earlier sample were more finely divided than those of the latter. If these particles could be sorted they would probably bring up the proportion of Mytilus and Ostrea, because Macoma does not pulverize as easily as the other two species. Be that as it may, the relationship of the species to one another is the important factor, and in both cases it is the same. Since both Mytilus and Ostrea prefer rocky or gravelly shores, while Macoma is a mud-flat inhabitant the larger proportions of the former two species should also be reflected in the rock or stone content of the samplings. That factor checks with a proportion of 7.8% stone in the 1950 sampling as against 4.9% in the 1916 one (Ibid. p. 19). Coupled with this ecological factor also is the proportion of barnacles which attach to small stream pebbles which are probably from tidal delta of the creek. In the 1950 sampling there was 4.0% of this form while the previous sampling contained 2.0%.

As for variation of species by depth, only the 1950 sampling can be taken as reflecting trends for the entire history of the site, although as stated above,



Son-299
Son-321
Mrn-266
Mrn-307
CCo-151
CCo-295
Ala-307
Ala-309
Sac-107
S.F. Bay
Ala-328
SCl-356
Pacific Ocean
Monterey Bay
Mnt-229
10 mi.
A
(Sites)
CCo-295
Ala-307
Ala-309
CCo-151
(Depth in feet)
30
25
20
15
10
5
0
Mytilus or Ostrea
Macoma
B

FIGURE I.

the samples obtained in 1916 and in 1950 might bear comparison for that portion of the site above 12 feet.

In looking at Table 3 two facts are outstanding. The first is that throughout the history of the mound, Mytilus edulis was a major item in the diet. On the other hand, the two other major species in the site vary with the depth in a complementary manner. It is most significant that Ostrea lurida constitutes 44.1% of the shell at the bottom of the site as compared with the mere trace of Macoma nasuta. Graphically speaking the curve for Ostrea trends (with minor fluctuations) steadily downward to 10% from the older to the more recent levels of the site. The converse of this trend is to be found in tracing the proportions of Macoma nasuta which from practical absence in the bottom increases to rank as a major component in top levels of the midden with a percentage of 36.4. The rise in proportion of this species is rather sporadic until the height of six feet from the surface of the mound is reached, where it takes a significant jump, falls off a bit and at the three foot level becomes definitely established as a staple element in the diet. This fact could be easily observed in the sheer face of the excavation where the white shells formed a "cap" over the material below.

The manner in which these trends complement each other is offered as evidence corroborating the validity of the sampling technique employed. Similar results were obtained in 1916 (Gifford, 1916, p. 28, Table 20), but due to the uncontrolled samples, the findings were somewhat inconclusive.

About two miles from West Berkeley south along the east bay shore there existed another large midden, the Emeryville mound. This too was situated at the mouth of a small creek (Temescal) originating in the Berkeley Hills. If the two sites were occupied at the same time, we might expect that they would contain about the same proportions of shellfish fauna, because the shore conditions are now identical.[10] A comparison of the data offered by Gifford (Ibid., p. 27, Table 15; p. 28, Table 20) for the two sites indicates the same trends. Mytilus edulis tends to be constant and averages 35% of the shell, while both Macoma nasuta and Ostrea lurida show the same type complementary tendencies. A significant variance occurs, however, at the relative level at which Macoma nasuta first becomes abundant. At Emeryville the proportion of this species to Mytilus and Ostrea reaches 22% at 19.5 below the surface of the mound. This is relatively much deeper than the level at which the shift occurs at West Berkeley (i.e. at 6 feet), for Uhle's excavation approached thirty feet in Emeryville,[11] (as against 17 feet in West Berkeley).

This would seem to imply that only the upper one-third of the West Berkeley mound was contemporaneous with the upper three-quarters of Emeryville. In other words, the West Berkeley site was probably abandoned while the Emeryville village was still in its formative period (see fig. 1B).

Before we discuss the possible reasons for the sudden occurrence of Macoma nasuta in these two sites let us look at the data from another large east Bay mound, Ellis Landing (CCo-295). This site was dug in 1906 and 1908 by N. C. Nelson, whose report appeared in 1910. Soil samples were collected during excavation and subsequently analyzed, the results appearing in Gifford's 1916 paper. In Table 13 of Gifford's paper we find a comparison between Mytilus edulis and Macoma nasuta, (other species occurred in quantities of 1% or less of the total shell). In this site the trend is for Macoma nasuta to gradually replace Mytilus edulis (with some violent fluctuations, however). Out of a total of seventeen feet of depth for the samples this change takes place suddenly at a depth of ten feet. This depth, then, would be comparable to 6 feet at West Berkeley and 19.5 at Emeryville.

A comparison might be warranted between these differences in proportions of shell left as residue from food with the results of Gifford's study of shell artifact types (Gifford, 1947, p. 57). Bone artifact types were included with shell artifact types in making these comparisons; the bone artifacts were published in Gifford, 1940. Unfortunately the data available to him from West Berkeley (in both regards) was relatively meager and no shell artifacts were salvaged from the lower 13 feet of Ellis Landing. From Emeryville mound, however, he had the opportunity to examine 7,594 shell artifacts from which 48 types were identified.[12] The types from these three sites were compared to those from the Windmiller mound (Sac-107), along the Consumnes River. This latter site was divided into two cultural manifestations by Gifford, a lower portion was considered as being early, and an upper portion evidently comprised deposits laid down by a later and different culture group. As a result of these comparisons of shell artifact types he concluded that the upper 15 feet of Ellis Landing bore cultural connections chiefly with upper Windmiller. From more scanty data he found that West Berkeley shell (and bone) artifact types corroborated the evidence from Ellis Landing in correlating more closely to upper Windmiller. Comparisons of 27 shell and bone artifact types from Emeryville shared with Windmiller indicated, "a considerable degree of contemporaneity of the two mounds" (Ibid., p. 58), although, "the Windmiller lower stratum probably was used for burials before Emeryville mound began" (Ibid. The latter quotation indicates that demonstrable contemporaneity occurs only between upper Windmiller and Emeryville). In these comparisons the author segregated the upper 12 feet of Emeryville from the lower 19 feet (Ibid., Table 9), presumably on the basis of shell and bone artifact types with one result that the lower Emeryville stratum was affiliated most closely with the upper of the two Windmiller strata.

Thus, at Emeryville, West Berkeley and Ellis Landing we have evidence of an ecologic change as shown by changes in proportions of mollusks used for food, as well as a cultural change in at least one of these sites (Emeryville), as shown by shell and bone artifacts. However, the two types of changes are difficult to relate, for the faunistic break occurred at a depth of 19.5 feet in this mound while the cultural division occurred at about 12 feet.

Emeryville was a large, complicated site and the earlier investigators were hard put to it to interpret what they observed. Both Uhle and Nelson depicted stratigraphic sketches showing more or less well-defined layers (Uhle, 1907, plate 4; Nelson, ms. in University of California Museum of Anthropology cited by Beardsley, 1947, p. 180). Schenck, however, denied that strata existed at all, although he admitted certain "features" consisting of heavy calcined layers and/or heavy curved lenses of clamshells occurring down to a depth of 22 feet. Beardsley agreed with Uhle and Nelson, and on the basis of their diagrams and Schenck's own photographs stated that there existed a "disconformity in the dip of strata at about fifteen feet depth, the lower strata extruding at a much more nearly horizontal angle than those above" (Beardsley, 1947, p. 180). He further pointed out that "this testimony for what it is worth checks with Ellis Landing stratifications and that in Marin county sites, for the cultural cleavage zone is not only higher than the midden disconformity in each case, but higher by about the same proportion of total distance to the surface" (Ibid.).

Cultural Sequence in San Francisco Bay Mounds

Independently of Gifford's work a cultural sequence in California archaeology has been based on human burial positions and associated artifact types, including those of shell (Lillard, Heizer and Fenenga, 1939; Heizer and Fenenga, 1939; Heizer, 1941, 1949; Beardsley, 1947; 1948). This scheme is anchored in the stratigraphy of the Windmiller site in which the lower stratum (that in the subsoil) is a component of the Early Horizon in Central California while the upper strata are divided into Middle and Late Horizon components. All three horizons are manifested in other sites (components), with the later two horizons appearing stratigraphically related in several such sites. One of the latest published charts of the cultural and temporal relationships set up under this scheme shows the lower portion of the Emeryville mound equated with the Ellis Landing facies of the Middle Horizon (Heizer, 1949, p. 3, fig. 1). "Facies" designates a subdivision of a Horizon comprised of a number of similar components or sites in the same general area or Province (see discussion by Beardsley, 1948, p. 3). That is, Ellis Landing is considered a typical site of a cultural configuration including the lower portion of Emeryville, as well as the West Berkeley site. On the other hand, the upper part of the Emeryville site is placed early in the Late Horizon. Thus it will be seen that cultural change at Emeryville is postulated not on the basis of shell and bone artifact types (of Gifford) alone, but also upon evidence of human interment as illustrated by Beardsley (1947; 1948, p. 15, fig. 3). His charts show the cultural cleavage as ranging from about 8 to 13 feet in depth. This is in essential agreement with the critical depth of 12 feet ascertained by Gifford. Therefore, in this regard, Gifford's general findings are validated, but with more complete data, cultural delineations areally and temporally, have been considerably refined.

The partial replacement of some other species by the clam Macoma nasuta was noted in the first general survey of the San Francisco Bay area in these words, "Certain mounds do nevertheless furnish indications of probable local changes in the preponderating species; and whenever these changes are marked, it is the mussel which is most abundant in the lower strata while the clam becomes suddenly quite excessive in the upper horizons" (Nelson, 1909, p. 338, underlining mine); many new sites have now been added to his list). Louderback adds that it is impossible to say whether the causes are biological or geological, but that the rate of sedimentation has been a vital factor. He also points out that, "the sinking of the region and the disappearance of rock bound shores would have seriously affected the life of the mussel" (Ibid.). Nelson again discusses the problem with relation to the Ellis Landing mound (Nelson, 1910, pp. 375-378), and again he postulates subsidence of the bay area as the factor causing the differences in proportions of Macoma nasuta, to other species. This postulated subsidence of the region, "flooded the lower margin of the delta and insulated the Potrero San Pablo, producing a stretch of shallow water in which silt could deposit to make a suitable habitat for the clam" (Ibid.).

At least two authorities disagree with Nelson's explanation of this phenomenon. Gifford offers a cultural explanation to this and similar variations of prominent shell species in Ellis Landing and other mounds and attributes it to "instances of the mound-dwellers' overtaxing the supply of one particular species and thus being forced to rely more on other species" (Gifford, 1916, p. 10). Schenck disagrees with both of his colleagues, attributing the variations to "seasonal conditions or activities" (Schenck, 1926, p. 173).

The present writer agrees with the latter two (as would Nelson, undoubtedly), in that their explanations suffice for the minor variations or fluctuations of proportions of species in the mounds. But neither of these elucidations offer reasons for the sudden appearance of Macoma nasuta in large quantities in these three major sites. On the other hand, Nelson's contention seems to be corroborated in the statements made by Packard regarding the molluscan fauna of the bay, "The tubular bottom samples have revealed the fact that conditions have not been equally favorable to molluscan life during different periods of time.... The reason for such fluctuating conditions is not evident....These changes may be due to variations in the silting-up of the basin of deposition whereby during certain periods deposition proceeded at too rapid a rate to favor abundant molluscan life. Such variations might be expected as a result of local diastrophic movements, such as are indicated by changes of level registered by the Indian shell mounds around the bay."[13]

Thus, on the basis of present evidence Nelson's observations appear to be correct. In one particular he was wrong, however. This is in regard to the relationship between Macoma nasuta and Mytilus edulis. The latter species does not appear to have suffered appreciably from the rising of the tide line and silting-in of the bay. Nelson was probably misled by the fact that Ostrea lurida did not occur in quantity in the Ellis Landing mound, the site in which he was particularly interested. There, Macoma almost excluded Mytilus at several levels, yet near the top of the mound, they bore similar proportions to one another (Gifford, 1916, p. 27, table 13). As we have seen it was Ostrea lurida which gave way before the silting-in of the bay, as evidenced in remains from Emeryville and West Berkeley. This species is known to be relatively intolerant to new ecologic conditions, whereas species of Mytilus more readily adapt to such change.

Louderback (1939, p. 788) gives a description of the shore conditions previous to the silting-in of the bay adjacent to the three large shellmounds under discussion, "One class may be grouped as those streams that come out of comparatively steep-fronted mountain masses, within which they are agents of actual erosion, and reach the bay by flowing over a sloping plain between the mountain fronts and bay water surface. Such streams are best developed on the east side of the bay, and they have built alluvial cones or fans which spread out from the mouth of their canyons, across the plain toward and into the bay....It is believed that these continuous cone sheets were formed subaerially and have since been covered by bay water and sediment."

The other San Francisco bay area site analyzed here, El Sobrante (CCo-151) is situated on San Pablo Creek some 5 miles east of the mouth, and about two miles from San Pablo Bay in a line over the hills to the north. The data are contained in Tables 5 and 6. Mytilus edulis dominates the proportions of shell, while a small species of barnacle is next. The gravel habitat of these two species is reflected in the relatively large proportion of stone which occurs in the form of small pebbles. The mussels were eaten, but the barnacles are too small to eat and were undoubtedly brought in inadvertently. From the low proportion of Macoma one might suggest that the site is relatively old for this area. When more archaeology is done in the San Francisco Bay area, along with well controlled sampling of sites, these associations will be better understood.

Shell Content of Some Coastal Sites North of San Francisco Bay

There is much ethnological evidence that Bodega Bay was an important center of shellfish gathering activity in Late Horizon times. This was true, though with a somewhat different emphasis during the Middle Horizon, and is borne out by the archaeology and results of soil sampling from a site accumulated during this period. This site, Son-299, is a large midden situated near the bay end of a marsh on the west side of what is properly called Bodega Harbor and commonly known as Bodega Bay. The site, some 300 feet long, 150 feet wide and about 13 feet deep, was partially excavated by a University of California Archaeological Survey party in the summer of 1949. At that time a number of soil samples were taken by a method now considered inadequate. One foot square pillars were isolated and then removed by one foot levels. These samples were then sifted through ¼ inch (7 mm) screens without being weighed. Material caught by the screen was bagged and brought back to the Museum of Anthropology. The reasons for now considering those samples inadequate is that they were not first weighed so that the proportion of shell to the entire mound could be calculated, and because screens of ¼ inch mesh allow too much shell to go through. The critical screen size for sorting without the aid of a glass is about 1/8 inch, and, while some shell passes through, the proportion held is much more satisfactory than for a larger screen size.

One of the column samplings was sorted in its entirety in the fall of 1949. The total weight of the shell in this column amounted to over 55,000 grams. However, the percentage of residue was considered too high because fragments were not sorted down finely enough. This was a physical impossibility to accomplish in a few months of part-time application. Therefore another column sampling taken in the same manner, was sorted during the Spring of 1950. About one-fourth of each sample brought back from this column was sorted. The weight of samples ranged from about 1400 to 3200 grams with a total of some 15,000 grams from all samples. These were sorted down as finely as possible, that is, to about the size which would be held by a 1/8 inch screen. The unidentified shell proportion was reduced to a negligible percentage. The results of this analysis are presented in Table 9 below.

While the sorting technique had been refined to a more satisfactory degree, we still did not know what the proportion of shell was to the other mound components. Accordingly an opportunity was afforded the writer of obtaining another series of samples in the summer of 1950. This time the samples were taken from a nearby vertical face exposed by recent bulldozing operations at the site. To the eye the constituents appeared to bear similar relations to each other.

It was found from the analysis of this latter sample (see tables 1 and 2) that the mean proportion of shell was 34.8%, the other large component was soil and small shell fragments to the proportion of 60.4%.

It can be seen in Tables 8-10 that the proportions of shell species obtained in the 1949 and 1950 samplings are similar to the point of being identical in some cases. The advantages of a larger sampling are reflected in the somewhat stronger indications of the presence of Saxidomus nuttalli. However, the tendency of this species to be more prominent toward the top of the mound is reflected in both samplings. This fact has important cultural connotations in that it points to a more intensive use of this species for food toward the end of the site occupation. If this trend were to continue into a Late Horizon site on the bay we would have some clue, however slight, as to how and when, relatively, this species began to occupy the attention of the inhabitants.

Therefore, a site ethnographically known to be occupied in Late Horizon times, designated as Tokau or Son-321 (Kelly, ms.) was sampled. An analysis of this sampling shows that from a combined average of 4.7% in the Middle Horizon site, Saxidomus climbs to an average of 10.8% in Son-321. Unfortunately this latter site has not been dug archaeologically, but if the indications of the soil samplings are valid, i.e., that the site is "Late Horizon", then we should find some of the familiar Saxidomus clamshell disc beads there, along with other prehistoric and historic manifestations of the Coast Miwok tribe.

Striking corroboration of this trend of Saxidomus is on record for the McClure site (Mrn-266) on the western shore of Tomales Bay. The lower levels of this site are placed in the Middle Horizon while the upper portion is placed in Phase II (i.e., latter part) of the Late Horizon. This cultural cleavage is paralleled by a difference in the proportions of shell in the site (or disconformity as the author calls it). Mytilus californianus predominated in beds in the lower (or Middle Horizon) strata of the site, while the upper strata (Late Horizon) contained a higher percentage of clams including Saxidomus nuttalli, Saxidomus giganteus and Macoma nasuta. This fact along with soil in the upper level which is blacker and softer from greater amounts of organic charcoal leads Beardsley (1947, pp. 71-72) to suggest, "some physiographic or climatic change, as much as cultural change in food patterns or fire building habits" as being responsible for the disconformity.

Aside from the cultural importance assumed by Saxidomus certain other revealing comparisons may be made of samples from Son-299 and Son-321. In the first place we see that Mytilus californianus was indeed a staple food with the occupants of both the Middle and the Late Horizon components. In the former it attains a proportion of 54.8% of all the shell and 19.1% of all the material in the site, while in the latter, the sea mussel constitutes 55.3% of the shell but only 3.9% of the total site. These figures, along with that of 92.6% residue, reflect the fact that Son-321 is composed mostly of sand.

Another striking feature in both Bodega Bay mounds is the strong proportion of horse-neck clams (Schizothaerus nuttallii). This species, living as it does deep in the sand flats, requires no little effort to be taken, yet the Indians ate it consistently from Middle Horizon times down into the later period. The clam, Macoma, a species of which was so very important in San Francisco Bay, was only moderately used at Bodega Bay in the earlier site (Son-299) and negligible in the later site (Son-321). The common market cockle Protothaca staminea was eaten more at Son-321 than at Son-299.

Site Mrn-307 is located on Estero Limantour (an adjunct of Drake's Bay) at the mouth of a small creek. The results of analysis of soil samples taken in 1950 appear on Tables 13 and 14. A very striking fact turned up by this analysis is the amount of crab eaten by the people who lived there. The proportion to other shellfish of 20.2% for these crustaceans is not paralleled in any analysis so far undertaken for the California area. The closest approach to it is the relatively large proportion of 2% of crab at the Castro mound (Gifford, 1916, p. 24, table 10). Furthermore, this is the first site discussed so far in which the proportion of the ever-present mussel, in one or the other species, is reduced to a mere 3.5%. Clinocardium is of a much higher percentage, 16.3%, than at any other site. In fact four species of clams combine to form comparable proportions, trailed only slightly by a fifth (Table 13). Since the deposit was only 3.5 feet deep (an average depth, however), at the point the sample was taken, few if any significant stratigraphic differences might be expected, and none are shown.[14]

Molluscan Composition of some Coastal Sites South of San Francisco Bay

Site Mnt-229 is located near the former mouth of Elkhorn Slough which empties into Monterey Bay. It was originally a site of fair size and probably attained a depth of at least 6 feet in places, but a road-cut runs through the former center of the mound. It was the desire of the writer to obtain samples from around the mouth of Elkhorn Slough because that location offers an excellent opportunity to check the extent to which contents of coastal shell middens reflect the shellfish fauna of the adjacent shore. An intensive study of the marine biology of this particular area was carried on from 1926 to 1935 (MacGinitie, 1935). It is one of the few littoral areas along the California coast studied in such a comprehensive manner.

The area was divided into a number of stations, according to type of bottom. Adjacent to our site the bottom conditions are described as muddy (Ibid., p. 642). While the investigator mentions that the bottom conditions were changing slowly, those for the stations we are concerned with, did not change appreciably during the period covered by his study.

Our sampling shows three species of clams to be present in significant proportions with a fourth less frequent (Table 15). This in no way contradicts what would be expected as a result of the ecological study. The most abundant species in the site, however, is the bay mussel, Mytilus edulis which MacGinitie (p. 721) says "grows everywhere at the Slough that it can find a place of attachment." This is the first site at which Protothaca staminea is evidenced in such a large proportion, 28.1% of the total shell, and MacGinitie (p. 725) indicates that this clam is common throughout the mouth of the slough. Clinocardium also occurs in larger proportions than it does in any of the sites examined farther north. Furthermore, this clam seems to have increased in abundance from bottom to top of the site.

In the southern coastal region of California, near Santa Barbara, there is evidence, though somewhat inconclusive, that changes in shellfish species have accompanied significant cultural changes. In the earliest cultural period delineated, the "Oak Grove" of D. B. Rogers, reference is repeatedly made to fragments of massive shells embedded in extremely hard, calcareous layers (Rogers, 1939, pp. 32-81, 157). The author does not mention species names but some clues are given in the following passages: "The surface of the site exhibits evidence of a long continued occupation in the remote past, the fragmentary shells being only those of the most durable varieties; even these are in a very chalky condition;" (Ibid. p. 71) the refuse is, "greatly disintegrated and contains little organic material that can be identified, except the thicker parts of some varieties of massive sea shells;" again, speaking of a refuse layer underlying what was evidently a later cultural deposit, "The massive shells which it contained were far less fragmentary, although they were quite chalky with age" (Ibid. p. 157).

The massive shells referred to could only represent a limited number of species. Most probably they are among those which Rogers was able to identify associated with the following or later culture period which he calls, the "Hunting Period". These are said to consist largely of Tivela (Pismo clam), and Polinices (a large marine snail) (Ibid. p. 358). The former especially has a large durable shell and furthermore, occurs naturally in large numbers in this area. The only other shellfish remains occurring plentifully in "Oak Grove" sites were echinoderm spines (Ibid. p. 353). The preservation of the relatively soft sea urchin spines indicates that conditions were such that other shellfish remains would probably also have been preserved, had they occurred in the first place.

The remains of what Rogers calls the "Hunting Period", although similar to those of the preceding period, could be more readily identified because they were much better preserved. Among these were the following: Ostrea, Cardium, Hinnites, Placoides (Lucina) and Saxidomus and crabs besides the two mentioned above (Ibid. pp. 32, 99). Rogers mentions in several places that the most abundant species was the Tivela (Pismo) clam with many massive specimens (Ibid. pp. 120, 145, 172) and summarizes shellfish occurrence in the "Hunting Period" strata with the following words, "Quantities of the larger sea shells give an indication of the varieties of shell fish that contributed to the peoples' diet. Of these I believe that the Tivela easily takes precedence, although Polinices is a very close second. I have found no echinoderm remains and very few of those of Mytilus in the refuse left by this group" (Ibid. p. 358).

From the evidence it is apparent that no significant changes took place in the shellfish deposits of Rogers' first two periods. That is not to say, however, that this implies corresponding cultural affinities.

A rather distinct characterization is offered for the shellfish fauna of the Canaliño period which lasted into historic times. The shells are said to be composed largely of Pecten, Solen, Mytilus, Olivella and oyster, while the most abundantly occurring shellfish were apparently mussels (Rogers, Ibid., 120, 156-157).

Rogers' observations as to abundance of species were all subjective and, therefore, any conclusions to be made from them with regard to significant changes in time of the shellfish diets of the people on the Santa Barbara Coast are extremely tenuous. However, there seem to have been differing emphases on kinds of shellfish eaten in the earlier and later periods. Perhaps there were gross differences in quantity also, for Olson states that there was relatively low shell content in sites of his Early Mainland Period which presumably correlates roughly with Rogers' "Oak Grove" culture (Olson, 1930, p. 16). During the former, large clams, probably Pismo, were favored, but in Canaliño times mussels were the shellfish most eaten.

Judging from the abundance of shellfish now found along the Santa Barbara coast, the inventory of species given by Rogers is probably incomplete, though it may suffice for the more important species. A list of shells from a site about 20 miles south of some of those examined by Rogers comprises eighteen species, fifteen of which are thought to have been used for food (Woodward, 1930) This site, which had historic artifacts near the surface, was undoubtedly contemporaneous with some of Robers' Canaliño period sites.

Woodward states that the most abundant species represented in his site was the Black Abalone (Haliotis cracerodii) and that solid layers of cockle shells

(Paphia staminea) occurred. Of the four species mentioned by Rogers for the late period, one does not appear in Woodward's list, viz., Solen. On the other hand, Rogers does not list Haliotis as being present in his late sites. While these facts may reflect differences in ecological factors it is more likely that they represent differences in observation with Rogers' data apparently the more incomplete.

Shell Middens of the North Pacific Coast and Elsewhere

Turning now to the Pacific Northwest coast we find at least two published observations of stratigraphic differences in shell middens. Drucker noted some striking differences in several of the sites he investigated in Tsimshian and Kwakiutl territory. A Coast Tsimshian site on Anian Island had chiefly clam shell toward the top and chiefly mussel toward the bottom (Drucker, 1943, p. 65, fig. 17). Of a Northern Kwakiutl site he says, "Tests to determine the back edge of the deposit showed the midden to contain a fairly large proportion of clam (Saxidomus nuttalli Conr., Venerupis staminea Conr.) and cockle (Cardium clinocardium nuttali Conr.) shell there, rather than mussel shell as in the outer (and probably older) part of the site" (Ibid., p. 89).

This type of stratification is described for a site on the southern Northwest Coast also. The lower portion of the site had less shell and appeared to be composed chiefly of mussel shell while the upper strata contained more shell comprised mostly of five species of clams, along with some mussel and lenses of echinoid remains (King, 1950, pp. 7-9).

Observations made at sites on the Olympic Peninsula of Washington over thirty years ago are pertinent to these later studies in that general area. Reagan (1917, p. 18)[15] found glass trade beads in the uppermost strata of some sites. These layers were composed principally of shells, relatively few of which were those of the Pacific oyster, (Ostrea lurida). Underlying the top layers were strata, which differed, "in a lack of white man's things and in a greater abundance of Pacific oyster shells." (Ibid.)

Reagan's observations along with those of Drucker and King appear to offer striking corroboration of our findings at San Francisco Bay where mussels and/or oysters were relatively more abundant in the lower strata of some sites than they were in the upper layers of the same sites.

Using a method very similar to that described in this paper, Morrison (1942, p. 383) found, "a slight but general upstream retreat of the freshwater fauna of the Tennessee River in the time interval between the mound occupation and the present." However, he apparently found no stratigraphic changes of any significance.

Very stimulating work on problems of the age of shellmounds as evidenced by their shell content was done by E. S. Morse. He demonstrated measurable differences between shells from mounds and those of the same species from adjacent beaches. These measurements were expressed by indices of the length and width of bivalves and univalves, as well as indices of the length and width of the apertures of the latter. The nature of the differences indicated that the sea was colder at the time the shells in the mounds were gathered. This, he found to be true not only for certain deposits along the New England coast, but also along the coast of Japan (Morse, 1925, pp. 432-434; 1879, pp. 23-25). While Morse's investigations were not stratigraphic in the sense emphasized here, the implications of his findings are of the same nature for the ecological factors affecting change in size of a given species also affect the faunistic complex of a given area. However, his method has not as yet been widely applied to test such variations within shellmounds.

At another New England site, evidence for ecological change as reflected in molluscan fauna is presented by Byers and Johnson (1940, pp. 91-92) who note a preponderance of oysters in the East Heap on Martha's Vineyard. This fact is contrasted to that of a near-by site wherein clams seem to predominate.

Some of the best known instances of variations of shellfish content in middens are from Florida. Goggin in summarizing the knowledge of these phenomena in that area points to correlations of such occurrences with cultural horizons. For example, the shells of a species of clam, Donax, have been found to be most numerous in two Atlantic coast sites. Other sites in that area are composed chiefly of shells of oysters. The former two sites fall within the Archaic horizon while the heaps rich in oyster shells belong in the later St. John's I and II periods (Goggin, 1948, pp. 228-231; 1949, pp. 23-33).

Another species, the West Indies top shell, Livona pica, occurs abundantly in sites on the lower east coast of Florida, but does not now live in the adjacent waters (Goggin, 1948, p. 230).

Goggin also cites instances of changes in size of shells in archaeological sites in which the oldest and most recent shells are similar in size while those of an intermediate period are of a larger size. These differences may be connected with archaeological periods (Ibid. p. 231).

Steenstrup and his colleagues (1851) first drew attention to the problems of relationships of shell middens to man. They found that some species represented in middens on the shores of the Baltic Sea were much larger than their counterparts still living. Furthermore, one species, the oyster, which was abundant in the mounds, no longer grows naturally in that vicinity (Avebury, 1865, pp. 179-180; Rau, 1885, p. 36). Many of these Baltic Sea middens have now been assigned to the Ertebølle phase of the Mesolithic culture of Western Europe (e.g. see Kroeber, 1948, p. 670).

Climatic Factors in Relation to Molluscan Life

One of the more obvious factors governing the littoral fauna of an area is that of climate. Ecological conditions, such as salinity, temperature and currents are reflections of this factor. Somewhat more indirectly, bottom conditions may change with variations in shore line level, again associated with climate.

In shellmounds on the central Californian coast there are at least two different types of evidence which may reflect climatic change. One type of evidence involves variations of different magnitudes in the species of shellfish found. The other is evidence of rise of sea level on some sites. The two phenomena may be connected, especially if both were caused by climate. However, there are other factors to be considered. Species change in the middens might possibly have been caused by an over-exploitation of one, and a consequent shift in emphasis to another form. This argument can be countered with the fact the species involved, in most cases, require different bottom conditions (as between Macoma and Mytilus or Ostrea)[16] so that when one was plentiful on a particular shore, the other could not be. Also the corroborative evidence from sites on the Pacific Northwest coast appears to be more likely on the basis of climatic change affecting the entire coastline (and probably the world) than by postulating a similar exhaustion of the same or similar species.

The problem of fluctuation of sea level is of great ecological importance. There now seems to be general agreement among authorities on the problem that sea level sank from 230 to 330 feet during the last glacial maximum (Flint, 1947, p. 437). After this it rose until the end of the Altithermal (4500 years before present) to a point at least 5 to 6 feet higher than the present level (Antevs, personal communication; Flint, 1947, p. 442; MacNeil, 1950, pp. 1307-1308). Most pertinent to our immediate problem is fairly conclusive evidence of a recent trend toward warmer world-wide average temperature which is probably a cause of the trend toward the rise of oceans relative to land. Evidence for temperature rise of about 0.5° to 2.2° C for the past hundred years is cited by Flint, (1947, pp. 499-500). This appears to be the cause of the net shrinkage of living glaciers during the same period with a consequent rise of sea-level of the order of 2.5 inches per century (Ibid. and p. 428; see also Rappleye, 1947, pp. 41-43). These findings are not entirely conclusive for all coasts of the world and there have been some significant oscillations in the trends (see Knox, 1940, pp. 767, 777-779. Goldthwait, 1935).

Using these data with caution we may be able to throw some further light on the problem of inundation of San Francisco Bay shellmounds. Submergence of 15 to 18 feet of the mounds at Ellis Landing and Brooks' Island (Nelson, 1909, p. 354; 1910, p. 364 ff) is of course a minimum figure for, as Louderback (Ms., p. 32) points out, the original inhabitants of the mounds probably did not live at the edge of high tide waters, but perhaps ten or more feet above that level. This would mean a rise in the bay waters of at least 25 feet since the first occupancy.

Three independent estimates as to the time span represented in the Ellis Landing mound range from 3000 to 3700 years (Cook, 1946, p. 52; Nelson, 1909, p. 346; 1910, p. 371; Gifford, 1916, p. 13). With a minimum of at least 200 years since the abandonment of this site, since it falls within the middle Central California Horizon, we get a figure of the order of 4000 years since the site was first occupied. A sea level rise at the rate of 2.5 inches per century would only give a rise of about 9 feet for 4000 years. Because we have little evidence on which to base a greater rate of sea level rise during this period we will have to let that estimate stand.

This figure leaves us with a differential of from 6 to 16 feet to be accounted for. A strong possibility if not probability, is that the bay shore has been not a little affected by tectonic movements in the last few millenia. While the San Francisco Bay area has been somewhat more stable than the Los Angeles - Long Beach area (see Grant and Shepard, 1939; Grant, 1944 and Leypoldt and McHenry, 1942) in recent years, there are evidences of tectonic changes which affected the bay level in the geologically recent past. The magnitude and time element involved in these changes has not yet been entirely worked out, but it appears that some of these changes, including water level may have affected the east side of the bay (where the shellmounds in question lay) more than the west side of the bay (Louderback, personal communication).

With regard to development of bottom condition which are implied in the changes from mussel to clam, Louderback writes, "The development of the bay was a slow process. In the early stages the streams must have retained their identities, followed the lines of their earlier channels, and been flanked by tidal marshes, and most of their load of sediment was carried to the sea. More than half the time from the beginning of sea level rise to the present (possibly 8,000 - 10,000 years) must have passed before the advancing sea water traversed Carquinez Canyon to reach the edge of the present Suisun Bay. With increasing depth the bay system became a great settling basin for the retention of detritus carried by the tributary streams, although still some of the transported material (an unknown fraction) reached the ocean" (Louderback, ms., p. 32).

Conclusions

Significant changes in the proportions of shellfish fauna represented occur at various levels in aboriginal Californian coastal middens (Fig. 1A) Indications are that similar variations are present in other middens throughout the world. In some San Francisco Bay shellmounds, these faunal changes may have been the result of a rise in sea-level as evidenced by the fact that the bases of several mounds are over fifteen feet below the high-tide line. This alteration in sea-level was probably due to eustatic rise of the world's oceans. At San Francisco Bay a certain amount of tectonic movement may have accounted for part of the variations in levels of the mound bottoms. Here too, silting-in of portions of the bay helps explain the predominance of a species of clam in the upper levels over mussels and oysters in the lower strata of several of the sites examined.

Further studies of the type presented here and of other non-artifactual data from archaeological sites will significantly augment findings derived from analyses of artifacts.

NOTES

1. The writer wishes to thank Professors E. W. Gifford, R. F. Heizer, and S. F. Cook of the University of California for their advice and co-operation in the project resulting in this paper. Acknowledgment for aid in identifying shellfish remains is gratefully extended to Professor J. Wyatt Durham of the University of California and to Messrs. Allyn G. Smith, Leo G. Hertlein and their associates at the California Academy of Sciences. Site designations are those of the University of California Archaeological Survey under whose auspices most of the field work involved in this study was done.

2. For information as to the distribution and nature of North American shell middens see, Martin, Quimby and Collier, 1947; for Central America, Linné, 1929; for Central and South America, Steward, (ed.), 1946-1950.

3. Gifford, 1916, pp. 12-13 estimated the Ellis Landing and Emeryville mounds weighed about 51,085 and 55,885 short tons respectively.

4. Since then four papers on the subject have appeared; Cook and Treganza, 1947; Treganza and Cook, 1948; Cook and Treganza, 1950; Cook and Heizer, 1951. Though not emphasized here, data obtained from soil sampling may and has been employed as a basis for estimating the age of shellmounds, see Nelson, 1909; Gifford, 1916; and Cook, 1946.

5. Samples of this site were earlier analyzed by Gifford (1916). Site numbers are those given by the University of California Archaeological Survey.

6. Personal observation concurred with by Dr. A. E. Treganza who is in charge of excavation of the site.

7. Gifford, 1916, pp. 25, 28 includes two Humboldt Bay sites in his analysis; see also Loud, 1918, pp. 239, 339-344.

8. The geoduck occurs more abundantly to the north however, though its proportional use by the Lower Chinook is not known except that the ethnographer mentions it as being among the favored species.

9. At that time much of the archaeology in California was of a rather perfunctory nature (with some notable exceptions, such as at Emeryville by Uhle and at Ellis Landing by Nelson). The concept of obtaining rigidly controlled soil samples was not well worked out, and consequently those available for analysis would not meet requirements as set forth here.

10. Emeryville, according to Gifford's analysis averaged 59.9% shell, while West Berkeley averaged 52.5%. The present analysis shows an average of 23.1% for West Berkeley, see table 2.

11. The samples from Emeryville were collected during the Uhle-Merriam excavation of 1902, published by Uhle in 1907; the depth referred to here was measured from Uhle's diagrams, plate 4, figures 1 and 2.

12. The shell species represented in the artifacts were of the genera, *Haliotis* and *Olivella* neither of which was apparently used for food at that site.

13. Packard, 1918, pp. 223-224. This paper is the final report on the molluscan fauna of San Francisco Bay gathered by Sumner, et al, 1914.

14. The higher proportion of unidentified shell in the upper stratum indicates the greater difficulty of sorting due to adhering clayey soil.

15. In this paper Reagan figures 93 drawings of 51 species of shellfish from sites in the vicinity of La Push, Washington (p. 14 ff, plates 1-4).

16. Although requiring the same type of bottom conditions, Mytilus edulis is found higher in the tidal zone than Ostrea, Ricketts and Calvin, 1948, pp. 151, 262.

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Table 1

Means of proportions of shellfish species in sites analysed*

	Ala-307	CCo-151	Son-299(1)	Son-299(2)	Son-321	Mrn-307	Mnt-229
1 Clinocardium nuttallii	0.5	0.03	2.1	5.4	1.5	16.3	10.4
2 Hinnites multirugosus	-	-	-	0.2	-	-	-
3 Macoma sp.	10.3	0.5	6.0	6.0	0.9	11.8	3.2
4 Mytilus californianus	-	-	54.8	54.7	55.3	-	-
5 Mytilus edulis	46.9	98.6	0.1	0.1	-	3.5	37.1
6 Ostrea lurida	34.9	0.03	0.8	0.3	0.9	-	-
7 Pholas pacifica	0.1	-	-	-	-	-	-
8 Protothaca staminea	0.02	X	6.9	5.9	8.8	9.1	28.1
9 Saxidomus nuttalli	-	-	3.9	5.5	10.8	21.6	-
10 Schizothaerus nuttallii	-	-	18.0	16.7	14.4	11.8	17.6
11 Acmaea sp.	-	-	0.03	0.09	0.07	-	-
12 Crepidula sp.	-	-	0.01	-	-	-	-
13 Haliotis rufescens	-	-	-	0.008	-	-	-
14 Odostomia sp.	X	-	-	-	-	-	-
15 Olivella biplicata	-	-	0.1	0.04	-	-	-
16 Littorina scutulata	0.04	X	0.004	0.001	X	0.03	-
17 Polinices lewisii	-	-	0.05	0.2	-	1.4	-
18 Tegula sp.	-	-	0.4	0.5	1.6	-	-
19 Thais sp.	-	-	0.1	0.05	-	0.06	-
20 Balanus sp.	4.0	1.1	2.5	2.7	3.7	0.18	0.9
21 Crab	X	-	0.6	0.4	0.1	20.2	0.2
22 Cryptochiton stelleri	-	-	0.05	0.3	-	-	-
23 Katherina tunicata	-	-	0.4	0.1	-	-	-
24 Mopalia muscosa	-	-	0.01	0.03	-	-	-
25 Strongylocentrotus purpuratus	-	-	0.4	0.08	0.2	-	-
26 Helminthoglypta arrosa	-	-	0.007	0.01	0.2	-	-
27 Land snail (sp.)	-	-	-	-	-	X	-
Unidentified shell	3.3	-	3.0	0.3	1.6	4.2	2.5

Table 2

Means of proportions of gross components in sites analysed in Table 1

	Ala-307	CCo-151	Son-299	Son-299	Son-321	Mrn-307	Mnt-299
Shell	23.1	14.7	34.8	-	6.8	16.31	3.2
Bone	0.1	X	0.2	-	0.05	0.5	0.02
Charcoal	0.04	.052	0.08	-	0.05	0.04	X
Stone	7.8	22.6	4.5	-	0.3	2.18	0.3
Residue	69.0	62.6	60.4	-	92.6	80.8	96.4

Notes to Tables 1-2

Nos. 1-10: Bivalves (Clams)
11-19: Univalves (Snails)
20: Barnacles
22-24: Chitons
25: Sea Urchin
26: Land snail

Son-299(1) -- Sample procured in 1950
Son-299(2) -- Sample procured in 1949

* Proportions are expressed in percentages

An "X" indicates the presence of the species or component, weighing less than 0.1 gram.

Table 3

West Berkeley (Ala-307)(1)

Proportions by species of total shell in eample

Component	Depth in feet from surface 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17
1 Clinocardium nuttallii(3)	0.4	0.1	0.2	0.2	0.5	X*	0.6	2.1	[illegible]	0.4	0.01	0.4	0.9	X	-	1.2	0.3
2 Macoma nasuta	36.4	32.4	29.8	8.9	11.9	16.9	1.8	0.5	[illegible]	X	0.01	0.6	0.7	0.7	1.5	-	X
3 Mytilus edulis	42.7	39.0	42.2	46.2	52.0	45.3	48.5	48.5	[illegible]	54.4	57.9	49.0	54.9	40.5	42.0	49.9	49.3
4 Ostrea lurida	10.0	15.6	15.9	19.4	20.1	28.0	45.4	45.8	[illegible]	46.0	41.3	48.2	41.0	57.0	53.8	42.3	44.1
5 (Pholas pacifica)(2)	0.08	0.2	-	0.2	0.2	X	0.09	X	[illegible]	0.3	0.01	X	X	-	-	-	-
6 Protothaca staminea	-	X	-	X	-	-	-	-		-	-	0.3	-	-	-	-	-
7 Littorina scutulata	-	-	-	-	-	X	0.08	X		0.2	0.2	X	X	-	X	-	-
8 Odostomia sp.	-	-	-	-	-	-	-	-		-	-	-	X	-	-	-	-
9 Crab	X	-	-	-	-	-	-	X		-	-	-	-	-	-	-	-
10 Balanus sp.	5.0	9.6	3.5	13.5	5.4	3.1	2.4	1.6	[illegible]	2.1	1.0	1.4	2.2	1.5	1.6	6.6	6.4
11 Unidentified shell	5.2	3.2	8.7	11.6	9.4	6.7	1.4	1.5	[illegible]	0.4	0.4	0.09	0.3	X	0.07	-	-

Table 4

West Berkeley (Ala-307)

Proportions of components in each sa[illegible]

	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17
Shell	25.8	32.6	23.4	24.6	25.8	33.2	22.8	19.0	[illegible]	24.6	24.8	22.2	30.2	20.8	26.9	8.2	7.2
Bone	0.06	0.3	0.2	0.1	0.02	0.08	0.06	0.04	[illegible]	0.04	0.06	0.1	0.3	0.1	0.2	0.02	0.02
Charcoal	0.1	0.02	0.02	0.02	0.04	0.04	0.02	-	[illegible]	0.02	0.06	0.1	0.06	0.04	0.06	X	X
Stone	10.5	7.4	18.2	15.0	10.7	5.5	6.4	6.4	[illegible]	5.4	2.6	5.3	8.2	6.2	5.5	8.2	3.8
Residue	63.4	59.4	57.8	60.1	63.4	60.1	70.7	74.5	[illegible]	69.9	72.4	72.3	60.1	72.8	67.4	83.5	88.9

Notes on species in tables and other species ocng in site.

(1) Each sample weighed 500 g.
(2) A boring clam, probably this species.
* X means present but weighed less than 0.1 g.
Occurred, but not in samples: Sea mussel (Mytilus californianus), Limpet (Acmaea sp.)valves, Horn shell (Cerithidea californica), and others, (Olivella biplicata and Thais lamellosa), Lnail (sp.)

(3) For popular identification of species in this and following tables see notes to t.I.

Table 5

Comparison of two samplings of West Berkeley site (Ala-307)

Means of proportions of shell	1916 Percent	1950 Percent
Mytilus edulis	41	47
Ostrea lurida	19	35
Macoma nasuta	4	10
Unidentified shell	32	3

Table 6

El Sobrante (CCo-151)

Proportions by species of total shell in each sample by one foot intervals

	0-1	1-2	2-3	3-4
Balanus crenatus	0.9	1.1	1.1	1.3
Clinocardium nuttallii	0.1	X	-	-
Littorina scutulata	-	-	X	X
Macoma sp.	-	0.8	0.8	0.4
Mytilus edulis	98.7	97.9	98.2	98.4
Protothaca staminea	X	-	-	-
Ostrea lurida	0.1	-	-	-

Table 7

El Sobrante (CCo-151)

Proportions of components in each sample by one foot intervals

	0-1	1-2	2-3	3-4
Shell	16.6	14.3	14.7	13.2
Stone	41.7	18.0	12.1	18.4
Bone	X	.03	X	.05
Charcoal	.09	.06	.03	.03
Residue	41.6	67.6	73.1	68.2

Table 8

Bodega Bay (Son-299)

Proportions by species of total shell in each sample (of 1950)

		0-1	1-2	2-3	3-4	4-5	5-6	6-7
1	Clinocardium nuttallii	-	2.1	1.2	1.1	1.8	3.8	3.8
2	Hinnites multirugosus	-	-	-	-	-	-	-
3	Macoma sp.	3.3	5.3	10.4	8.1	7.9	5.4	4.3
4	Mytilus californianus	54.0	57.0	43.9	53.2	37.6	54.7	66.8
5	Mytilus edulis	0.03	0.1	0.1	0.3	0.2	0.08	0.06
6	Ostrea lurida	0.6	0.7	0.7	0.8	1.4	1.0	0.7
7	Protothaca staminea	2.7	11.6	9.5	6.8	10.1	7.8	3.8
8	Saxidomus nuttalli	10.5	7.0	1.4	8.5	3.5	0.03	0.5
9	Schizothaerus nuttallii	16.9	8.8	24.6	11.0	27.4	21.0	15.5
10	Acmaea sp.	X	0.06	X	X	0.06	X	0.05
11	Crepidula sp.	-	0.1	-	-	-	-	-
12	Haliotis rufescens	-	-	-	-	-	-	-
13	Olivella biplicata	0.2	0.03	0.1	0.5	0.03	0.2	0.01
14	Littorina scutulata	-	-	X	-	X	-	0.01
15	Polinices lewisii	-	-	-	0.5	-	-	0.04
16	Tegula sp.	0.3	0.4	0.4	0.9	0.4	0.3	0.3
17	Thais sp.	0.8	0.09	-	-	-	-	0.06
18	Balanus sp.	2.1	2.5	3.5	2.8	5.2	1.8	1.5
19	Crab	0.5	0.8	0.5	0.5	1.1	0.5	0.4
20	Cryptochiton stelleri	-	-	-	-	-	-	0.2
21	Katherina tunicata	1.8	0.3	0.1	0.3	0.09	0.7	0.2
22	Mopalia muscosa	-	-	-	-	0.1	-	-
23	Strongylocentrotus purpuratus	0.3	0.6	0.4	0.4	0.2	0.3	0.4
24	Helminthoglypta arrosa	0.03	0.03	-	-	-	-	-
	Unidentified shell	6.8	3.6	2.9	4.1	2.7	2.1	1.4

Table 9

Bodega Bay (Son-299)

Proportions of components in each sample (of 1950)

Shell	34.25	33.98	34.17	18.32	32.06	35.34	47.2
Bone	0.1	0.5	0.1	0.2	0.2	0.3	0.2
Charcoal	-	-	0.01	0.6	0.1	0.2	0.2
Stone	1.02	1.39	2.11	1.62	8.16	5.44	8.9
Residue	64.61	64.09	63.61	79.80	59.32	58.80	43.5

Table 10

Bodega Bay (Son-299)

Proportions by species of total shell by one-foot intervals in each sample in column N-3 (1949)

	0-1	1-2	2-3	3-4	4-5½	5½-7
1 Clinocardium nuttallii	4.1	6.2	22.8	-	2.6	4.3
2 Hinnites multirugosus	-	-	-	-	-	2.0
3 Macoma sp.	11.6	6.8	6.9	0.2	1.5	11.1
4 Mytilus californianus	29.0	44.3	37.2	87.2	80.8	34.7
5 Mytilus edulis	0.02	0.03	0.01	0.2	0.4	-
6 Ostrea lurida	0.2	0.4	0.5	0.3	0.4	0.1
7 Protothaca staminea	11.8	6.7	1.7	1.2	1.8	12.0
8 Saxidomus nuttalli	14.9	4.3	2.5	0.09	0.9	9.9
9 Schizothaerus nuttallii	22.6	23.2	19.7	7.1	8.8	22.9
10 Acmaea sp.	0.05	0.06	0.9	0.1	0.1	0.03
11 Crepidula sp.	-	-	-	-	-	-
12 Haliotis rufescens	-	0.4	-	-	-	-
13 Olivella biplicata	0.08	0.09	-	-	-	0.04
14 Littorina scutulata	-	-	-	0.008	-	-
15 Polinices lewisii	0.04	0.03	1.1	0.05	0.2	-
16 Tegula sp.	0.3	0.5	1.6	0.6	0.003	0.3
17 Thais sp.	0.04	0.003	0.007	0.02	0.04	0.07
18 Balanus sp.	4.1	4.5	3.0	1.3	1.4	0.6
19 Crab	0.3	0.4	0.7	0.5	0.5	0.2
20 Cryptochiton stelleri	-	0.6	0.6	0.3	0.2	0.04
21 Katherina tunicata	-	0.2	0.2	0.3	0.03	0.2
22 Mopalia muscosa	-	0.01	0.2	0.02	-	-
23 Strongylocentrotus purpuratus	0.04	0.09	0.2	0.2	0.01	0.08
24 Helminthoglypta arrosa	0.05	0.01	-	-	-	-
Unidentified shell	0.3	0.5	0.02	0.2	0.1	1.3

Table 11

Bodega Bay (Son-321)

Proportions of total shell in each sample

	0-1	1-2	2-3	3-4
1 Clinocardium nuttallii	1.3	0.8	2.4	1.7
2 Macoma sp.	0.6	0.8	1.0	1.7
3 Mytilus californianus	64.7	52.4	58.2	42.5
4 Ostrea lurida	-	0.8	1.7	1.2
5 Protothaca staminea	6.6	17.2	7.3	0.4
6 Saxidomus nuttalli	17.0	1.8	1.0	34.3
7 Schizothaerus nuttallii	5.7	14.7	24.7	7.4
8 Acmaea sp.	-	-	-	0.4
9 Littorina sp.	-	-	-	X
10 Tegula funebralis	-	4.6	-	1.7
11 Balanus sp.	2.5	5.7	2.1	4.6
12 Crab	-	0.3	-	0.4
13 Strongylocentrotus purpuratus	0.3	0.3	X	0.4
14 Helminthoglypta arrosa	-	-	-	1.2
Unidentified shell	0.9	0.8	1.7	1.7

Table 12

Bodega Bay (Son-321)

Proportions of components in each sample

Shell	6.4	7.8	8.4	4.8
Bone	X	0.02	0.02	0.02
Charcoal	X	0.02	0.02	0.02
Stone	0.4	0.3	0.3	0.2
Residue	93.1	91.6	91.2	94.8

Table 13

Drake's Bay on Estero Limantour (Mrn-307)

Proportion by species of total shell in each sample

		½-1	1-2	2-3	3-3½
1	Clinocardium nuttallii	11.8	16.6	12.7	23.9
2	Macoma sp.	14.4	13.3	8.1	13.9
3	Mytilus edulis	8.7	4.0	1.7	2.4
4	Protothaca staminea	14.0	9.9	8.1	6.1
5	Saxidomus nuttalli	10.1	14.4	35.8	16.0
6	Schizothaerus nuttallii	18.1	15.2	7.9	10.2
7	Polinices lewisii	-	0.4	2.6	-
8	Littorina sp.	0.02	-	-	-
9	Thais sp.	-	-	-	X
10	Cancer sp.	13.6	20.4	20.4	24.4
11	Balanus	0.04	0.01	0.02	0.01
12	Land snail (sp.)	X	X	-	X
	Unidentified shell	8.5	5.1	2.5	2.8

Table 14

Drake's Bay on Estero Limantour (Mrn-307)

Proportions of components in each sample

Shell	9.9	18.1	22.9	14.4
Bone	0.2	0.2	0.4	1.0
Charcoal	X	0.06	0.02	0.08
Stone	0.8	3.6	2.8	1.5
Residue	88.9	77.9	73.8	83.2

Table 15

Elkhorn Slough (Mnt-299)

Proportions by species of total shell in each sample

		0-1	1-2	2-3	3-4	4-5
1	Clinocardium nuttallii	16.8	18.8	9.6	5.4	4.7
2	Macoma sp.	1.5	3.7	6.0	0.9	4.7
3	Mytilus edulis	29.2	42.3	42.9	31.5	43.0
4	Protothaca staminea	43.8	29.2	25.4	19.4	29.7
5	Schizothaerus nuttallii	5.8	-	12.5	41.8*	15.6
6	Balanus sp.	-	2.2	X	1.8	X
7	Crab	X	1.5	-	-	-
8	Unidentified shell	4.4	2.2	3.4	1.8	2.3

Table 16

Elkhorn Slough (Mnt-299)

Proportions of components in each sample

Shell	2.7	2.7	3.5	4.5	2.6
Bone	-	0.02	0.04	0.04	-
Charcoal	X	-	-	-	-
Stone	0.2	0.2	0.2	0.7	0.08
Residue	97.0	97.0	96.2	94.7	97.2

* One large valve