RECENT MARINE SEDIMENTS OF CARMEL BAY, CALIFORNIA

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THESIS

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of
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by

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December 1971

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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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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.

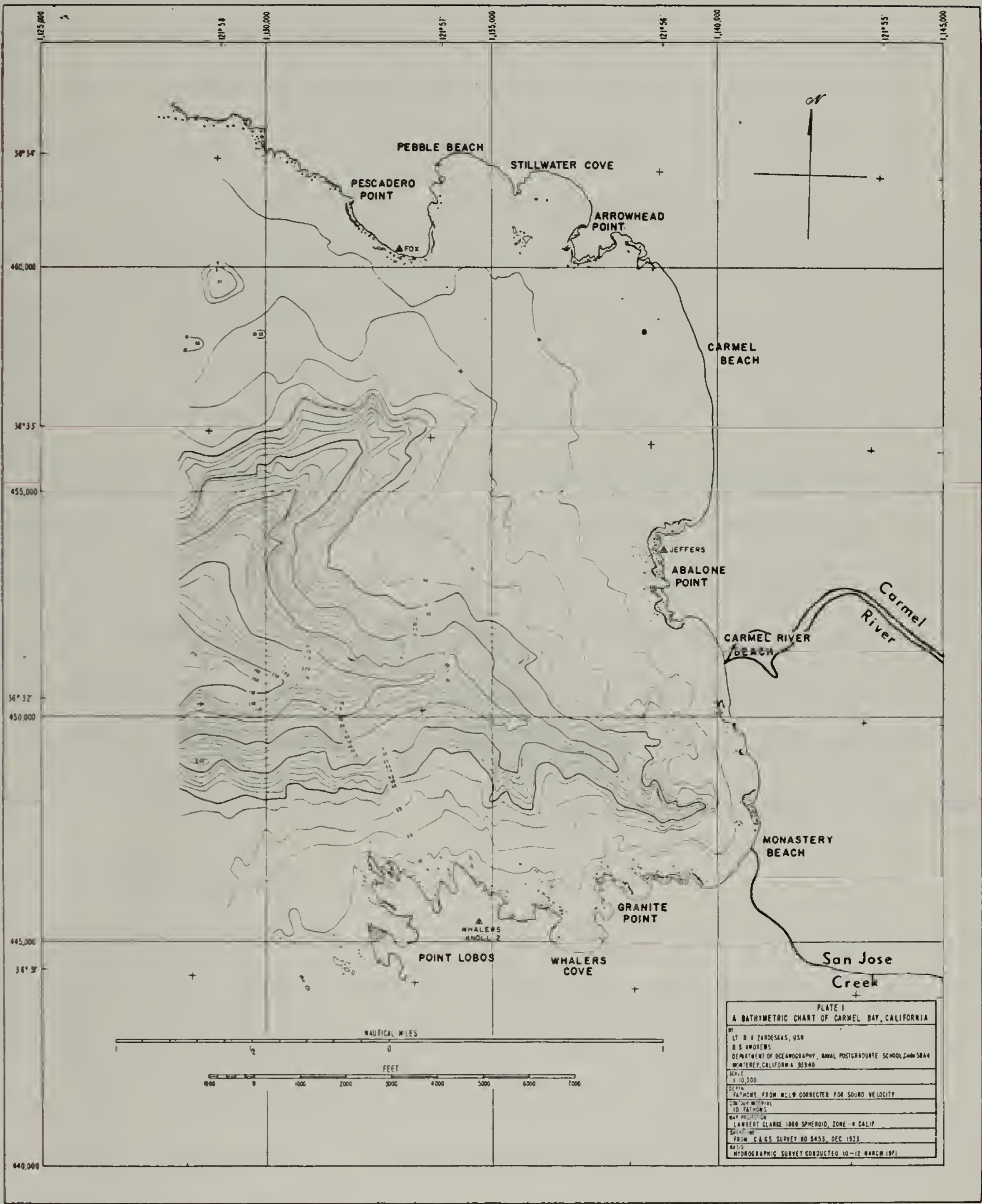


Figure 2. Carmel Bay Bathymetry. (After Zardeskas, 1971)

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 breeching 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 interlayed 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

[California State Department of Water Resources, 1969]. 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 pryifera) 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

				SAND-SILT-CLAY RELATIONSHIPS[1]					FOLK and WARD VALUES[2]		
Sample No.	Latitude N	Longitude W	Depth (fm)	Gravel %	Sand %	Silt %	Clay %	Class	Mean	Dev.	Skew.
1	36°-33.50'	121°-58.18'	17	20.35	79.21	0.45	0.0	1	0.11	1.49	-0.34
2	36-33.55	121-57.88	13	34.88	64.79	0.33	0.0	5	-0.70	0.88	-0.03
3	36-33.27	121-57.57	28	25.14	74.72	0.14	0.0	5	-0.61	0.62	-0.01
4	36-33.20	121-57.38	33	16.74	82.86	0.40	0.0	1	0.31	1.34	-0.20
5	36-32.98	121-57.08	52	0.76	74.65	24.59	0.0	2	3.45	1.40	0.17
6	36-32.81	121-56.80	26	0.22	99.45	0.33	0.0	1	2.32	0.55	-0.13
7	36-32.68	121-56.59	18	0.29	96.05	3.66	0.0	1	2.00	0.90	0.08
8	36-32.48	121-56.33	18	0.62	98.80	0.58	0.0	1	2.47	0.63	-0.25
9	36-32.36	121-56.17	16	0.61	98.92	0.47	0.0	1	2.42	0.63	-0.27
10	36-32.11	121-55.88	17	28.47	71.40	0.13	0.0	5	-0.70	2.06	-0.42
11	36-31.90	121-55.74	19	0.0	84.00	16.00	0.0	1	3.07	0.98	0.21
12	36-31.70	121-55.65	26	0.01	89.16	10.83	0.0	1	2.93	0.86	0.15
13	36-31.56	121-55.62	16	0.08	64.73	32.93	2.25	2	3.69	1.22	0.07
14	36-31.54	121-55.80	9	0.18	89.44	10.38	0.0	1	1.60	1.68	0.30
15	36-31.49	121-56.06	15	23.35	76.30	0.35	0.0	1	0.09	1.58	-0.14
16	36-31.58	121-56.31	22	6.78	92.08	1.14	0.0	1	1.45	1.43	-0.20
17	36-32.87	121-57.58	126	0.08	72.14	27.78	0.0	2	3.54	1.23	0.15
18	36-34.18	121-58.51	23	44.08	55.89	0.04	0.0	5	-0.99	0.95	-0.19
22	36-33.40	121-57.12	23	1.81	98.02	0.17	0.0	1	1.11	0.78	-0.16

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

[2] Phi notation, Folk 1968.

TABLE I (continued)

Sample No.	Latitude N	Longitude W	Depth (fm)	SAND-SILT-CLAY RELATIONSHIPS Gravel %	Sand %	Silt %	Clay %	Class	FOLK and WARD VALUES Mean	Dev.	Skew.
23	36°-33.47'	121°-56.91'	19	0.01	99.70	0.29	0.0	1	2.03	0.65	0.08
24	36-33.43	121-56.49	10	0.0	99.15	0.85	0.0	1	2.53	0.62	-0.08
25	36-33.32	121-56.19	6	0.01	98.23	1.75	0.0	1	2.47	0.66	0.07
26	36-33.09	121-56.54	12	70.69	28.60	0.71	0.0	8	-2.56	3.34	0.74
27	36-33.05	121-56.19	8	0.06	99.82	0.12	0.0	1	1.92	0.64	0.15
28	36-32.97	121-56.35	10	42.84	56.89	0.27	0.0	5	-1.02	2.31	-0.72
29	36-33.18	121-56.83	23	0.06	98.64	1.30	0.0	1	2.47	0.58	0.02
30	36-33.14	121-57.92	27	0.19	86.46	13.35	0.0	1	2.22	1.59	0.50
32	36-32.63	121-57.32	46	2.98	66.81	26.24	3.98	2	3.11	2.15	-0.00
33	36-32.42	121-56.96	52	19.89	66.81	13.30	0.0	5	1.07	2.49	0.23
34	36-32.12	121-56.27	25	1.48	84.62	10.60	3.30	1	3.10	1.40	-0.08
35	36-31.90	121-55.93	60	0.08	49.65	50.27	0.0	3	4.22	1.45	0.23
36	36-31.79	121-55.85	25	0.00	89.96	10.04	0.0	1	3.07	0.74	0.01
39	36-31.82	121-56.20	108	0.02	83.74	16.24	0.0	1	2.89	1.13	0.05
40	36-31.54	121-56.59	30	16.19	83.73	0.08	0.0	1	0.26	1.23	-0.34
41	36-31.58	121-56.87	20	55.53	44.40	0.07	0.0	8	-1.18	0.97	-0.14
42	36-32.22	121-56.69	128	0.21	46.28	50.43	3.08	3	4.08	1.39	-0.06
43	36-33.82	121-57.75	7	40.54	59.35	0.11	0.0	5	-0.76	0.90	0.05
44	36-34.11	121-58.21	16	2.90	96.43	0.67	0.0	1	1.61	0.54	-0.19
45	36-33.81	121-58.21	21	4.35	95.55	0.10	0.0	1	0.34	0.67	-0.20
47	36-33.59	121-56.73	12	84.04	14.21	1.75	0.0	10	-3.34	2.09	0.72
47B	36-33.59	121-56.74	12	0.16	99.69	0.15	0.0	1	1.34	0.43	-0.17
48	36-33.81	121-56.52	6	1.98	97.65	0.36	0.0	1	2.05	0.64	0.09
53	36-31.85	121-56.51	100	0.05	39.03	55.36	5.56	2	4.45	1.41	0.26
54B	36-31.67	121-56.86	34	32.92	50.92	16.16	0.0	5	0.72	2.96	0.37

TABLE I (continued)

Sample No.	Latitude N	Longitude W	Depth (fm)	SAND-SILT-CLAY RELATIONSHIPS Gravel %	Sand %	Silt %	Clay %	Class	FOLK and WARD VALUES Mean	Dev.	Skew.	Depth from Top of Core (mm)
56	36°-31.73'	121°-57.20'	76	0.17	39.47	54.05	6.31	2	4.63	1.77	0.21	
57	36-31.78	121-57.60	84	1.42	40.74	47.80	10.05	2	4.53	2.61	0.20	
58	36-32.64	121-57.82	170	0.04	51.97	43.77	4.22	2	3.97	1.30	0.18	
59	36-32.34	121-57.70	178	0.12	40.71	53.27	5.90	2	4.71	1.59	0.22	
60	36-32.22	121-57.11	184	0.09	61.06	38.85	0.0	2	3.71	1.40	0.22	
61	36-32.03	121-57.43	218	0.95	41.18	51.01	6.86	2	4.36	1.84	0.27	
62	36-32.02	121-57.92	250	0.00	48.73	45.97	5.30	2	4.07	1.47	0.21	
63	36-31.71	121-58.12	49	13.24	61.34	20.91	4.52	2	2.17	2.77	-0.17	
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	0
C1B	36-32.02	121-56.79	177	0.88	98.22	0.90	0.0	1	0.93	0.95	-0.01	175
C1C	36-32.02	121-56.79	177	13.14	86.59	0.27	0.0	1	0.04	0.95	0.09	1000
C1D	36-32.02	121-56.79	177	25.00	74.78	0.22	0.0	5	-0.16	1.33	-0.01	1860 (Bottom)

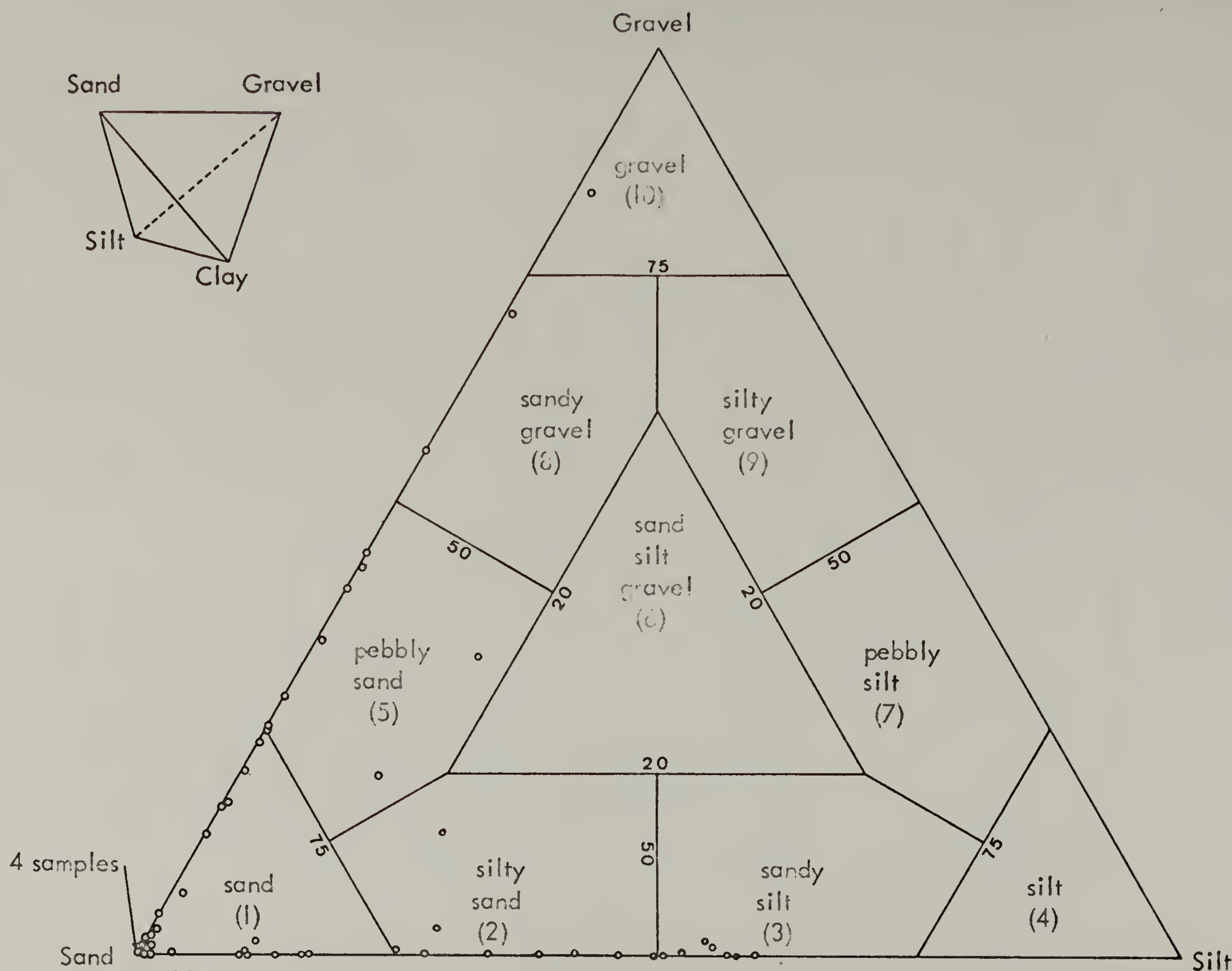


Figure 4. Tertiary Diagram: Sand-Silt-Gravel Relationships.
(After Krumbein and Sloss, 1963, p. 158)

canyon. 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 0.43Ø for Sample 47B to 3.34Ø 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.

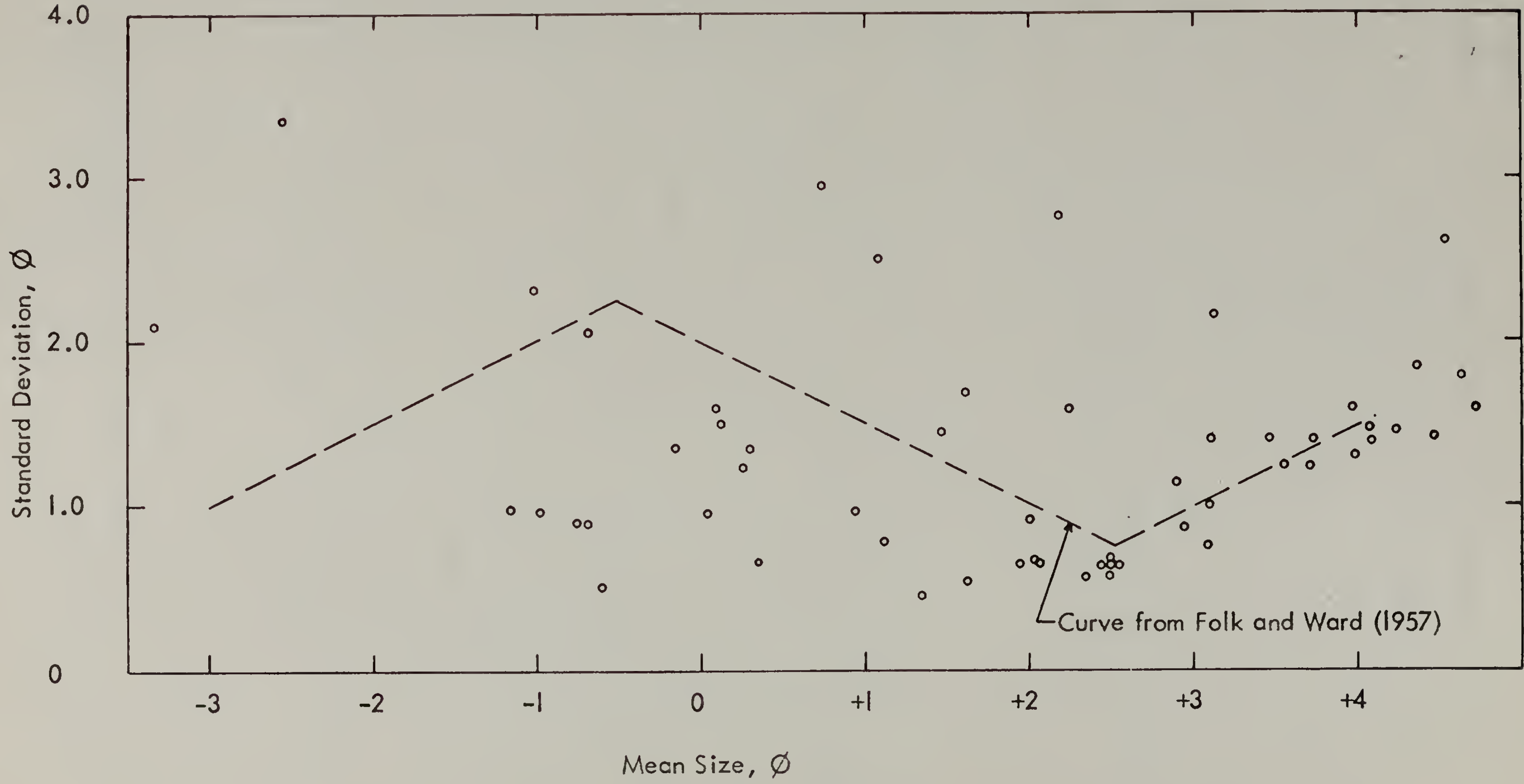


Figure 5. Standard Deviation as a Function of Mean Grain Size.

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 0.0Ø 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 0.0Ø 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.

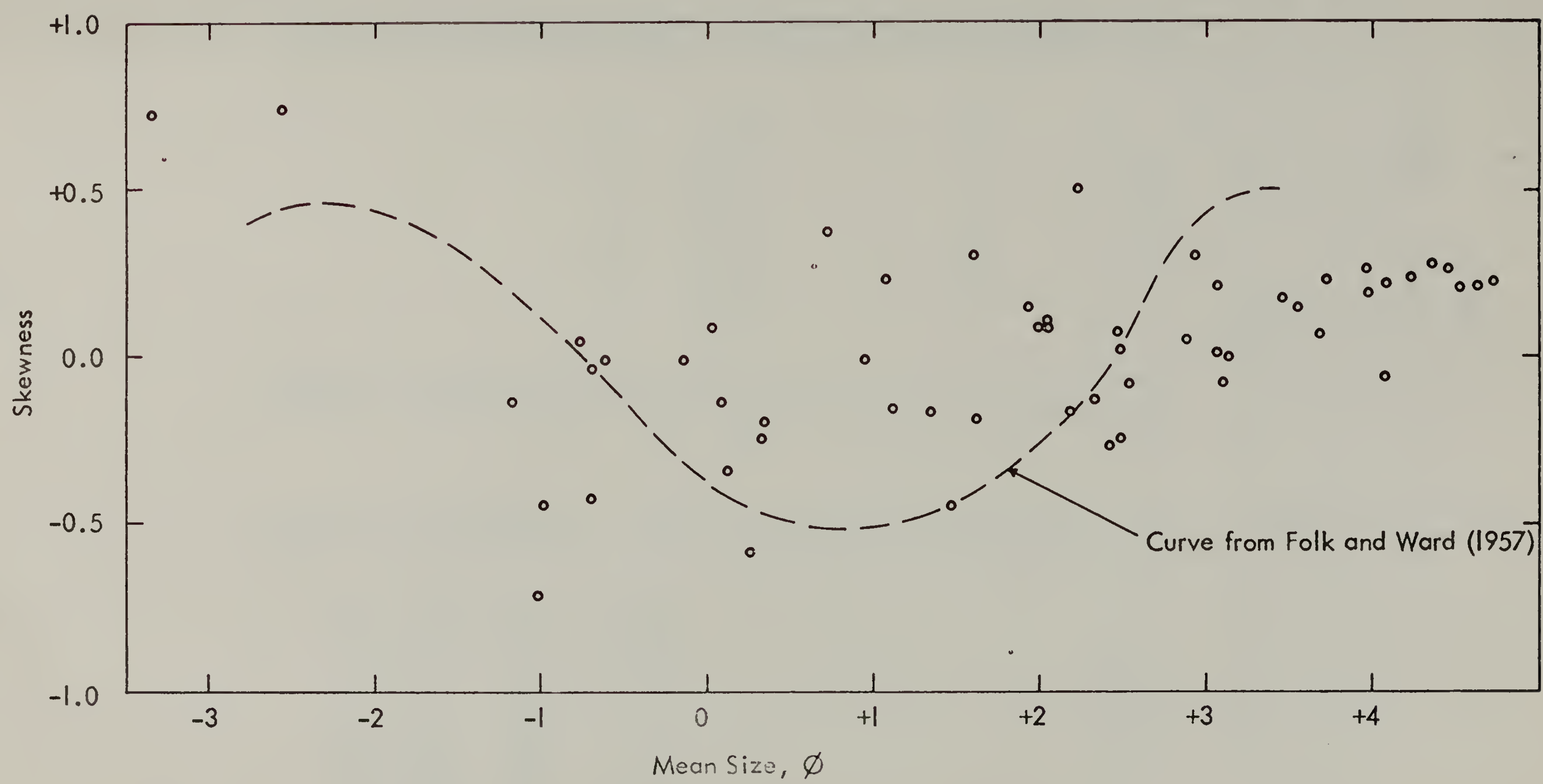


Figure 6. Skewness as a Function of Mean Grain Size.

TABLE II

ESTIMATES OF SAMPLE SHELL CONTENT

Visual observation of the 0.0Ø and larger fraction of each sample yielded the following estimates of shells, shell fragments, worm tubes, bryozoan colonies, corals, and echinoderm spines.

Sample	Shells	Remarks	Sample	Shells	Remarks
1	100		33	100	
2	100		34	40	
3	50		35	00	
4	70		36	00	
5	90	Kelp fragments	39	00	
6	00		40	20	
7	50		41	70	
8	00		42	05	
9	10		43	70	
10	05		44	60	
11	00		45	80	
12	00		47	50	
13	00	Kelp fragments,	47B	50	
		1 peanut shell	48	40	
14	00	9 sand dollars	53	10	
15	100		54B	100	Several 3-4"
16	50				annelid worms
17	100	Kelp fragments	56	10	
18	100		57	80	
22	90		58	100	Kelp fragments
23	80		59	100	Kelp fragments
24	10		60	00	
25	00		61	70	Kelp fragments
26	05		62	10	Kelp fragments
27	20		63	100	One small
28	03				spiny urchin
29	10		C1A	00	Kelp fragments
30	100		C1B	00	
32	70		C1C	00	
			C1D	00	

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.

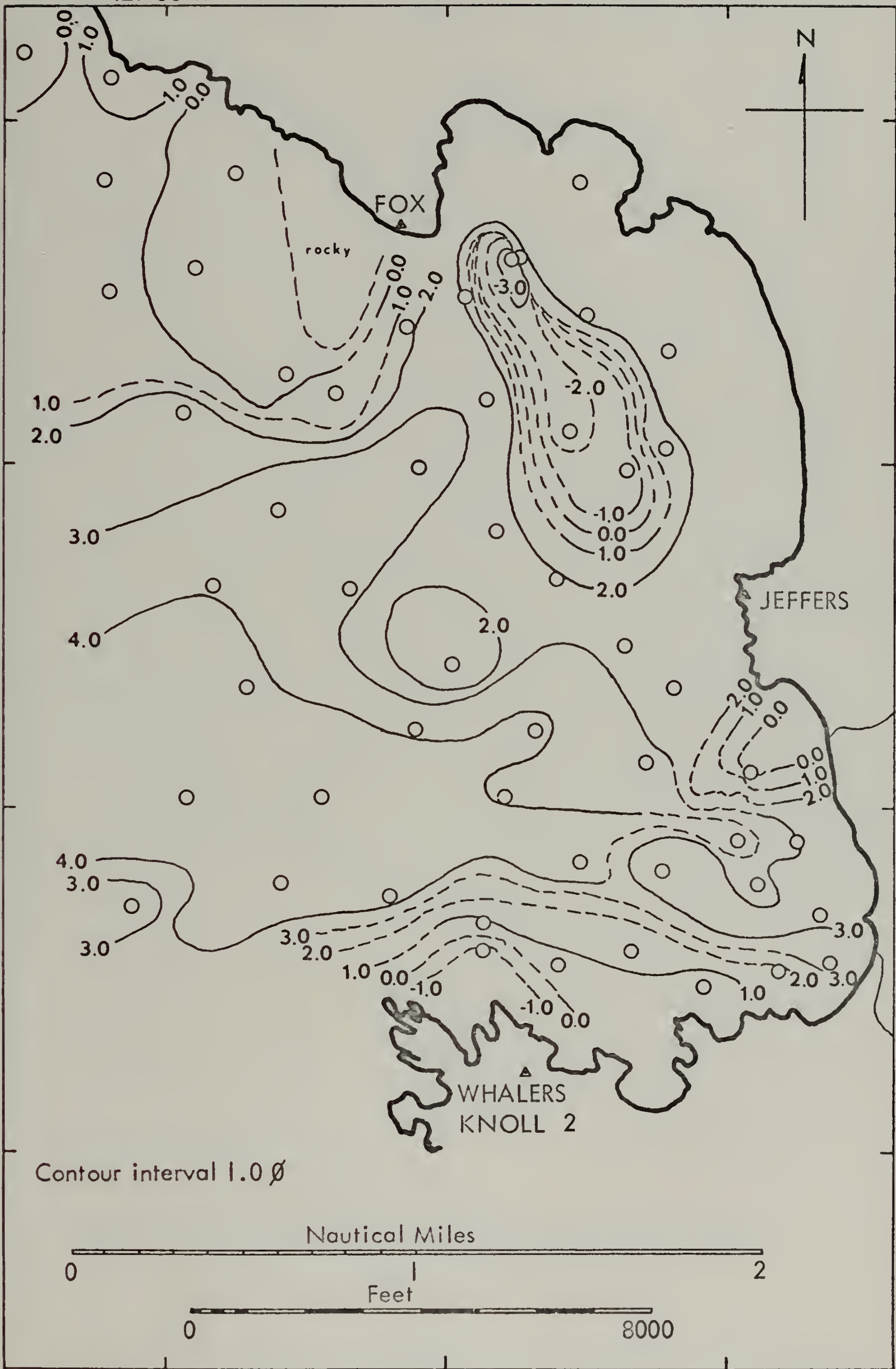


Figure 7. Sediment Mean Grain-Size Distribution.

Figure 8. Sediment Standard Deviation Distribution.

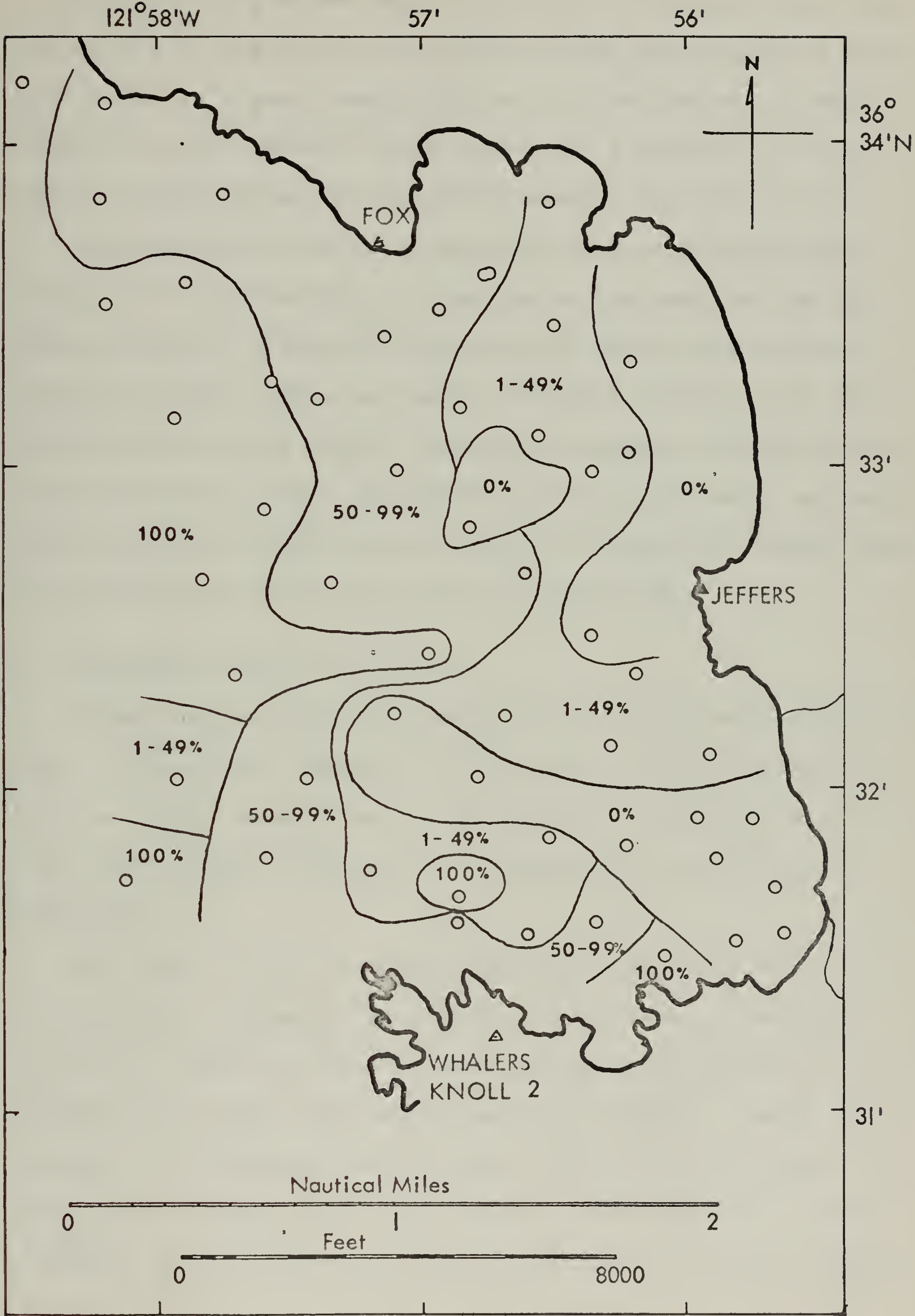


Figure 9. Sediment Shell Content.

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

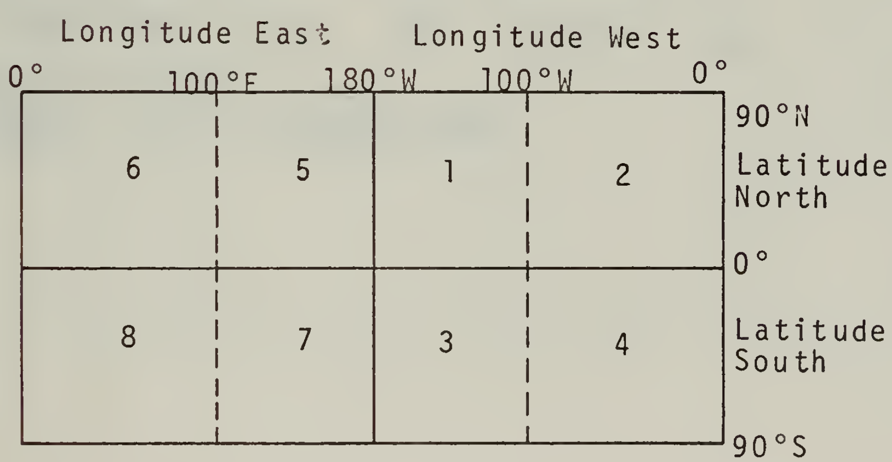
Col	
1- 9	cruise number
10-12	sample number
13-18	sample type
19-20	extra i.d. number
21-22	month
23-24	day
25-28	year
29-34	latitude (XX XX.XX) punch only X's
35-40	longitude (XX XX.XX)
57-61	depth from top of core (XXXXX.)
62-66	length of core (XXXXX.)
79	octant (see below)

Cols 1-28 are all alphanumeric and can contain any legal keypunch character.

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



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

SAMPLER TYPE  GRAB  DATE 04/23/1971  LAT. 36-31.70N   LONG. 121-55.65W
DEPTH FROM TOP OF CORE       0. MM.    LENGTH OF CORE       0. MM.

              PHI    SAMPLE  FRACTION  ACCUMULATED
              SIZE   WEIGHT  PERCENT     PERCENT
             -1.00  0.0057    0.01        0.01
             -0.50  0.0097    0.02        0.02
              0.0   0.0096    0.02        0.04
              0.50  0.0105    0.02        0.06
              1.00  0.0627    0.10        0.16
              1.50  0.5295    0.84        1.00
              2.00  7.7071   12.24       13.23
              2.50  7.8808   12.51       25.74
              3.00 19.3421   30.71       56.45
              3.50 13.2295   21.00       77.45
              4.00  7.3848   11.72       89.17
              4.50  2.6150    4.15       93.32
              5.00  1.7500    2.78       96.10
              5.50  2.4550    3.90      100.00

             POST-ANALYTICAL WEIGHT IS  62.9919

    PHI SIZES AT PERCENT LEVEL OF
      1 (C)      5        16        25        50 (M)   75       84       95
      1.50      1.73     2.13      2.48      2.91     3.43     3.71     4.78 4 PT.
      1.50      1.78     2.13      2.48      2.90     3.43     3.75     4.78 LINEAR

    SAND, SILT, CLAY, RELATIONSHIPS
      GRAVEL      SAND     SILT      CLAY      TOTAL    SAND/MUD    TYPE
       0.01      89.16    10.83      0.0      100.00      8.24     SAND

    TRASK VALUES       4 PT. PHIS
      Q1        Q2        Q3        SO      LOG SO      SKG
     0.180     0.133     0.093     1.389     0.143     0.97

    INMAN VALUES
      MEDIAN     MEAN      DEV.      SKEW.    2ND SKEW.     KURT.
       2.91      2.92      0.79      0.02       0.44        0.93

    FOLK AND WARD VALUE
     MEAN         2.91     FINE SAND
     DEVIATION    0.86     MODERATELY SORTED
     SKEWNESS     0.12     POSITIVELY SKEWED
     KURTOSIS     1.32     LEPTOKURTIC

    TRASK VALUES       LINEAR PHIS
      Q1        Q2        Q3        SO      LOG SO      SKG
     0.180     0.134     0.093     1.393     0.144     0.96

    INMAN VALUES
      MEDIAN     MEAN      DEV.      SKEW.    2ND SKEW.     KURT.
       2.90      2.94      0.81      0.05       0.47        0.85

    FOLK AND WARD VALUE
     MEAN         2.93     FINE SAND
     DEVIATION    0.86     MODERATELY SORTED
     SKEWNESS     0.15     POSITIVELY SKEWED
     KURTOSIS     1.28     LEPTOKURTIC
```

```
C*************************************************************************
C
C     SEDIMENT SIZE ANALYSIS MAIN PROGRAM
C
C*************************************************************************
C
      COMMON /BLK1/PHIS(8,2),NINM,NFAW,NSSC,SUMNL,NTRSK                  SIZE0010
      REAL NEG/'-   '/                                                   SIZE0020
      DATA ANORTH/'N   '/,SOUTH/'S   '/,EAST/'E   '/,WEST/'W   '/        SIZE0030
      DIMENSION FRWT(100),PRCT(100),CRMC(20),STMC(20),EXMC(20),CRMB(20),SIZE0040
     1STMB(20),EXMB(20),TITLE(20),ICR(20),JCR(20)                        SIZE0050
      REAL*8    CRUZ,CRUZR,CRMB,CRMC,SMPLR                               SIZE0060
      DIMENSION T(100),PHI(100),ACPC(100)                                SIZE0070
      DATA KKK/0/,MAT/0/,MBT/0/,MED/0/,KSM/0/                            SIZE0080
      NINOT=1                                                            SIZE0090
  902 N2=1                                                               SIZE0100
      NA=1                                                               SIZE0110
      NZ=1                                                               SIZE0120
      NL=1                                                               SIZE0130
      NB=1                                                               SIZE0140
      M=0                                                                SIZE0150
      PAWT=0.                                                            SIZE0160
      DO 903 K=1,100                                                     SIZE0170
      T(K)=4.09                                                          SIZE0180
      ACPC(K)=999.99                                                     SIZE0190
      FRWT(K)=0.0                                                        SIZE0200
  903 PHI(K)=99.99                                                       SIZE0210
      MA=0                                                               SIZE0220
      MB=0                                                               SIZE0230
      MBT=0                                                              SIZE0240
      MC=0                                                               SIZE0250
      MED=0                                                              SIZE0260
      SUMWT=0.0                                                          SIZE0270
      SUMPC=0.0                                                          SIZE0280
      ACPC(1)=0.0                                                        SIZE0290
      READ(5,20) TITLE                                                   SIZE0300
   20 FORMAT(20A4)                                                       SIZE0310
    1 NK=1                                                               SIZE0320
    2 READ(5,26)CRUZR,MCR,STATR,SMPLR,EXID,MO,DA,YR,LATA,DEGLT,LNGA,     SIZE0330
     1 DEGLN,PHIR,SIGN,BFWT,DEPTHR,CRLN,IQUD,NE                          SIZE0340
   26 FORMAT(A7,A2,A3,A6,3A2,A4,I2,F4.2,I2,2F4.2,A1,4X,F7.4,2F5.0,12X,   SIZE0350
     12I1)                                                               SIZE0360
      TIMES=1.                                                           SIZE0370
      IF(SIGN.EQ.NEG) TIMES=-1.                                          SIZE0380
      PHIR=(TIMES*PHIR)                                                  SIZE0390
    3 IF(PHIR.LT.3.9) GO TO 29                                           SIZE0400
      IF(NZ.EQ.1) GO TO 48                                               SIZE0410
      IF(PHIR.LE.4.1) GO TO 46                                           SIZE0420
```

```
      NZ=2                                                              SIZE0430
      GO TO 29                                                          SIZE0440
   46 NZ=1                                                              SIZE0450
      GO TO 44                                                          SIZE0460
   48 IF(NL.EQ.2) GO TO 44                                              SIZE0470
      NL=2                                                              SIZE0480
      NZ=2                                                              SIZE0490
   29 FRWTR=BFWT                                                        SIZE0500
      IF(FRWTR.GE.0.) GO TO 52                                          SIZE0510
      IF((FRWTR+.01).GE.0.) GO TO 25                                    SIZE0520
      WRITE(6,51) FRWTR                                                 SIZE0530
   25 FRWTR=0.0                                                         SIZE0540
   52 PAWT=PAWT+FRWTR                                                   SIZE0550
      SUMWT=PAWT                                                        SIZE0560
      GO TO 49                                                          SIZE0570
   44 IF(NK.EQ.2) GO TO 59                                              SIZE0580
      NK=2                                                              SIZE0590
      FWT1=BFWT*50.                                                     SIZE0600
      GO TO 2                                                           SIZE0610
   59 FWT2=BFWT*50.                                                     SIZE0620
      FRWTR=FWT1-FWT2                                                   SIZE0630
      IF(FRWTR.GE.0.) GO TO 53                                          SIZE0640
      IF((FRWTR+0.01).GE.0.) GO TO 55                                   SIZE0650
   60 WRITE(6,51) FRWTR                                                 SIZE0660
   51 FORMAT(25X,  'WEIGHING ERROR. FRACTION WEIGHT WAS ',F10.4,' BEFORESIZE0670
     1BEING SET TO ZERO')                                               SIZE0680
   55 FRWTR=0.0                                                         SIZE0690
   53 FWT1=FWT2                                                         SIZE0700
      NINOT=2                                                           SIZE0710
      IF(NE.LT.8) GO TO 52                                              SIZE0720
   54 PAWT=PAWT+FRWTR+FWT2                                              SIZE0730
      SUMWT=PAWT                                                        SIZE0740
      K=K+1                                                             SIZE0750
      M=M+1                                                             SIZE0760
      KK=KK+1                                                           SIZE0770
      PHI(K)=PHIR                                                       SIZE0780
      FRWT(K)=FRWTR                                                     SIZE0790
      K=K+1                                                             SIZE0800
      M=M+1                                                             SIZE0810
      KK=KK+1                                                           SIZE0820
      FRWT(K)=FWT2                                                      SIZE0830
      PHI(K)=12.                                                        SIZE0840
      IF(PHIR.LE.11.) PHI(K)=PHIR+1.                                    SIZE0850
      GO TO 100                                                         SIZE0860
   49 IF(NA.EQ.2) GO TO 50                                              SIZE0870
      NA=2                                                              SIZE0880
C     DETERMINE OCTANT FROM FIRST CARD OF SAMPLE                        SIZE0890
      DK=WEST                                                           SIZE0900
```

```
      IDH=LNGA                                                          SIZE0910
      IF(IQUD-2) 8,9,11                                                 SIZE0920
    8 IDH=IDH+100                                                       SIZE0930
    9 DG=ANORTH                                                         SIZE0940
      GO TO 23                                                          SIZE0950
   11 IF(IQUD-4) 12,13,15                                               SIZE0960
   12 IDH=IDH+100                                                       SIZE0970
   13 DG=SOUTH                                                          SIZE0980
      GO TO 23                                                          SIZE0990
   15 DK=EAST                                                           SIZE1000
      IF(IQUD-6) 17,16,19                                               SIZE1010
   17 IDH=IDH+100                                                       SIZE1020
   16 DG=ANORTH                                                         SIZE1030
      GO TO 23                                                          SIZE1040
   19 IF(IQUD.GE.8) IDH=IDH+100                                         SIZE1050
      DG=SOUTH                                                          SIZE1060
   23 CRUZ=CRUZR                                                        SIZE1070
      NCR=MCR                                                           SIZE1080
      STAT=STATR                                                        SIZE1090
      EXC=EXID                                                          SIZE1100
      DPTH=DEPTHR                                                       SIZE1110
      WRITE (6,800) TITLE                                               SIZE1120
  800 FORMAT('1',26X,20A4)                                              SIZE1130
      WRITE (6,801) CRUZ,NCR,STAT,EXC,SMPLR,MO,DA,YR,LATA,DEGLT,DG,     SIZE1140
     1IDH,DEGLN,DK,DEPTHR,CRLN                                          SIZE1150
  801 FORMAT(/39X,'CRUISE ',A7,A2,' SAMPLE NUMBER ',A3,' EX ID ',A2//25XSIZE1160
     1,' SAMPLER TYPE ',A6,' DATE ',A2,'/',A2,'/',A4,'  LAT. ',I2,'-',  SIZE1170
     2F5.2,A1,'   LONG. ',I3,'-',F5.2,A1/26X,'DEPTH FROM TOP OF CORE ', SIZE1180
     3F7.0,' MM.    LENGTH OF CORE ',F7.0,' MM.')                       SIZE1190
      NB=2                                                              SIZE1200
      KK=0                                                              SIZE1210
      K=0                                                               SIZE1220
      IF(FRWTR.NE.0.) N2=3                                              SIZE1230
      PHIA=-12.0                                                        SIZE1240
      GO TO 1                                                           SIZE1250
C     SAVE PHI & FRACTION WT. FROM EACH DETAIL CARD                     SIZE1260
   50 KK=KK+1                                                           SIZE1270
      K=K+1                                                             SIZE1280
      PHI(K)=PHIR                                                       SIZE1290
      FRWT(K)=FRWTR                                                     SIZE1300
      IF(NE.GE.8) GO TO 100                                             SIZE1310
C     SET FLAG (N2=2) IF NEW PHI LESS THAN LAST PHI                     SIZE1320
      IF(PHIA.GE.PHIR) N2=2                                             SIZE1330
      PHIA=PHIR                                                         SIZE1340
      M=M+1                                                             SIZE1350
      IF(NINOT-1) 1,1,2                                                 SIZE1360
  100 M=K                                                               SIZE1370
C     DETERMINE FRACTION PERCENTS AND ACCUMULATED %                     SIZE1380
```

```
      DO 67 K=1,M                                                       SIZE1390
      PRCT(K)=(FRWT(K)/PAWT)*100.                                       SIZE1400
      SUMPC=SUMPC+PRCT(K)                                               SIZE1410
      ACPC(K)=SUMPC                                                     SIZE1420
   67 CONTINUE                                                          SIZE1430
      CALL TVAL(T,ACPC,M)                                               SIZE1440
      IF(SUMPC.LT.99.94.OR.SUMPC.GT.100.06) GO TO 1500                  SIZE1450
      IF(N2-2) 103,1666,1990                                            SIZE1460
  103 WRITE(6,802) (PHI(J),FRWT(J),PRCT(J),ACPC(J),J=1,KK)              SIZE1470
  802 FORMAT('0',40X,'PHI     SAMPLE   FRACTION   ACCUMULATED'/41X,'SIZE SIZE1480
     1WEIGHT   PERCENT      PERCENT'/(40X,F6.2,F8.4,F8.2,F12.2))        SIZE1490
      KJK=KK                                                            SIZE1500
      WRITE (6,79) PAWT                                                 SIZE1510
   79 FORMAT( /40X,'POST-ANALYTICAL WEIGHT IS',F9.4)                    SIZE1520
      SUMNL=ACPC(KK)                                                    SIZE1530
      NSSC=2                                                            SIZE1540
      NTRSK=1                                                           SIZE1550
      NINM=1                                                            SIZE1560
      NFAW=1                                                            SIZE1570
      JJ=0                                                              SIZE1580
      DO 77 I=1,KK                                                      SIZE1590
      IF(FRWT(I).EQ.0.) GO TO 77                                        SIZE1600
      JJ=JJ+1                                                           SIZE1610
      T(JJ)=T(I)                                                        SIZE1620
      ACPC(JJ)=ACPC(I)                                                  SIZE1630
      PHI(JJ)=PHI(I)                                                    SIZE1640
   77 CONTINUE                                                          SIZE1650
      KK=JJ                                                             SIZE1660
      KJK=JJ                                                            SIZE1670
      IF(SUMNL.GE.72.0) GO TO 105                                       SIZE1680
      NSSC=1                                                            SIZE1690
      WRITE(6,809) PHI(KK)                                              SIZE1700
  809 FORMAT('0',29X,'DID NOT INTERPOLATE ANY PHI SIZES BECAUSE'/29X,   SIZE1710
     1'ACCUMULATED PERCENT AT ',F5.2,' DID NOT EXCEED'/29X,'72 PERCENT')SIZE1720
      GO TO 160                                                         SIZE1730
  105 IF(4.LT.KK) GO TO 111                                             SIZE1740
      WRITE(6,815) KK                                                   SIZE1750
  815 FORMAT(' ',28X,' ONLY ',I3,' DETAIL CARDS SO ONLY SAND.'/30X,'SILTSIZE1760
     1, CLAY RELATIONSHIPS CALCULATED.')                                SIZE1770
      GO TO 901                                                         SIZE1780
C     COMPUTE T-VALUES                                                  SIZE1790
  111 CALL INTRP(ACPC,PHI,T,KK)                                         SIZE1800
  160 CALL SNSTCL(PHI,ACPC,SUMPC,KJK)                                   SIZE1810
      CALL CTIFW                                                        SIZE1820
C     INCREMENT COUNTERS AND GO TO NEXT SAMPLE                          SIZE1830
  901 KKK=KKK+KK+1                                                      SIZE1840
      KSM=KSM+1                                                         SIZE1850
      I=I+1                                                             SIZE1860
```

```
      NINOT=2                                                           SIZE1870
      IF(NE.NE.9) GO TO 902                                             SIZE1880
C     PRINT RESULTS AND MESSAGES                                        SIZE1890
  950 WRITE(6,860) KSM,KKK                                              SIZE1900
  860 FORMAT('1',30X,'THIS BATCH OF CARDS CONTAINED DATA FROM ',I4,' SAMSIZE1910
     1PLES'/30X,' FOR A TOTAL OF ',I4,' CARDS.')                        SIZE1920
      IF(MBT.GT.0) WRITE(6,863) (CRMB(L),ICR(L),STMB(L),EXMB(L),L=1,MBT)SIZE1930
  863 FORMAT('0',29X,'CARDS OUT OF ORDER ON THE FOLLOWING SAMPLES'/31X, SIZE1940
     1'CRUISE',5X,'SAMPLE ',5X,'EXID'//(33X,A7,A2,A3,A2))               SIZE1950
      IF(MC.GT.0) WRITE(6,864) (CRMC(L) ,JCR(L),STMC(L),EXMC(L),L=1,MC) SIZE1960
  864 FORMAT('0',29X,'NO ZERO PERCENT CARDS ON THE FOLLOWING STATIONS'/ SIZE1970
     131X,'CRUISE',5X,'SAMPLE ',5X,'EXID'//(33X,A7,A2,A3,A2))           SIZE1980
      MTT=MBT+MC+MED                                                    SIZE1990
      IF(MTT.GT.0) GO TO 959                                            SIZE2000
      WRITE(6,861)                                                      SIZE2010
  861 FORMAT('0',30X,'CONGRATULATIONS    NO ERRORS WERE FOUND IN THIS BASIZE2020
     1TCH OF CARDS')                                                    SIZE2030
      GO TO 960                                                         SIZE2040
  959 WRITE (6,865) MTT                                                 SIZE2050
  865 FORMAT('0',29X,'SORRY OLD CHAP, BUT YOU MADE ',I3,' ERRORS ON THE SIZE2060
     1DATA'/30X,'FOR THIS RUN. NEXT TIME BE MORE CAREFUL')              SIZE2070
  960 RETURN                                                            SIZE2080
 1666 WRITE(6,8666)                                                     SIZE2090
 8666 FORMAT('0',29X,'CARDS OUT OF ORDER. CHECK VALUES BELOW.')         SIZE2100
      MBT=MBT+1                                                         SIZE2110
      CRMB(MBT)=CRUZ                                                    SIZE2120
      ICR(MBT)=NCR                                                      SIZE2130
      STMB(MBT)=STAT                                                    SIZE2140
      EXMB(MBT)=EXC                                                     SIZE2150
      GO TO 1501                                                        SIZE2160
 1990 WRITE(6,8990)                                                     SIZE2170
 8990 FORMAT('0',28X,'NO ZERO PERCENT CARD.'/30X,'CHECK VALUES BELOW')  SIZE2180
      MC=MC+1                                                           SIZE2190
      CRMC(MC)=CRUZ                                                     SIZE2200
      JCR(MC)=NCR                                                       SIZE2210
      STMC(MC)=STAT                                                     SIZE2220
      EXMC(MC)=EXC                                                      SIZE2230
      GO TO 1501                                                        SIZE2240
 1500 WRITE(6,830) PAWT                                                 SIZE2250
  830 FORMAT('0',32X,'SUM OF FRACTION WEIGHTS DID NOT EQUAL POST ANALYTISIZE2260
     1CAL WEIGHT'/32X,'WHICH WAS ',F8.3,' . CHECK THE VALUES BELOW FOR ESIZE2270
     2RRORS.')                                                          SIZE2280
 1501 WRITE(6,831)                                                      SIZE2290
  831 FORMAT('0',40X,' PHI  FRACTION  FRACTION  ACCUM.  T-'/41X,' SIZE  SIZE2300
     1WEIGHT    PERCENT   PRCT  VALUE')                                 SIZE2310
      WRITE(6,833) (PHI(J),FRWT(J),PRCT(J),ACPC(J),T(J),J=1,KK)         SIZE2320
  833 FORMAT('0',40X,F5.2,F9.3,F9.2,F8.2,F7.3)                          SIZE2330
      WRITE(6,8333) SUMWT                                               SIZE2340
```

```
 8333 FORMAT('0',29X,'SUM FRACTION WEIGHTS = ',F8.3,' GRAMS')           SIZE2350
      MED=MED+1                                                         SIZE2360
      GO TO 901                                                         SIZE2370
  999 RETURN                                                            SIZE2380
      END                                                               SIZE2390
C
C***********************************************************************
C
C     INTERPOLATION SUBPROGRAM
C
C***********************************************************************


      SUBROUTINE INTRP(ACPC,PHI,T,KK)                                   SIZE2400
      DIMENSION ACPC(1),PHI(1),T(1)                                     SIZE2410
      COMMON /BLK1/PHIS(8,2),NINM,NFAW,NSSC,SUMNL,NTRSK                 SIZE2420
      REAL   PC(8)/1.,5.,16.,25.,50.,75.,84.,95./,XTT(8)/-2.325,        SIZE2430
     1-1.645,-.995,-.674, 0.0,.674,.995,1.645/                          SIZE2440
      PHIS(6,1)=99.99                                                   SIZE2450
      PHIS(6,2)=99.99                                                   SIZE2460
      PHIS(7,1)=99.99                                                   SIZE2470
      PHIS(7,2)=99.99                                                   SIZE2480
      PHIS(8,1)=99.99                                                   SIZE2490
      PHIS(8,2)=99.99                                                   SIZE2500
      NINT=0                                                            SIZE2510
 1101 IF(NINT.EQ.0) GO TO 1102                                          SIZE2520
      PHIS(NINT,1)=YYA                                                  SIZE2530
      PHIS(NINT,2)=YYL                                                  SIZE2540
 1102 NINT=NINT+1                                                       SIZE2550
      XPC=PC(NINT)                                                      SIZE2560
      XT=XTT(NINT)                                                      SIZE2570
      DO 151 L=1,KK                                                     SIZE2580
      IF(ACPC(L)-XPC) 151,152,153                                       SIZE2590
  151 CONTINUE                                                          SIZE2600
  152 YYA=PHI(L)                                                        SIZE2610
      YYL=PHI(L)                                                        SIZE2620
      GO TO 210                                                         SIZE2630
  153 IF(XPC-75.0) 154,155,157                                          SIZE2640
  155 IF(SUMNL.GE.75.0) GO TO 156                                       SIZE2650
      NINT=9                                                            SIZE2660
      GO TO 1197                                                        SIZE2670
  157 IF(XPC.GT.84.0) GO TO 159                                         SIZE2680
      IF(SUMNL.LT.84.) GO TO 168                                        SIZE2690
  156 IF(L-KK) 195,197,197                                              SIZE2700
  159 IF(SUMNL-95.0) 169,156,156                                        SIZE2710
  168 IF(SUMNL.LT.81.0) GO TO 1475                                      SIZE2720
      NINT=10                                                           SIZE2730
      GO TO 1197                                                        SIZE2740
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```
  169 IF(SUMNL.LT.92.0) GO TO 1476                                      SIZE2750
      NINT=11                                                           SIZE2760
 1197 XT=XTT(NINT-3)                                                    SIZE2770
      GO TO 197                                                         SIZE2780
  154 IF(L.LE.2) GO TO 196                                              SIZE2790
  195 LA=2                                                              SIZE2800
      GO TO 199                                                         SIZE2810
  196 LA=1                                                              SIZE2820
      GO TO 199                                                         SIZE2830
  197 LA=3                                                              SIZE2840
  199 LS=L-LA                                                           SIZE2850
      X=XT                                                              SIZE2860
      X1=T(LS)                                                          SIZE2870
      X2=T(LS+1)                                                        SIZE2880
      X3=T(LS+2)                                                        SIZE2890
      X4=T(LS+3)                                                        SIZE2900
      Y1=PHI(LS)                                                        SIZE2910
      Y2=PHI(LS+1)                                                      SIZE2920
      Y3=PHI(LS+2)                                                      SIZE2930
      Y4=PHI(LS+3)                                                      SIZE2940
C     AITKENS FOUR POINT INTERPOLATION                                  SIZE2950
      P12=((Y1*(X2-X))-(Y2*(X1-X)))/(X2-X1)                             SIZE2960
      P13=((Y1*(X3-X))-(Y3*(X1-X)))/(X3-X1)                             SIZE2970
      P14=((Y1*(X4-X))-(Y4*(X1-X)))/(X4-X1)                             SIZE2980
      P123=((P12*(X3-X))-(P13*(X2-X)))/(X3-X2)                          SIZE2990
      P124=((P12*(X4-X))-(P14*(X2-X)))/(X4-X2)                          SIZE3000
      YYA=((P123*(X4-X))-(P124*(X3-X)))/(X4-X3)                         SIZE3010
C     LINEAR INTERPOLATION                                              SIZE3020
      X11=T(L-1)                                                        SIZE3030
      X22=T(L)                                                          SIZE3040
      Y11=PHI(L-1)                                                      SIZE3050
      Y22=PHI(L)                                                        SIZE3060
      YYL=(X-X11)*(Y22-Y11)/(X22-X11)+Y11                               SIZE3070
      IF(L.LE.2) YYA=YYL                                                SIZE3080
  210 IF(NINT.LT.8) GO TO 1101                                          SIZE3090
      INI=NINT-7                                                        SIZE3100
      PHIS(NINT,1)=YYA                                                  SIZE3110
      PHIS(NINT,2)=YYL                                                  SIZE3120
      WRITE(6,803) ((PHIS(II,K),II=1,8),K=1,2)                          SIZE3130
  803 FORMAT('0',29X,'PHI SIZES AT PERCENT LEVEL OF      '              SIZE3140
     1  /32X,'1 (C)     5        16',7X,'25',7X,'50 (M)    75',7X,'84',7X,SIZE3150
     2'95'/27X,8F9.2,' 4 PT.'/27X,8F9.2,' LINEAR')                      SIZE3160
      RETURN                                                            SIZE3170
 1275 NM3=NINT-3                                                        SIZE3180
      PHIS(NM3,1)=YYA                                                   SIZE3190
      PHIS(NM3,2)=YYL                                                   SIZE3200
      IPH=NM3                                                           SIZE3210
      IPER=PC(NM3)                                                      SIZE3220
```

```
      IF(NINT.EQ.11) NFAW=2                                             SIZE3230
 1300 WRITE (6,1301) IPER,((PHIS(II,K),II=1,8   ),K=1,2)                SIZE3240
 1301 FORMAT('0',29X,'PHI SIZES AT PERCENT LEVEL OF    (',I2,           SIZE3250
     *                                               ' LEVEL EXTRAPOLSIZE3260
     1ATED)'              /32X,'1(C)',6X,'5',7X,'16',7X,'25',7X,'50(M)  SIZE3270
     275',7X,'84'/30X,F5.2,7F9.2,' 4 PT.'/30X,F5.2,7F9.2,' LINEAR')     SIZE3280
      RETURN                                                            SIZE3290
 1475 IPER=84                                                           SIZE3300
      NINM=2                                                            SIZE3310
      GO TO 1400                                                        SIZE3320
 1476 NFAW=2                                                            SIZE3330
      IPER=95                                                           SIZE3340
      GO TO 1400                                                        SIZE3350
 1400 WRITE (6,1401) IPER,((PHIS(II,K),II=1,8   ),K=1,2)                SIZE3360
 1401 FORMAT('0',29X,'PHI SIZES AT PERCENT LEVEL OF (',I2,              SIZE3370
     *                                            ' LEVEL NOT EXTRAPSIZE3380
     1OLATED)'             /32X,'1(C)',6X,'5',7X,'16',7X,'25',7X,'50(M) SIZE3390
     275',7X,'84'/30X,F5.2,7F9.2,' 4 PT.'/30X,F5.2,7F9.2,' LINEAR')     SIZE3400
      RETURN                                                            SIZE3410
      END                                                               SIZE3420
C
C***********************************************************************
C
C     SUBPROGRAM WHICH IS THE EQUIVALENT OF PLOTTING, BY HAND, THE GRAIN
C     SIZE AGAINST THE ACCUMULATED PERCENTAGE.
C
C***********************************************************************


      SUBROUTINE TVAL(T,ACPC,M)                                         SIZE3430
      DIMENSION T(1),ACPC(1)                                            SIZE3440
      REAL TBLPC(87)/0.0,01.20,03.59,04.78,05.96,07.14,08.32,09.48,     SIZE3450
     1 10.64,11.79,12.93,14.06,15.17,16.28,17.36,18.44,19.50,20.54,     SIZE3460
     2 21.57,22.57,23.57,24.54,25.49,26.42,27.34,28.23,29.10,29.95,     SIZE3470
     3 30.78,31.59,32.38,33.15,33.89,34.61,35.31,35.99,36.65,37.29,     SIZE3480
     4 37.90,38.49,39.07,39.62,40.15,40.66,41.15,41.62,42.07,42.51,     SIZE3490
     5 42.92,43.32,43.70,44.06,44.41,44.74,45.05,45.35,45.64,45.91,     SIZE3500
     6 46.16,46.41,46.64,46.86,47.06,47.26,47.44,47.61,47.78,47.93,     SIZE3510
     7 48.08,48.21,48.34,48.46,48.57,48.68,48.78,48.87,48.96,49.04,     SIZE3520
     8 49.11,49.20,49.31,49.40,49.60,49.70,49.80,49.90,50.0/            SIZE3530
      REAL TBLT(87)/0.00,0.03,0.09,0.12,0.15,0.18,0.21,0.24,0.27,0.30,  SIZE3540
     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,  SIZE3550
     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,  SIZE3560
     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,  SIZE3570
     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,  SIZE3580
     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,  SIZE3590
     6    2.13,2.16,2.19,2.22,2.25,2.28,2.31,2.34,2.37,2.41,2.46,2.51,  SIZE3600
     7    2.65,2.75,2.88,3.08,4.09/                                     SIZE3610
```

```
C       CALCULATE T-VALUE                                                       SIZE3620
        DO 68 K=1,M                                                             SIZE3630
        IF(ACPC(K).LT.100.0) GO TO 62                                           SIZE3640
   61   T(K)=4.09                                                               SIZE3650
        GO TO 68                                                                SIZE3660
   62   DLPC=ACPC(K)-50.                                                        SIZE3670
        IF(DLPC) 64,63,65                                                       SIZE3680
   63   T(K)=0.0                                                                SIZE3690
        GO TO 68                                                                SIZE3700
   64   GMPC=-DLPC                                                              SIZE3710
        GO TO 66                                                                SIZE3720
   65   GMPC=DLPC                                                               SIZE3730
   66   DO 69 L=1,87                                                            SIZE3740
        IF(TBLPC(L)-GMPC) 69,70,71                                              SIZE3750
   69   CONTINUE                                                                SIZE3760
   70   TCALC=TBLT(L)                                                           SIZE3770
        GO TO 72                                                                SIZE3780
   71   TCALC=(GMPC-TBLPC(L-1))*(TBLT(L)-TBLT(L-1))/(TBLPC(L)-TBLPC(L-1))+SIZE3790
       1TBLT(L-1)                                                               SIZE3800
        IF(TCALC.GT.4.09) GO TO 61                                              SIZE3810
   72   IF(DLPC.GE.0.0) GO TO 74                                                SIZE3820
        TCALC=-TCALC                                                            SIZE3830
   74   T(K)=TCALC                                                              SIZE3840
   68   CONTINUE                                                                SIZE3850
        RETURN                                                                  SIZE3860
        END                                                                     SIZE3870
C
C*************************************************************************
C
C       SUBPROGRAM FOR COMPUTING SAND-SILT-CLAY RELATIONSHIPS
C
C*************************************************************************


        SUBROUTINE SNSTCL(PHI,ACPC,SUMPC,KJK)                                   SIZE3880
        DIMENSION PHI(1),T(1),ACPC(1)                                           SIZE3890
        REAL*8 CLASS(9)/' SAND    SILT     CLAY     SANDY   SILTY  CLAYEY   SIZE3900
       1          -SILT    -CLAY    '/                                          SIZE3910
        INTEGER SUBS(33)/1,7,7,2,7,7,3,7,7,1,8,9,5,1,7,4,2,7,6,1,7,6,2,7,  SIZE3920
       14,3,7,5,3,7,7,7,7/                                                      SIZE3930
        NI=0                                                                    SIZE3940
        RATIO=9999.99                                                           SIZE3950
        GRSN=0.0                                                                SIZE3960
        SAND=0.0                                                                SIZE3970
        SILT=0.0                                                                SIZE3980
        CLAY=0.0                                                                SIZE3990
        SANDP=0.0                                                               SIZE4000
        IF(PHI(KJK).LT.-1.0) GO TO 380                                          SIZE4010
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```
      DO 302 KG=1,KJK                                                   SIZE4020
      IF(ABS(PHI(KG)+1.0).LE..0001) GO TO 303                           SIZE4030
      IF(PHI(KG)+1.0) 302,303,307                                       SIZE4040
  302 CONTINUE                                                          SIZE4050
  303 GRSN=ACPC(KG)                                                     SIZE4060
  307 IF(PHI(KJK).LT.4.0) GO TO 312                                     SIZE4070
      DO 309 KS=1,KJK                                                   SIZE4080
      IF(ABS(PHI(KS)-4.0).LE..0001) GO TO 310                           SIZE4090
      IF(PHI(KS)-4.0) 309,310,313                                       SIZE4100
  309 CONTINUE                                                          SIZE4110
  310 SAND=ACPC(KS)                                                     SIZE4120
      SANDP=SAND-GRSN                                                   SIZE4130
      FMUD=SUMPC-SAND                                                   SIZE4140
      IF(FMUD.NE.0.) RATIO=SAND/FMUD                                    SIZE4150
      GO TO 313                                                         SIZE4160
  312 SAND=SUMPC-GRSN                                                   SIZE4170
      SANDP=SAND                                                        SIZE4180
      GO TO 380                                                         SIZE4190
  313 IF(ABS(PHI(KJK)-8.0).LE..0001) GO TO 314                          SIZE4200
      IF(PHI(KJK).LT.8.0) GO TO 317                                     SIZE4210
  314 DO 315 KSL=1,KJK                                                  SIZE4220
      IF(ABS(PHI(KSL)-8.0).LE..0001) GO TO 316                          SIZE4230
      IF(PHI(KSL).GE.8.0) GO TO 316                                     SIZE4240
  315 CONTINUE                                                          SIZE4250
  316 SILT=ACPC(KSL)-SAND                                               SIZE4260
      CLAY=SUMPC-SAND-SILT                                              SIZE4270
      GO TO 320                                                         SIZE4280
  317 SILT=SUMPC-SAND                                                   SIZE4290
  320 NI=1                                                              SIZE4300
      IF(SAND.GE.75.0) GO TO 380                                        SIZE4310
      NI=2                                                              SIZE4320
      IF(SILT.GE.75.0) GO TO 380                                        SIZE4330
      NI=3                                                              SIZE4340
      IF(CLAY.GE.75.0) GO TO 380                                        SIZE4350
      NI=4                                                              SIZE4360
      IF(SAND.GE.20.0.OR.SILT.GE.20.0.OR.CLAY.GE.20.0) GO TO 380        SIZE4370
      N4=1                                                              SIZE4380
      IF(CLAY/SILT.LT.1.) N4=2                                          SIZE4390
      IF(SAND/SILT.LT.1.) GO TO (341,334),N4                            SIZE4400
      GO TO (334,336),N4                                                SIZE4410
  334 IF(CLAY/SAND.LT.1.) GO TO (338,337),N4                            SIZE4420
      GO TO (340,339),N4                                                SIZE4430
  336 NI=5                                                              SIZE4440
      GO TO 380                                                         SIZE4450
  337 NI=6                                                              SIZE4460
      GO TO 380                                                         SIZE4470
  338 NI=7                                                              SIZE4480
      GO TO 380                                                         SIZE4490
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339 NI=8                                                                SIZE4500
    GO TO 380                                                           SIZE4510
340 NI=9                                                                SIZE4520
    GO TO 380                                                           SIZE4530
341 NI=10                                                               SIZE4540
380 WRITE(6,804)                                                        SIZE4550
804 FORMAT('0',28X,' SAND, SILT, CLAY, RELATIONSHIPS'/30X,              SIZE4560
   1'  GRAVEL      SAND       SILT       CLAY      TOTAL    SAND/MUD     TYPE')SIZE4570
    NN=3*(NI-1)+1                                                       SIZE4580
    N1=SUBS(NN)                                                         SIZE4590
    N2=SUBS(NN+1)                                                       SIZE4600
    N3=SUBS(NN+2)                                                       SIZE4610
    WRITE(6,87) GRSN,SANDP,SILT,CLAY,SUMPC,RATIO,CLASS(N1),CLASS(N2),   SIZE4620
   1 CLASS(N3)                                                          SIZE4630
 87 FORMAT(' ',29X,F8.2,5F9.2,3X,3A6)                                   SIZE4640
    RETURN                                                              SIZE4650
    END                                                                 SIZE4660
C
C***********************************************************************
C
C     SUBPROGRAM FOR COMPUTING TRASK, INMAN, AND FOLK AND WARD STATISTICS
C
C***********************************************************************


    SUBROUTINE CTIFW                                                    SIZE4670
    COMMON /BLK1/PHIS(8,2),NINM,NFAW,NSSC,SUMNL,NTRSK                   SIZE4680
    REAL*8 ZMEN(20)/'VERY COARSE SANDCOARSE SAND      MEDIUM SAND      FSIZE4690
   1INE SAND        VERY FINE SAND  COARSE SILT     MEDIUM SILT      FINSIZE4700
   2E SILT       VERY FINE SILT  CLAY                '/                 SIZE4710
    REAL*8 DEVI(18)/'VERY WELL SORTED        WELL SORTED             MSIZE4720
   1ODERATELY SORTED        POORLY SORTED           VERY POORLY SORTED SIZE4730
   2     EXTREMELY POORLY SORTED'/                                      SIZE4740
    REAL*8 SKEW(15)/'VERY NEGATIVELY SKEWED  NEGATIVELY SKEWED       NSIZE4750
   1EARLY SYMMETRICAL       POSITIVELY SKEWED       VERY POSITIVELY SKESIZE4760
   2WED  '/                                                             SIZE4770
    REAL*8 KURT(15)/'PLAYTKURTIC             MESOKURTIC              LSIZE4780
   1EPTOKURTIC              VERY LEPTOKURTIC        EXTREMELY LEPTOKURTSIZE4790
   2IC   '/                                                             SIZE4800
    REAL TLFD(7)/0.0,0.35,0.50,1.,2.,4.,99.99/,TLFS(6)/-3.,-.3,-.1,.1,SIZE4810
   1.3,9.99/,TLFK(6)/0.,.9,1.11,1.5,3.,99.99/                           SIZE4820
    REAL HEAD(6)/'4 PT. PHIS  LINEAR PHIS '/                            SIZE4830
    INTEGER ITLFSC(6)/2*1,2,3,4,5/                                      SIZE4840
    DO 1000 LL=1,2                                                      SIZE4850
    IF(NSSC.EQ.1) GO TO 400                                             SIZE4860
C   CALCULATE TRASK VALUES                                              SIZE4870
    PHI5=PHIS(2,LL)                                                     SIZE4880
    PHI16=PHIS(3,LL)                                                    SIZE4890
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      PHI25=PHIS(4,LL)                                                  SIZE4900
      PHI50=PHIS(5,LL)                                                  SIZE4910
      PHI75=PHIS(6,LL)                                                  SIZE4920
      PHI84=PHIS(7,LL)                                                  SIZE4930
      PHI95=PHIS(8,LL)                                                  SIZE4940
      Q1=2.**(-PHI25)                                                   SIZE4950
      Q2=2.**(-PHI50)                                                   SIZE4960
      Q3=2.**(-PHI75)                                                   SIZE4970
      SO=SQRT(Q1/Q3)                                                    SIZE4980
      FLGSO=ALOG10(SO)                                                  SIZE4990
      SKG=SQRT((Q1*Q3)/(Q2*Q2))                                         SIZE5000
      LLL=3*(LL-1)+1                                                    SIZE5010
      LLT=LLL+2                                                         SIZE5020
      WRITE(6,805)(HEAD(LLK),LLK=LLL,LLT),Q1,Q2,Q3,SO,FLGSO,SKG         SIZE5030
  805 FORMAT('0',28X,' TRASK VALUES ',5X,3A4/                           SIZE5040
     *                          29X,'   Q1        Q2         Q3         SIZE5050
     1 SO     LOG SO     SKG'/30X,F6.3,4F9.3,F8.2)                      SIZE5060
      IF(NTRSK.GT.1) GO TO 1000                                         SIZE5070
C     CALCULATE INMAN VALUES                                            SIZE5080
      IF(NINM.GT.1) GO TO 505                                           SIZE5090
      FIMD=(PHI16+PHI84)/2.0                                            SIZE5100
      FIDV=(PHI84-PHI16)/2.0                                            SIZE5110
      FISK=(FIMD-PHI50)/FIDV                                            SIZE5120
      IF(PHI95.EQ. 99.99) GO TO 504                                     SIZE5130
      F2SK=(((PHI95+PHI5)/2.)-PHI50)/FIDV                               SIZE5140
      FIKU=(((PHI95-PHI5)/2.)-FIDV )/FIDV                               SIZE5150
      WRITE(6,806) PHI50,FIMD,FIDV,FISK,F2SK,FIKU                       SIZE5160
  806 FORMAT('0',29X,'INMAN VALUES'/32X,'MEDIAN    MEAN',5X,'DEV.     SKSIZE5170
     1EW.    2ND SKEW.    KURT.'/32X,F5.2,3F9.2,2F11.2)                 SIZE5180
      GO TO 600                                                         SIZE5190
  504 WRITE(6,92) PHI50,FIMD,FIDV,FISK                                  SIZE5200
   92 FORMAT('0',29X,'INMAN VALUES   (COULD NOT CALCULATE 2ND SKEWNESS ASIZE5210
     1ND KURTOSIS)'/30X,'MEDIAN    MEAN      DEV.     SKEW.'/30X,F5.2,  SIZE5220
     23F9.2)                                                            SIZE5230
      GO TO 600                                                         SIZE5240
  505 WRITE(6,93)                                                       SIZE5250
   93 FORMAT('0',28X,' INMAN PLUS FOLK AND WARD VALUES NOT CALCULATED BESIZE5260
     1CAUSE'/29X,' NEXT TO LAST ACCUMULATED PERCENT WAS LESS THAN 84')  SIZE5270
      GO TO 1000                                                        SIZE5280
  400 WRITE(6,91)                                                       SIZE5290
   91 FORMAT('0',28X,' NOT ABLE TO CALCULATE TRASK, INMAN, OR FOLK AND WSIZE5300
     1ARD'/29X,' VALUES BECAUSE NEXT TO LAST ACCUMULATED PERCENT DID NOTSIZE5310
     2'/29X,' EXCEED 72')                                               SIZE5320
      GO TO 1000                                                        SIZE5330
C     CALCULATE FOLK AND WARD VALUES                                    SIZE5340
  600 IF(NFAW.EQ.1) GO TO 601                                           SIZE5350
      WRITE (6,94)                                                      SIZE5360
   94 FORMAT('0',29X,'COULD NOT CALCULATE FOLK AND WARD VALUES BECAUSE NSIZE5370
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     1EXT'/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 I1=2*(I-1)+1
      I2=I1+1
      WRITE (6,807) FMZ,(ZMEN(II),II=I1,I2)
  807 FORMAT('0',29X,'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
      I2=I1+2
      WRITE (6,131) FDEV,(DEVI(II),II=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 ((PHI 5+PHI95)-(2.*PHI50))/(2.*(PHI95-PHI5))
      DO 608 L=1,6
      IF(TLFS(L).GE.FSK) GO TO 609
  608 CONTINUE
  609 IFSKTL=ITLFSC(L)
      I1=3*(IFSKTL-1)+1
      I2=I1+2
      WRITE(6,142) FSK,(SKEW(II),II=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
      I1=3*(IFKTL-1)+1
      I2=I1+2
      WRITE(6,162) FKG,(KURT(II),II=I1,I2)
  162 FORMAT(31X,'KURTOSIS',F8.2,4X,3A8)
 1000 CONTINUE
      RETURN
      END
```

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13 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 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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