Recent marine sediments of Carmel Bay, California

Carter, Lee Scott

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RECENT MARINE SEDIMENTS OF CARMEL BAY, CALIFORNIA

Lee Scott Carter
NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

RECENT MARINE SEDIMENTS
of
CARMEL BAY, CALIFORNIA

by

Lee Scott Carter

Thesis Advisor: R. S. Andrews

December 1971

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Recent Marine Sediments
of
Carmel Bay, California

by

Lee Scott Carter
Lieutenant, United States Navy
B.S., Naval Postgraduate School, 1970

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN OCEANOGRAPHY

from the
NAVAL POSTGRADUATE SCHOOL
December 1971
ABSTRACT

Fifty-six sediment samples were collected within Carmel Bay for textural analysis to determine their statistical properties. The sediments found within the Carmel Submarine Canyon consist, for the most part, of poorly to very poorly sorted very fine sand and coarse silt. The shelf area surrounding the canyon is primarily comprised of moderately to very poorly sorted sand, with a small area of very poorly sorted gravel in the northeastern section of the Bay. Consideration of textural parameters such as mean size, standard deviation, and skewness suggest that the sediments of the Bay are under the influence of a dynamic sediment transport mechanism. The Bay appears to be a sedimentary system primarily isolated from adjacent coastal sediment sources, with the major sources of sedimentary deposits being terrigeneous debris from the Carmel River, erosion and weathering of the local coastline and offshore rocks by wave and weather, and the shells and tests of numerous calcareous marine organisms. Movement of sediments by slumping and gravity sliding down the Carmel Submarine Canyon appears to be the only form of sediment removal within the Bay.
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ACKNOWLEDGMENTS

The author is deeply indebted to Dr. Robert S. Andrews of the Department of Oceanography, Naval Postgraduate School, Monterey, California for his assistance. Assistance in the collection and processing of samples is gratefully acknowledged from Lcdr. Charles K. Roberts, USN; Lt. Ralph A. Zardeskas, USN; Lt. John P. Simpson, USN; Mr. Jack C. Mellor; Mr. Lawrence Leopold; Miss Norma Tatum; Miss Theodora Cristobel; Mrs. Cynthia J. Carter; and the crews of the Naval Postgraduate School 63-foot Hydrographic Research Vessel and USNS BARTLETT (T-AGOR-13). Grateful acknowledgment is also made to Miss Sharon D. Raney of the W. R. Church Computer Center at the Naval Postgraduate School for her preparation of the computer program for sediment size analysis.

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I. INTRODUCTION

The objective of this study was to describe the distribution of the recent marine sediments of Carmel Bay, California. To accomplish this objective, 52 grab samples and 1 gravity core were collected within the Bay.

Among the previous studies of the marine sediments of Carmel Bay are two M.S. theses by students of the Naval Postgraduate School; one on the sediments at the head of the Carmel Submarine Canyon [Wallin, 1968], and one on a heavy mineral investigation of Carmel Bay beach sands [Griffin, 1969]. Judge [1970] reported on one sample taken at Carmel River Beach and analyzed for size distribution and heavy mineral content.

A. DESCRIPTION OF CARMEL BAY

Carmel Bay is located on the Coast of California approximately 160 km south of the entrance to San Francisco Bay (Fig. 1) and 9 km south of the southern extreme of Monterey Bay. The Bay is generally rectangular in shape with dimensions of about 4.3 km in the north-south direction and 3.6 km in the east-west direction (Fig. 2).

The Bay is bounded on the north by the community of Pebble Beach, on the east by the City of Carmel, and on the south by Point Lobos State Reserve.

The Bay drains approximately 670 square km of watershed through two watercourses, the Carmel River and San Jose Creek (Fig. 2) [California State Department of Water Resources, 1969].
Figure 1. Location of Carmel Bay, California.
Figure 2. Carmel Bay Bathymetry. (After Zardeskas, 1971)
The discharge from the Carmel River is quite seasonal with heavy runoff during the rainy winter months and virtually no runoff during the summer and fall months. During the summer and fall months the beach berm crest closes off the river mouth, forming a small fresh-water lagoon on the backshore. After the start of the rainy season, and as conditions dictate, the mouth of the river is forced open by bulldozer to reduce the danger of severe flood damage if the river is unable to breach the berm crest by itself. Normally this forced opening of the mouth is required only once or twice a year; however, during the winter of 1966-1967 the river mouth was forced open 25 times by crews from the Point Lobos Reserve State Park [Mr. Donald Rich, personal communication]. This breaching results in the carrying off of large amounts of sedimentary debris into the ocean. The flow of water from San Jose Creek is normally so meager that very little water ever reaches the shore of the Bay except during periods of heavy winter rains.

B. REGIONAL GEOLOGY

The geology of the area surrounding Carmel Bay has been studied in some depth by Lawson [1893], Beal [1915], Bowen [1965], and Nili-Esfahani [1965]. Bowen's publication is the basis for much of the following information.

There are several different formations associated with the geology of Carmel Bay and its associated watersheds. These watersheds constitute an important source of supply of fresh materials for the sediments of the Bay. The most conspicuous of the rocks is the Santa Lucia porphyritic biotite
granodiorite. This formation was intruded deep into the Paleozoic Sur Series early in the Cretaceous period. Through uplift and erosion much of the Sur Series was removed, leaving only the granodiorite. Subsequent depression presented the opportunity for further marine deposition. During the Paleocene age the Carmelo Series, consisting of interlaid beds of sandstones, siltstones and conglomerates, was deposited. The Middle Miocene Chamisal Formation overlays the Carmelo east of the Bay and this is in turn overlain by Middle Miocene iddingsite andesite lava which outcrops at five or six points around the Bay. The lava is in turn overlain by Middle and Upper Miocene Monterey siliceous shale.

Granodiorite outcrops are found at three points around the shore of the Bay: Pescadero Point, Abalone Point, and Point Lobos. The Carmelo outcrops in the northern area of the Bay in the vicinity of Stillwater Cove and to the south in the vicinity of Whaler's Cove. A massive outcrop of lava exists at Arrowhead Point, with a smaller one appearing to the south of Carmel Beach. The remainder of the shoreline consists of the Quaternary sandstones which lie above the Monterey shale, and Recent unconsolidated sand and gravel.

The upper watershed of the Carmel River is composed primarily of Paleozoic metamorphic gneisses of the Sur Series. These metamorphics are an important source of supply of heavy minerals to the sediments and beaches of Carmel Bay. The lower portion of the watershed is comprised primarily of Santa Lucia granodiorite and Tertiary sedimentary rocks.
These sedimentary rocks, being generally soft, are subject to intense weathering, and contribute a much greater amount of sedimentary material for transport to the sea than do the much harder crystalline metamorphic and granitic rocks of the area. San Jose Creek follows a path that takes it through Monterey shale and Santa Lucia granodiorite.

C. BATHYMETRY

A complete bathymetric survey of Carmel Bay was made in March of 1971 (Fig. 2). This was the first survey made of the entire Bay which utilized echo-sounding equipment [Zardeskas, 1971]. The current U.S. Coast and Geodetic Survey chart of the Bay (C&GS 5476) is based on data collected in 1933 utilizing lead line soundings and sextant navigation.

The Bay is transected by the Carmel Submarine Canyon, which has its origin immediately offshore of San Jose Creek and its termination where it branches with the Monterey Submarine Canyon some 21 km to the northwest of the mouth of San Jose Creek. The bed of San Jose Creek, which flows through a narrow V-shaped canyon throughout its 10 miles of length, tends to follow the Blue Rock Fault [Griffin, 1969] and appears to be a direct landward extension of the Carmel Submarine Canyon. Carmel Canyon is similarly a narrow V-shaped canyon cut into granodiorite [Shepard, 1963].

The area to the south of the Carmel Submarine Canyon axis is bounded by small pocket beaches, rocky cliffs and large offshore rocks, both submerged and exposed. Numerous ravines
traverse the nearshore shelf and intersect the edge of the canyon at a water depth of about 50 fm.

The coastline to the north of the canyon axis is also very rocky, with large offshore rocks and small pocket beaches. The bottom has a much gentler slope than the area to the south, and, as in the south, reaches a depth of approximately 50 fm before rapidly dropping off into the canyon. The eastern side of the Bay is bounded by three sandy beaches: San Jose Beach (sometimes called Monastery Beach), Carmel River Beach, and Carmel Beach (Fig. 2), each separated from the next by a rugged outcrop of granodiorite (plus some Miocene lava between Carmel River Beach and Carmel Beach). The head of the canyon is located about 200 m offshore from San Jose Beach (Monastery Beach) with the rim of the canyon occurring at depths of 7 fm to 10 fm [Wallin, 1968, p. 17]. One major branch of the canyon incises the northern shelf of the Bay.

D. GENERAL OCEANOGRAPHY

References in recent literature concerning the physical oceanographic properties of Carmel Bay are noticeably lacking. Records of measurements of the currents and thermal structure of the Bay are virtually nonexistent.

The tides in the Bay are of the mixed type characteristic of the Pacific Coast of the United States [Sverdrup, Johnson, and Fleming, 1942]. The diurnal difference between mean lower low water and mean higher high water is 5.2 feet [U.S. Coast and Geodetic Survey, 1971].
II. SAMPLE COLLECTION

Samples were collected by ship, using a Shipek grab sampler and a 2.75-inch outside diameter, 700-lb total weight gravity corer. Fifty-two grab samples and one gravity core (Station C-1) were collected during the period from April to June 1971 (Fig. 3). Stations were located by measuring the horizontal angles between known landmarks around the Bay utilizing a sextant. Sample depth was obtained by fathometer, or by wire depth when electronic soundings were not available.

It was not possible to occupy some stations in the vicinity of Carmel Beach and Pescadero Point due to heavy concentrations of kelp (*Macrocystis pyrifera*) in these areas. Several sample collections were attempted in the kelp-free areas off of Pescadero Point, but only a few rock dwelling tunicates and gastropods were collected, suggesting a rocky bottom.

Grab samples were placed in double plastic bags and refrigerated until processed. The gravity core in its plastic liner was capped and sealed and stored in a cool, dark location in an upright position until cut and processed.
Figure 3. Carmel Bay Sediment Sample Locations.
III. SAMPLE ANALYSIS

A. MECHANICAL ANALYSIS PROCEDURE

Grain-size analyses were conducted in accordance with the procedures outlined in Krumbein and Pettijohn [1938]. Grab samples were split to obtain a representative subsample of about 60 g. Three of the grab samples (Samples 10, 26, and 47) contained a large number of large pebbles, making splitting of the sample difficult. Therefore, each of these samples was analyzed in its entirety. The core was split lengthwise into two equal halves and four subsamples were taken.

All subsamples were washed in distilled water to desalt. Each subsample was then allowed to settle and the excess water decanted off. The subsample was then wet sieved through a 4.0Ø screen to separate the sand- and gravel-size fractions from the silt- and clay-size fractions. The fine fraction (>4.0Ø) was collected in a 1000-ml sedimentation cylinder and the coarse fraction was dried.

The dried coarse fraction was then size graded with screens according to the Wentworth scale using phi notation [Folk, 1968]. This was accomplished by sieving at a 0.5Ø interval through 3-inch diameter sieves shaken on a Ro-tap automatic shaking machine for 10-min. The three large samples (Samples 10, 26, and 47) were sieved through 8-inch screens. The fraction retained on each sieve was weighed to the nearest
0.1 mg and the 3.0Ø, 3.5Ø, and 4.0Ø fractions were placed in vials for later microscopic analysis.

The fraction finer than 4.0Ø (pan fraction) obtained during dry sieving was next added to the 1000-ml cylinder containing the fine fraction obtained by wet sieving. A peptizing agent (Calgon) was then added and a pipette analysis was performed on each subsample with a 0.5Ø interval. Wadell's correction of Stoke's law was used to determine the settling velocities of the different sized particles. Each 20-ml pipette aliquot was dried and weighed to the nearest 0.1 mg, taking into account the weight of the dried peptizer in the sample.

Those silt-clay samples which obviously contained less than 5% of the total sample weight were not analyzed using the pipette method, but were instead transferred to a 50-ml beaker, dried, and weighed directly to check this assumption.

B. COMPUTER ANALYSIS OF RAW DATA

Statistical parameters for describing the size distribution in each sample were calculated on an IBM 360 Computer. A size analysis computer program prepared by W. R. Anikouchine [Dinger, 1970, p. 31] was slightly modified to provide a printed output of phi sizes at the 5th, 16th, 25th, 50th, 75th, 84th, and 95th percentile levels, gravel-sand-silt-clay relationships, plus Trask values, Inman values, and Folk and Ward values [Collias, et al., 1963], using both linear and four point interpolation methods. A copy of the computer program
and a sample of the computer output is listed at the end of this thesis. Computer data card formats are listed in Appendix A.
IV. PRESENTATION OF DATA

A. TEXTURE OF SEDIMENTS

The tabulated results of the computer size analysis are presented for the gravel, sand, silt, and clay percentages and the linear interpolation of the Folk and Ward statistics (Table I). While the term "gravel" does not appear in Wentworth size classifications, it is commonly used to represent the combination of granules and pebbles; i.e., particles coarser than -1.0Ø and finer than -6.0Ø [Folk, 1968].

1. Mean Grain-Size

The mean grain-size of the sediments of Carmel Bay covered a wide range of values from -3.34Ø (Sample 47) to 4.71Ø (Sample 59).

Sand-silt-clay-gravel relationships were plotted on a sand-silt-gravel diagram similar to that devised by Shepard [Collias, et al., 1963, p. 33]. The sand-silt-gravel diagram (Fig. 4) is one face of a tetrahedron used by Krumbein and Sloss [1963, p. 158] to plot sand-silt-clay-gravel relationships. All of the Carmel Bay samples contained less than 20% clay, thus allowing the samples to be plotted on the sand-silt-gravel face of the tetrahedron. The samples ranged in texture from gravel (Sample 47) to sandy-silt (Samples 35, 42, 53, 56, 57, 59, and 61) (Fig. 4), with 28 of the 56 samples containing more than 75% sand. The mean grain size was generally larger near shore and decreased out toward and into the submarine...
### TABLE I

**CARMEL BAY SAMPLE LOCATIONS, SAND-SILT-CLAY RELATIONSHIPS, AND SIZE STATISTICS**

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Latitude N</th>
<th>Longitude W</th>
<th>Depth (fm)</th>
<th>Gravel %</th>
<th>Sand %</th>
<th>Silt %</th>
<th>Clay %</th>
<th>Class</th>
<th>Mean</th>
<th>Dev.</th>
<th>Skew</th>
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</thead>
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<tr>
<td>1</td>
<td>36°33.50'</td>
<td>121°58.18'</td>
<td>17</td>
<td>20.35</td>
<td>79.21</td>
<td>0.45</td>
<td>0.0</td>
<td>1</td>
<td>0.11</td>
<td>1.49</td>
<td>-0.34</td>
</tr>
<tr>
<td>2</td>
<td>36°33.55</td>
<td>121°57.88</td>
<td>13</td>
<td>34.88</td>
<td>64.79</td>
<td>0.33</td>
<td>0.0</td>
<td>5</td>
<td>-0.70</td>
<td>0.88</td>
<td>-0.03</td>
</tr>
<tr>
<td>3</td>
<td>36°33.27</td>
<td>121°57.57</td>
<td>28</td>
<td>25.14</td>
<td>74.72</td>
<td>0.14</td>
<td>0.0</td>
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<td>-0.61</td>
<td>0.62</td>
<td>-0.01</td>
</tr>
<tr>
<td>4</td>
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<td>121°57.38</td>
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<td>16.74</td>
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<td>0.40</td>
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<td>0.31</td>
<td>1.34</td>
<td>-0.20</td>
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<td>1.11</td>
<td>0.78</td>
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---

1 Krumbein and Sloss, 1963 (See Fig. 4 for class meaning).

2 Phi notation, Folk 1968.
<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Latitude N</th>
<th>Longitude W</th>
<th>Depth (ftm)</th>
<th>Gravel %</th>
<th>Sand %</th>
<th>Silt %</th>
<th>Clay %</th>
<th>Class</th>
<th>FOLK and WARD VALUES</th>
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<th>Dev.</th>
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<td>99.70</td>
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<td>Longitude W</td>
<td>Depth (fm)</td>
<td>Gravel %</td>
<td>Sand %</td>
<td>Silt %</td>
<td>Clay %</td>
<td>Class</td>
<td>Mean</td>
<td>Dev.</td>
<td>Skew.</td>
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<td>45.97</td>
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<td>4.52</td>
<td>2</td>
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</tr>
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</table>

Core Sample:

|        | | | | | | | | | | | |
|--------|---|---|---|---|---|---|---|---|---|---|
|        |   |   |   |   |   |   |   |   |   |   |
| C1A    | 36°32.02 | 121°56.79 | 177 | 0.28 | 54.89 | 39.29 | 5.55 | 2 | 3.96 | 1.59 | 0.26 |
| C1B    | 36°32.02 | 121°56.79 | 177 | 0.88 | 98.22 | 0.90  | 0.0  | 1 | 0.93 | 0.95 | -0.01 |
| C1C    | 36°32.02 | 121°56.79 | 177 | 13.14| 86.59 | 0.27  | 0.0  | 1 | 0.04 | 0.95 | 0.09 |
| C1D    | 36°32.02 | 121°56.79 | 177 | 25.00| 74.78 | 0.22  | 0.0  | 5 | -0.16| 1.33 | -0.01 |

**Depth from Top of Core (mm):**

|        | | | | | | | | | | | |
|--------|---|---|---|---|---|---|---|---|---|---|
|        |   |   |   |   |   |   |   |   |   |   |
|        |   |   |   |   |   |   |   |   |   |   |
|        |   |   |   |   |   |   |   |   |   |   |
|        |   |   |   |   |   |   |   |   |   |   |

(Bottom)
Figure 4. Tertiary Diagram: Sand-Silt-Gravel Relationships. (After Krumbein and Sloss, 1963, p. 158)
An offshore area of coarser material was also located in the northeastern portion of the Bay between Fox and Jeffers bench marks (Fig. 3). Core C-1 showed a marked increase in mean grain-size with depth.

2. Standard Deviation

Standard deviation values ranged from a value of 0.430 for Sample 47B to 3.340 for Sample 26. Sample 47B was the only sample collected within the Bay that was well sorted. Nine samples were classified as very poorly sorted with the remainder of the samples being approximately evenly divided between moderately sorted and poorly sorted.

Folk and Ward's [1957] statistical analysis of the sediments of a river bar in Texas revealed that a plot of mean grain-size vs. standard deviation for their group of samples showed a definite trend line of sinusoidal nature. Comparison of the Carmel Bay plot of mean grain-size vs. standard deviation (Fig. 5) with the results obtained by Folk and Ward (dashed line on plot) shows a marked similarity between the two, suggesting the sediments of the Bay are under the influence of some form of dynamic transport. Some anomalies do exist however. These anomalies may possibly be explained by the fact that all of the anomalous samples (Samples 2, 3, 18, 32, 33, 41, 43, 47, 54B, 57, and 63) except one (Sample 26) are composed primarily of shell fragments and other calcareous marine organism remains, and are located in water less than 50 fm deep. Differences in density and grain shape of these samples compared to those of mineral strains could well cause a different type of sorting behavior.
Figure 5. Standard Deviation as a Function of Mean Grain Size.
3. **Skewness**

Skewness values ranged from +0.74 (Sample 26) to -0.72 (Sample 28). The samples were approximately evenly divided between positively and negatively skewed (Fig. 6), and tended to follow the trend obtained by Folk and Ward (dashed line on plot) in their river bar study. The departures of the skewness values for Carmel Bay samples from those of Folk and Ward may be explained by recognizing the difference between river and continental shelf depositional environments and sources.

B. **SHELL CONTENT**

Visual inspection was made of the 0.00 and larger fractions of each sample and an estimate made of the percentage of shells, shell fragments, worm tubes, bryozoan colonies, corals, and echinoderm spines contained in each sample (Table II). All of these constituents were grouped under the heading of "shells." These estimates revealed approximately 20% of the samples contained 100% "shells" in their 0.00 and coarser fractions, 25% of the samples contained 50% to 99% "shells," 30% contained 1% to 49% "shells," and the remaining 25% of the samples contained no visible amount of "shells."

Considerable amounts of small particles of vegetable matter (probably kelp) were noted in eight of the samples (Samples 5, 13, 17, 58, 59, 61, 62, and C-1A). Of additional interest was the fact that Sample 14 contained nine living sand dollars (*Dendraster excentricus*) when brought aboard ship. No other benthic organisms or their remains were noted within this sample.
Figure 6. Skewness as a Function of Mean Grain Size.

Curve from Folk and Ward (1957)
### TABLE II

**ESTIMATES OF SAMPLE SHELL CONTENT**

Visual observation of the 0.00 and larger fraction of each sample yielded the following estimates of shells, shell fragments, worm tubes, bryozoan colonies, corals, and echinoderm spines.

<table>
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<th>Sample</th>
<th>Shells</th>
<th>Remarks</th>
<th>Sample</th>
<th>Shells</th>
<th>Remarks</th>
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</tr>
<tr>
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<td>90</td>
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<td>47</td>
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<td>50</td>
<td></td>
<td>54B</td>
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<td>C1D</td>
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C. PEBBLE COMPOSITION

Within the gravel fraction were rock fragments derived from the local shorelines. Samples 4, 26, and 47 contained lava pebbles, probably derived from the lava flows on Arrowhead Point. Granodiorite pebbles were found in Samples 1, 4, 15, 26, 28, and 41, while pebbles of Monterey shale were found in Sample 10. Sample 26 contained some andesite porphyry pebbles probably derived from the Carmelo. The accumulation of these gravels could represent beach sedimentation during the Pleistocene lowering of sea level as shown by Martin [1964, p. 135].
V. DISCUSSION AND INTERPRETATION

A. SEDIMENT DISTRIBUTION PATTERN

The sediment distribution pattern within Carmel Bay can be broken into two separate environments. The sediments around the periphery of the Bay range from gravel to fine sand, while the sediments found within the Carmel Submarine Canyon are almost exclusively very fine sand and coarse silt (Fig. 7). The only exception to this is the deposit of fine sand found within the canyon near its head.

The rocky areas to the north and south of the Bay contain considerable numbers of benthic organisms and the shells and tests of these organisms constitute a significant part of the coarse grained, poorly sorted sediments in these areas. Figure 8 shows the distribution of standard deviation of the sediments and Figure 9 describes the sediment shell distribution. Offshore transport of these shells and tests toward the canyon by currents and wave action has broken their constituent members into smaller and smaller pieces, resulting in a corresponding reduction in mean grain-size with distance from shore.

As might be expected, the area off of the mouth of the Carmel River also displays a concentration of coarse grained, very poorly sorted sediments, composed primarily of terrigenous material.
Figure 7. Sediment Mean Grain-Size Distribution.
Figure 8. Sediment Standard Deviation Distribution.
Figure 9. Sediment Shell Content.
Two anomalous areas appear to exist within the Bay. In the middle of the Bay is a pocket of very poorly sorted coarse sand centered around Sample 33, and in the northeast area, between Fox and Jeffers bench marks, is a deposit of very poorly sorted gravel encompassing Samples 26, 28, and 47.

A mixed pattern of fine and very fine sand exhibiting moderate to poor sorting is found near the head of the submarine canyon. A detailed description of the sediments in the head of the canyon was made by Wallin [1968]. The sediments of the canyon itself consist of poorly sorted very fine sand and coarse silt. The eight samples previously mentioned which contained considerable amounts of vegetable matter were all located at or near the axis of the canyon.

B. SEDIMENT SOURCES AND SINKS

Carmel Bay represents essentially a closed sedimentary system. The physical nature of Point Lobos, to the south, and Cypress Point, about 1 km to the north of Pescadero Point, is such that littoral transport of sediments into the Bay is negligible.

The Carmel River is undoubtedly the largest supplier of terrigeneous sediments for the Bay. The river is dormant during the summer and fall, thus contributing nothing to the sedimentary system, but during periods of heavy runoff large amounts of sedimentary debris are carried into the Bay. San Jose Creek is very small and its only contribution to the sediments of the Bay occurs during periods of maximum runoff.
The rocky areas to the north and south of the Bay, as well as the rocky outcrops on the eastern edge provide sediments to the Bay in two different forms. Analysis of the shell distribution of the Bay (Fig. 9) reveals the large part that is played in the composition of the Bay sediments by the shells and tests of the organisms living on and around these rocky areas. The weathering and decomposition of these rocky shorelines and outcrops must also make a substantial contribution to the sedimentary processes of the Bay.

Analysis of statistical wave data and wave refraction diagrams for Carmel Bay by Wallin [1968] showed that 90% of all deep water wave energy in the area emanated from the sector between west and north-northwest. This analysis also revealed that littoral transport would be southward from Carmel River Beach toward the canyon head, and eastward along Point Lobos toward the canyon head. This would require the only loss of sediments from the Bay to be via the submarine canyon itself.

Evidence of sediment loss via the canyon is presented by both Moritz [1968] and Wallin [1968]. They report the observation of several sandfalls on the north wall of the canyon head over a period of about 10 years. These sandfalls apparently run intermittently depending upon the sea conditions and the slope of the bottom. The sandfalls are reported to be largely dormant during the summer and fall, with activity increasing coincident with the flow of the Carmel River through the berm.

Shepard and Emery [1941, p. 100-102], in their studies of the head of the Carmel Submarine Canyon, noted a net fill of
some 18 feet along the floor of the canyon in the inner section during the period 1934-1939. They concluded that this filling was so rapid that the canyon head would be filled within the next few years unless there was a large slide on the bottom. Shepard and Emery also noted that the old Carmel Bay survey of 1883 indicated shallower soundings than they obtained, suggesting a slide or slump had taken place during the intervening period. Moritz and Wallen observed a slump scar on the southeastern rim of the canyon while diving in this area, indicating slumping to be another mechanism by which sediment is transported to deeper water.
SUMMARY AND CONCLUSIONS

Carmel Bay is a distinctive feature of the California coastline by virtue of its role as a sedimentary system primarily isolated from adjacent coastal sediment sources, and as the origin of the Carmel Submarine Canyon.

The recent marine sediments of the Bay consist primarily of moderate to poorly sorted sand and coarse silt deposits. One small area of very poorly sorted gravel is located in the northeastern sector of the Bay. Comparison of plots of mean grain-size vs. standard deviation and mean grain-size vs. skewness with similar plots obtained by Folk and Ward suggest that the sediments of the Bay are under the influence of some form of dynamic transport.

Fresh sedimentary materials are supplied to the Bay from several sources. The Carmel River is undoubtedly the prime supplier of terrigeneous sedimentary materials to the Bay, followed by erosion and weathering of the shoreline and offshore rocks, and terrigeneous materials supplied by San Jose Creek. The shells and tests of marine organisms also form a significant part of the sediments of the Bay. Considerable amounts of fine vegetable matter were also observed in several of the samples taken at or near the axis of the canyon.

The physical nature of the coastline immediately to the north and south of Carmel Bay effectively prohibits any littoral transport of sediments into the Bay, and wave
refraction studies have shown that the sediments within the Bay tend to be transported by littoral drift to the head of the Carmel Submarine Canyon. Transportation into deeper water via the submarine canyon appears to be the only active mechanism for removal of sediments from the Bay.
SUGGESTIONS FOR FURTHER STUDY

Until quite recently little marine geological research had been carried out within Carmel Bay. At present, Naval Postgraduate School (NPS) and San Jose State College, San Jose, California, studies are being conducted within the Bay concerning:

1. the marine geology of Carmel Bay (J. P. Simpson, NPS, in progress);
2. methods of sediment transport between the mouth of the Carmel River and the head of the Carmel Submarine Canyon (B. F. Howell, NPS, in progress);
3. sediment transport within Whalers Cove (L. Leopold, San Jose State College, in progress).

Further studies that would be useful in defining the marine environment of the Bay would include:

1. heavy mineral analysis of the sediments;
2. carbon, carbonate, and organic nitrogen analysis of the sediments;
3. current and water column structure determinations within the Bay.
APPENDIX A

Computer Data Card Formats

For each sample:

Card 1: title card

Col 1-80 contain alphanumeric information to appear at the top of the output.

Card 2: identifier for sample

Col 1-9 cruise number
10-12 sample number
13-18 sample type
19-20 extra i.d. number
21-22 month
23-24 day
25-28 year
29-34 latitude (XX XX.XX) punch only X's
35-40 longitude (XX XX.XX)
57-61 depth from top of core (XXXXX.)
62-66 length of core (XXXXX.)
79 octant (see below)

Card 3: sample detail cards

Col 41-44 phi size (absolute value) F4.2 (decimal assumed)
45 sign of phi size (+ or -)
50-56 fraction weight F7.4 (decimal assumed)
80 end of data flag
=8 if last phi size for this sample
=9 if last phi size for all samples

Coding for Octant of Geographic Position

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<th>Longitude East</th>
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<tr>
<td>0°</td>
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41
**SAMPLE OF COMPUTER OUTPUT**

RECENT MARINE SEDIMENTS OF CARMEL BAY, CALIFORNIA - LT. L.S. CARTER

CRUISE 71-HRV-02 SAMPLE NUMBER 012 EX ID 00

SAMPLE TYPE: GRAB  DATE: 04/23/1971  LAT: 36°31.70N  LONG: 121°55.65W

DEPTH FROM TOP OF CORE: 0.00 MM. LENGTH OF CORE: 0.00 MM.

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<th>SAMPLE</th>
<th>FRACTION</th>
<th>ACCUMULATED</th>
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<tr>
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<td>0.01</td>
<td>0.01</td>
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<td>0.02</td>
<td>0.02</td>
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<td>0.02</td>
<td>0.04</td>
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<td>0.02</td>
<td>0.06</td>
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POST-ANALYTICAL WEIGHT IS: 62,9919

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<td>0.133</td>
<td>0.093</td>
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<td>DEV.</td>
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<td>2ND SKEW.</td>
<td>KURT.</td>
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<td>0.134</td>
<td>0.093</td>
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<td>INMAN VALUES</td>
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<td>MEAN</td>
<td>DEV.</td>
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42
SEDIMENT SIZE ANALYSIS MAIN PROGRAM

COMMON /BLK1/PHIS(8,2),NIM,NFAW,NSSC,SUMNL,NTRSK
REAL NEG/-1.
DATA ANORTH/IN',/SOUTH/IS',/EAST/IE',/WEST/IW'/
DIMENSION FRWT(100),PRCT(100),CRCM(20),STMC(20),EXMC(20),CRMB(20),
1 STM8(20),EXMB(20),TITLE(20),JCR(20),JCR(20),
REAL CRUZ,CRZR,CRMB,CRCM,SMPLR
DIMENSION T(100),PHI(100),ACPC(100)
DATA KKK/0/,MAT/0/,MBT/0/,MED/0/,KSM/0/
NINOT=1

902 N2=1
NA=1
N2=1
NL=1
NB=1
M=0
PAWT=0.
DO 903 K=1,100
T(K)=4.09
ACPC(K)=999.99
FRWT(K)=0.0
903 PHI(K)=99.99
MA=0
MB=0
MBT=0
MC=0
MED=0
SUMWT=0.0
SUMPC=0.0
ACPC(1)=0.0
READ(5,20) TITLE
20 FORMAT(20A4)
1 NK=1
2 READ(5,26) CRUZ,MCR,STATR,SMPLR,EXID,MO,DA,YR,LATA,DEGLT,LNGA,
1 DEGLN,PHIR,SIGN,BFRT,DEPTHR,CRLN,IOUD,NE
26 FORMAT(A7,A2,A3,A6,3A2,A4,I2,F4.2,I2,2F4.2,A1,4X,F7.4,2F5.0,12X,
1211)
TIMES=1.
IF(SIGN.EQ.NEG) TIMES=-1.
PHIR=(TIMES*PHIR)
3 IF(PHIR.LT.3.9) GO TO 29
IF(NZ.EQ.1) GO TO 48
IF(PHIR.LE.4.1) GO TO 46
NZ=2
GO TO 29
46 NZ=1
GO TO 44
48 IF(NL.EQ.2) GO TO 44
NL=2
NZ=2
29 FRWTR=BFWT
IF((FRWTR.GE.0.)) GO TO 52
IF((FRWTR+.01).GE.0.)) GO TO 25
WRITE(6,51) FRWTR
25 FRWTR=0.0
52 PAWT=PAWT+FRWTR
SUMWT=PAWT
GO TO 49
44 IF(NK.EQ.2) GO TO 59
NK=2
FWT1=BFWT*50.
GO TO 2
59 FWT2=BFWT*50.
FRWTR=FWT1-FWT2
IF((FRWTR.GE.0.)) GO TO 53
IF((FRWTR+.01).GE.0.)) GO TO 55
60 WRITE(6,51) FRWTR
51 FORMAT(25X,'WEIGHING ERROR. FRACTION WEIGHT WAS ',F10.4,' BEFORE BEING SET TO ZERO')
55 FRWTR=0.0
53 FWT1=FWT2
56 NINT=2
IF(NL.LT.8) GO TO 52
54 PAWT=PAWT+FRWTR+FWT2
SUMWT=PAWT
K=K+1
M=M+1
KK=KK+1
PHI(K)=PHIR
FWT(K)=FRWTR
K=K+1
M=M+1
KK=KK+1
FRWTR(K)=FWT2
PHI(K)=12.
IF(PHI.LE.11.) PHI(K)=PHI+1.
GO TO 100
49 IF(NA.EQ.2) GO TO 50
NA=2
C DETERMINE OCTANT FROM FIRST CARD OF SAMPLE
DK=WEST
44
IDH=LNGA,
  IF (IQUD=2) 8,9,11
  IDH=IDH+100
  9 DG=ANTHRH
  GO TO 23
  11 IF (IQUD=4) 12,13,15
  12 IDH=IDH+100
  13 DG=ANTHRH
  GO TO 23
  15 DK=EAST
  IF (IQUD=6) 17,16,19
  17 IDH=IDH+100
  16 DG=ANTHRH
  GO TO 23
  19 IF (IQUD.GE.8) IDH=IDH+100
  DG=ANTHRH
  GO TO 23
  23 CRUZ=CUZ
  NCR=MCR
  STAT=STATR
  EXC=EXID
  DPTH=DEPTHR
  WRITE (6,800) TITLE
  800 FORMAT ('1',26X,20A4)
  WRITE (6,801) CRUZ,NCR,STAT,EXC,SMPLR,MO,DA,YR,LATA,DEGLT,DG,
  IDH,DECLN,DK,DEPTHR,CRLN
  801 FORMAT ('39X,'CRUISE ','A7,A2,' SAMPLE NUMBER ','A3,' EX ID ','A2/25X,
  1,' SAMPLER TYPE ','A6,' DATE ','A2,'/','A2,'/','A4,' LAT ','I2,'-';
  2F5.2,A1,' LONG ','I3,-',F5.2,A1/26X,'DEPTH FROM TOP OF CORE ',
  3F7.0,' MM. LENGTH OF CORE ','F7.0,' MM.')
  NB=2
  KK=0
  K=0
  IF (FRWTR.NE.0.) N2=3
  PHI=12.0
  GO TO 1
  C SAVE PHI & FRACTION WT. FROM EACH DETAIL CARD
  50 KK=KK+1
  K=K+1
  PHI(K)=PHIR
  FRWTR(K)=FRWTR
  IF (NE.GE.8) GO TO 100
  C SET FLAG (N2=2) IF NEW PHI LESS THAN LAST PHI
  IF (PHIA.GE.PHIR) N2=2
  PHI=PHIR
  M=M+1
  IF (NINOT-1) 1,1,2
  100 M=K
  C DETERMINE FRACTION PERCENTS AND ACCUMULATED %
DO 67 K=1,M
PRCT(K)=(FRWT(K)/PAWT)*100.
SUMPC=SUMPC+PRCT(K)
ACPC(K)=SUMPC
67 CONTINUE
CALL TVAL(T,ACPC,M)
IF(SUMPC.GT.99.94.)GO TO 1500
IF(NZ-2)103,1666,1990
103 WRITE(6,802) (PHI(J),FRWT(J),PRCT(J),ACPC(J),J=1,KK)
802 FORMAT('0',40X,'PHI SAMPLE FRACTION ACCUMULATED'/41X,'SIZE
KJK=KK
WRITE(6,79) PAWT
79 FORMAT(1/40X,'POST-ANALYTICAL WEIGHT IS',F9.4)
SUMNL=ACPC(KK)
NSSC=2
NTRSK=1
NINM=1
NFAW=1
JJ=0
DO 77 I=1,KK
IF(FRWT(I).EQ.0.)GO TO 77
JJ=JJ+1
T(JJ)=T(I)
ACPC(JJ)=ACPC(I)
PHI(JJ)=PHI(I)
77 CONTINUE
KJ=JJ
KJK=JJ
IF(SUMNL.GE.72.0)GO TO 105
NSSC=1
WRITE(6,809) PHI(KK)
809 FORMAT('0',29X,'DID NOT INTERPOLATE ANY PHI SIZES BECAUSE'/29X,
 'ACCUMULATED PERCENT AT ',F5.2,' DID NOT EXCEED'/29X,'72 PERCENT')
GO TO 160
105 IF(4.LT.KK)GO TO 111
WRITE(6,815) KK
815 FORMAT('0',28X,'ONLY ',I3,' DETAIL CARDS SO ONLY SAND.'/30X,'SILT',
 'CLAY RELATIONSHIPS CALCULATED.')
GO TO 901
C COMPUTE I-VALUES
111 CALL INTRP(ACPC,PHI,T,KK)
160 CALL STNCTL(PHI,ACPC,SUMPC,KJK)
CALL STIFW
C INCREMENT COUNTERS AND GO TO NEXT SAMPLE
901 KKK=KKK+KK+1
KSM=KSM+1
I=I+1
**C**

```
590  PRINT  RESULTS  AND  MESSAGES
595  WRITE(6,860)  KSM,KKK
600  FORMAT('I',30X,'THIS  BATCH  OF  CARDS  CONTAINED  DATA  FROM  ',I4,'  SAME
601  1PLES','/30X,'FOR  A  TOTAL  OF  ',I4,'  CARDS.')
602  IF(MBT.GT.0)  WRITE(6,863)  (CRMB(L),ICR(L),STMB(L),EXMB(L),L=1,MBT)
603  FORMAT('0',29X,'CARDS  OUT  OF  ORDER  ON  THE  FOLLOWING  SAMPLES'/'31X,
604  1'Cruise',5X,'Sample',5X,'Exid'/'(33X,A7,A2,A3,A2))
605  IF(MC.GT.0)  WRITE(6,864)  (CRMC(L),JCR(L),STMC(L),EXMC(L),L=1,MC)
606  FORMAT('0',29X,'NO  ZERO  PERCENT  CARDS  ON  THE  FOLLOWING  STATIONS'/'
607  1'.Cruise',5X,'Sample',5X,'Exid'/'(33X,A7,A2,A3,A2))
608  MT=MBT+MC+MED
609  IF(MT.GT.0)  GO  TO  959
610  WRITE(6,861)
611  FORMAT('0',30X,'CONGRATULATIONS  NO  ERRORS  WERE  FOUND  IN  THIS  BATCH
612  1'OF  CARDS.')
613  GO  TO  960
614  959  WRITE(6,865)  MT
615  865  FORMAT('0',29X,'SORRY  OLD  CHAP,  BUT  YOU  MADE ',I4,'  ERRORS  ON  THE
616  1'DATA'/30X,'FOR  THIS  RUN.  NEXT  TIME  BE  MORE  CAREFUL')
617  960  RETURN
1666  WRITE(6,866)
1666  FORMAT('0',29X,'CARDS  OUT  OF  ORDER.  CHECK  VALUES  BELOW.')
1990  MNT=MBT+1
1990  CRMB(MBT)=CRUZ
1990  ICR(MBT)=NCR
1990  STMB(MBT)=STAT
1990  EXMB(MBT)=EXC
1990  GO  TO  1501
1990  WRITE(6,8990)
1990  FORMAT('0',28X,'NO  ZERO  PERCENT  CARD.'/'30X,'CHECK  VALUES  BELOW')
1990  MC=MC+1
1990  CRMC(MC)=CRUZ
1990  JCR(MC)=NCR
1990  STMC(MC)=STAT
1990  EXMC(MC)=EXC
1990  GO  TO  1501
1990  WRITE(6,8990)  PACT
830  FORMAT('0',32X,'SUM  OF  FRACTION  WEIGHTS  DID  NOT  EQUAL  POST  ANALYSIS
831  1'CAL  WEIGHT'/32X,'WHICH  WAS ',F8.3,'.  CHECK  THE  VALUES  BELOW  FOR  ES
833  2'ERRORS.')
1500  WRITE(6,830)
1500  FORMAT('0',40X,'PHI  FRACTION  FRACTION  ACCUM.  T=/41X,'SIZE
1501  1'WEIGHT  PERCENT  PRCT  VALUE')
1501  WRITE(6,831)  (PHI(J),FRWT(J),PRCT(J),ACPC(J),T(J),J=1,KK)
833  WRITE(6,833)
```
SUBROUTINE INTRP(ACPC, PHI, T, KK)
DIMENSION ACPC(1), PHI(1), T(1)
COMMON /BLK1/PHIS(8,2), NINT, NFAW, NSSC, SUMNL, NTRSK
REAL PC(8)/1.75, 16., 25., 50., 75., 84., 95./, XTT(8)/-2.325,
1.645, -.995, -.674, 0.0, .674, .995, 1.645/
PHIS(6,1) = 99.99
PHIS(6,2) = 99.99
PHIS(7,1) = 99.99
PHIS(7,2) = 99.99
PHIS(8,1) = 99.99
PHIS(8,2) = 99.99
NINT = 0
1101 IF(NINT.EQ.0) GO TO 1102
PHIS(NINT,1) = YYA
PHIS(NINT,2) = YYL
1102 NINT = NINT + 1
XPC = PC(NINT)
XT = XTT(NINT)
DO 151 L = 1, KK
IF((ACPC(L) - XPC) .LT. 151, 152, 153
151 CONTINUE
152 YYA = PHI(L)
YYL = PHI(L)
GO TO 210
153 IF(XPC .GT. 75.0) 154, 155, 157
155 IF(SUMNL .GE. 75.0) GO TO 156
NINT = 9
GO TO 1197
157 IF(XPC .LT. 84.0) GO TO 159
IF(SUMNL .LT. 84.) GO TO 168
156 IF(L - KK) 195, 197, 197
159 IF(SUMNL .LT. 95.0) 169, 156, 156
168 IF(SUMNL .LT. 81.0) GO TO 1475
NINT = 10
GO TO 1197
169 IF(SUMNL.LT.92.0) GO TO 1476
   NINT=11
1197 XT=XTT(NINT-3)
   GO TO 197
154 IF(L.LE.2) GO TO 196
195 LA=2
   GO TO 199
196 LA=1
   GO TO 199
197 LA=3
199 LS=L-LA
   X=XT
   X1=T(LS)
   X2=T(LS+1)
   X3=T(LS+2)
   X4=T(LS+3)
   Y1=PHI(LS)
   Y2=PHI(LS+1)
   Y3=PHI(LS+2)
   Y4=PHI(LS+3)
   C AIKENS FOUR POINT INTERPOLATION
   P121=(Y1*(X2-X1)-(Y2*(X1-X1)))/(X2-X1)
   P131=(Y1*(X3-X1)-(Y3*(X1-X1)))/(X3-X1)
   P123=(P121*(X3-X1)-(P131*(X2-X1)))/(X3-X2)
   P124=(P124*(X4-X3)-P144*(X2-X3))/(X4-X2)
   YYA=((P123*(X4-X3)-(P124*(X3-X3)))/(X4-X3)
   C LINEAR INTERPOLATION
   X11=T(L-1)
   X22=T(L)
   Y11=PHI(L-1)
   Y22=PHI(L)
   YYL=(X-X11)*(Y22-Y11)/(X22-X11)+Y11
   IF(L.LE.2) YYA=YYL
210 IF(NINT.LT.8) GO TO 1101
   INIT=NINT-7
   PHIS(NINT,1)=YYA
   PHIS(NINT,2)=YYL
   WRITE(6,803) ((PHIS(NINT,K),K=1,8),K=1,2)
803 FORMAT('0',29X,'PHI SIZES AT PERCENT LEVEL OF
   1/32X, 1 (C) 5 1617X, 257X, 50 (M) 7518417X, 7X,
   2/32X, 1 (C) 4 PT. 1/27X, 8F9.2, LINEAR"
RETURN
1275 NM3=NINT-3
   PHIS(NM3,1)=YYA
   PHIS(NM3,2)=YYL
   IPH=NM3
   IPER=PC(NM3)
IF(NINT.EQ.11) NFAW=2
1300 WRITE (6,1301) IPER,((PHIS(I1,K),II=1,8 ),K=1,2)
1301 FORMAT(’0’,29X,PHI SIZES AT PERCENT LEVEL OF ’12,
* LEVEL EXTRAPOL
IATED’) /32X,’1(C’),6X,’5’,7X,’16’,7X,’25’,7X,’150(M)’
275’,7X,’84’/30X,F5.2,F7F9.2,’ 4 PT.’/30X,F5.2,F7F9.2,’ LINEAR’)’
RETURN
1475 IPER=84
1476 NFAW=2
GO TO 1400
1400 WRITE (6,1401) IPER,((PHIS(I1,K),II=1,8 ),K=1,2)
1401 FORMAT(’0’,29X,PHI SIZES AT PERCENT LEVEL OF ’12,
* LEVEL NOT EXTRAP
IATED’) /32X,’1(C’),6X,’5’,7X,’16’,7X,’125’,7X,’150(M)’
275’,7X,’84’/30X,F5.2,F7F9.2,’ 4 PT.’/30X,F5.2,F7F9.2,’ LINEAR’)’
RETURN
END

SUBROUTINE TVAL(T,ACPC,M)
DIMENSION T(1),ACPC(1)
REAL TBLPC(87)/0.0,01.20,03.59,04.78,05.96,07.14,08.32,09.48,
1 10.65,11.79,12.93,14.06,15.17,16.28,17.36,18.44,19.50,20.54,
2 21.61,22.75,23.87,24.98,26.11,27.23,28.35,29.47,30.59,31.71,
3 32.84,33.97,35.09,36.21,37.33,38.45,39.57,40.69,41.81,42.93,
4 44.05,45.17,46.29,47.41,48.53,49.65,50.77,51.89,53.01,54.13,
5 55.25,56.37,57.49,58.61,59.73,60.85,61.97,63.09,64.21,65.33,
6 66.45,67.57,68.69,69.81,70.93,72.05,73.17,74.29,75.41,76.53,
7 77.65,78.77,79.89,81.01,82.13,83.25,84.37,85.49,86.61,87.73,
8 49.11,49.20,49.31,49.40,49.60,49.70,49.80,49.90,50.00/0
REAL TBLT(87)/0.00,0.03,0.06,0.09,0.12,0.15,0.18,0.21,0.24,0.27,0.30,
1 0.33,0.36,0.39,0.42,0.45,0.48,0.51,0.54,0.57,0.60,0.63,0.66,
2 0.69,0.72,0.75,0.78,0.81,0.84,0.87,0.90,0.93,0.96,0.99,1.02,
3 1.05,1.08,1.11,1.14,1.17,1.20,1.23,1.26,1.29,1.32,1.35,1.38,
4 1.41,1.44,1.47,1.50,1.53,1.56,1.59,1.62,1.65,1.68,1.71,1.74,
5 1.77,1.80,1.83,1.86,1.89,1.92,1.95,1.98,2.01,2.04,2.07,2.10,
6 2.13,2.16,2.19,2.22,2.25,2.28,2.31,2.34,2.37,2.41,2.44,2.51,
7 2.55,2.79,2.88,3.03,3.09,4.09/0
C
CALCULATE T-VALUE
DO 68 K=1,M
61 T(K)=4.09
GO TO 68
62 DLPC=ACPC(K)-50.
IF(DLPC) 64,63,65
63 T(K)=0.0
GO TO 68
64 GMPC=DLC
GO TO 66
65 GMPC=DLPC
66 DO 69 L=1,87
IF(TBLPC(L)-GMPC) 69,70,71
69 CONTINUE
70 TCA= TBL(L)
GO TO 72
71 TCA= (GMPC-TBLPC(L-1))*(TBL(L)-TBLPC(L-1))/(TBLPC(L)-TBLPC(L-1))
72 IF(TCA.GT.4.09) GO TO 61
74 IF(DLPC.GE.0.0) GO TO 74
74 T(K)=TCA
68 CONTINUE
RETURN
END

C
******************************************************************************************
C
SUBPROGRAM FOR COMPUTING SAND-SILT-CLAY RELATIONSHIPS

C
******************************************************************************************

SUBROUTINE SNSTCL PHI,ACPC,SUMPC,KJK
DIMENSION PHI(1),T(1),ACPC(1)
REAL*8 CLASS(1)/I/ SAND SILT CLAY SANDY SIY PILY CLAHEY
1 
INTEGER SUBS(33)/1,7,7,7,7,7,7,1,8,9,5,1,7,4,2,7,6,1,7,6,2,7,
1 5,7,5,5,5,5,5,5,5,
N1=0
RATIO=99.99
PSN=0.0
SAND=0.0
SILT=0.0
CLAY=0.0
SANDP=0.0
IF(PHI(KJK).LT.-1.0) GO TO 380
DO 302 KG=1,KJK
  IF(ABS(PHI(KG)+1.0).LE.0001) GO TO 303
  IF(PHI(KG)+1.0) 302,303,307
302 CONTINUE
303 GRSN=ACPC(KG)
307 IF(PHI(KJK).LT.4.0) GO TO 312
  DO 309 KS=1,KJK
  IF(ABS(PHI(KS)-4.0).LE.0001) GO TO 310
  IF(PHI(KS)-4.0) 309,310,313
309 CONTINUE
310 SAND=ACPC(KS)
  SANDP=SAND-GRSN
  FMUD=SUMPC-SAND
  IF(FMUD.NE.0.) RATIO=SAND/FMUD
  GO TO 313
312 SAND=SUMPC-GRSN
  SANDP=SAND
  GO TO 380
313 IF(ABS(PHI(KJK)-8.0).LE.0001) GO TO 314
  IF(PHI(KJK)-8.0) 313,314,317
314 DO 315 KSL=1,KJK
  IF(ABS(PHI(KSL)-8.0).LE.0001) GO TO 316
  IF(PHI(KSL)-8.0) 315,316,320
315 CONTINUE
316 SILT=ACPC(KSL)-SAND
  CLAY=SUMPC-SAND-SILT
  GO TO 320
317 SILT=SUMPC-SAND
320 NI=1
  IF(SAND.GE.75.0) GO TO 380
  NI=2
  IF(SILT.GE.75.0) GO TO 380
  NI=3
  IF(CLAY.GE.75.0) GO TO 380
  NI=4
  IF(SAND.GE.20.0.OR.SILT.GE.20.0.OR.CLAY.GE.20.0) GO TO 380
  N4=1
  IF(CLAY/SILT.LT.1.) N4=2
  IF(SAND/SILT.LT.1.) GO TO (341,334),N4
  GO TO (334,336),N4
334 IF(CLAY/SAND.LT.1.) GO TO (338,337),N4
  GO TO (340,339),N4
336 NI=5
  GO TO 380
337 NI=6
  GO TO 380
338 NI=7
  GO TO 380
SUBROUTINE CTFW
COMMON /BLK1/PHIS(8,2),NINM,NFAW,NSSC,SUMNL,NTRSK
REAL*8 ZMEN(20),'VERY COARSE SAND
LINE SAND 'VERY FINE SAND
2E SILT 'Very Fine Silt Clay
REAL*8 DEVI(18),'Very Well Sorted
10DERATELY SORTED 'Poorly Sorted
2 EXTREMELY POORLY SORTED
REAL*8 SKEW(15),'Very Negatively Skewed
1EARLY SYMETRICAL 'Positively Skewed
2WED 'Very Positively Skewed
REAL*8 KURT(15),'Playtkurtic
LEPTOKURTIK 'Very Leptokurtic
2IC '1
REAL TLFD(7)/0.0,0.35,0.50,1.0,2.4,99.99/,
1.3,9,999/,
REAL HEAD(6)/'4 PT. PHIS 'LINEAR PHIS' /
INTEGER ITLFSG(6)/2*1,2,3,4,5/
DO 1000 LL=1,2
IF(NSSC.EQ.1) GO TO 400
CALCULATE TRASK VALUES
PH15=PHIS(2,LL)
PH16=PHIS(3,LL)
PHI25=PHI5(4,LL)
PHI50=PHI5(5,LL)
PHI75=PHI5(6,LL)
PHI84=PHI5(7,LL)
PHI95=PHI5(8,LL)
Q1=2.**(PHI25)
Q2=2.**(PHI50)
Q3=2.**(PHI75)
SO=SORT(Q1/Q3)
FLGSO=ALOG10(SO)
SKG=SQRT((Q1*Q3)/(Q2*Q2))
LLL=3*(LL-1)+1
LTT=LLL+2
WRITE(6,805)(HEAD(LLK),LLK=LLL,LTT),Q1,Q2,Q3,SO,FLGSO,SKG
805 FORMAT('0.',28X,'TRASK VALUES',...,Q1,Q2 Q3
* 1 SO LOG SO SKG/30X,F6.3,4F9.3,F8.2)
C CALCULATE INMAN VALUES
IF(NINM,GT.1) GO TO 505
FTMD=(PHI16-PHI14)/2.0
FIDV=(PHI84-PHI16)/2.0
FISK=(FIMD-PHI50)/FIDV
IF(PHI95,EQ.99.99) GO TO 504
F2SK=(((PHI95+PHI5)/2.)-PHI50)/FIDV
FIKU=(((PHI95-PHI5)/2.)-FIDV)/FIDV
WRITE(6,806)PHI50,FIDM,FIDV,FISK,F2SK,FIKU
806 FORMAT('0.29X,'INMAN VALUES'/32X,'MEDIAN MEAN',5X,'DEV.'...5X,'32X,F5.2,3F9.2,2F11.2)
C 2ND SKEW. KURT. /32X,F5.2,3F9.2,2F11.2)
GO TO 600
504 WRITE(6,92)PHI50,FIDM,FIDV,FISK
92 FORMAT('0.',29X,'INMAN VALUES (COULD NOT CALCULATE 2ND SKEWNESS AS...F5.2,)
GO TO 600
505 WRITE(6,93)
93 FORMAT('0.',28X,'INMAN PLUS FOLK AND WARD VALUES NOT CALCULATED BECAUSE...F5.2)
GO TO 1000
400 WRITE(6,91)
91 FORMAT('0.',28X,'NOT ABLE TO CALCULATE TRASK, INMAN, OR FOLK AND WARD VALUES...F5.2)
GO TO 1000
C CALCULATE FOLK AND WARD VALUES
600 IF(NFAM,EQ.1) GO TO 601
WRITE(6,94)
94 FORMAT('0.',29X,'COULD NOT CALCULATE FOLK AND WARD VALUES BECAUSE NSIZE5370
10 EXT#30X,'TO LAST ACCUMULATED PERCENT DID NOT EXCEED 92.')

C COMPUTE MEAN AND DETERMINE CATEGORY

601 FMZ=(PHI16+PHI50+PHI84)/3.0
DO 300 I=1,10
ZVAL=I-1
IF(FMZ,LT,ZVAL) GO TO 301
300 CONTINUE
I=10
301 I=2*(I-1)+1
12=I+1
WRITE (6,807) FMZ,(ZMEN(I),I=I1,I2)
807 FORMAT('0',12X,'FOLK AND WARD VALUE'/31X,'MEAN',F12.2,4X,2A8)

C COMPUTE DEVIATION AND DETERMINE CATEGORY
FDEV=(PHI84-PHI16)/4.+(PHI95-PHI5)/6.6
DO 604 L=1,7
IF(TLFD(L).GE.FDEV) GO TO 605
604 CONTINUE
605 IFDTL=L-1
IF(IFDTL.EQ.0) IFDTL=1
I1=3*(IFDTL-1)+1
558I1+2
WRITE (6,131) FDEV,(DEVI(I),I=I1,I2)
131 FORMAT(31X,’DEVIATION’,F7.2,4X,3A8)

C COMPUTE SKEWNESS AND DETERMINE CATEGORY
FSK=(PHI16+PHI84-2.0*PHI50)/(2.*((PHI84-PHI16)))
1+((PHI5+PHI95)-(2.*PHI50))/(2.*(PHI95-PHI5))
DO 608 L=1,6
IF(TLFS(L).GE.FSK) GO TO 609
608 CONTINUE
609 IFSKTL=ITLSC(L)
I1=3*(IFSKTL-1)+1
12=I1+2
WRITE(6,142) FSK,(SKEW(L),I1=I1,I2)
142 FORMAT(31X,’SKEWNESS’,F8.2,4X,3A8)

C COMPUTE KURTOSIS AND DETERMINE CATEGORY
FKG=(PHI95-PHI5)/(2.44*(PHI75-PHI25))
DO 612 L=1,6
IF(TLFK(L).GE.FKG) GO TO 613
612 CONTINUE
613 IFKTL=L-1
IF(IFKTL.EQ.0) IFKTL=1
II=3*(IFKTL-1)+1
12=I1+2
WRITE(6,162) FKG,(KURT(L),I1=I1,I2)
162 FORMAT(31X,’KURTOSIS’,F8.2,4X,3A8)

1000 CONTINUE
RETURN
END
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Fifty-six sediment samples were collected within Carmel Bay for textural analysis to determine their statistical properties. The sediments found within the Carmel Submarine Canyon consist, for the most part, of poorly to very poorly sorted very fine sand and coarse silt. The shelf area surrounding the canyon is primarily comprised of moderately to very poorly sorted sand, with a small area of very poorly sorted gravel in the northeastern section of the Bay. Consideration of textural parameters such as mean size, standard deviation, and skewness suggest that the sediments of the Bay are under the influence of dynamic sediment transport mechanism. The Bay appears to be a sedimentary system primarily isolated from adjacent coastal sediment sources, with the major sources of sedimentary deposits being terrigeneous debris from the Carmel River, erosion and weathering of the local coastline and offshore rocks by wave and weather, and the shells and tests of numerous calcareous marine organisms. Movement of sediments by slumping and gravity sliding down the Carmel Submarine Canyon appears to be the only form of sediment removal within the Bay.
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