# A GEOARCHAEOLOGICAL STUDY OF PRISONERS HARBOR, SANTA CRUZ ISLAND, NORTHERN CHANNEL ISLANDS, CALIFORNIA - PAST SEA LEVELS AND DELTAIC DEPOSITS OF AN INSULAR STREAM

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## ABSTRACT

In 1991-1992 a study of near-shelf sediments was conducted off the Santa Barbara Channel coast of Santa Cruz Island, California in the embayment called Prisoners Harbor utilizing both geophysical survey and geological coring techniques. In 1991 a FM swept-frequency, CHIRP sonar was used to collect over 56 km (35 mi) of high-resolution seismic data of near-shore shelf sediments. In the following year, a series of shallow sediment samples (up to -4 meters below sea-floor (mbsf) were taken in the Prisoners Harbor embayment. The sediment samples were taken at locations selected on the basis of the 1991 geophysical data.

The study's objectives were to 1) evaluate the textural and geochemical nature of the sediments; 2) use the textural and geochemical data to evaluate the local or extralocal origin of the sediments (mainland or insular terrigenous sediments); and 3) evaluate geophysical evidence for Pleistocene/ Holocene sea level models in the southern California region. Implications for preservation of inundated archaeological sites in the Channel Islands are apparent.

**Keywords**: Prisoners Harbor, Channel Islands, Santa Cruz Island, geoarchaeology, sea level, seismic profiling, geological coring, wave-notch scarps, sediment analysis, magnetic susceptibility, stable isotopes, dating.

## INTRODUCTION

The study's objective was to investigate the seafloor adjacent to Santa Cruz Island of the Northern Channel Islands, off north-central California (Figure 1), for evidence of past sea level as well as conduct studies of Pleistocene/Holocene sediment facies. The study called for the detection of reliable past sea level indicators (terraces, notches) using shallow seismic profiling then the subsequent coring of shelf sediments. A working hypothesis was the later Pleistocene/Holocene fluctuations (ca. 18,000 BP to present day) in sea level had allowed for the development of geomorphic features on the coastal shelf, due to the alternately drowning (transgression) and exposure (regression) of the insular coast.

Theories for Holocene sea level in the Santa Barbara Basinland the Southern California Continental Borderland postulate at least three periods of stable sea level significantly below that of today. Nardin et al. (1981:331-333) established four Holocene sea-levels for the Santa Monica shelf at -58 m (<18,000 BP), -24 m (12,000 BP), -46 m (11,000 BP) and -20 m (ca. 7,000 BP) with ages for the -58 m, -24 m, and -20 m derived from radiocarbon dates for Holocene mollusk shells and correlations with Curray's (1965) sea level curve for the Texas shelf situated off San

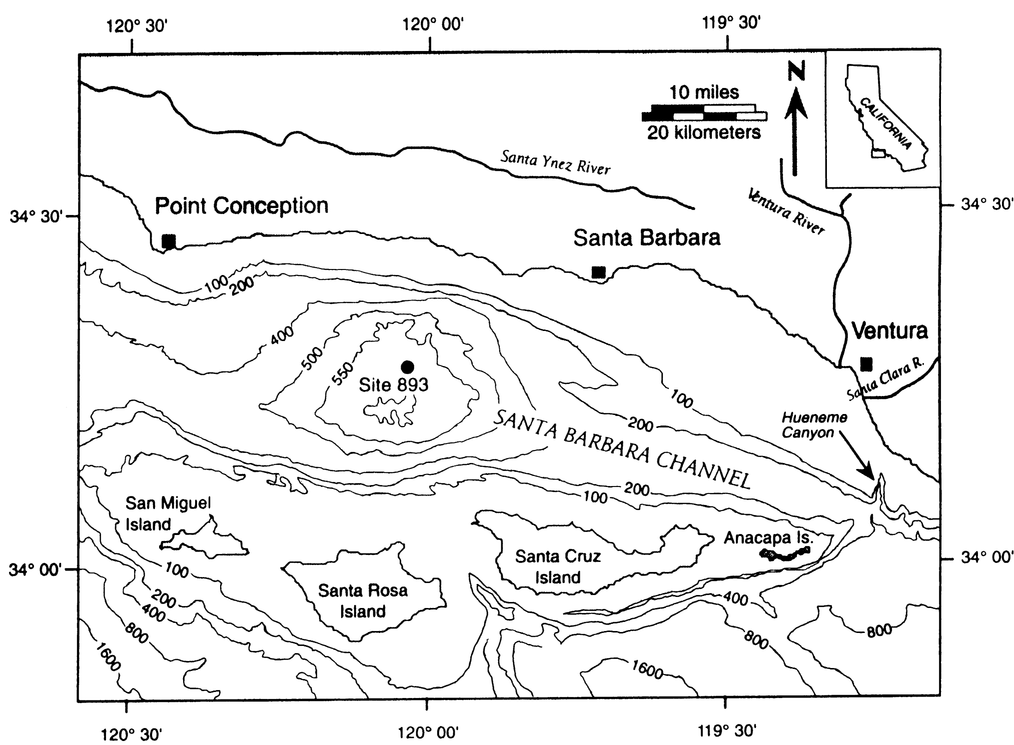


**Figure 1. Northern Channel Islands, California.**

Diego (Figure 2a). The maximum regression is in agreement with that of other writers (Orr and Berger 1966; Clark et al. 1978; Kennett and Behl 1993). The -58m and -46m stillstands are less securely dated but are reasonably placed within the present limits of sea-level chronology for the California Continental Borderland.

The placement, spatially and temporally, of past sea level has direct implications for the understanding of the early human and megafaunal colonization of the Northern Channel Islands. As recently as 1994 we have seen this dramatically illustrated with the discovery of a nearly intact dwarf mammoth skeleton on neighboring Santa Rosa Island (Johnson 1994; Agenbroad 1998). As shown in Figure 2b

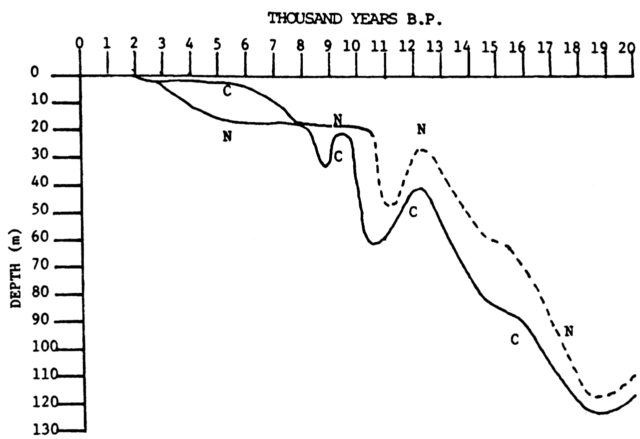


**Figure 2a. Flandrian sea level fluctuation curves for the Santa Monica (Nardin et al. 1981) and Texas (Curray 1965) shelves. The Texas Shelf, designated C, is situated off San Diego. The dashed line for the Santa Monica Shelf indicated where time control is lacking. Drawing after Nardin et al. 1981.**

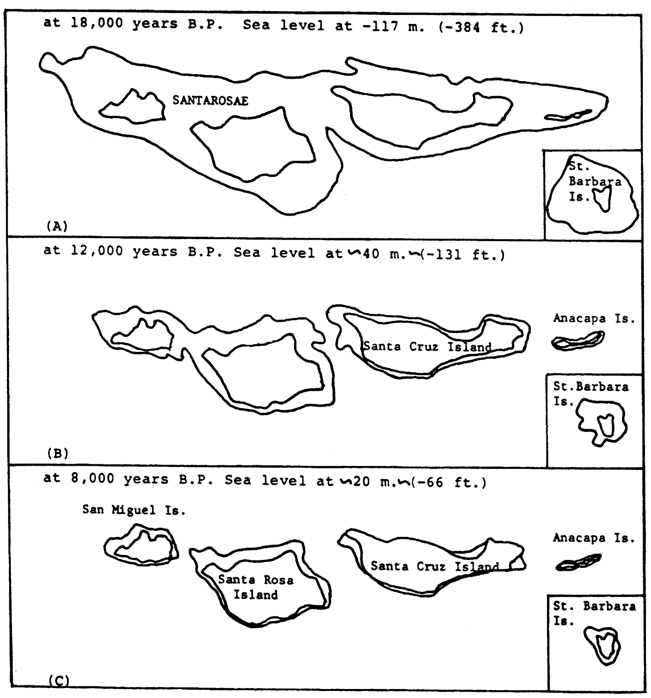


**Figure 2b. Reconstruction of Northern Channel Islands with different Flanderian coastlines.**

the impact of sea level on their exposed land mass has been significant with today's being only 26% of that at the glacial maximum (Orr and Berger 1966:1679). The earliest occupation of the islands is speculative, ranging from perhaps as early as 29,000 years ago (Broecker and Kulp 1957) but such dates for human and/or associated megafauna (dwarf mammoth) colonization are controversial suffering from challenges on the basis of geoarchaeology and the lack of definite archaeological evidence (Berger 1976; Cushing et al 1986). More conservative estimates have the first human occupations of the islands in the early Holocene (Hudson 1985:28-30). This latter view is supported by recent carbon dates from a cave on San Miguel Island of 10,700 years BP (Erlandsen et al. 1996:335-373). Many of the earliest archaeological sites have been exposed along uplifted shorelines suggesting that evidence for even earlier occupation may lie on the drowned island shelf, hence a principal reason for geoarchaeological study.

**Geology and Sediments of the Santa Barbara Basin**

The Santa Barbara Channel is a shallow marine basin formed between the mainland and the Northern Channel Islands. Structurally it is a continuation of the Greater Santa Barbara Embayment whose geology is described by Fischer (1972). It is located in the western Transverse Ranges of the southern California uplift (Yerkes et al. 1980). Formation of the basin and others to the south is explained in terms of interactions between the North American and Pacific plates from Cretaceous to Holocene times (Blake et al. 1978; Crouch 1979; Howell et al. 1980). These plate collisions and subsequent transform motion created the basis of the California Borderland which reached their present configuration in the late Miocene or early Pliocene (Howell et al. 1980; Nardin 1981). The connection of the Northern Channel Islands was broken before or during the mid-late Pleistocene (Axelrod 1967:295). This is inferred from a concordance of formations and complex faulted anticlinal structure seen between the islands and the nearby Santa Monica mountains. The area is part of the same geosyncline which was uplifted sometime in the Miocene. No Pliocene rocks are present on the Channel Islands (Axelrod 1967). More recent work by Junger and Johnson (1980:33-39) indicate upper Pliocene and Quaternary strata covering and buttressing the flanks of the Anacapa Ridge, a submerged east-west tectonic structure connecting West Anacapa Island to the mainland with a minimum depth of -236 m. Their work casts doubt at least on a late Pleistocene date for a land bridge between the islands and the mainland. They argue persuasively that there was no land bridge in the entire Quaternary since water depths were never less than -100 m (Junger and Johnson 1980:38).

Off-and-on volcanism and other tectonic activity has been a feature of the geologic history of the Santa Barbara Embayment since the Cretaceous (Vedder et al. 1969; Ingle 1980; Dott 1969). Early and post-Miocene uplift-subsidence activity separated the island chain from the Santa Monica mountains producing a silled, shallow (ca. -550m) basin today restricted in exchange with open ocean water on the east and west. The western sill is at a depth of -475 m and that of the eastern Hueneme Sill is at -225 m ( Figure 1) with water depths between the islands at approximately -50 m. The shelves and slopes of the mainland and islands comprise most of the basin's area of 2292 km$^2$ or 97.6 % while a small 2.4% (56 km$^2$) is flat ocean floor in the central part of the basin. The ocean, together with wind-driven surface currents, has produced relatively deep and uniform anaerobic sediments across its area (Kennett and Behl 1993).

Thornton (1981) describes the sediments of the deeper, central basin as hemipelagic with terrigenous sediments dominating a smaller pelagic, biogenic portion. On the mainland side of the basin clayey-silt is derived from the Ventura and Santa Clara rivers (Figure 1) and is entrained in the west-flowing Anacapa Current (Thornton 1981). These suspended sediments are silt-sized fractions with sand occurring only near the river source and the adjacent Hueneme Sill area. Ninety-five percent of the basin is covered with silts and the Holocene stratigraphy of the basin is produced by seasonal terrigenous input with subsequent redistribution by currents. In the deeper basin, ca. -550 m, the sediments are laid down in laminated layers or varves resulting in a record of climatic change for the Pleistocene. Sediments on the shallow shelf of Northern Channel Islands were believed to be of Holocene/Late Pleistocene age with any discontinuities in their stratigraphy the result of seismic events or, more likely, erosional processes (Drake et al. 1972; Gorsline et al. 1996:93-110).

Until only recently (1992) with the acquisition of two deep sediment cores at site 893 (-68.8 mbsf and -196.5 mbsf) (Figure 1). from the central Santa Barbara Basin by the Ocean Drilling Program, no pre-Holocene, Quaternary sediment sequence had been obtained from the Santa Barbara Basin (Kennett et al. 1994:18). Initial results of the study of those cores indicate a well-preserved late Quaternary laminated sediment sequence rich in biogenic inclusions ranging from Isotope stages 6 to 1 (Kennett et al. 1994:15). Global paleoclimatic cycles were reflected in the litho and biofacies of the Santa Barbara Basin cores.

## METHODS

### Geophysical

This study utilized a swept FM frequency seismic profiling CHIRP sonar that emits a wide band FM pulse that is phase and amplitude compensated to correct for variations in frequency response from a range of frequencies from 2 to10 kHz. The returning pulse is compared to a digital replica of the outgoing pulse using a Fourier transform array processor that is resident in device. This signal processing achieves a gain over background noise which in turn is dependent on signal duration and bandwidth. Conventional shallow subbottom profiler systems have a time-bandwidth product of 1 where CHIRP values can range from 10 to 1000.

Reflectors identified in the analysis of the seismic records were also evaluated as potential sediment sampling sites as well as direct indicators of stillstands. Navigation and mapping used the Global Positioning System (GPS). The survey consisted of "strike lines" parallel to the coast with tie or "dip lines" orthogonal to the strike lines. Survey offsets were 33 m (100 ft) with line lengths of 1.852 km (1 nm). A total of ten strikelines and three dip lines were surveyed in Prisoners Harbor (Figure 3). Data was also taken to the east in an adjacent embayment known as Chinese Harbor but is not reviewed for this article.

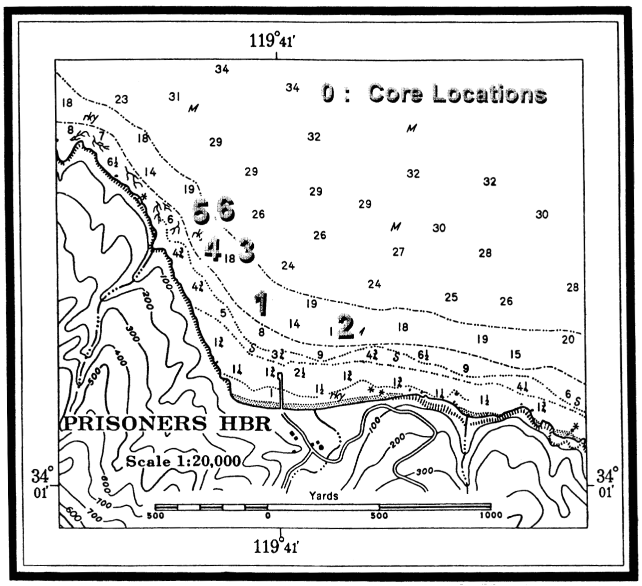


**Figure 3. Detail of Prisoners Harbor embayment, Santa Cruz Island, showing the location of coring locations. Depths in fathoms.**

### Geological Coring

A total of 11 sediment samples were taken at locations shown in Figure 3 and the sediments retained for laboratory study. The samples were taken using a standard soil recovery tube driven, by diver teams, to the required depths below the sea floor. The sample was immediately encased upon extraction in a plastic sample bag, sealed and taken to the surface. The sediment samples were logged, dried, and stored before laboratory studies were undertaken.

The following analyses of the sediment samples were done:

a. textural (Fleaker Method)
b. geochemistry (XRF & mass spectrometry)
c. mineralogy (petrographic microscopy)
d. magnetic susceptibility (magnetic bridge, moving coil)

## RESULTS

### Geophysical Studies

Geophysical profiles of Prisoners Harbor provided confirmatory evidence for three and possibly four seismic features interpreted as erosional surfaces truncated by wave-notch scarps at -58, -46, and -24/20 meters depth. These features compare with similar ones seen in Lailua Bay, Hawaii (Figure 4). The -58 m scarp was seen in Line 4 (Figure 5) an east to west strike line run on the outer portion of the narrow Santa Cruz shelf. The truncation of this erosional surface occurs at timing mark "tt". The erosional unconformity is interpreted as a Pleistocene surface covered by a relatively recent homogenous Holocene sediment unit averaging 1 to 2 m thickness accept at the truncation. Line 12 (Figure 6), another east to west strikeline, shows a sharp reflector near the -46 m depth dipping gently eastward. Sediment depths are greater, up to six meters, and the erosional surface truncates at timing mark wp38. At wp36 a shorter parallel reflector pinches off after extending eastward from the truncation. This reflector is interpreted as interbedded coarse sediments (gravel, etc.) within the Holocene sediment drape.

The erosional surface above -46 m slopes up and westward on Line 5, an east to west strikeline, to terminate in a wave notch feature at -24/20 m depths, timing mark wp41 (Figure 7). The sediments are thick (up to 6 meters) and parallel interbedding is seen between timing marks wp42 and wp43. Again, these stronger seismic reflectors are interpreted as coarse sediments within the overall Holocene sedimentary unit of the Prisoners Harbor embayment. Upslope of the wave-notch feature the softer sediments are less than a meter in thickness.

The erosional features (terrace surfaces and wave-notch scarps) are confirmatory of features described by Osborne et al. (1980) and Nardin et al. (1981) from their studies of the Santa Monica Bay. Their interpretation of these features was that of Pleistocene erosional surfaces (terraces) overlain by both Pleistocene and Holocene sedimentary units. This is in agreement with the earlier recognition of five

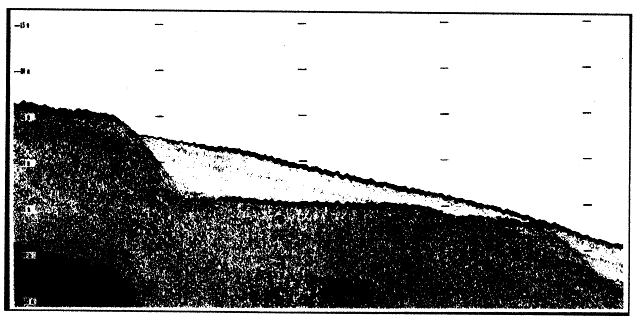

**Figure 4. Seismic profile of Lailua Bay, Oahu, Hawaii. Sediment thicknesses of up to 20 m overlay paleoreef terraces at depths of -80, -85, and -100 m. These terraces were formed by sea level stillstands in the Pleistocene. Data generated by 0.6 to 3 kHz sub-bottom profiling system. (Reproduced from Ericksen et al. 1997.)**

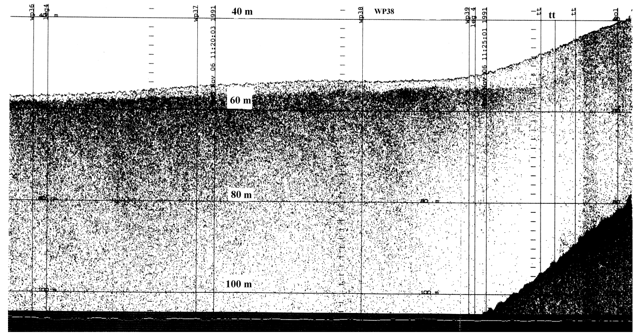


**Figure 5. Seismic profile, line 4, Prisoners Harbor. At way point "tt" is the -58 m wave scarp.**

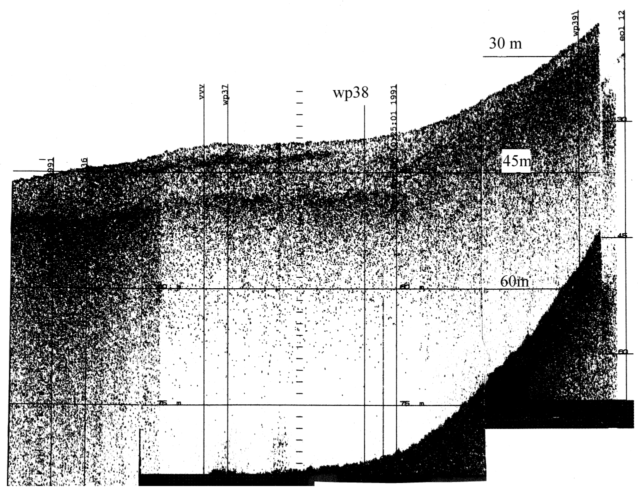


**Figure 6. Seismic profile, line 12, Prisoners Harbor. At way point "wp38" is the -46 m wave scarp. Downslope is seen an erosional surface and interbedded sediments.**

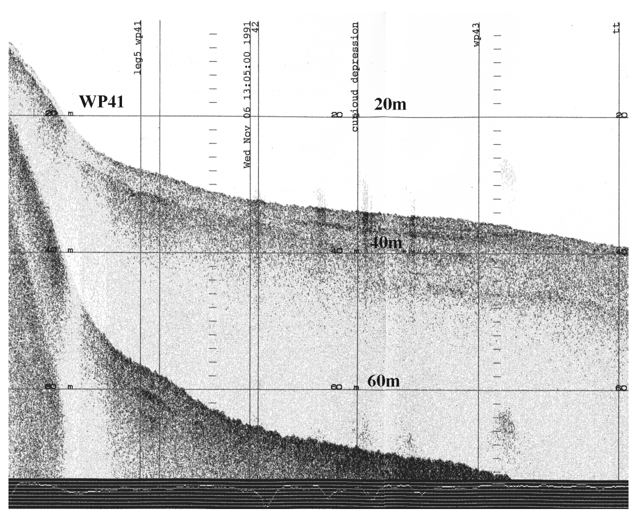


**Figure 7. Seismic profile, line 5, Prisoners Harbor. After time mark "wp41" is evidence of the wave-notch terrace(s) at -24/ 20 m. An erosional surface is evident at roughly -46 m around time mark wp43.**

well-defined submerged terraces between -10 and -130 m water depths (Emery 1960; Milliman and Emery 1968). Junger and Johnson (1980) identified three submerged terraces across the Anacapa Ridge. The upper terrace is at -100 m and the lower terrace at -200 m with the intermediate terrace between but poorly developed. The upper terrace is most likely the uplifted expression of the Wisconsin lowstand. The unconformities (surfaces) and wave-notch scarps are directly reflective of Flanderian sea level for the California Continental Borderland during late Pleistocene-early Holocene times. Geological coring was carried out in Prisoners Harbor to characterize and date the shelf sediments there.

**Geological Coring Studies**

The 11 shallow cores were driven to depths of -1.25 to -3.96 mbsf into the Prisoners Harbor sediment drape at locations shown in Figure 3. Locations were determined by use of GPS positioning as well as fathometer readings. As the cores were all driven and recovered by divers, the bulk of the coring samples were taken from sediments at or near the -20 m erosional feature in an attempt to intercept the lower lithostratigraphic contact with the exception of location 2. Coring location 2 was on the nearshore shelf east of Prisoners Harbor, off the mouth of Eagle Canyon (Figure 3). Here the sediments were thin and believed to be unconsolidated. As one will see the entire suite of the samples were from relatively homogenous Holocene sediments within the Prisoners Harbor embayment.

**Lithology and Texture**

The sediment prism of the Prisoners Harbor embayment is composed of slightly biotic, moderately well-sorted, medium to fine silty sand, medium brown (10YR4/1) in color. Marine shell fragments are present in all the samples while two samples (2a,2b) from off Eagle Canyon also contained subround-to-round pebbles. The small gravel is of a plutonic, metasedimentary or argillaceous nature reflecting the mineralogy of the Santa Monica Mountains, e.g., a core of argillaceous metasedimentary rocks (slates, phyllites, and schists) with intrusive granodiorite and quartz diorite of Pre-Cenozoic age (Weaver and Doerner 1967:15). These rocks are in turn, capped by Cretaceous to Miocene sedimentary and volcanic rocks (Savula 1978; Harden 1998:402-403).

To evaluate the mineralogy of the sediment fractions samples were impregnated and then thin sectioned. The thin sections were stained with sodium cobaltinitrite to distinguish feldspars, polished and examined under a standard petrographic microscope and point counted. The sand fractions are dominated by sub-rounded or immature quartz and feldspar with a rich heavy mineral fraction in some samples. The micas, notably biotite, are not that prominent.

To determine the texture of the Prisoners Harbor, the 11 samples were analyzed according to procedures for the Fleaker method as outlined by Indorante et al. (1990). The results are shown in Table 1. Thornton (1981) has characterized the surficial sediments by use of two straight forward ratios of sand:mud and of silt:clay. Grain sizes are typically those of sand and coarse silt for the northern and southern shelves (Thornton 1981:102-103). In the deeper Basin—over 200 m depths—sediments are nearly devoid of sand ($\leq$10%) (Thornton 1981:110). The Basin sediments are characterized by equal parts silt and clay or a ratio of 1:1 (Thornton 1981:295). On a broad-brush scale, one can describe the size fractions of the Santa Cruz Island shelf at 60-70% sand and up to 30% "mud" or clay and silt. Typically, the northern shelf has a sand:mud ratio of 1.0 with the mouths of rivers, such as the Ventura and Santa Clara, having less than 10% clay and shelves having clay contents of less than 20%. On the island shelves, the sand:mud ratio is 1.0 on the slope with sand increasing upshelf. This was apparent in the particle size data from the Prisoners Harbor cores (Table 1).

**Table 1. Textural study of Prisoners Harbor sediments.**

| Core | Clay % | Silt % | Sand % | Sediment Type | Depth (m) |
|---|---|---|---|---|---|
| 1a | 13 | 53 | 34 | silt loam | -2.01 |
| 1b | 17 | 60 | 24 | silt loam | -2.44 |
| 1c | 7 | 24 | 69 | sandy loam | -3.05 |
| 2a | 3 | 3 | 94 | sand | -1.25 |
| 2b | 4 | 9 | 87 | sandy/ loamy sand | -2.13 |
| 3a | 15 | 54 | 32 | silt loam | -3.05 |
| 3b | 12 | 39 | 48 | loam | -3.96 |
| 4a | 6 | 21 | 73 | sandy loam | -2.13 |
| 4b | 5 | 24 | 71 | sandy loam | 2.84 |
| 5a | 6 | 29 | 65 | sandy loam | -3.05 |
| 5b | 9 | 39 | 52 | loam/sandy | -3.96 |

The highest clay percentages were seen in cores taken at Locations 1 and 3 (Table 1). At Location 1 the clay percentage decreased with depth (13-17 vs. 7%). The same was true at Location 3 but to a lesser extent (15 vs. 12%). At Location 1 the silt fraction was clearly dominant (53 and 60%) in cores 1a and 1b implying a sand:mud ratio of nearly 1:3. Silt dominated at Location 3 as well (54 and 39%). Silt was proportionately high at Location 5 (29 and 39%).

There was no clear size trend with an increasing depth of cores. At Location 1 the sand fraction exceeded that of silt by an inverse amount (69:24%). Sand was seen in equivalent amounts at Locations 3/4 and 5 (52-73%). The sand fraction was highest at Location 2 but this was anticipated due to the very nearshore location and the shallow sediment depths. Inspection of Table 1 shows a sediment prism strongly shifted to the sand-silt fractions with the clay fraction, present but not at levels seen for the slope or deeper basin.

The explanation for this particle size distribution was likely one of coarser fractions of sand and silt deposited near sediment sources e.g., drainages and the lighter fractions being seasonally transported to the deeper Basin by suspension and along the bottom as a nepheloid layer (Drake et al. 1972; Bull and Kemp 1996:143-144; Anderson 1996:10-12; Gorsline et al. 1996:99). The size fractions at Prisoners Harbor defined a relatively thick Holocene sediment prism supplied by the largest catchment on the island with the embayment acting as a "trap" for seasonable outflows of terrigenous sediments.

In the deeper Basin, particularly the laminated sediments, silt content is dependent on the seasonal sediment supply (Bull and Kemp 1996:143). Because of bioturbation, mechanical movement and other factors, shelf sediments have less of a "seasonal" signal relative to the silt fraction. Nonetheless it is possible to speculate that high silt fractions seen in cores 1a, 1b, 3a, 3b and 5b may reflect, albeit poorly, a seasonal variation in the sediment flux due to runoff into Prisoners Harbor.

### Magnetic Susceptibility

The magnetic character (nature) of sediment while varying with magnetic mineral content and the oxidation state of iron species, was readily evaluated by use of magnetic induction. The cored sediments were placed in a magnetic susceptibility bridge and the induced magnetism measured in S.I. units (Table 2). In measurements in the deeper Santa Barbara basin as well as shallower shelf environments to the south of the Northern Channel Islands, the magnetic susceptibility varied in the horizontal distribution of terrigenous sediments and with changes due to digenesis in vertical sections (Kennett et al. 1994:32-39) in the deeper basin sediments below the oxygen minimum zone. The sediments from Prisoners Harbor exhibited a magnetic susceptibility more closely akin to that seen for California Continental Borderland shelf sediments than that of the deeper Basin.

There were no dramatic excursions in susceptibility values for the sediments with the exception of core 3a. This core had one of the higher clay, silt values (15:54%) and hence the lowest amount of sand. It is probable that the coarser grained material e.g., sand, is where the bulk of the magnetic signal lies. This is in agreement with observations made on the sediments from the 893 site studies by the Ocean Drilling Project that is to say magnetic susceptibility is strongly correlated with grain size (Kennett et al. 1994:37).

**Table 2. Magnetic susceptibility of Prisoners Harbor sediments.**

| Sample # | Depth (m) | Weight (g) | $\chi_g$ (SI Units) |
|---|---|---|---|
| 1a | -2.01 | 6.54 | 1.63 |
| 1b | -2.44 | 6.24 | 1.63 |
| 1c | -3.05 | 6.77 | 2.07 |
| 2a | -1.25 | 6.8 | 1.87 |
| 2b | -2.13 | 6.35 | 1.49 |
| 3a | -3.05 | 2.08 | 0.365 |
| 3b | -3.96 | 6.55 | 1.95 |
| 4a | -2.13 | 7.17 | 1.92 |
| 4b | -2.84 | 7.12 | 2.22 |
| 5a | -3.05 | 6.19 | 1.84 |

### Geochemical

The sediment core samples were examined using x-ray florescence (XRF) and mass spectroscopy (carbon and nitrogen isotopes). The results are shown in Tables 3 and 4. There was a relative lack of variability across the mineral suite (Table 4), indicating a lithological homogeneity across the sediment prism at least to the degree that the sediments reflect a common source as to origin, e.g. the Santa Monica Mountain rocks of Santa Cruz Island. The Loss-on-Ignition (LOI) data showed some variability in the organic carbon content which was elevated in core 3b (9.31%) and lowest in core 2a (3.51%), the shallow, sandy sediment located off Eagle Canyon.

The isotopic data showed variability in both the $\delta^{13}C$ and $\delta^{15}N$ isotopic signatures (Tables 3a and 3b). The $\delta^{13}C$ values of the Prisoners Harbor sediments were in good agreement with the reported $\delta^{13}C$ range for the Santa Barbara Basin, of -21.2 to 22.2, reported by Schimmelmann and Tegner (1991). In general there appears to be higher, more negative, $\delta^{13}C$ values for sediments influenced by terrigenous organic matter (Hagadorn, 1996:115). The carbon isotopic range for Prisoners Harbor sediments was -20.46 to -23.96.

The one exception to the observed carbon isotopic variation was that of core 26 with a $\delta^{13}C$ value of -17.25 (Table 3a). Here again the sediments off Eagle Canyon showed differences to the rest of Prisoners Harbor. In the nitrogen isotopic values, the difference between the Eagle Canyon sediments and that of the Central Valley/Prisoners Harbor was quite pronounced with a $\delta^{15}N$ range of +4.48 to +5.73 for Prisoners Harbor and values of +10.20 and +11.93 for Eagle Canyon (Table 3b). This difference may reflect more directly on sediment sources, e.g., lithology, than any other factor.

### Radiocarbon Dating

One carbon sample was extracted from core 1b of adequate size for AMC-radiocarbon dating by Beta Analytic Laboratories. The sample was taken from sediments at -2.44 mbsf and dated to 160+/-40 BP (Beta -115477). This surprisingly young age raises questions as to the extent and rapidity of sediment deposition in the Prisoners Harbor embayment and has very direct implications for the burial depth and preservation of any late Pleistocene/early Holocene archaeological sites that may be located on the island shelf.

## CONCLUSIONS

The geophysical data gathered by this study show features that correlate well with submerged shorelines identified elsewhere in the southern California region at -20 m

**Table 3a. Carbon isotopic values for Prisoners Harbor sediments.**

| Sample I.D. | Sample Weight (mg) | Ampt. (V) | CONC total %C | delta blk cont 13CVSPDB |
|---|---|---|---|---|
| PH1A | 54.389 | 3.170 | 0.77 | -23.92 |
| PH1B | 51.360 | 4.638 | 1.29 | -24.29 |
| PH1C | 51.523 | 4.933 | 1.35 | -20.46 |
| PH2A | 59.058 | 0.309 | 0.07 | -22.13 |
| PH2B | 61.665 | 1.310 | 0.27 | -17.25 |
| PH3A | 52.504 | 2.896 | 0.73 | -24.08 |
| PH3B | 53.310 | 5.682 | 1.61 | -23.96 |
| PH4A | 51.832 | 1.853 | 0.46 | -21.85 |
| PH4B | 56.877 | 2.046 | 0.46 | -22.85 |
| PH5A | 52.105 | 2.725 | 0.69 | -21.41 |
| PH5B | 54.213 | 4.087 | 1.04 | -22.58 |

**Table 3b. Nitrogen isotopic values for Prisoners Harbor sediments.**

| Sample I.D. | Sample Weight (mg) | Ampt. (V) | CONC total %N | delta blk cont 15NvAir | blk corr at % 15N |
|---|---|---|---|---|---|
| PH1A | 54.389 | 1.155 | 0.06 | 5.48 | 0.36787 |
| PH1B | 51.360 | 1.638 | 0.09 | 5.00 | 0.36769 |
| PH1C | 51.523 | 0.955 | 0.05 | 5.73 | 0.36796 |
| PH2A | 59.058 | 0.154 | 0.01 | 11.93 | 0.37022 |
| PH2B | 61.665 | 0.335 | 0.02 | 10.20 | 0.36959 |
| PH3B | 53.310 | 1.854 | 0.10 | 4.48 | 0.36751 |
| PH4A | 51.832 | 0.546 | 0.03 | 5.46 | 0.36786 |
| PH4B | 56.877 | 0.581 | 0.03 | 5.28 | 0.36780 |
| PH5A | 52.105 | 0.733 | 0.04 | 5.27 | 0.36779 |
| PH5B | 54.213 | 1.111 | 0.06 | 5.03 | 0.36771 |

**Table 4. Metallic oxide values for Prisoners Harbor sediment.**

| Sample | A120 3% XRF | Ca0 % XRF | Cr20 3% XRF | Fe203 % XRF | K20 % XRF | Mg0 % XRF | Mn0 % XRF | Na20 % XRF | P205 % XRF | Si02 % XRF | Ti02 % XRF | LOI % XRF | Total % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PH1A | 16.41 | 3.72 | <0.01 | 5.68 | 1.39 | 1.75 | 0.04 | 3.94 | 0.13 | 57.86 | 1.06 | 7.14 | 99.12 |
| PH1B | 15.72 | 3.51 | <0.01 | 6.51 | 1.34 | 2.09 | 0.05 | 3.77 | 0.15 | 55.90 | 1.12 | 8.59 | 98.75 |
| PH1C | 16.24 | 5.40 | <0.01 | 5.06 | 1.06 | 1.74 | 0.05 | 4.25 | 0.13 | 58.36 | 1.08 | 5.68 | 99.05 |
| PH2A | 15.93 | 4.30 | <0.01 | 4.24 | 1.26 | 1.19 | 0.04 | 4.26 | 0.13 | 63.01 | 1.03 | 3.51 | 98.90 |
| PH2B | 15.40 | 4.63 | <0.01 | 4.25 | 1.30 | 1.23 | 0.03 | 4.25 | 0.16 | 61.27 | 0.92 | 5.02 | 98.54 |
| PH3A | 15.73 | 3.50 | <0.01 | 5.84 | 1.32 | 1.94 | 0.04 | 4.25 | 0.13 | 56.91 | 1.06 | 7.82 | 98.44 |
| PH4A | 16.27 | 4.05 | <0.01 | 4.42 | 1.23 | 1.48 | 0.04 | 4.50 | 0.14 | 60.05 | 0.92 | 4.79 | 98.69 |
| PH4B | 16.25 | 4.75 | <0.01 | 4.35 | 1.14 | 1.47 | 0.05 | 4.60 | 0.13 | 60.47 | 0.94 | 4.90 | 9.05 |
| PH5A | 16.09 | 5.07 | <0.01 | 4.55 | 1.07 | 1.50 | 0.04 | 4.26 | 0.12 | 59.71 | 0.96 | 5.09 | 98.46 |
| PHRB | 15.60 | 4.84 | <0.01 | 5.09 | 1.20 | 1.70 | 0.05 | 4.26 | 0.13 | 58.37 | 0.98 | 6.94 | 99.06 |

and -46 m, -58 m. An age of 11,000 BP was assigned the deeper shoreline value (Broecker et al. 1960). The upper sediments (ca. 1 to 3 m) on the Santa Cruz Island shelf were generally grayish silts of a modern marine origin. Underlying these were sediments that were more consolidated with some organic content. That the compacted clay-rich sediments of the near-shelf of Santa Cruz Island are of local terrigenous origin has explanatory merit given Day's (1979) recognition a of minor influx of sediment from the Northern Channel Islands into the larger sediment budget of the basin as a whole. At -60 m there is suggestive evidence of an incised channel in the Prisoners Harbor embayment. This feature is most probably a paleochannel of today's Central Valley drainage. The fill in the paleochannel appears to be composed of course fractions e.g., gravel and rock, laid down during periods of greater precipitation such as the late glacial - early Holocene. Sediment rates for this shallow shelf can only be guessed although those in the deeper California Borderland basins such as Tanner Basin appear to be about 1cm/100 years (cf. Carbone 1984) and the same for Santa Barbara (Thornton 1981) in the later Pleistocene/early Holocene.

All of the objectives set out for this research were met to one degree or another. In the title of this study the term *geoarchaeological* is prominent yet the study results clearly appear to be more geological than archaeological. Nonetheless, the study's results have direct implications for the timing and presence of inundated archaeological sites on the Santa Cruz shelf. Additionally, the erosion or preservation of any such site is directly related to the rapidity of sea level rise and subaerial exposure or burial.

In terms of the three explicit objectives the study results were as follows:

- Isotopically and mineralogically the Prisoners Harbor sediments indicated the local nature of the source lithology at a scale of individual catchment/drainage, e.g., Central Valley versus Eagle Canyon;
- Texturally and chemically, the bulk of the Prisoners Harbor sediments were relatively homogenous and inferred to represent a Holocene-aged sediment fan;
- The sediments were texturally and chemically of island (local) origin as opposed to mainland (extralocal) origin;
- The geophysical data clearly showed three or even four, wave-notch scarps and associated terraces at -58, -46, and -24/20 meters below the present sea level. These data were confirmatory of similar seismic data observed in the adjacent Santa Monica Basin; and
- The one absolute date of 160+/-40 BP pointed to a relatively recent origin, and rapid deposition, of at least the upper portion of the sediment prism in Prisoners Harbor.

While the geophysical data point to late Pleistocene erosional features (and deposition) the geological coring was unable to penetrate to those surfaces. From an archaeological standpoint it is believed these surfaces hold the greatest potential for buried sites of late Pleistocene/early Holocene. The broad terrace above -58 m is relatively deeply buried (2 to 6 m sediment thickness) and the sloping surface above -46 to -24 m has interbedded deposits that may contain subaerial archaeological facies.

The shallow sediment drape above -20 m suggests a lack of preservation of archaeological features. If the new timing of entry of human groups into the New World (prior to 12,000 BP) and if coastal migration is a reasonable model then the location and areal extent of the Northern Channel Islands, at that time, would have presented significant land and resources for these migratory groups (Wright 1999:53-63).

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