RECENT SEDIMENTS IN PUGET SOUND

AND PORTIONS OF WASHINGTON SOUND

AND LAKE WASHINGTON

by

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ABSTRACT

Based on environmental occurrence, grain size distribution, carbonate content, and water content, the sediments of Puget Sound, Washington Sound, and Lake Washington are classified into the following types: shelf sand, slope sand, depositional channel sand, residual channel sand, basin mud, basin mud rich in sand grains, basin sand with mud matrix, lake mud, compacted glacial clay, and dumped materials.

Factors governing water content, salinity of interstitial water, clay ratio, and carbonate content are evaluated. This analysis shows that the carbonate content of the sediments depends on (1) the rate of lime deposition, chiefly as benthonic shell fragments, foraminifera tests, and fine calcareous particles of uncertain origin, (2) the rate of deposition of non-calcareous clastic materials, and (3) the rate of solution of carbonate in the sediments.

A deficiency of granules, coarse sand, and coarse silt in Puget Sound and Lake Washington sediments is explained by sediment transport and the composition of parental glacial deposits.

Streams and shoreline erosion supply annually about 35.5×10^5 metric tons of sediment to Puget Sound, of which about three-quarters is deposited in the Sound at an estimated average overall rate of 0.6 mm per year, and about one-quarter is carried out into the open sea. Puget Sound sediment distribution shows both normal and reverse sediment by-passing as a consequence of the variable currents.

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He is grateful to colleagues of the Oceanographic Laboratories who have given advice and technical assistance, and to Dr. T. G. Thompson, the former director of the Laboratories, and Dr. R. H. Fleming, the Executive Officer of the Department of Oceanography, for making available the M. V. BROWN BEAR, ONCORHYNCHUS, and HYDAH for this study.

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1. INTRODUCTION

1.1 SCOPE AND PURPOSE OF INVESTIGATION

This study, which began in March 1950, is the first geological study of the recent sediments of Puget Sound and Washington Sound. More than two-thirds of Puget Sound and small portions of Washington Sound and Lake Washington (Figure 1) were covered in this investigation, with special emphasis on Elliott Bay and other selected areas illustrating certain environment types.

The objectives of this investigation were:

(a) To study the bottom characteristics and sediment distribution in various marine environments such as estuaries, semi-stagnant embayments, aerated embayments, deltas, steep slopes, mid-channel depressions, nondepositional and depositional tidal channels, and in a contiguous fresh water lake;

(b) To interpret the genetic significance of carbonate content, water content, and other analytical properties of the sediments;

(c) To present a tentative classification of Puget Sound and Washington Sound sediments based on environmental occurrence, sediment texture and size distribution, and carbonate content;

(d) To evaluate the Puget Sound sedimentation budget, based on the annual supply of sediment to Puget Sound by streams and shoreline erosion, the rate of sedimentation in Puget Sound, and the seaward transport of sediments out of Puget Sound; and

(e) To evaluate the sediment by-passing theory and present a stratigraphic concept of sedimentation in epicontinental seas under a humid climate, such as that of Puget Sound.

A total of 112 grab samples, 66 Phleger cores, 23 piston cores, and 5 miscellaneous samples were collected from different areas (Table 1) and analyzed for water content, salinity of interstitial water, color, grain size, and carbonate content. These data were treated statistically and the results are presented in tables, scatter diagrams, histograms, sediment distribution maps, and profile sketches in support of the author's findings. The positions of all samples and cores appear in Figures 2, 3, 4, and 9.

1.2 DESCRIPTION OF THE AREA

1.2a Geography and Topography

The Puget Lowland or Puget Sound Basin is aligned north-south between the Coast Range and Cascade Mountain Range. It extends from the Fraser River on the north to the divide between the Chehalis and Cowlitz River Basins on the south. This divide separates the Puget Lowland from the Willamette Lowland in Oregon and southern Washington.

The main water body of Puget Sound, which is separated from Washington Sound by the Strait of Juan de Fuca, lies in the center of the Puget Lowland. Puget Sound and Washington Sound together constitute a drowned, intricate system of glacially modified narrow channels. In

TABLE 1

DISTRIBUTION AND TYPE OF SAMPLES ANALYZED FROM PUGET SOUND, WASHINGTON SOUND, AND LAKE WASHINGTON

Area	Grab Samples	Phleger Cores	Piston Cores	Misc. Samples	TOTAL
Elliott Bay	78[a]	8	6	2	94
Commencement Bay	4	11	-	-	15
Nisqually Reach	3	4	-	-	7
Puget Sound mid-channel	6	11	-	1[b]	18
Possession Sound and North	-	10	-	-	10
Hood Canal	-	18	-	-	18
Washington Sound	19[c]	-	15	1	35
Lake Washington	1	4	2	1	8
Lake Union	1	-	-	-	1
TOTAL	112	66	25	5	

[a]Six additional grab samples were collected but not analyzed.

[b]Phleger core 18P was collected during the Bonneville Power Line Survey.

[c]Fifteen additional grab samples were collected but not analyzed.

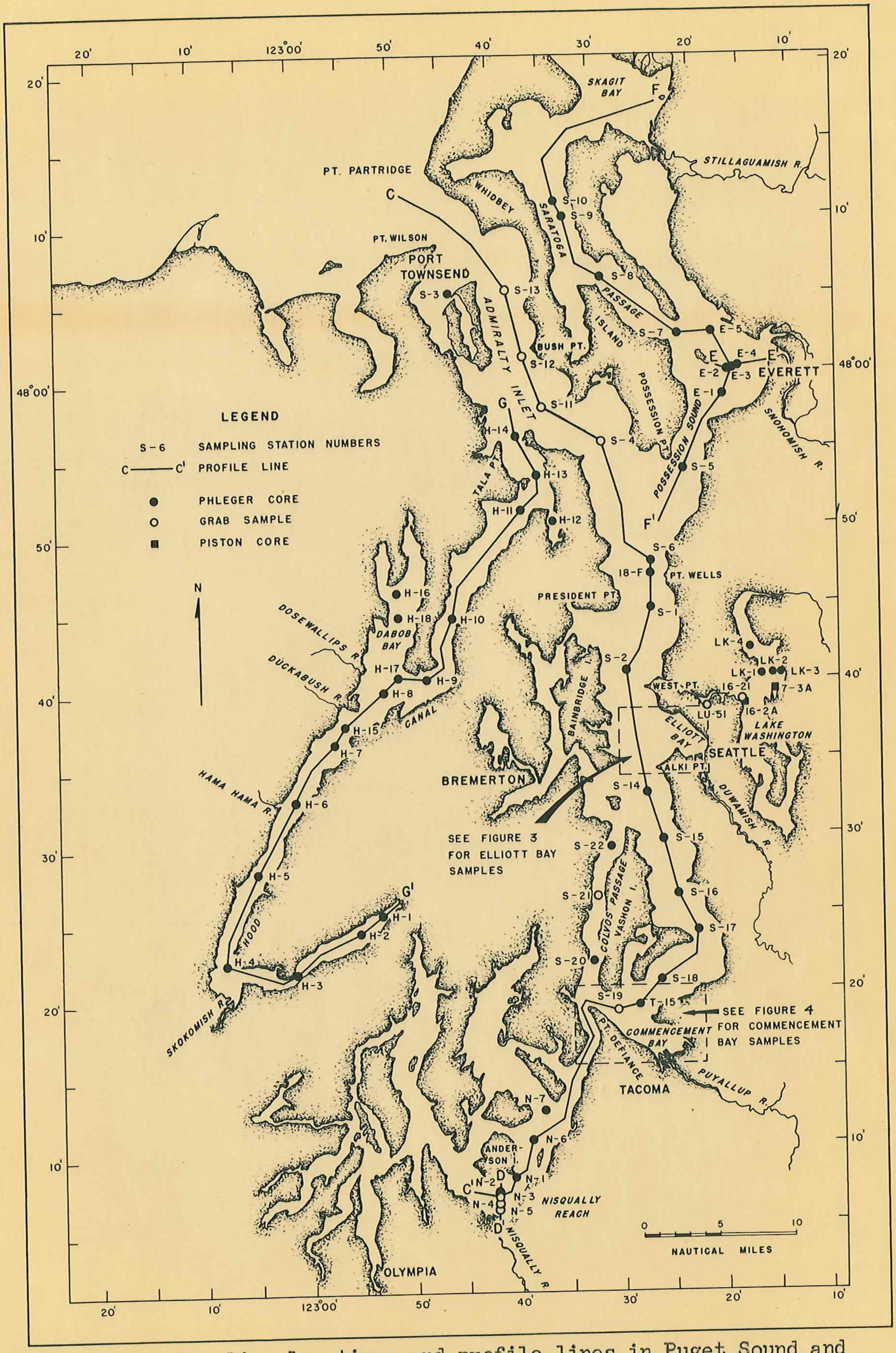

Figure 2. Sampling locations and profile lines in Puget Sound and Lake Washington.

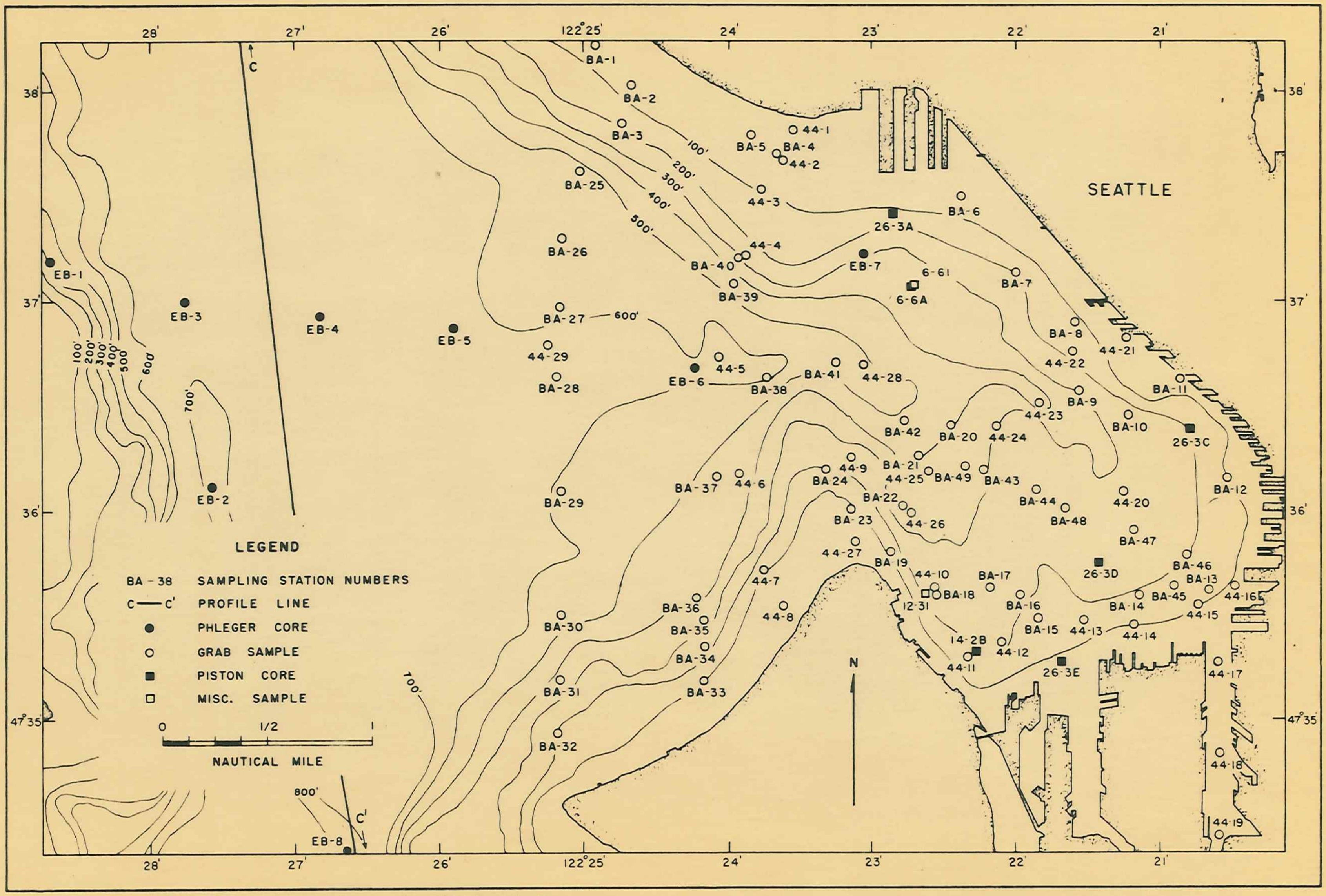

Figure 3. Sampling locations in Elliott Bay.

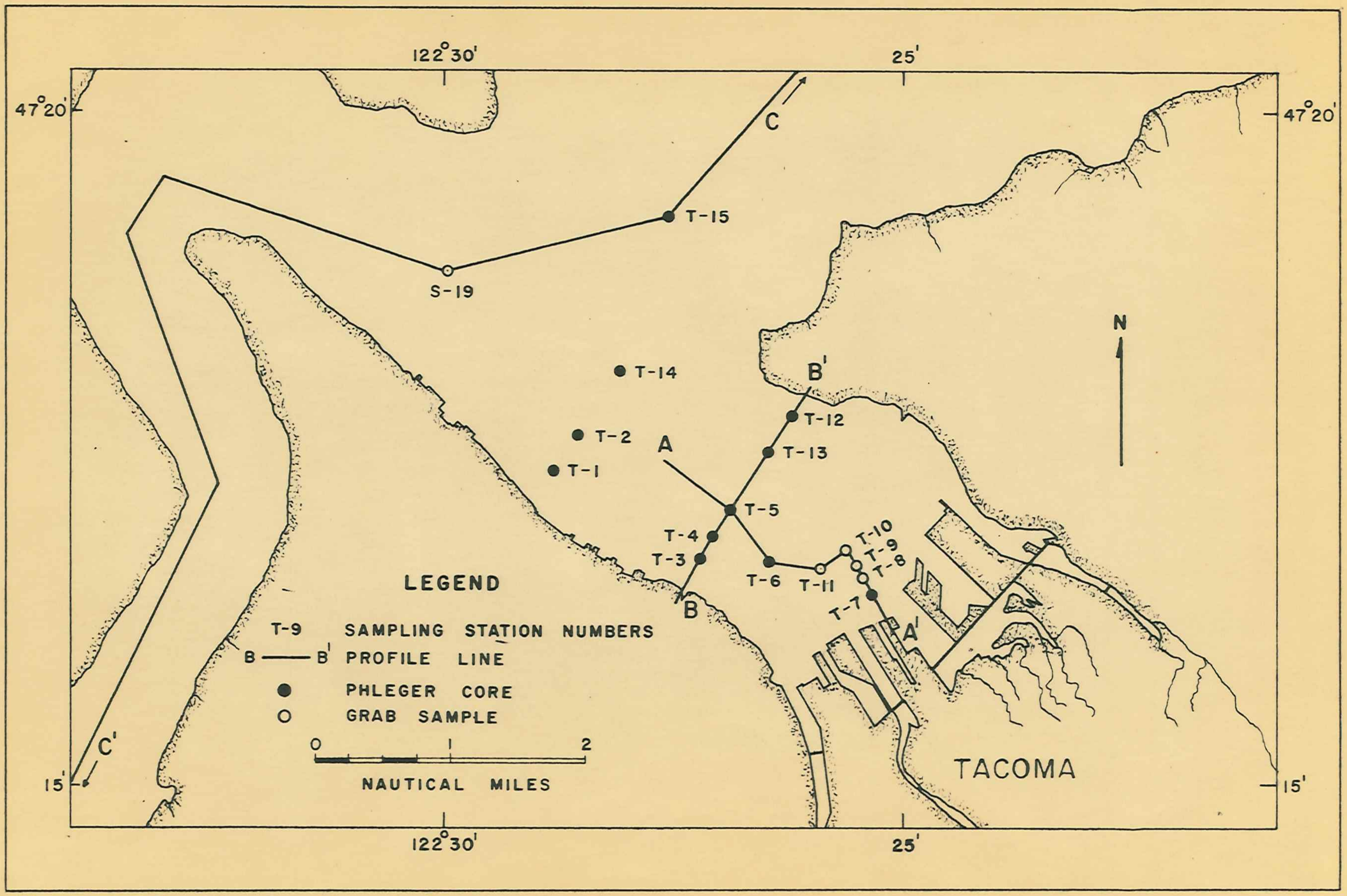

Figure 4. Sampling locations in Commencement Bay.

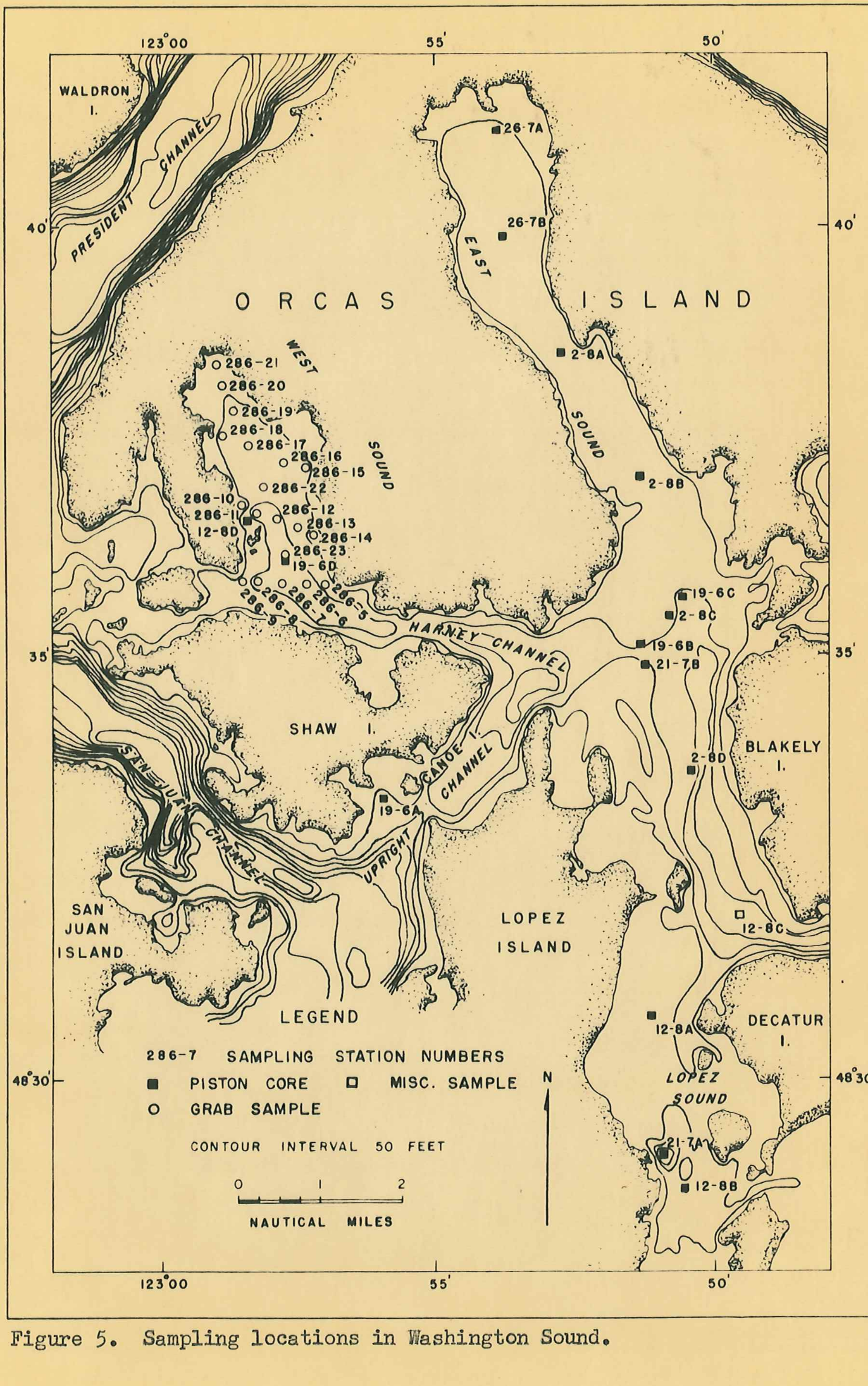

Figure 5. Sampling locations in Washington Sound.

the Puget Lowland, there are also minor troughs filled with fresh-water lakes, such as Lake Washington and Lake Sammamish.

Washington Sound, constituting those waters between the Strait of Juan de Fuca and Georgia Strait, is composed of three main channels or straits; namely, Haro, San Juan, and Rosario, ranging in mid-channel depth from 250 to 1,000 feet. It also embraces numerous smaller channels and several long and shallow estuarine embayments.

Puget Sound is about 75 miles long, extends south from the Admiralty Inlet and Deception Pass and branches into various inlets or "canals" toward its southern end. It occupies an area of 767 square nautical miles, and has a total volume of 26.5 cubic nautical miles. The 1,157 nautical miles of shoreline enclosing Puget Sound is faced mostly by bluffs, composed of glacial deposits, and ranging from 50 to 500 feet in height (University of Washington, Department of Oceanography, 1953 a, p. 1 and p. 4). The bottom in the northern part is steep-sided with the mid-channel floor generally about 600 feet below sea level and reaching a maximum depth of about 900 feet in the deeper holes (Figure 6). In the southern sections, a depth of 300 feet is typical with a maximum of 546 feet in a deep hole near McNeil Island.

According to the major topographic sills or lateral constrictions and general configuration, Puget Sound may be subdivided into four sections; namely,

(a) The main body of Puget Sound (northern and central parts) extending from the 240-foot sill at the entrance of Admiralty Inlet to the 150-foot sill at Tacoma Narrows.

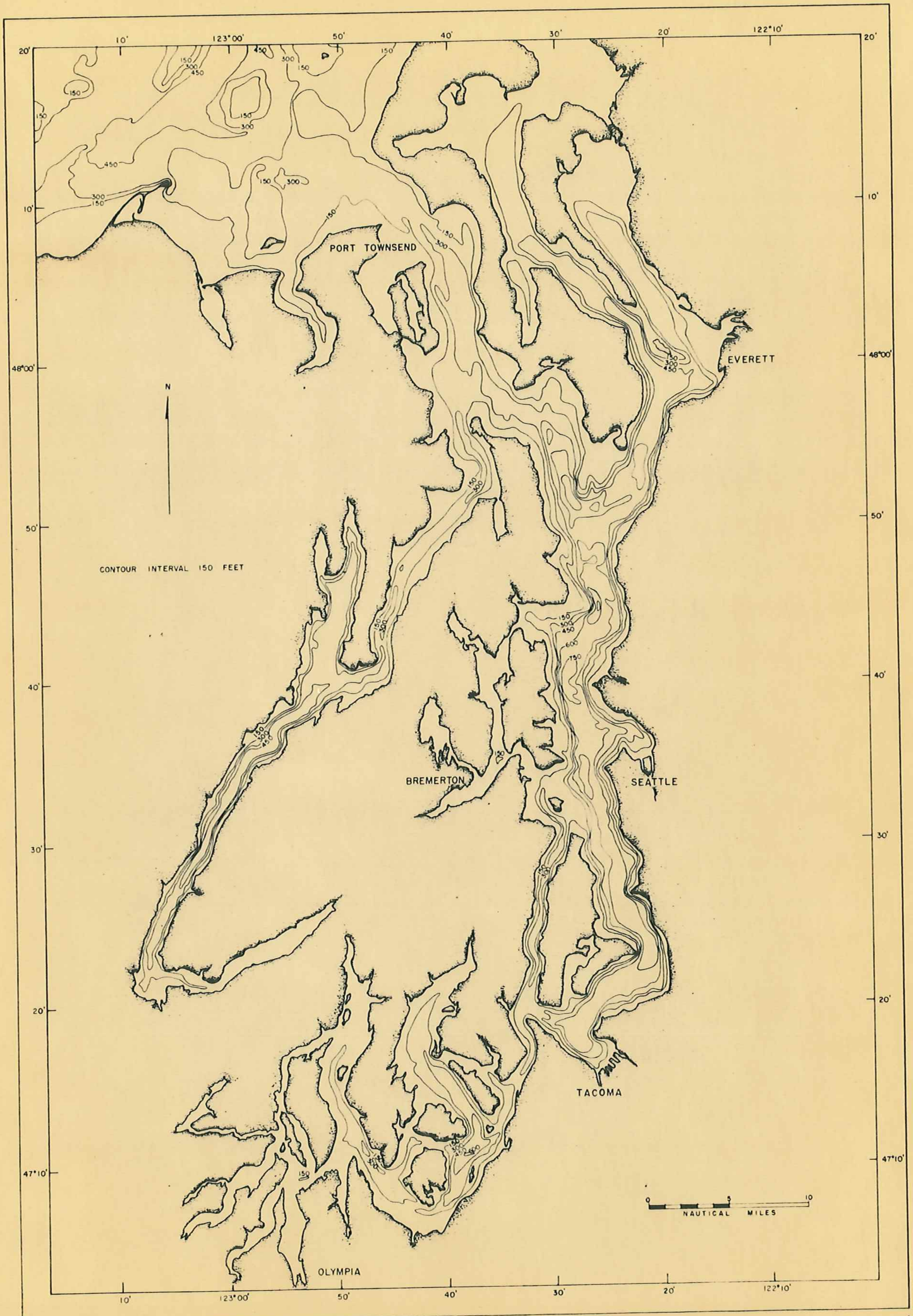

Figure 6. Bathymetric chart of Puget Sound (based on U.S.C. & G.S. Charts).

(b) The Lower Sound (southern part) south of Tacoma Narrows.

(c) Hood Canal which is separated from Admiralty Inlet by a 150-foot sill and extends southward about 50 nautical miles.

(d) Possession Sound and northward, extending from the relatively narrow entrance of Possession Sound which connects the Puget Sound main body without the presence of a sill, to the 96-foot sill at Deception Pass; includes Port Susan, Saratoga Passage, and Skagit Bay.

The drainage area of Puget Sound Basin, estimated at 8,552 square nautical miles (University of Washington, Department of Oceanography, 1953 a, p. 87) feeds 13 principal streams: Skagit, Stillaguamish, Snohomish, Sammamish, Cedar, Duwamish, Puyallup, Nisqually, Deschutes, Skokomish, Hamma Hamma, Duckabush, Dosewallips, Big Quilcene, and Little Quilcene. Glacial materials, largely outwash sands and gravels with smaller amounts of ground moraine and isolated patches of lake and swamp deposits, mantle the lowland part of the drainage area. In the mountainous drainage areas, bedrock is exposed.

1.2b <u>Oceanography</u>

<u>General</u>

Puget Sound and Washington Sound waters show diverse physical and chemical characteristics, varying from the thoroughly mixed, turbulent and swift flowing waters in the narrow tidal channels to stratified and occasionally poorly aerated waters in the long and shallow estuaries.

Temperature

The temperature of surface water in Washington Sound varies generally between 10° C and 11° C in the summer months, and is 2° or 3° lower in winter. In the main body of Puget Sound, the surface waters measure about 14° C in summer and 8.5° C in winter. Slightly lower temperatures are recorded for the bottom waters. Mixing in Tacoma Narrows lowers the temperature to 12° C during the summer months (Thompson and Robinson, 1955, pp. 2104-2105).

The uniformity of temperature with depth and season in Puget Sound and Washington Sound arises largely from tidal mixing in the narrow passages and channels (University of Washington, Department of Oceanography, 1953 c, p. 91). Extreme temperatures, high in summer and low in winter, are to be expected in the shallow water where circulation is poor such as at the heads of closed embayments and along the beaches.

Salinity

Due to the inflow of rivers, Puget Sound and Washington Sound average 1 to 5 °/oo lower in salinity than surface water in the open sea off the Washington coast. The period of lowest salinity is from March to May, following the normal period of heavy precipitation and runoff (University of Washington, Department of Oceanography, 1953 c, pp. 91-92).

In the central portion of Puget Sound's main basin, the salinity of surface waters varies from less than 27.5 °/oo in April and May to 30.0 °/oo in autumn months, and at 600 feet depth it varies annually from 29.5 to 30.5 °/oo (University of Washington, Department of

Oceanography, 1953 a, pp. 91-92). Because of mixing in the Tacoma Narrows, rather uniform salinities of 27 °/oo to 29 °/oo are prevalent at all depths in most of the southern section of the Sound (Thompson and Robinson, 1953, p. 2105).

Dilution by Fraser River runoff reduces the salinity to 24.4 °/oo or lower at the surface of Washington Sound but the bottom waters are only slightly affected (Thompson and Robinson, 1953, p. 2105).

Oxygen Content

The surface waters in Puget Sound and Washington Sound contain about 8 to 10 milligrams of oxygen per kilogram of water, although lower concentrations are observed during the winter months. In places of considerable dilution by river runoff, the dissolved oxygen is as high as 13 milligrams per kilogram of water (Thompson and Robinson, 1953, p. 2105).

Complete stagnation of bottom waters has not been detected in this region. Although the semi-stagnant and poorly-aerated bottom waters in restricted embayments, such as East Sound, West Sound, and Hood Canal, contain some hydrogen sulphide, they generally contain three or more milligrams of dissolved oxygen per kilo, permitting the existence of some benthonic life.

Tides

As elsewhere along the Pacific Coast, the tide of Puget Sound and Washington Sound is of the mixed type, the height difference between successive lows exceeding that between successive highs. The tides also exhibit semi-monthly maxima related to the declination of the moon, and semi-annual maxima near the winter solstice in December and the summer solstice in June (University of Washington, Department of Oceanography, 1953 c, p. 106).

The mean rise of the tide above mean lower low water in Washington Sound is 7.9 feet (Thompson and Robinson, 1953, p. 2103). Within Puget Sound, the range of the tide and its characteristics vary considerably with both time and location. In general, the range increases, and the times of high and low tide are increasingly delayed in passing from the entrance at Port Townsend to the southern end of Puget Sound. The tides at Seattle, which can be considered characteristic of the central section of Puget Sound, have respectively mean and diurnal ranges of 7.6 and 11.3 feet, with the estimated highest and lowest tides (referred to mean lower low) being 14.8 and -4.5 feet, respectively. This gives an estimated range of 19.3 feet (University of Washington, Department of Oceanography, 1953 c, pp. 105-106).

The volume of water within the tidal prism (MHW - MLLW) in Puget Sound is estimated at 1.27 cubic nautical miles (University of Washington, Department of Oceanography, 1953 b, p. 104), of which about 95 percent passes through Admiralty Inlet and 5 percent through Deception Pass (University of Washington, Department of Oceanography, 1953 a, p. 1).

Currents

The tidal currents in Puget Sound and Washington Sound, although actuated by the same force that brings about the tide, bear no constant relationship to the tide, either in velocity or time. The current velocities at any locality in Puget Sound (figures 7 and 8) depend chiefly on the cross-sectional area of the channel and the volume of the tidal prism landward from the particular locality. They are also influenced to some extent by irregular bottom topography, river discharge, and meteorological conditions. Average surface current velocities decrease progressively toward the tributary arms of the Sound. The currents are usually strongest at the surface in mid-channel and decrease in velocity toward the shore and near the bottom.

The greatest velocities occur in constricted channels, such as Admiralty Inlet, Tacoma Narrows, and Deception Pass, which have velocities accompanying tropic tides of 4.2, 5.1, and 7.2 knots, respectively (University of Washington, Department of Oceanography, 1953 c, p. 110). The corresponding surface velocities in the deeper and wider channels are generally less than 1 knot. Under extreme conditions, the estimated mid-channel current between President Point and Point Wells does not exceed 3.3 knots at the surface and 1.4 knots 16 inches from the bottom (University of Washington, Department of Oceanography, 1953 c, p. 131). Normally a net outflow of less saline water occurs at the surface, and an inflow of more saline water at depth.

In Washington Sound, the tidal streams produce strong and complex currents at both surface and depth, bearing no simple relationship between each other nor to the tidal phase.

Wind Waves

Characteristic winds blowing parallel to the channel of Puget

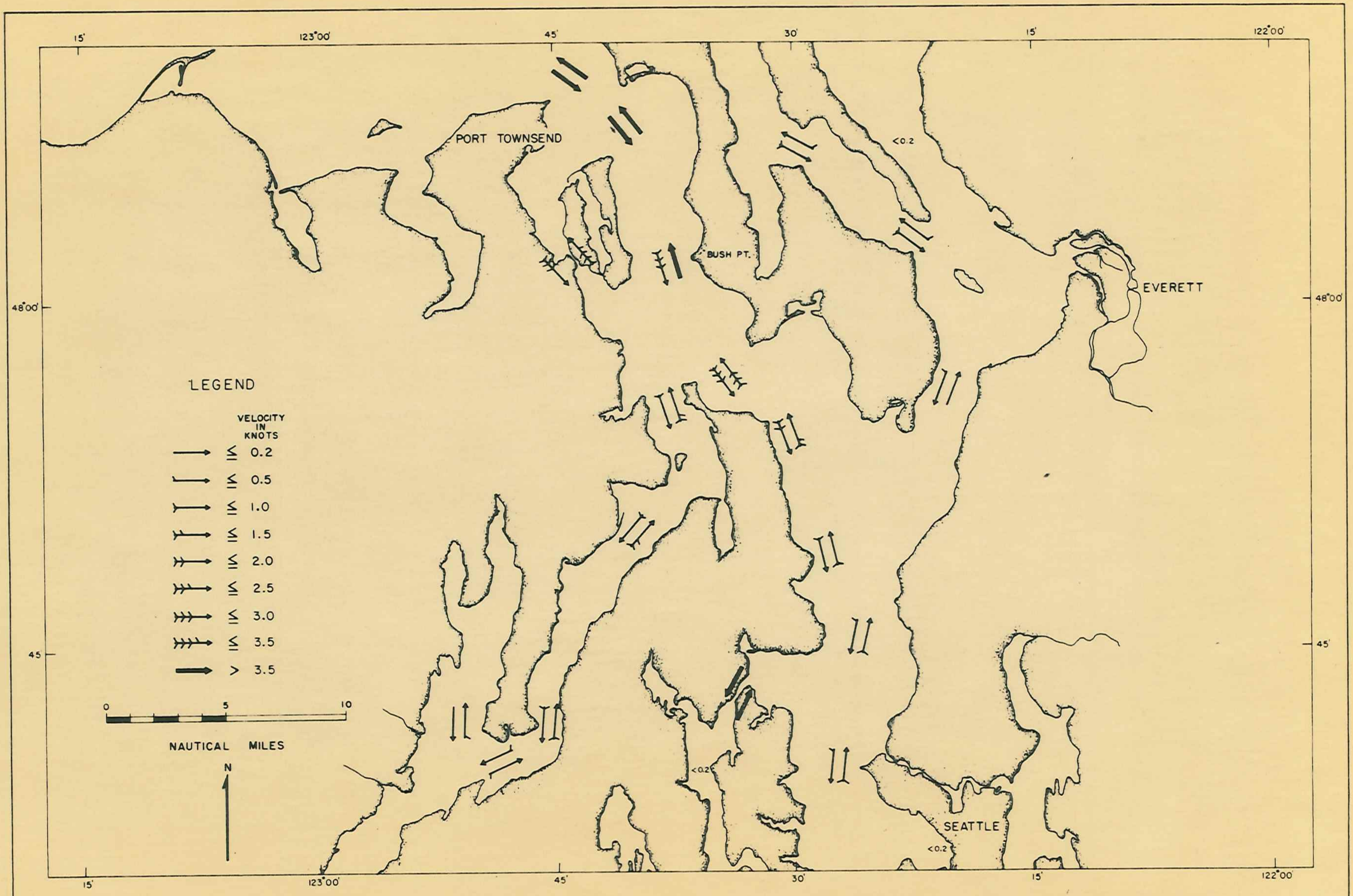

Figure 7. Surface tidal currents in Puget Sound, Port Townsend to Seattle. The arrows show tropic velocities. (Adapted from U.S.C. & G.S. current charts).

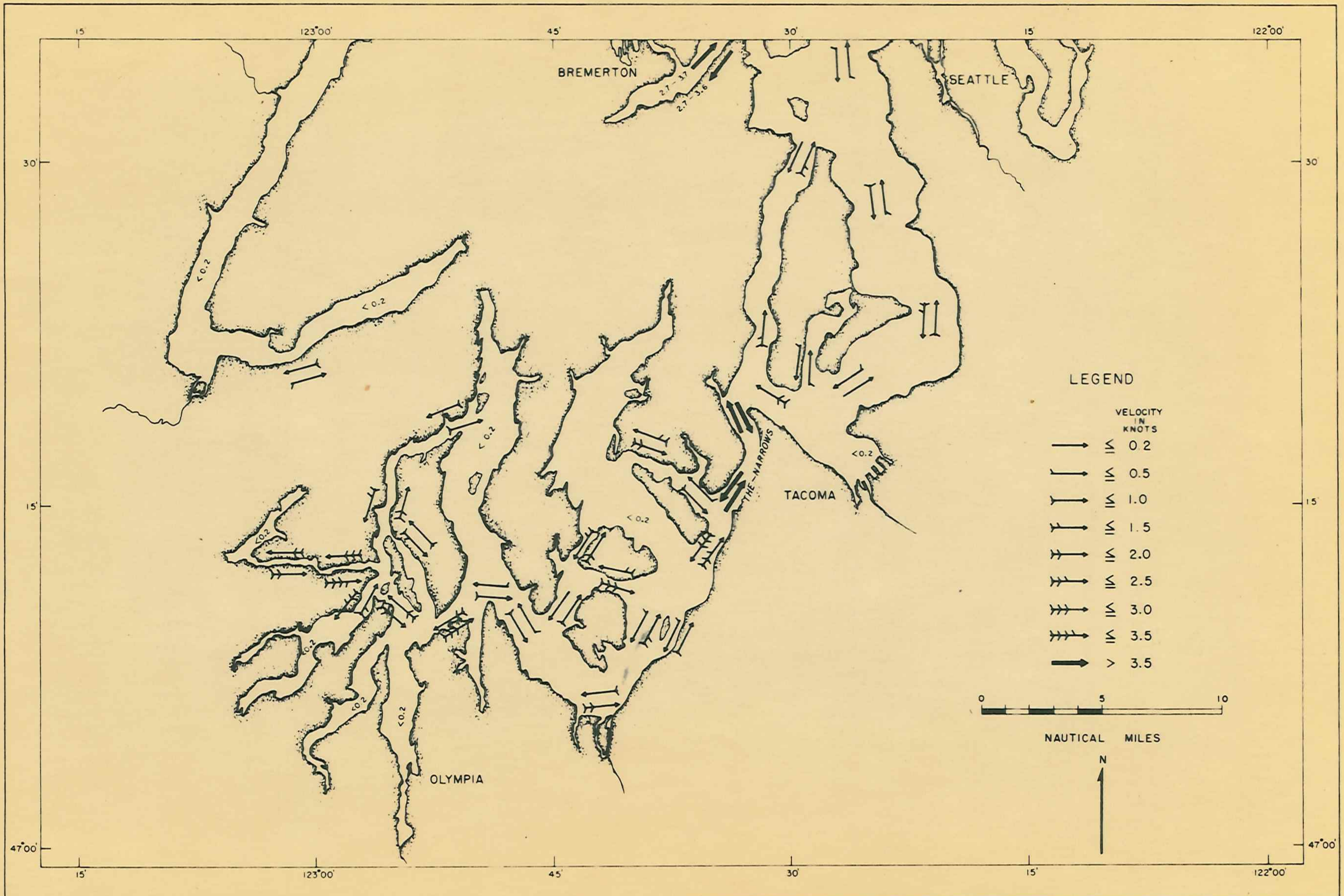

Figure 8. Surface tidal currents in Puget Sound, Seattle to Olympia. The arrows show tropic velocities. (Adapted from U.S.C. & G.S. current charts).

Sound produce waves larger than those produced by cross-channel winds with a smaller fetch.

The average wind in Seattle is somewhat under 10 knots, giving an average wave height of less than 2 feet in Puget Sound. Maximum wave heights in winter do not exceed 12 feet (University of Washington, Department of Oceanography, 1953 c, pp. 107-109).

1.3 REVIEW OF PREVIOUS WORK

The U. S. Coast and Geodetic Survey has measured the tides and tidal currents at key locations in Puget Sound and Washington Sound and publishes annual tide tables, annual current tables, and Puget Sound current charts. Hydrographic charts ranging in scale from 1/5,000 to 1/80,000 are also made by the Coast Survey.

Investigations and research on special topics of physical, chemical, and biological oceanography of this region have been undertaken by the staff of the Department of Oceanography of the University of Washington.

The radioactivity and radium content of Puget Sound and Washington Sound sediments has been studied extensively by Utterback and Sanderman (1938 and 1948), Sanderman and Utterback (1941), Burcham (1942), Wilson (1942), Reinertson (1947), Creager (1948), and Blank (1950).

The Foraminifera in the Puget Sound and Washington Sound sediments have been studied by Cushman and Todd (1947). A total of 77 species belonging to 38 benthonic genera were identified, but no planktonic forms were found. Ray Sleeper (personal communication), in a microscopic examination of core samples along the profile from President Point to Point Wells, found Foraminifera in only one-third of the samples, and that the tests were few in number.

The Department of Oceanography of the University of Washington (1953 c) has completed an investigation of sediments and bottom characteristics along a profile from President Point to Point Wells for the purpose of evaluating the foundation for the submarine portion of a proposed Snohomish-Kitsap 230-KV cable.

Under a research project of the Department of Oceanography of the University of Washington, R. G. Bader (1954) has undertaken geochemical investigations of the sediments.

2. FIELD WORK AND INSTRUMENTATION

2.1 GENERAL STATEMENT

Field work was carried out in Puget Sound, Washington Sound, and Lake Washington during all seasons from April 4, 1950, to September 20, 1952, aboard the research vessels ONCORHYNCHUS, HYDAH, and BROWN BEAR. The samples (Table 1) were collected from predetermined locations according to a sampling grid. The desired amount of sample was also predetermined according to the expected coarseness of the sediments at that locality, a minimum of 125 grams for silty and clayey samples and larger amounts for coarser materials.

Because of the possible change of bottom characteristics in a seasonally varying environment, an effort was made to collect the entire suite of samples from each area during a quiet interval. However, duplicate samples from Elliott Bay collected at nearly identical positions in different seasons do not show any appreciable difference. This may suggest rather uniform environmental conditions from season to season for most of Puget Sound, except possibly in tidal channels and passages.

2.2 METHODS OF DETERMINING POSITION AND DEPTH

The depth of water at stations was obtained by echo-sounding. Positions at sea were determined generally by horizontal sextant angles; the intersection of two or more shore-tangents was frequently used in Washington Sound; radar was employed when the weather was hazy or foggy; and on some occasions positions were determined by comparing sounding lines with the hydrographic chart.

2.3 COLLECTION OF SAMPLES AND CORES

2.3a Grab Samples

A LaFond-Dietz snapper-type sampler (LaFond and Dietz 1948, pp. 34-37) was used to collect samples of mud and sand, and a Petersen-dredge (Hough 1939, p. 661) for coarser materials. To reduce the sampling error, efforts were made to keep the sample container water tight, thus preventing the selective washing of the sample during hauling to the surface.

2.3b Phleger Cores

A gravity core sampler, lined with a 1-3/8" diameter plastic tube, was used in soft bottom to collect short cores varying from 1 to 3 feet in length. Core shortening, resulting primarily from internal sidewall friction in the tube, is estimated at 20 to 40 percent of the depth of penetration.

2.3c Piston Cores

The piston core sampler used during this investigation was fabricated according to Maurice Ewing's modification of Kullenberg's (1947) original device, for the purpose of operating on small vessels with limited winch strength. The sampler, equipped with a 1-1/2" diameter coring tube (10 to 20 feet long) and weighted with 200 to 400 pounds of lead, was allowed 10 to 12 feet of free fall.

The cores were split lengthwise and examined immediately aboard ship. The texture, color, and other physical characteristics served as basis for cutting the cores into 1/2 to 6-inch sections. Each section was scraped clean of surface smears and bottled.

Twenty-three piston-cores were collected from East Sound, West Sound, Lopez Sound, Elliott Bay, and Lake Washington (Table 1). The core lengths range from 32" to 169" with corresponding penetration lengths ranging between 51" and 180". On the average, the core length corresponds to about 85% of the depth of penetration, giving a 15% shortening in core length. Much of the reduction in core length results from smaller diameter of the cutting edge which is 5% less than the inside diameter of the coring tube. Thus in the coring tube, the core is permitted to increase its diameter at the expense of its length. The remaining reduction in core length can be accounted for by the inside friction between the core and tube.

3. LABORATORY WORK

3.1 COLOR

The color of samples were determined by comparison with the Rock-color chart (National Research Council, Rock-color Chart Committee, 1948). In order to avoid color changes during storage due to loss of water, decomposition of organic matter, bacteria, etc., the moist color of a fresh sample was recorded usually within a week after collection. The dry color of the samples was recorded after they had been oven-dried for two hours at 105° C.

The dry color of samples ranges from two to three shades lighter than the corresponding wet color. The hue is often unchanged but sometimes the dried material is slightly more reddish, probably owing to partial dehydration of the hydrated oxides of iron in the sediments.

For most of the cores, the upper few cm were oxidized to browner tint than the underlying sediments.

3.2 WATER CONTENT

The water contents of core sections were determined by weighing approximately 10 grams of wet sediment and drying for two hours at 105° C, after which the sample was weighed again. The difference in wet weight and dry weight expressed in percent of the wet weight of the sample is a measure of its water content. Experiments were made with samples allowing them to dry at 105° C for periods ranging from 1/2 hour to 24 hours. These experiments showed that the samples reached a constant weight after 2 hours of drying and that this period was sufficient for the removal of all interstitial water.

The water content varies from 30 to 70 percent, depending on the texture and compaction of the sediments.

3.3 SALINITY OF INTERSTITIAL WATER

Several milliliters of distilled water were added to 1 to 2 grams of weighed dry sample. This was filtered by repeated washings with distilled water, until all sea salts in the sample had been removed. Chlorine in the filtrate was then titrated with silver nitrate solution, using potassium chromate as an indicator (Sverdrup, Johnson, and Fleming, 1946, p. 30). The result was taken as the amount of chlorine in the dry sample, and computed as salinity of interstitial water in the sediments based on its measured water content.

The salinity of the interstitial water in 10 cores from Washington Sound ranged from 26 °/oo to 30 °/oo, coinciding roughly with the range in salinity of the water in situ at the present time.

3.4 CARBONATE CONTENT

A total of 129 samples, representing different areas of Puget Sound and Washington Sound, were analyzed for carbonate content by the acid digestion method (Revelle, 1944, p. 45). Approximately 1 gram of dry sample, crushed to pass through a 60-mesh sieve, and magnetic grains removed, was treated with 0.2 N hydrochloric acid until effervescence ceased. Additional acid was added and the sample was allowed to stand for 12 hours, in order to assure complete reaction. It was then filtered, washed with distilled water, dried, and weighed. The weight loss resulting from acid treatment was regarded as the total amount of carbonate and recorded as percent in the dry sample.

The carbonate content obtained by this method may be slightly high because small amounts of other mineral constituents, such as pyrite, clay minerals, and organic matter, are attacked by the acid. However, the method is reported to have only 1% error as compared with the carbon dioxide method (Revelle, 1944, p. 45).

It is presumed that the carbonates are present essentially in solid form in the sediments. According to Emery and Rittenberg (1952, p. 785), carbonates are present in essentially solid form in sediments; the carbonates dissolved in the interstitial water amounts to only 0.001 percent of the dry weight.

The carbonate content of the samples analyzed ranges generally from 2 to 12%, with a minimum value of 0.36% and a maximum of 99%.

3.5 GRAIN SIZE (MECHANICAL ANALYSIS)

3.5a Method of Analysis

The size distribution of the majority of samples was determined by combined wet-sieving, dry-seiving, and the pipette method

(Krumbein and Pettijohn, 1938, Chapters 3 and 6).

A sample, ranging in weight from 20 to 100 grams, depending on its coarseness, was first soaked in distilled water and washed repeatedly by decantation to remove sea salts. It was then shaken for 30 minutes in the presence of sodium hexametaphosphate on a rotary shaker and washed through a 200-mesh seive. The material retained on the screen was dried and placed in a set of seives (Table 2) which was then shaken for 15 minutes on a Ro-Tap shaker. The separate size fractions obtained were weighed and recorded. The fractions finer than 200-mesh obtained by wet and dry seiving were combined and analyzed by the pipette method.

Pipette determinations were made for sizes between 0.0625 to 0.00049 mm (1/2 μ), which is well within the range covered by Stoke's law (Revelle, 1944, p. 75).

Extraneous fragments, such as pieces of coal, cinder, glass, and concrete, and complete shells, which were transported and deposited by other than natural physical agencies, were discarded and are not included in the size analysis. Only the minute shell fragments and wood fragments, which displayed a fair range of size distribution indicating that they were transported and deposited together with sediments by physical agencies in situ, were counted in the size distribution.

5.5b Method of Presenting Data

The Wentworth grade-scale in millimeters and its corresponding phi-scale (Krumbein and Pettijohn, 1938, p. 85, p. 90, and p. 244) were used for presenting mechanical analysis data (Table 2).

The mechanical analysis data were computed into weight percentages and then presented as cumulative frequency curves by using phi-diameter as the independent variable (i.e., abscissa) and cumulative percentage as the dependent variable, both in the arithmetic scale.

Cumulative frequency curves for all samples analyzed were compared and grouped genetically into 29 main types. This classification was based on the correspondence of individual curves and their resemblance in slope and curvature, particularly the curvature of tails near both the coarser and finer ends. Several types of cumulative curves are illustrated in Figure 9.

For evaluating the hydrodynamic significance of the origin of sediment types (Doeglas, 1946, p. 19, p. 30), cumulative curves were plotted on arithmetic probability paper (Figure 10) to determine whether they give single straight lines, or curves consisting of several straight line-segments. Clay grades (< 0.0039 mm) were left out of this presentation since the natural suspended state of clay cannot be reproduced in mechanical analysis.

From each cumulative curve, the 10-percentile (P10ø), 25-percentile or first quartile (Q1ø), 50-percentile or median-diameter (Mdø), 75-percentile or third quartile (Q3ø), and 90-percentile (P90ø) were recorded in the phi-scale, and then converted into statistical measures according to the following equations.

TABLE 2

GRADE SCALES OF SIZE USED IN ANALYSIS

Wentworth Scale[a] (diameter in mm.)		Phi-scale[b]	A.S.T.M. Mesh Number[c]	Name
16.00		-4.0		
8.00		-3.0	2½	Pebble
4.00		-2.0	5	
2.00		-1.0	10	
1.00		0.	18	
0.500	1/2	1.0	35	Sand
0.250	1/4	2.0	60	
0.125	1/8	3.0	120	
0.074		3.75	200	Fine Sand
0.0625	1/16	4.0		
0.0312	1/32	5.0		
0.0156	1/64	6.0		Silt
0.0078	1/128	7.0		
0.0039	1/256	8.0		
0.00195	1/512	9.0		
0.00098	1/1024	10.0		Clay
0.00049	1/2048	11.0		
< 0.00049	< 1/2048			Colloidal clay[d]

[a]Krumbein and Pettijohn, 1938, p. 80.

[b]Krumbein and Pettijohn, 1938, pp. 84-85.

[c]Krumbein and Pettijohn, 1938, p. 81.

[d]Twenhofel, 1950, p. 201: Particles finer than 1/2 m are defined as colloidal clay.

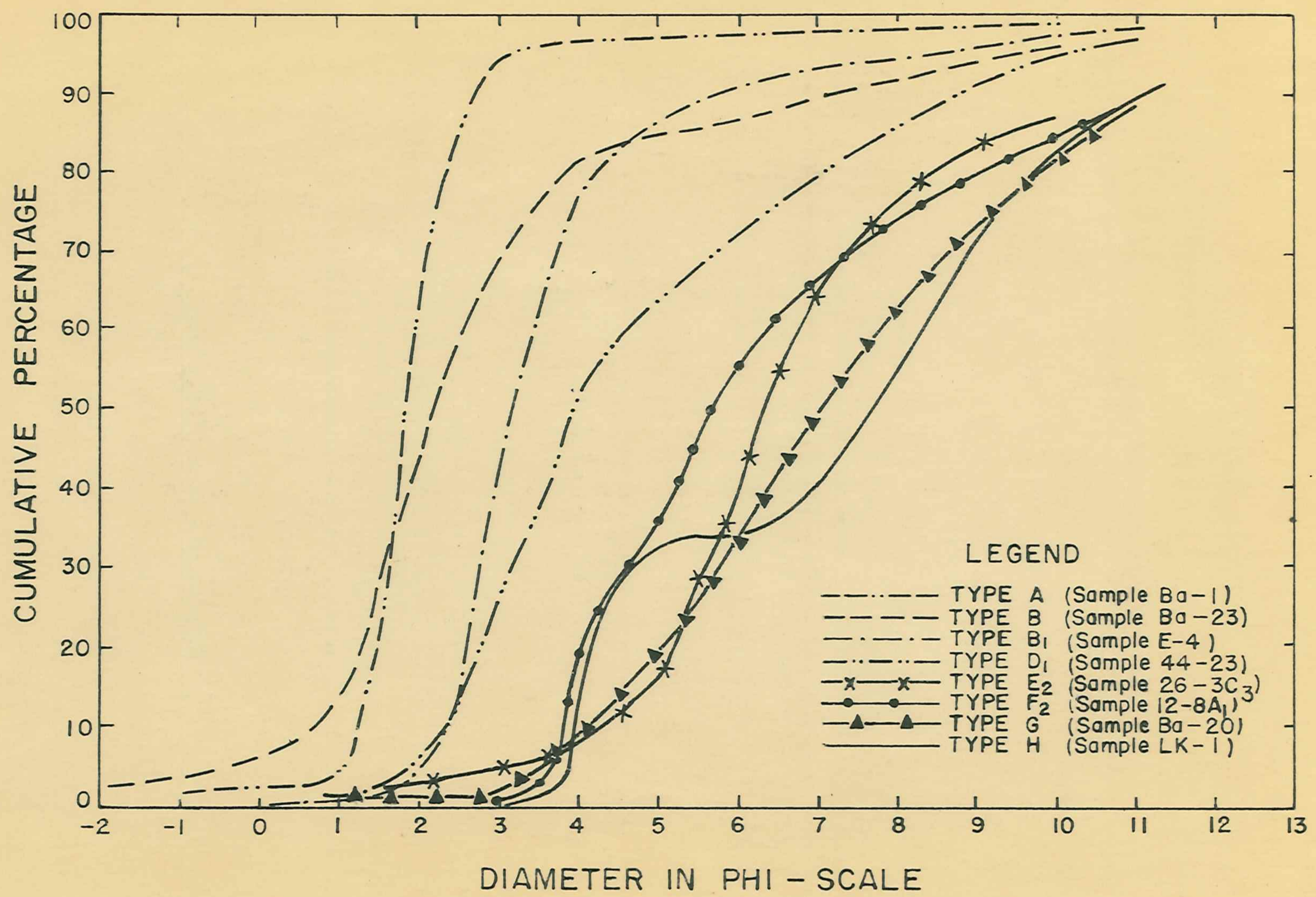

Figure 9. Typical cumulative frequency curves of Puget Sound, Washington Sound, and Lake Washington sediments plotted according to phi-scale.

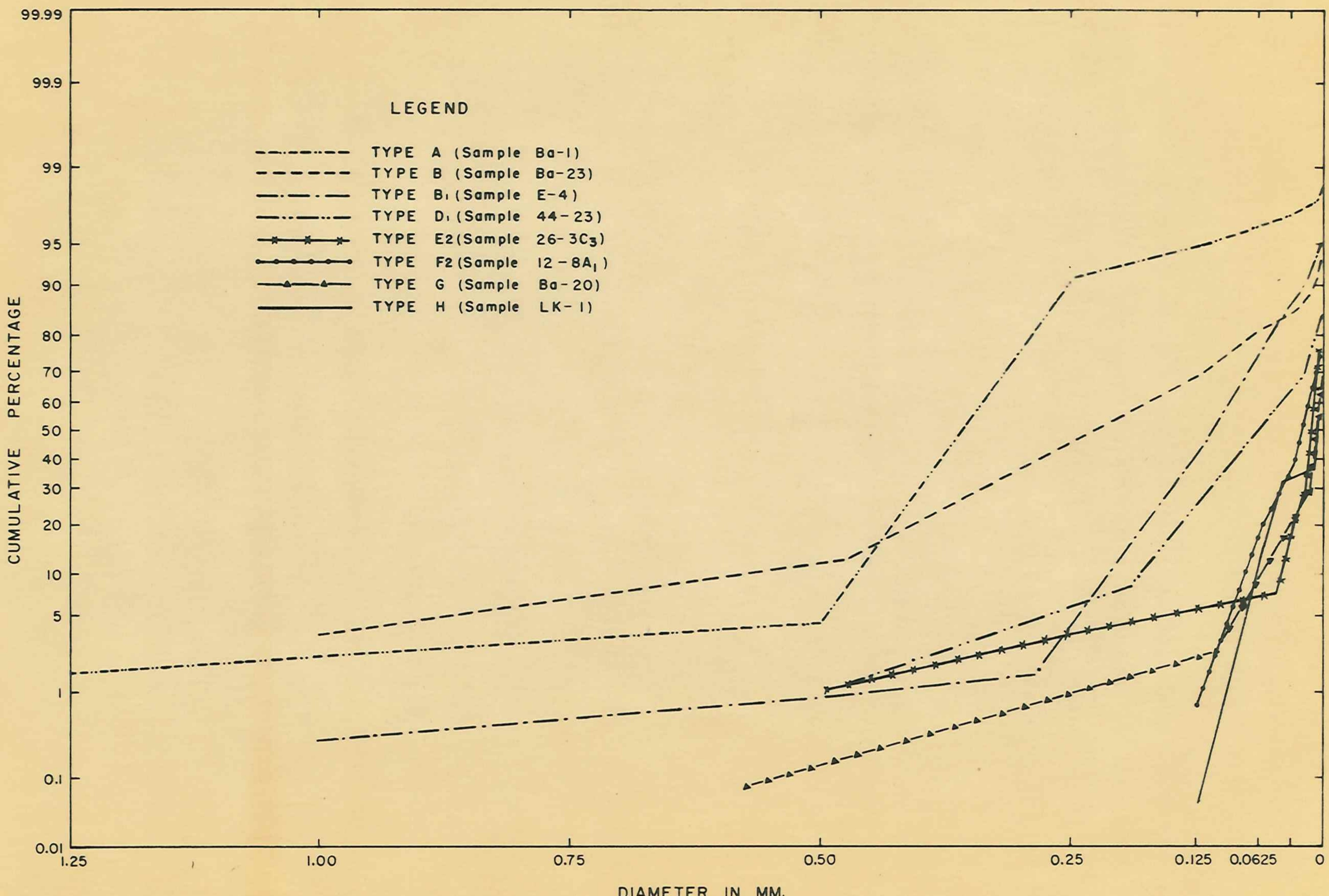

Figure 10. Typical cumulative frequency curves of Puget Sound, Washington Sound, and Lake Washington sediments plotted on arithmetic probability paper.

The median diameter is the mid-point or 50-percentile of the cumulative size-frequency curve (Krumbein and Pettijohn, 1938, p. 229). The median diameter in phi-units can be converted easily into the millimeter scale by a conversion chart (Krumbein and Pettijohn, 1938, Figure 112 on p. 234). Since the size frequency distribution of a deposit indicates the frequency distribution of current velocities that prevailed during deposition (Douglas, 1946, p. 36), it follows that the median diameter may indicate to some extent the predominant velocity of prevailing currents.

The quartile deviation or sorting coefficient in phi-units (QDø) is equal to half of the number of Wentworth grades lying between the first and third quartiles and is expressed as $QD\phi = (Q3\phi - Q1\phi)/2$ (Krumbein and Pettijohn, 1938, pp. 230-234). Trask's sorting coefficient (Sø) is defined as $Q1/Q3$, where Q1 is the third quartile and Q3 is the first quartile, or as the arithmetic equivalent of quartile deviation (Krumbein and Pettijohn, 1938, pp. 230-231). The values of QDø and Sø can be mutually transformed by means of a conversion chart (Krumbein and Pettijohn, 1938, Figure 110 on p. 235). Based on comparison of sediment types, it is concluded that values of QDø less than 0.5 indicate excellent sorting; less than 1.5, good sorting; about 1.60, normal sorting; between 2.0 and 2.5, poor sorting; and greater than 2.5, extremely poor sorting.

The degree of sorting of a deposit is largely a function of the effectiveness of currents and waves as sorting agents. Generally a less variable current produces a better degree of sorting.

Quartile skewness, defined as $SKq\phi = (Q1\phi - Q3\phi) - Md\phi$, is a measure of the degree of asymmetry of the size distribution, showing the relative position of the mode with respect to the median (Krumbein and Pettijohn, 1938, p. 236). A positive value indicates the frequency curve is skewed in the direction of the positive ϕ axis, or in other words, there is more fine-grained material than coarse-grained. Similarly, a negative value means that more of the material is course grained (Krumbein and Pettijohn, 1938, pp. 237-238). The genetic meaning of skewness is still not fully understood, but doubtedless is related tothe mechanical composition of sediment load originally carried by transporting agents, the manner of differenciation during transportation, and mixing of various sized sediment particles during deposition.

Quartile Kurtosis, defined as $Kq\phi = (Q3\phi - Q1\phi)/2(P90\phi - P10\phi)$, is a measure of the peakedness of the frequency size distribution curve (Krumbein and Pettijohn, 1938, p. 238). Kurtosis decreases in value with increasing peakedness. Being a ratio of two spreads, it is independent of the unit of measurement used. Similar to sorting coefficient, Kurtosis is also related to the selective process of transportation. Lower Kurtosis value or higher degree of peakedness is generally accompanied by higher degree of sorting.

The modal grain diameter is defined as the diameter which is most frequent in the size distribution, and therefore lies directly at the peak of the frequency curve (Krumbein and Pettijohn, 1938, p. 245). Sediment size frequency distribution may be unimodal or multiple-modal, depending whether one or more modes are present.

For each sample, percentages of the four main size grades, gravel, sand, silt, and clay, were recorded. The clay ratio is defined by the author as the ratio between the amount of colloidal clay (0.0049 mm) to the total amount of clay (0.0039 mm).

3.3 <u>Textural Classification</u>

Modified after Niggli's classification (1938), the author has presented a textural and nomenclatural system of classification for sediment aggregates based on quartile measures of size distribution (Figure 11). If both the first and third quartiles fall within the limits set for any given size grade, the unmodified term such as "clay" is used. A compound name is applied, if one quartile falls in one size class and the other quartile in another class.

Using the same nomenclatural system, the author has presented also a new textural system of classification for clastic sediments based on their median diameters and coefficients of sorting (Figure 12), assuming that the size distribution is absolutely symmetrical or $Md\phi = (Q1\phi - Q3\phi)/2$. According to this classification, the descriptive name of a sediment aggregate is based on its median diameter and coefficient of sorting. And, conversely, the median diameter and

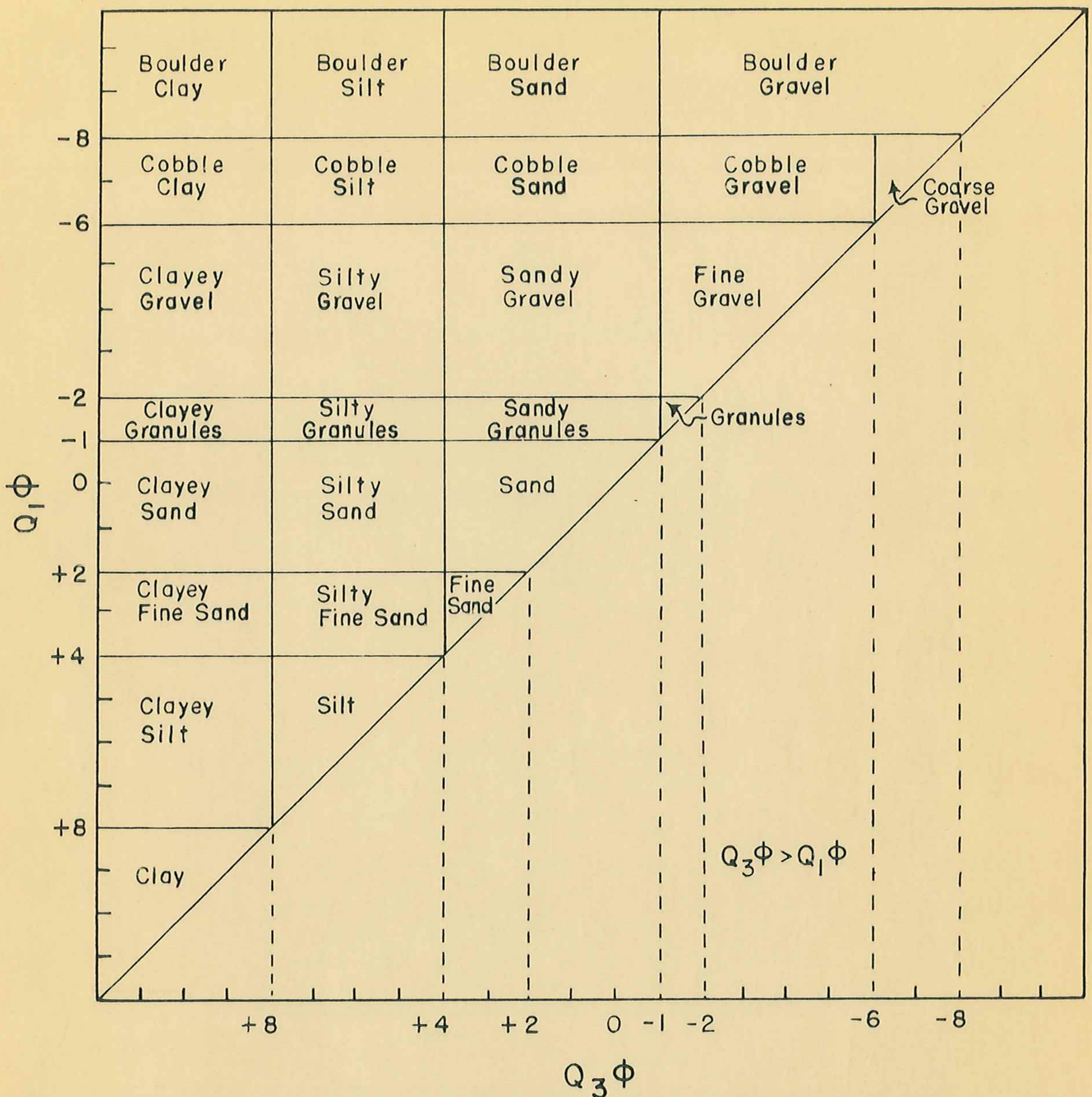

Figure 11. Textural classification of clastic sediments based on quartile measures (modified after Niggli).

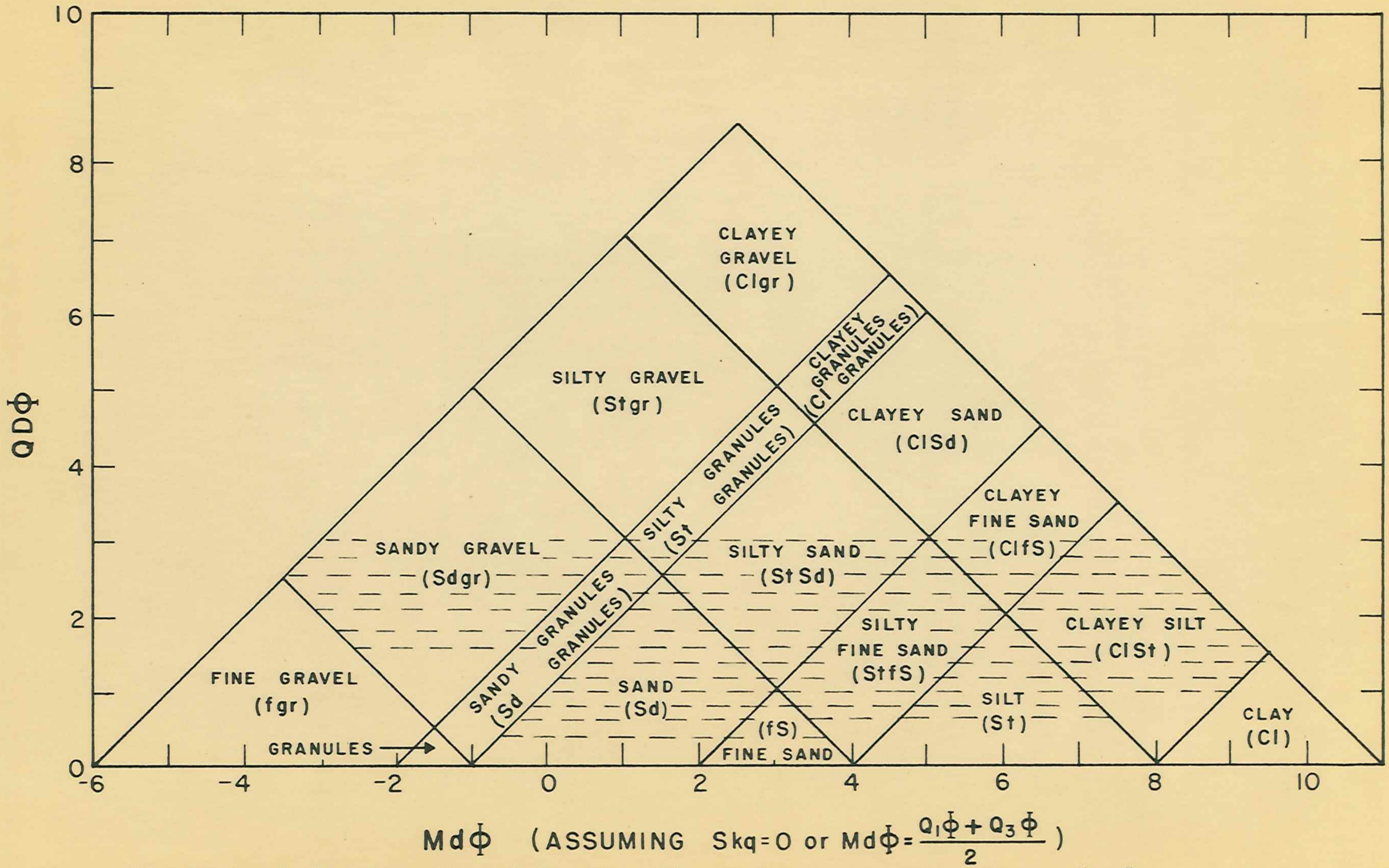

Figure 12. Textural classification of clastic sediments based on median diameter (Mdϕ) and sorting coefficient (QDϕ) (modified after Niggli).

coefficient of sorting can be determined when the name of a sediment aggregate is known.

3.6 EVALUATION OF SAMPLING AND LABORATORY ERRORS

Based on duplicate sample sets taken from Elliott Bay within 200 yards of each other, the total sampling and laboratory error was evaluated in terms of percentage of deviation in phi median diameter (Table 3). The basin sediments in Elliott Bay have an average value of 1.7% of deviation in Mdø (Table 3) with a corresponding probable error of 1.15% (Table 4), excluding the enormously high values of two sets of samples which involve either dumped materials or questionable data.

Independent sampling and laboratory errors were then computed. As shown in Table 4, they are insignificant

The sampling error has a limited range for any type of sediment, depending on its heterogeneity. The small sampling error for the comparitively homogeneous basin sediments in Elliott Bay also holds true for the sediments in mid-channel depressions and basin mud elsewhere. Owing to their extreme heterogeneity, slope sediments in Puget Sound have an extremely high sampling error, as gravels and mud are sometimes intermixed or occur close together.

In general, the total sampling and laboratory error is small and has no serious effect on sedimentary data for the areas investigated, as the variation of median diameter and other measures among successive samples is usually several times the value of the total error. In a few

TABLE 3. BASIC DATA FOR ELLIOTT BAY SEDIMENTS USED IN EVALUATING SAMPLING AND LABORATORY ERRORS

Sample Number	Date of Collection	Position Lat. N.	Position Long. W.	Water Depth (feet)	Distance from shore (yards)	Distance between 2 Stations (yards)	Mdφ	Mean Mdφ	Deviation in Mdφ	% of Deviation in Mdφ
Ba-4	Dec 4, '51	47°37'41"	122°23'39"	42	390	120	2.03	2.165	0.14	6.23[a]
44-2	Apr 4, '50	37'49"	23'37.5"	41	450		2.30			
44-4	Apr 4, '50	37'13"	23'53"	260	1400	100	2.31	2.28	0.03	1.31
Ba-40	Apr 10, '52	37'12"	23'55"	324	1460		2.25			
6-6A1	June 6, '51	37'04"	22'42.5"	348	1330	<15	7.25	7.235	0.02	0.21
6-61	June 6, '51	37'04"	22'42.5"	348	1330		7.22			
Ba-43	Apr 10, '52	36'11"	22'13"	318	1400	200	7.24	7.275	0.04	0.48
Ba-49	Apr 10, '52	36'11.5"	22'21"	348	1320		7.31			
Ba-13	Dec 13, '51	35'36.5"	20'38"	132	300	140	3.77	3.76	0.01	0.27
44-15	Apr 4, '50	35'32"	20'45"	106	370		3.75			
44-26[b]	Apr 4, '50	35'58"	22'45"	348	660	150	4.52		1.32	22.60
Ba-22	Dec 13, '51	36'01"	22'47"	360	680		7.16			
Ba-18	Dec 13, '51	35'35"	22'32"	282	430	130	4.88	3.315	3.32	100.00
12-31[c]	Mar 12, '51	35'36"	22'38"	250	320		-1.75			

[a]Average deviation in Mdφ for 5 sets of duplicate samples from Ba-4 to 44-15 is 1.7%.

[b]Analytical data of this sample is questionable.

[c]Sample is dumped material.

TABLE 4

SAMPLING AND LABORATORY ERRORS FOR BASIN SEDIMENTS IN ELLIOTT BAY

Average Value of Error	Total Error E[a]	Independent Errors		
			Laboratory error e_2[b]	
		Sampling error e_1 due to horizontal and vertical inhomogeneity of sediments, nature of sampler used, and location of error.	e_{2a} Error due to sample splitting, seiving, and pipetting.	e_{2b} Error due to weighing samples, and computing and plotting data.
% deviation in Mdϕ	1.7	1.46	0.54	0.68[c]
% probable error[d] in Mdϕ	1.15	0.99	0.36	0.46

[a] Krumbein and Pettijohn, 1938, p. 266. The total error is related to sampling and laboratory errors by the expression, $E = \sqrt{(e_1)^2 + (e_2)^2}$.

[b] The total laboratory error is related to independent errors by the expression, $e_2 = \sqrt{(e2a)^2 + (e2b)^2}$. e2 was arrived at 0.87% of deviation in Mdϕ, based on duplicate analyses of two test samples split from the same field sample ($14\text{-}2B_{10}$).

[c] Value based on duplicate procedures of weighing, computing, and plotting the same set of sieve and pipette fractions for sample $19\text{-}6A_1$.

[d] Krumbein, 1934, pp. 205-206, probable error = $0.6745\sqrt{\frac{\Sigma(d)^2}{N}}$, where N is the number of observations, and d is the difference between an individual observation and the mean of N observations.

places in the deeper portion of Elliott Bay where the variation among successive samples is so small that it approaches the order of magnitude of the total error, it would be difficult to determine whether the fluctuations are due to sampling and laboratory errors or the variation of the sediment.

4. SEDIMENT TYPES AND GENERAL DISTRIBUTION

4.1 GENERAL DISTRIBUTION OF SEDIMENTS

Charts showing the distribution of sediments in Puget Sound appear in Figures 13, 14, and 15. They are based on bottom notations of U. S. Coast and Geodetic Survey hydrographic charts, Canadian hydrographic charts, and the author's sampling and analytical data (Table 5).

The bottom materials are grouped into five classes: (1) mud, (2) sand, (3) gravel, (4) rock, and (5) mixtures of rock, gravel, and sand. Symbols indicating areas of prolific shell growth and accumulation are superimposed on the chart. A description of the sediment types and their depositional environments is given in Table 6. Mud is the most wide-spread sediment type in Puget Sound, occurring in mid-channel basins, estuaries, embayments, inlets, and deltas. It covers about two-thirds of the whole area. Sand occurs in shallow water near shore, in tidal channels, deltas, and on slopes, and occupies about one-sixth of the whole area. The remaining areas are gravel, rock, and mixtures of rock, gravel, and sand. These materials are restricted to tidal channels, banks, and slopes.

TABLE 5

SOURCES OF BASIC DATA USED IN PREPARATION OF SEDIMENT CHARTS

Base Chart	Scale of Base Chart	Charts Furnishing Supplementary Data	Additional Data
6460[a], Puget Sound Seattle to Olympia	1/80,000	6407, 6446, 6447, 6449, 6461	Author's Samples
6450, Puget Sound Admiralty Inlet to Seattle	1/80,000	6404, 6405, 6421, 6422, 6445, 6446, 6449	Author's Samples
6376, Anacortes to Skagit Bay	1/25,000	None	None
6378, Bellingham Bay	1/40,000	None	None
6407, Tacoma Harbor	1/15,000	None	Author's Samples
6380, Strait of Juan de Fuca to Georgia Straight	1/80,000	Canadian Charts 3422, 3450, 3451, 3499	Author's Samples

[a]Numbers designate U. S. Coast and Geodetic Survey Hydrographic Charts unless otherwise indicated.

TABLE 6

GENERAL TYPES OF PUGET SOUND SEDIMENTS AND BOTTOM CHARACTERISTICS (LEGEND FOR FIGURES 13, 14, 15)

Sediment Type	Bottom Notations of U. S. Coast and Geodetic Survey Hydrographic Charts	Sampling and Analytical data[a] Obtained by the Author	Occurence
Mud	M, gy M, gn M, bl M, bk M, br M, Cl, sft, stk	Clay, silt, clayey silt, fine sand, silty fine sand, clayey fine sand	Estuaries, embayments, inlets, mudflats, delta bottom-set beds, mid-channel basins and deep holes.
Sand	S, gy S, hrd (some of)	Sand, silty sand, clayey sand, granules, sandy granules, silty granules	Shallow water shelf zone, tidal flats, delta top-set and fore-set beds, depositional tidal channels, mid-channel steep slopes with temporary deposits.
Gravel	G, hrd (some of)	Gravel, sandy gravel	Non-depositional tidal channels, submarine banks, and non-depositional mid-channel steep slopes.
Rock[b]	Rd, rky, hrd (some of)	Angular fragments collected in sample or nothing recovered by repeated sampling.	
Mixture of rock, gravel, and sand	Mixed notations of Rk, rky, G, S, hrd	Rock, gravel, and sand samples collected within a short distance.	
Shell	Sh	Sample rich in shells of shell fragments.	

[a]Terminology of textural description defined in Figure 11.

[b]Including partially consolidated glacial deposits.

While the bottom notations on hydrographic charts are not very precise, they still yield a general pattern of sediment distribution and, in most cases, check fairly well with the author's sampling and analytical data.

The boundary lines between different types of sediment are somewhat arbitrary and generalized because of the incompleteness of bottom notations and the transitional nature of the sediments.

4.2 ENVIRONMENT

On the basis of environmental occurrence and bottom characteristics, Puget Sound and Washington Sound are classified into three main environmental groups: (1) areas of erosion and non-deposition, (2) regions of temporary deposition, and (3) areas of continuing deposition, each of which in turn is subdivided into other environmental types. Examples of these are presented in Table 7.

4.3 SEDIMENT TYPES

Based on their environmental occurrence, sediment texture, median diameter, sorting coefficient, skewness, and carbonate content, the sediments of Puget Sound, Washington Sound, and Lake Washington are classified into nine types, each of which is characterized by a given range of sediment characteristics (Table 6).

(a) "Shelf sand", texturally consisting of excellent to well-sorted sand, fine sand, silty fine sand, and silty sand, generally occurs between 0 to 250 feet in depth in strongly agitated shallow-water

TABLE 7

SEDIMENTARY ENVIRONMENT IN PUGET SOUND, WASHINGTON SOUND, AND APPROACHES

Environment Type		Examples	Bottom Characteristics[a]	Environmental Conditions
Erosional and non-depositional environment[b]	Non-depositional tidal channels	Admiralty Inlet Tacoma Narrows Guemes Channel (Anacortes) Hammersley Inlet (Shelton) San Juan Channel	Rk, G, Mix., and Sh. Rk, and Mix. G and Sh. S, G, and Rk Rk, G, Mix., and Sh.	Vigorous bottom currents, prolific benthonic life.
	Submarine banks	Mid-Channel Bank (Port Townsend) Dallas Bank (Juan de Fuca Str.)	Rk and G. Rk, S, G, and kelp.	Strong waves and currents, occasional kelp growth.
	Non-depositional steep slopes	Steep slopes of Puget Sound Mid-Channel	Rk, G, and Mix.	Currents and gravity prevent deposition on steep slopes.
Environment of temporary deposition	Steep slopes with temporary deposition	Moderately steep slopes of Puget Sound Mid-Channel	Thin sand patches accumulated on rocky slopes.	Temporary deposition when supply exceeds transportation or currents become weaker.
Depositional environment	Depositional tidal channels	Colvos Passage Saratoga Passage Hood Canal Entrance Nisqually Passage	S	Deposition of sand in tidal channels under moderately strong currents.
	Deltas: Delta near tidal channel	Nisqually delta Snohomish delta	S (with steep fore-set slope)	Stream fed sediments distributed and deposited by currents and waves near river mouths.
	Deltas: Delta in estuary	Puyallup delta Skagit delta Lummi R. delta	M and S (with gentle fore-set slope)	

TABLE 7 (Continued)

Environment Type			Examples	Bottom Characteristics[a]	Environmental Conditions
Depositional environment	Tidal deltas		Killisut Harbor entrance (Port Townsend)	S	One part of double deltas built in harbor at the inner end of entrance by flood tide, and other part outside harbor built by ebb tide.
			Washington Harbor or Sequim Bay entrance (in Juan de Fuca Strait)	S and Sh	
	Tidal Flats	Tidal flats (sandy)	Nisqually Flat Bellingham Bay and Samish Bay Padilla Bay (Anacortes) Port Susan (Everett)	S and M	Simultaneous deposition of sand and mud in areas partly emerged during low tide.
		Mud flats	Skagit Bay	M	
	Estuaries		Elliott Bay	M and S	Deposition near funnel-shaped river mouth under interplay of stream flow and tides.
	Aerated embayments		West Sound and narrow inlets at southern end of Puget Sound	Mud predominant and sand at entrance and near shore.	Deposition of suspended and tractional materials fed by flood currents and streams.
	Aerated mid-channel depressions		Puget Sound Central Section	M with S patches	Deposition of suspended matters in basins of relatively inert environment.
			Possession Sound	M	
			Carr Inlet	M	

TABLE 7 (Continued)

Environment Type		Examples	Bottom Characteristics[a]	Environmental Conditions
Depositional environment	Non-aerated (semi-stagnant) embayments	Hood Canal East Sound	$M(H_2S)$ and S $M(H_2S)$	Deficiency in oxygen and the possible presence of H_2S in semi-stagnant bottom waters. Deposition of suspended matter fed by streams and flood currents.
	Lagoons	Burley Lagoon (Bremerton) Port Gamble (Hood Canal entrance)	S & M M, S, and Sh	Deposition of sediments, plants, planktons and nektons in quiet and shallow lagoon waters.
	Marine (paralic) swamps	North Shore of Skagit Bay	M and grass	Shallow standing water or low wet ground occupied by relatively abundant plant life.

[a]Terminology of bottom characteristics defined in Table 6.

[b]No sharp distinction between erosional and non-depositional environments. Bottom undergoing erosion is mostly covered by coarse clastic sediments.

TABLE 8

GENETIC CLASSIFICATION OF PUGET SOUND, WASHINGTON SOUND, AND LAKE WASHINGTON SEDIMENTS

Sediment Type	Texture[a]	Average % Carbonate	Type of Cumulative Curve	Value of Statistical measures				Occurence
					Mdϕ	QDϕ	Sk$q\phi$	
Shelf sand	Sd, fS, Stfs, and StSd	0 to 4.0	A B B_1 C D_2 E_3	1.7 2.3 3.5 2.5 3.8 4.1	1.0 to 4.0	0.3 to 1.3	-0.1 to 0.5	Littoral zone, shallow water shelf zone, tidal flat, and delta top-set.
Slope sand	Sd, fS, StSd, StfS, St and ClSt	4.0 to 9.0	C D E E_2	2.5 3.8 5.1 6.7	3.0 to 6.0	1.0 to 2.0	0.2 to 0.6	Slopes of estuary, embayment, and Puget Sound mid-channel, and delta fore-set slope.
Depositional channel sand	Sd, fS, and StfS	0 to 3.0	A B B_2 C_1	1.7 2.3 1.5 3.5	1.0 to 3.0	0.3 to 1.5	-1 to 0.3	Tidal channel with moderately strong current.
Residual channel sand	SdGr, Sd granules and Sd	Low to extremely high	A_1 A_2 A_3	1.7 1.3 1.2	-1.0 to 2.0	1.0 to 3.0	-0.4 to -1.2	Tidal channel with extremely vigorous current.

TABLE 8 (Continued)

Sediment Type	Texture[a]	Average % Carbonate	Type of Cumulative Curve	Value of Statistical Measures: Mdφ		QDφ	Skqφ	Occurence
Basin mud	St, ClSt, StfS and ClfS	5.0 to 14.0	E E_1 E_2 F F_1 F_2 F-G G G_2 H H_1 I	5.1 5.4 6.7 5.8 5.4 5.8 6.8 7.8 7.9 6.8 4.7 9.0	5.0 to 9.0	1.3 to 2.0	-0.1 to 0.5	Puget Sound mid-channel depressions, mudflat, delta bottom-set, and basins in estuary and embayment.
Basin mud rich in sand grains and basin sand with matrix	StSd, StfS, ClfS and ClSt	4.0 to 9.0	B_3 C_2 D D_1 F H_1 Special H	5.3 2.4 3.8 4.0 5.8 4.7 5.7	2.0 to 6.0	2.0 to 3.0	-0.5 to 1.0	Basins near steep slope or tidal channel, basins with occasional current, and delta bottom-
Lake mud	StfS, ClfS, St and ClSt	2.0 to 4.0	F H H_1	5.8 6.8 4.7	5.0 to 7.0	2.0 ±	-0.4 to 1.0	Lake Washington fresh-water environment

TABLE 8 (Continued)

Sediment Type	Texture[a]	Average % Carbonate	Type of Cumulative Curve	Value of Statistical Measures				Occurrence
					Mdφ	Qdφ	Skqφ	
Compacted glacial clay	St, ClSt, StfS and ClfS	2.0 to 4.0	E_2 F G_1 I	6.7 5.8 7.7 9.0	6.0 to 9.0	1.5 to 2.0	0 to 0.2	Non-depositional bottom in Lake Washington and Puget Sound
Dumped earth, refuse, and materials dredged from bottom	Gravel, sandy or silty sediments	Variable	A_2 A_3 B_3	1.3 1.2 5.3	-2.0 to 5.0	> 2.5	-0.3 to -1.2	Elliott Bay and other harbors.

[a]Terminology of textural description defined in Figure 11.

and near-shore areas. Its characteristic uniform coarseness, good sorting, symmetrical size distribution, and low carbonate content indicate that only coarse non-calcareous materials of a narrow size range have been deposited. Constant reworking by waves and currents has winnowed away the fine constituents thus producing a deposit that is almost perfectly adjusted to the environment.

(b) "Slope sand", texturally consisting of normally sorted sand, fine sand, silty fine sand, silty sand, and clayey silt, occurs on depositional slopes of estuaries, in embayments, in mid-channels, and as delta fore-set beds. These can be regarded as representing a transitional environment between the strongly agitated shelf and the inert basin. As a mixed sediment type involving deposition of coarse materials derived from the shelf zone and fine materials of normal basin sedimentation, it varies considerably in average grain size, degree of sorting, and other characteristics.

(c) "Depositional channel sand", texturally consisting of excellent to well-sorted sand, fine sand, and silty fine sand, occurs in tidal channels with moderately strong currents, such as the entrance of Hood Canal, Colvos Passage, and Nisqually Passage, where surface currents may reach 1 to 2 knots at the peak of greater daily tropic currents. By selective and abrasive action of bottom currents, channel deposits have been continuously reworked, shifted, sorted, and worn to the extent that fine materials have been removed and only coarse clastic materials of a narrow size range remain on the bottom in adjustment with the hydrodynamic environment. Channel sands with low carbonate content generally are excellently sorted and possess unimodal and symmetrical size distribution. Owing to the presence of a large amount of shell fragments, sediments with high carbonate content are well to moderately well sorted, and have a bimodal and unsymmetrical size distribution, with their secondary and coarser mode representing the concentration of shell fragments.

(d) "Residual channel sediments", poorly to normally sorted sandy gravel, sandy granules, and sand, occur in tidal channels with extremely vigorous currents, such as Admiralty Inlet and Tacoma Narrows, where surface currents exceed 3 knots at the peakof greater daily tropic currents. By selective and abrasive action of vigorous bottom currents, sediments derived from bedrock bottom by scouring, or formed previously in situ under different environmental conditions, have been reworked, shifted, sorted, and worn down. This may occur to an extent that a portion of the sandy and silty materials have been removed from the deposit, thus leaving a type of "submarine lag gravel" on the bottom. However, the degree of sorting of residual channel gravel cannot be much improved by the selective action of currents, as interstices between pebbles are so large that some sand grains and shell fragments lodged therein are protected from removal.

(e) "Basin mud", texturally consisting of normally to poorly sorted silt, clayey silt, silty fine sand, and clayey fine sand, occurs in estuaries, embayments, deltas, and mid-channel depressions. Owing to its derivation by settling of fine suspended matter in a comparatively quiet basin environment, basin mud sediments are consistently fine, normally sorted, high in carbonate content, and the size distribution is slightly unsymmetrical skewed towards the finer grades. Because of the non-stagnant and slighted agitated environment, basin mud sediments in aerated basins differ from those in non-aerated or semi-stagnant basins such as East Sound and Hood Canal, in their slightly coarser average grain size, poorer degree of sorting, and absence of hydrogen sulphide odor.

(f) "Basin mud rich in sand grains" and "basin sand with mud matrix", texturally consisting of poorly sorted silty sand, silty fine sand, clayey fine sand, and clayey silt, occur in certain basins near steep slopes, tidal channels, or agitated bottom. Their comparative coarseness, extremely poor sorting, unsymmetrical and multiple-modal size distribution indicate that fine suspended matter of normal basin sedimentation and slope-derived or channel-derived sandy materials have been deposited together to form these mixed sediment types.

(g) "Lake mud" of Lake Washington, consisting of normally sorted silty fine sand, clayey fine sand, silt, and clayey silt, resembles the basin mud of the Puget Sound marine environment in many sediment characteristics. However, because of the fresh water lacustrine environment, lake mud is generally higher in water content, more poorly sorted, more irregular in size distribution, lower in colloidal clay content, and much lower in carbonate content than the Sound basin mud.

(h) "Compacted glacial clay", texturally consisting of normally sorted silt, clayey silt, silty fine sand, clayey fine sand, occurs in certain localities in both Puget Sound and Lake Washington, either as exposed non-depositional bottom or as a deposit covered by several inches of recent sediments. Where deposited in a fresh-water glacial lacustrine environment, compacted glacial clay resembles lake mud in its fine grain size, normal to poor sorting, and extremely low carbonate content, but differs from the latter in its high degree of compaction as indicated by its extremely low water-content.

(i) "Dumped materials", occurring in a few small areas in Elliott Bay, are extremely poorly sorted sediments of various degrees of coarseness, with extraneous ingredients, such as fragments of coal, cinders, concrete, glass, cable, wood, and fine sawmill dusts. They include dumped earth, refuse, or materials dredged from the bottom, and thus bear no genetic relation to the environment in which they occur.

5. COMPARISON AND INTERPRETATION OF SEDIMENT CHARACTERISTICS FOR DIFFERENT AREAS OF PUGET AND WASHINGTON SOUNDS

5.1 WATER CONTENT

The water content of Puget Sound and Washington Sound sediments varies considerably, ranging from 25% to 85% and increases generally with decreasing median diameter (Figure 16). This indicates that the water content of unconsolidated recent marine sediments as an indicator of porosity depends chiefly upon texture, with higher water content for finer sediments and lower water content for coarser sediments.

As a result of compaction at depth due to the burden of overlying strata, the water content decreases slightly with depth in cores. This decrease is approximately 5% to 10% for a ten-foot core of uniform silty clay texture. When stratification exists in the core, there is commonly an inverse relationship between water content and median diameter.

Lake Washington sediments, chiefly clayey silt of generally uniform texture, have either extremely high or extremely low water contents. Soft or "soupy" recent lake mud has a water content of about 80%, whereas compacted clay of possible glacial origin exposed on the lake bottom in some places or covered by several inches of soft lake mud in others has a water content of about 35% (Figure 16).

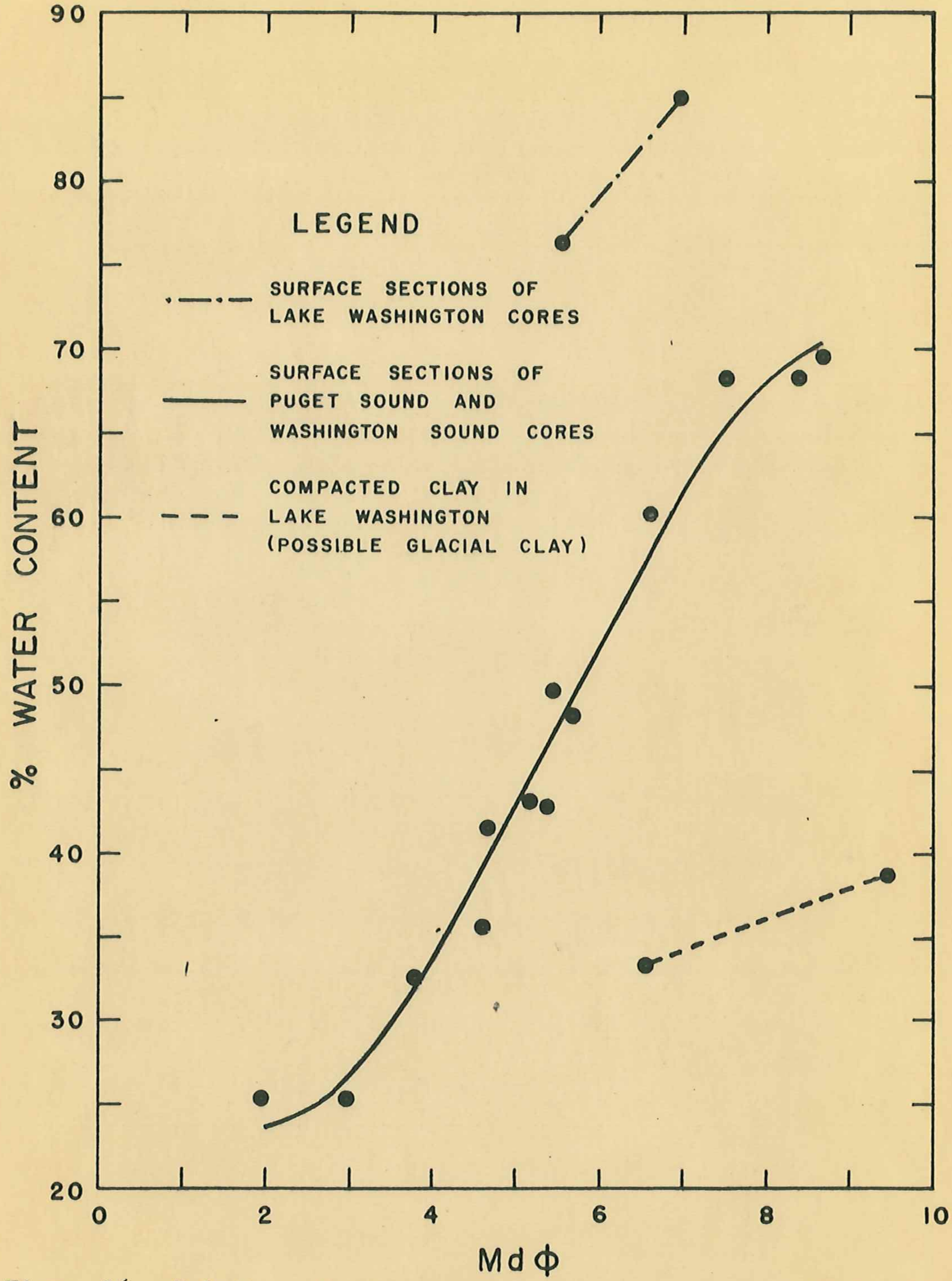

Figure 16. Relation of water content to median diameter (Mdϕ) for surface sections of sediment cores.

9.2 SALINITY OF INTERSTITIAL WATER

The salinity of interstitial water contained in Washington Sound sediments ranges generally from 25 °/oo to 30 °/oo, and equals approximately the salinity of Washington Sound sea water.

Analytical data of Washington Sound cores show no regular trend of salinity range with depth (i.e., with age). This may indicate that the salinity of bottom waters in that area was not appreciably different when the lower strata in the cores were deposited. The lack of regular salinity range with depth may be explained also by constant slow exchange between the interstitial water and the overlying bottom water, as well as by other factors. Such exchange of waters should be accelerated to some extent by burrowing organisms which rework the sediments.

In several cases, minor vertical variations of water content and salinity of interstitial water trend in opposite directions; that is, the salinity increases with accompanying decrease in water content (Figure 17). This relationship and the high salinity of water contained in certain strata may be explained possibly by a subsequent squeezing-out of water from certain strata, and the selective absorption of chlorides by the constituent grains of those strata.

9.3 RELATIVE ABUNDANCE OF MAIN TEXTURAL TYPES

Considering Puget Sound as a whole, including the main body, Hood Canal, Possession Sound, Elliott Bay, and Commencement Bay, three

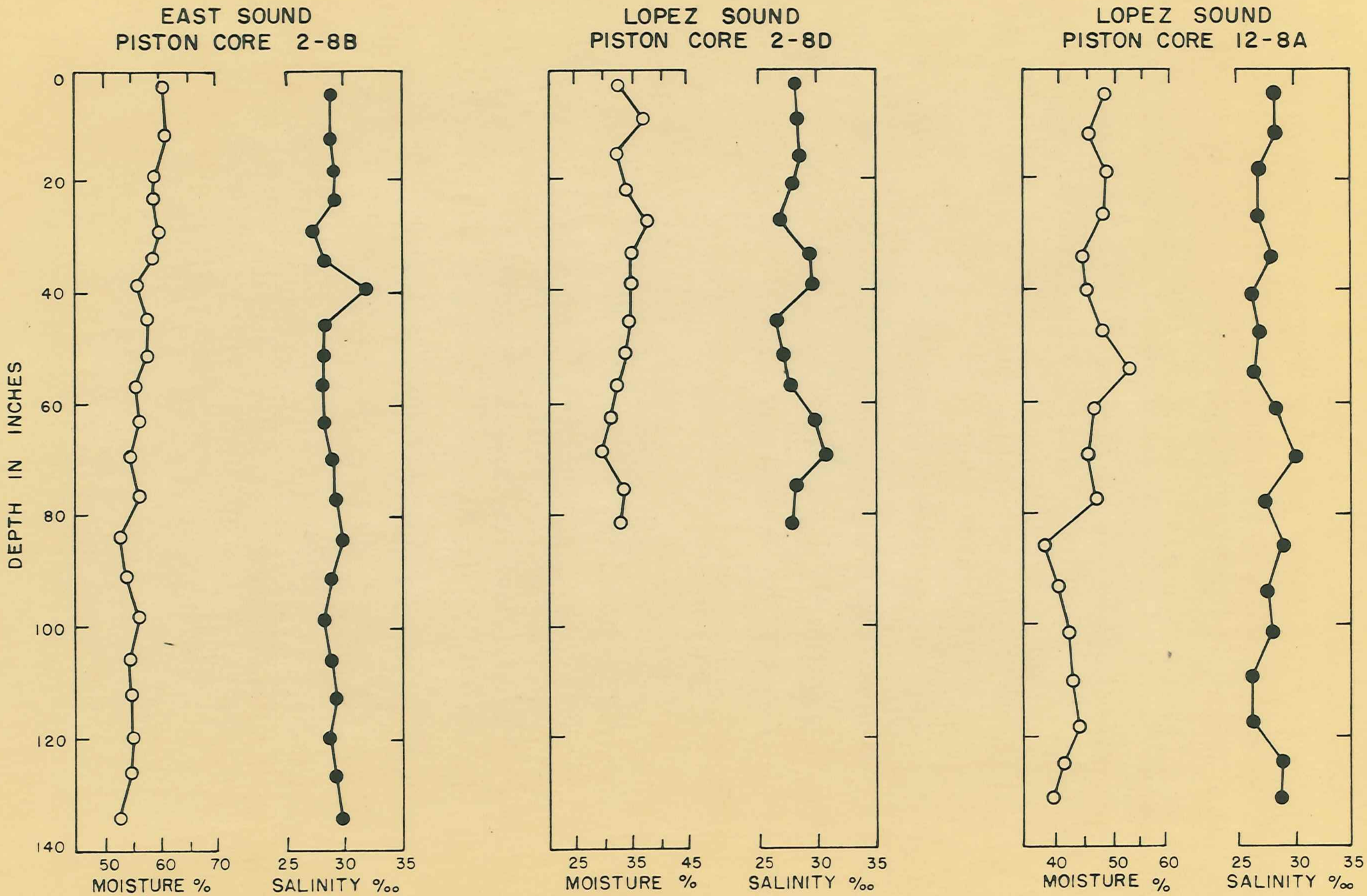

Figure 17. Relation of water content to salinity of interstitial water for three sediment cores.

textural types of sediment are most abundant: Clayey silt and clayey fine sand which constitute most of the basin mud; and sand which occurs as shelf and channel sediments (Table 9). As an exceptional case, Commencement Bay sediments are represented by the three abundant textural types: Silty fine sand occurring as delta top-set beds, clayey silt and silt constituting delta bottom-set beds, and basin mud.

Based on all analytical data, the main genetic types of Puget Sound sediment have been correlated with their depth of deposition, median diameter, and degree of sorting (Figure 18). This correlation indicates that the sediments are finer and more poorly sorted with increasing water depth. This is attributed to the increasing distance from the source of supply and to the decreasing selective action of transporting agents in deep water.

In East Sound, West Sound, and Lopez Sound, the sediments are represented by four predominant textural types: silt and clayey silt constituting basin mud, and fine sand and silty fine sand constituting shelf sediments.

Sediments in the calm environment of Lake Washington are composed chiefly of clayey silt, which covers about 98% of the lake area.

9.4 COMPARISON OF AVERAGE VALUES OF STATISTICAL MEASURES

A comparison of average values of median diameter for sediments of different areas (Table 10) shows that sediments of the Puget Sound main body are, on the average, coarser than in all other areas,

TABLE 9

DISTRIBUTION OF MAIN TEXTURAL GROUPS OF SEDIMENTS IN SEVERAL AREAS OF PUGET SOUND, WASHINGTON SOUND, AND LAKE WASHINGTON (VALUES ARE IN PER CENT)

Textural Groups of Sediments	Areas					
	Elliott Bay	Commencement Bay	Hood Canal	Puget Sound as a whole	East Sound West Sound and Lopez Sound	Lake Washington
Gravel	--	--	--	2.8	--	--
Sandy Gravel	2.4	--	--	1.7	--	8.3
Silty Gravel	--	--	--	--	--	--
Sandy Granules	--	--	7.1	4.1	--	--
Sand	18.8	6.7	35.7	20.1	2.9	--
Silty Sand	9.4	6.7	--	5.2	--	--
Clayey Sand	--	--	--	--	--	--
Fine Sand	5.9	--	--	4.8	17.6	--
Silty Fine Sand	22.4	46.7	21.4	20.6	20.6	16.7
Clayey Fine Sand	7.1	6.7	--	6.3	2.9	8.3
Silt	2.4	20.0	--	4.4	32.4	8.3
Clayey Silt	31.7	13.3	35.7	29.9	23.5	58.3
Clay	--	--	--	--	--	--
TOTAL	100.1	100.1	99.9	99.9	99.9	99.9

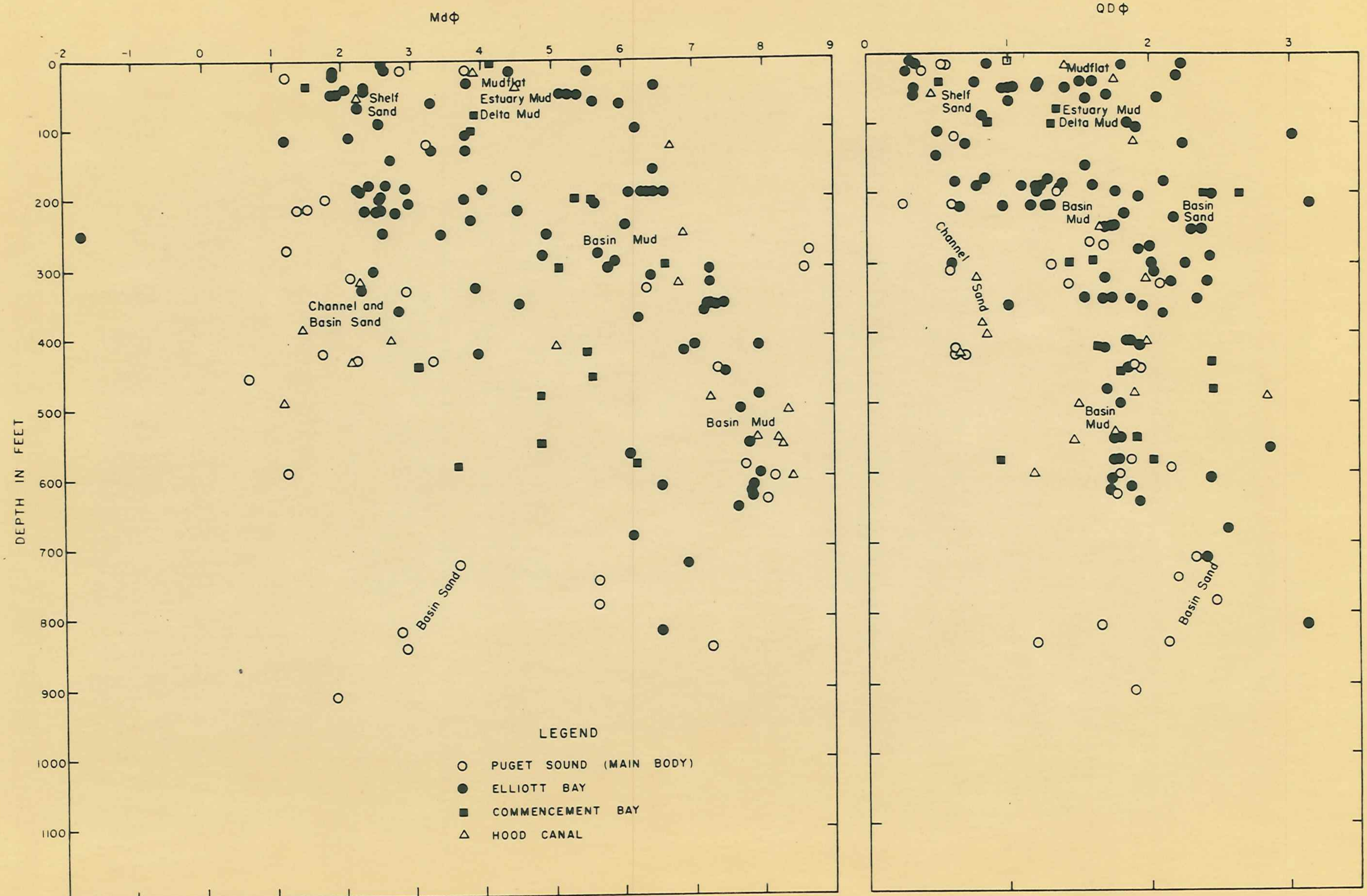

Figure 18. Relation of median diameter (Mdϕ) (left) and sorting coefficient (QDϕ) (right) to depth for Puget Sound sediments.

TABLE 10

SUMMARY OF STATISTICAL MEASURES FOR SEDIMENTS IN SEVERAL AREAS OF PUGET SOUND, WASHINGTON SOUND, AND LAKE WASHINGTON

Statistical Measures		Areas						
		Elliott Bay	Commencement Bay	Hood Canal	Main Body of Puget Sound	Puget Sound (overall)	East Sound West Sound and Lopez Sound	Lake Washington
Mdφ	Max.	7.86	6.62	8.42	8.65	8.65	8.70	9.45
	Min.	-1.75	1.47	1.14	-4.00	-4.00	1.18	1.05
	Ave.	4.75	4.65	5.22	3.69	4.40	5.11	6.13
QDφ	Max.	3.13	2.65	2.83	2.48	3.13	3.32	2.68
	Min.	0.32	0.50	0.46	0.25	0.25	0.31	1.27
	Ave.	1.67	1.69	1.46	1.43	1.52	1.35	2.02
Skqφ	Max.	1.50	0.53	1.09	1.22	1.50	0.78	1.38
	Min.	-0.74	-0.19	-0.11	-0.99	-0.99	-2.51	-1.67
	Ave.	0.22	0.30	0.24	0.25	0.26	0.29	0.24
Kqφ	Max.	0.32	0.30	0.34	0.35	0.35	0.35	0.36
	Min.	0.11	0.16	0.17	0.09	0.09	0.11	0.25
	Ave.	0.24	0.26	0.24	0.22	0.24	0.22	0.31

with an average Mdø value at 5.69. Coarse channel sands are widely distributed in this area in addition to its predominating basin muds. Because of the extensive occurrence of shelf sands and deltaic deposits, Elliott Bay and Commencement Bay sediments are also comparatively coarse, with an average Mdø value of about 4.7. The Puget Sound data indicates that median diameter of the sediments decreases progressively with water depth according to two variation series and that (1) basin mud in deeper water is finer than estuary and delta mud in shallower water, and (2) channel sand and basin sand in deeper water are finer than shelf sand in shallower water (Figure 18). In consequence of their quiet environment, the sediments of Hood Canal, East Sound, West Sound, and Lopez Sound are generally fine, with an average Mdø value of about 5.1 to 5.2. Lake Washington sediments are the finest of all areas, with an average Mdø of about 6.1.

Depending on the selective action of transporting agents, the average coefficient of sorting for sediments of different areas varies considerably (Table 10). Owing to wave action on shallow bottoms, the sediments in East Sound, West Sound, and Lopez Sound are well sorted, with an average QDø value of about 1.55. Sediments in the Puget Sound main body and Hood Canal are generally moderately well sorted. This applies to both the coarse channel sediments and fine basin muds. Because of the large supply of sediments and the comparatively weak current and wave action, Elliott Bay and Commencement Bay sediments are more poorly sorted, with an average QDø value about 1.70. Lake Washington sediments, including both the recent lake mud and glacial deposits, are poorly sorted with an average QDø value of about 2.0.

The average SKqø values for sediments of all areas range between 0.22 to 0.30, indicating an unsymmetrical size distribution skewed toward the finer grades. This, as previously stated, characterizes sediments of the basin mud type. The average Kqø value for sediments of all areas ranges from 0.22 to 0.31, indicating a moderate to poor degree of peakedness of the size distribution.

5.3 ABUNDANCE AND SCARCITY OF VARIOUS SIZE GRADES

Based on percentage frequencies of modal diameters of all samples, the accompanying histograms show the most and least abundant sediment size grades of several areas (Figure 19). The results differ from those based on median diameter. A sample with bi-modal size distribution usually has a median diameter lying between its primary and secondary modal diameters. However, sediments with multiple-modal size distribution are never predominant. In East Sound, West Sound, and Lopez Sound, only 5.6% of the sediments are multiple-modal; in Puget Sound as a whole, only 19.5% of the sediments are multiple-modal; and in Lake Washington, about 36.9% of the sediments are multiple-modal (Figure 19).

As indicated by the modal histogram (Figure 19), Elliott Bay sediments consist chiefly of two most abundant modal size groups: (1) the coarser group (2 to 4 phi-scale) of shoreline erosion-derived sandy materials constituting shelf sand, slope sand, and basin mud; and (2) the finer group (6 to 8 in phi-scale) of stream-discharged suspended material constituting basin mud. Commencement Bay sediments consist of

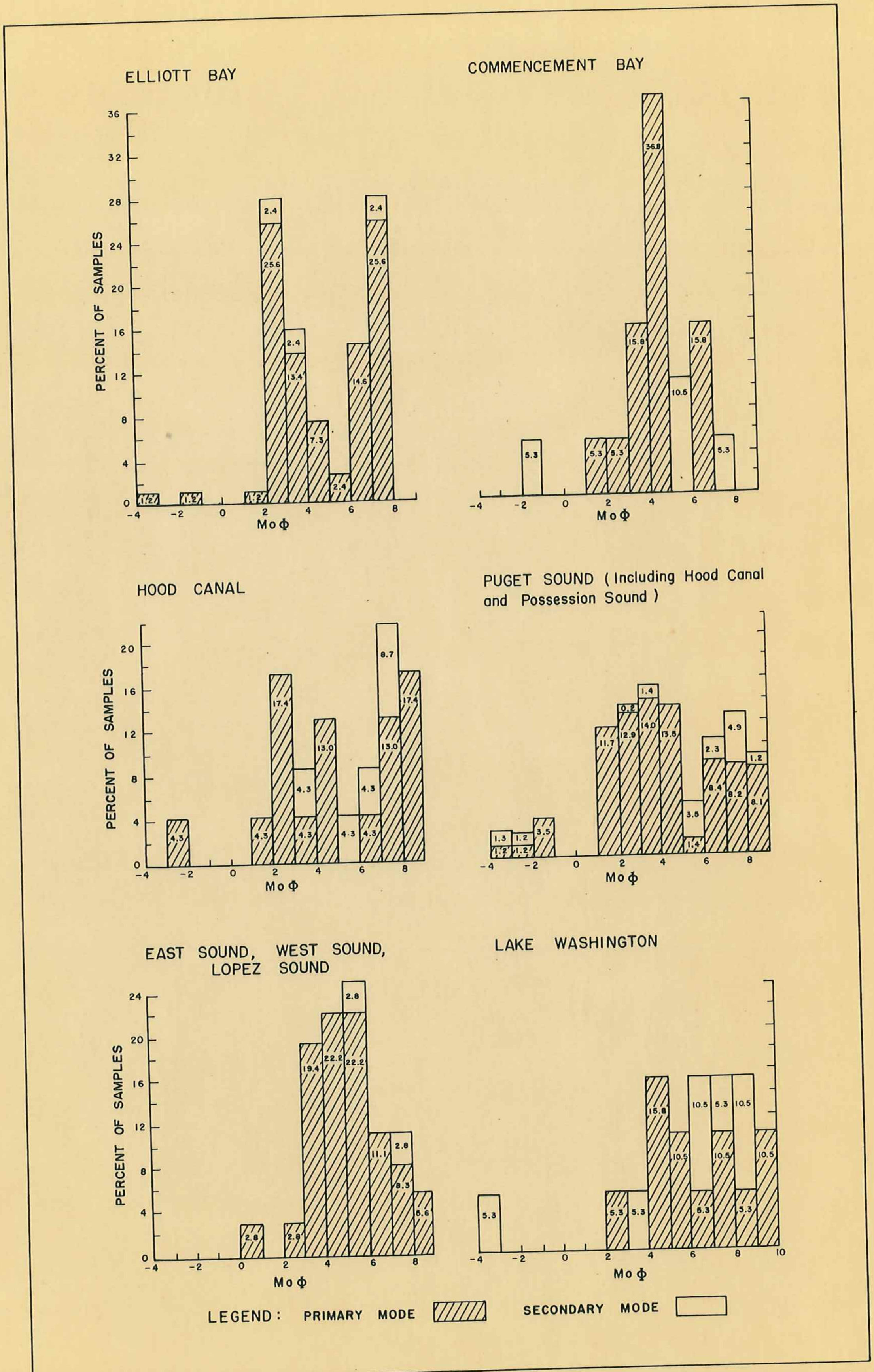

Figure 19. The percentage distribution of modal diameter in sediments of several areas in Puget Sound, Washington Sound, and Lake Washington.

two most abundant size groups: (1) the coarser group (3 to 5 in phi-scale) constituting delta top-set beds and shelf sands; and (2) the finer group (6 to 7 in phi-scale) comprising delta bottom-set beds and basin mud. Hood Canal sediments have three predominant size groups: (1) the coarsest group (2 to 3 in phi-scale) constituting channel sand of the entrance; (2) the intermediate group (4 to 5 in phi-scale) constituting shelf sand of the southern section; and (3) the finest group (7 to 9 in phi-scale) representing basin mud.

Considering Puget Sound as a whole, including Hood Canal and Possession Sound, the sediments consist of three most abundant modal size groups; the coarsest group (-4 to -1 in the phi-scale) constituting channel sand and shelf sand, and the finest group (6 to 9 in phi-scale) comprising basin mud. Modal size groups of Lake Washington sediments differ from Puget Sound sediments in the absence of channel sand and gravel, and consist chiefly of fine materials together with a small quantity of coarse glacial detritus.

Modal frequencies for Puget Sound and Lake Washington sediments (Figure 19) show a deficiency of materials of granule and coarse sand grades ranging from 2 to 1/2 mm in size (or -1 to 1 in phi-scale), and coarse silt grades ranging from 1/32 to 1/64 mm in size (or 5 to 6 in phi-scale). This deficiency can be explained by the transporting frequency of sediments of various size grades. According to Pettijohn (1949, p. 44) medium-sized sediment grains are transported by running water with less energy than is required for transporting finer or coarser sediment.

Theoretically, medium-sized gravel is most easily transported by traction, medium-sized sand by inertia suspension, fine silt and coarse clay by viscous suspension. Consequently, the abundant sediment grains in Puget Sound are medium-sized sediment grains of each of three size groups: (1) gravel, (2) sand, and (3) silt and clay. Finer and coarser grains, which require greater energy to transport, tend to remain near the source of derivation, and thus occur less abundantly in the Sound sediments.

As an alternative explanation, the deficiency of the two size groups may be considered as a feature inherited from the parent glacial deposits from which many Puget Sound sediments are derived. According to Pettijohn (1948, p. 41), some rocks undergoing granular disintegration tend to produce fine sand, and other undergoing block disintegration tend to produce gravel. According to Pettijohn, granules and coarse sand grains are relatively unstable products of mechanical disintegration. This may account in part for the deficiency of granules and coarse sand grades in Puget Sound glacial deposits and recent marine sediments. East Sound, West Sound, and Lopez Sound sediments do not show appreciable deficiency of these two size groups, perhaps because the small areas of investigation in Washington Sound are not representative of that whole suite of environments.

5.6 CLAY RATIO

The clay ratio is defined by the author as the ratio of colloidal clay (< 0.00049 mm or 1/2 micron) to the total clay content of a sediment sample. The percentage distribution of the clay ratio for sediments of several areas in Puget Sound, Washington Sound, and Lake Washington is presented in Figure 20. The significance of the clay ratio is somewhat obscure, but it is doubtlessly related in part to the original mechanical composition of the suspended material in sea water before it settled to the bottom. It is also the author's opinion that the clay ratio may be related in part to the degree of flocculation of suspended and settling clay particles. Flocculation of colloidal particles increases as the salinity increases. Thus, it is considered quite possible that the high clay ratios of sediments indicate that they were deposited in high salinity water in a highly flocculated state.

Most of the sediments in the Puget Sound main body have clay ratios varying between 0.30 and 0.40 (Figure 20). In the calm environment of Elliott Bay, Commencement Bay, and Hood Canal, most sediments have clay ratios varying between 0.25 and 0.55 (Figure 20). The rather uniform clay ratio for Puget Sound sediments, regardless of whether the sample is sandy, silty, or clayey in texture, is probably inherited from the homogeneous composition of the suspended matter in the sea water, brought about by a thorough mixing of suspended materials derived from both streams and shoreline erosion.

Sediments in East Sound, West Sound, and Lopez Sound generally have low clay ratios, varying between 0.20 and 0.35 (Figure 20). This is due possibly to the mechanical composition of suspended matter introduced by the Fraser River into Washington Sound.

In general, Lake Washington sediments are very low in colloidal clay content. Most of the lake mud clay ratios vary between 0.15 and 0.25 (Figure 20), indicating that either colloidal clay is lacking in the sediment supply, or that colloidal clay particles are unflocculated in the lake water and thus remain in suspension until carried out of the lake.

5.7 CARBONATE CONTENT

5.7a Carbonate Distribution in Puget Sound and Washington Sound Sediments

The percentage distribution of carbonate in the sediments of several areas in Puget Sound, Washington Sound, and Lake Washington is shown in Figure 21. In Hood Canal the channel sands have 2% to 5% of carbonate, the basin muds 10% to 16%, and the small areas of shelf sand 4% to 10%.

Sediments in the Puget Sound main body, including Nisqually Reach and Everett Harbor, vary considerably in carbonate content. The range is from 0% to 8% for noncalcareous channel sands and shelf sands, from 8% to 16% for basin muds in mid-channel depressions far from steep slopes, and 20% for calcareous channel sands in Admiralty Inlet.

In portions of Washington Sound, as in East Sound, West Sound, and Lopez Sound, the sediments are relatively high in carbonate content; about 8% to 16% for basin muds, and 4% to 8% for shelf sediments. These high values are due to the high rate of organic carbonate productivity. This is probably to some extent related to the high productivity of

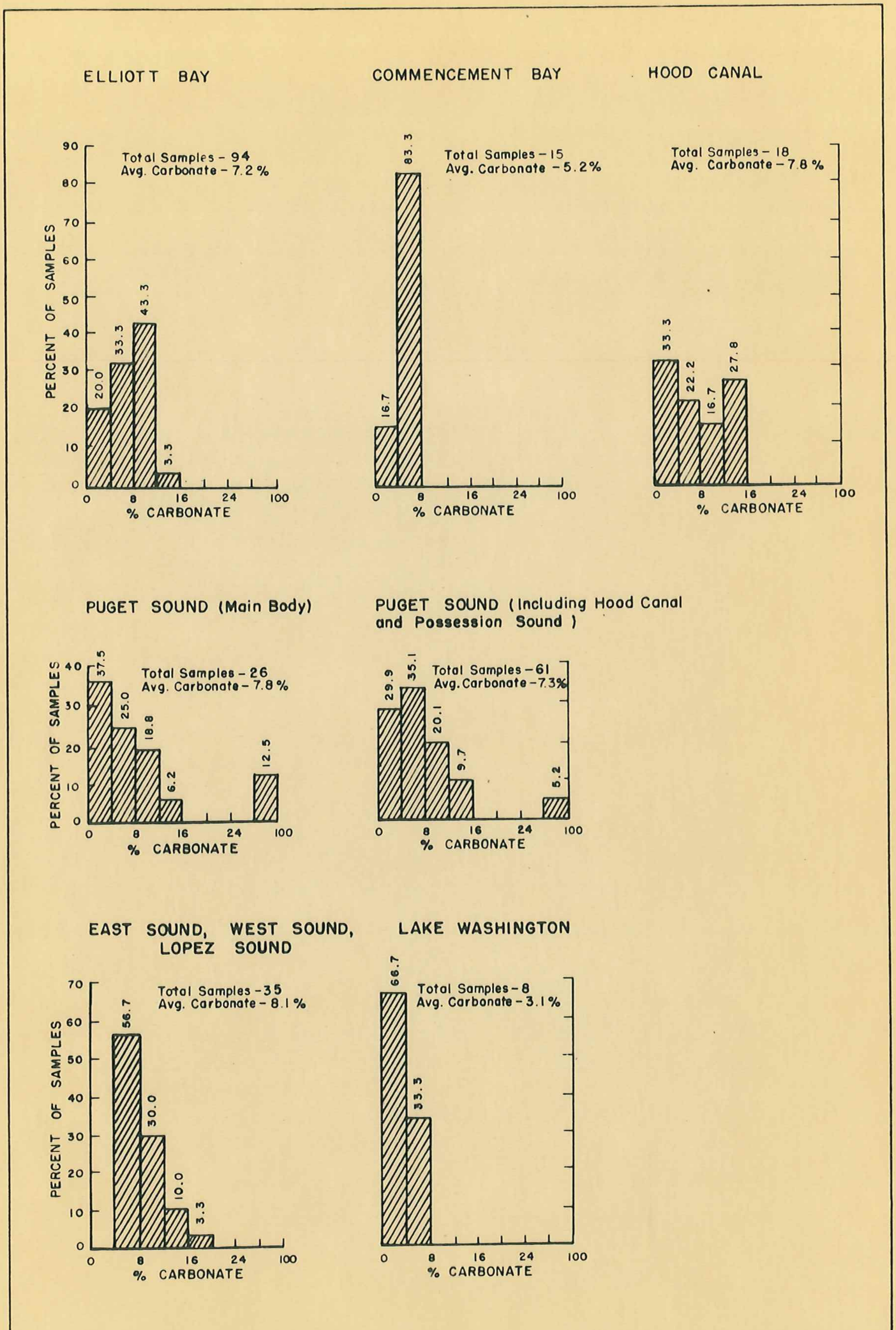

Figure 21. The percentage distribution of carbonate in sediments of several areas in Puget Sound, Washington Sound, and Lake Washington.

phytoplankton (Phifer, 1934, pp. 2047-2048). In Lake Washington, the low concentration of dissolved substances, the relatively high carbon dioxide content and the low pH of bottom waters reported by Scheffer and Robinson (1939, p. 140) possibly limit the population of lime-secreting organisms and favor solution of bottom carbonates. Consequently, the sediments are extremely low in carbonate content, ranging from less than 1% to 5.2%. Most of Elliott Bay sediments are basin muds with an 8% to 10% carbonate content (Figure 22). The percentage is slightly lower than that of basin mud in Puget Sound mid-channel because of large quantity of non-calcareous clastic supply. In Commencement Bay, owing to the large quantity of non-calcareous clastic materials supplied by the Puyallup River, sediments are generally low in carbonate content, mostly between 4% and 8%.

In comparison with the average carbonate content of ancient shallow-water deposits, which is estimated at 12.5% by Clarke (1924, p.34), the sediments in Puget Sound and portions of Washington Sound are apparently low in carbonates, with average values of about 7.5% and 8.1% respectively. Such deviation in carbonate percentage probably results from the rapid rate of deposition of non-calcareous clastic sediments, thus tending to dilute the calcareous materials present in Puget and Washington Sounds.

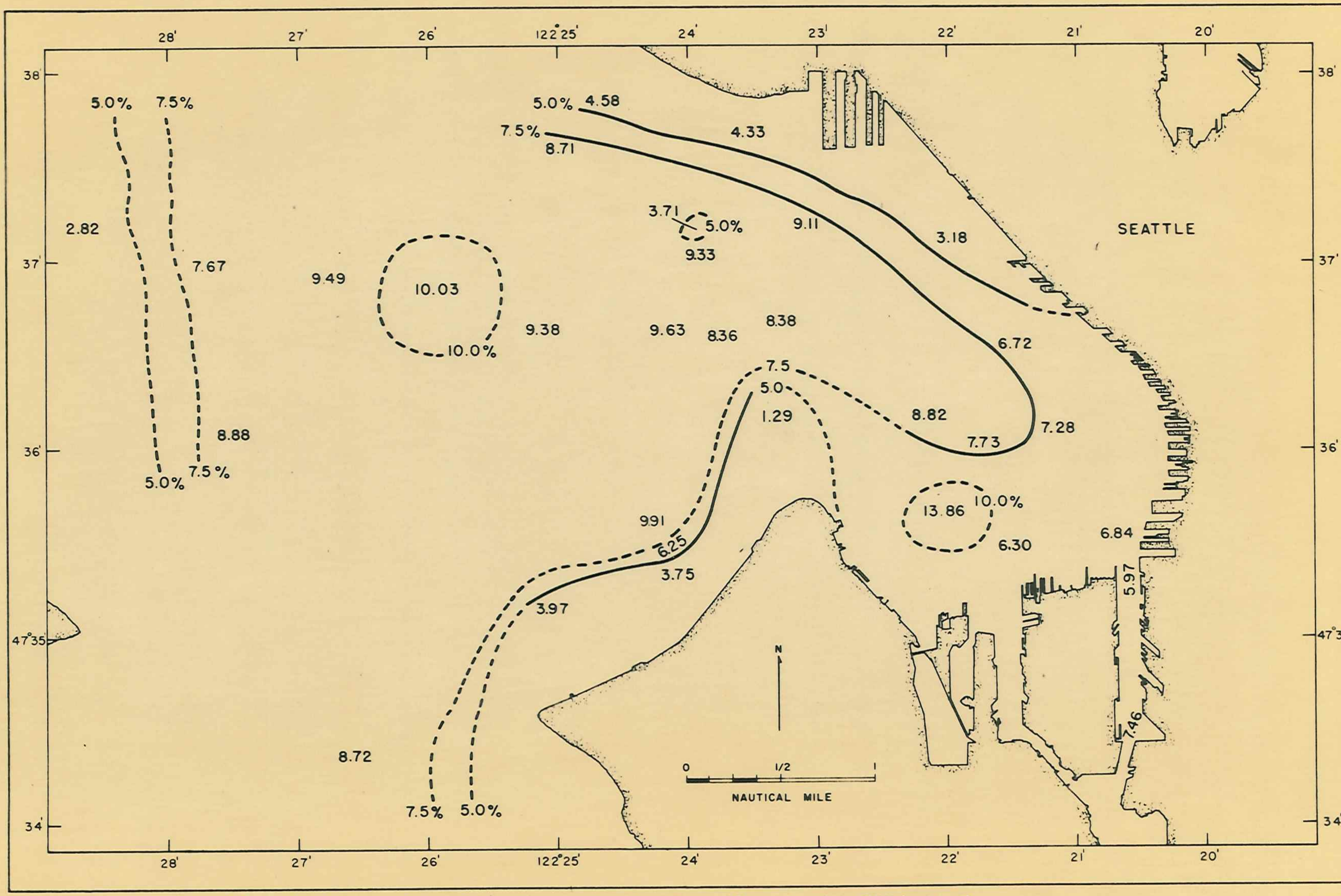

Figure 22. The distribution of carbonate content of sediments in Elliott Bay.

5.7b Factors Governing Carbonate Content

The carbonate content of sediments depends on three essential factors: (1) rate of lime deposition, (2) rate of deposition of non-calcareous clastic materials, and (3) the rate of solution of carbonate contained in the sediments.

The rate at which lime is deposited varies considerably in Puget Sound and Washington Sound, depending on the rate at which lime is formed in sea water and the local hydrodynamic environment permitting the settling of calcareous materials. It is believed that the rate of lime productivity is relatively high in East Sound and Hood Canal where the environment has been found to be favorable for high productivity of phytoplankton.

Based on a correlation between sediment grain size and carbonate content (Figure 23), it is concluded that carbonates in Puget Sound and Washington Sound sediments occur essentially in three different forms: (1) fragments of broken benthonic shells of about sand dimensions, (2) Foraminiferal tests of fine sand and coarse silt dimentions, and (3) very finely divided calcareous particles of uncertain origin, mostly of clay and fine silt sizes, possibly occuring as minute planktonic tests or bio-chemical precipitates.

The carbonate content of channel sands may be high or low, depending on the population of benthonic fauna. Certain calcareous channel sand, rich in fragments of broken benthonic shells, has the highest carbonate content, over 30% (Figure 23). Shelf sands and

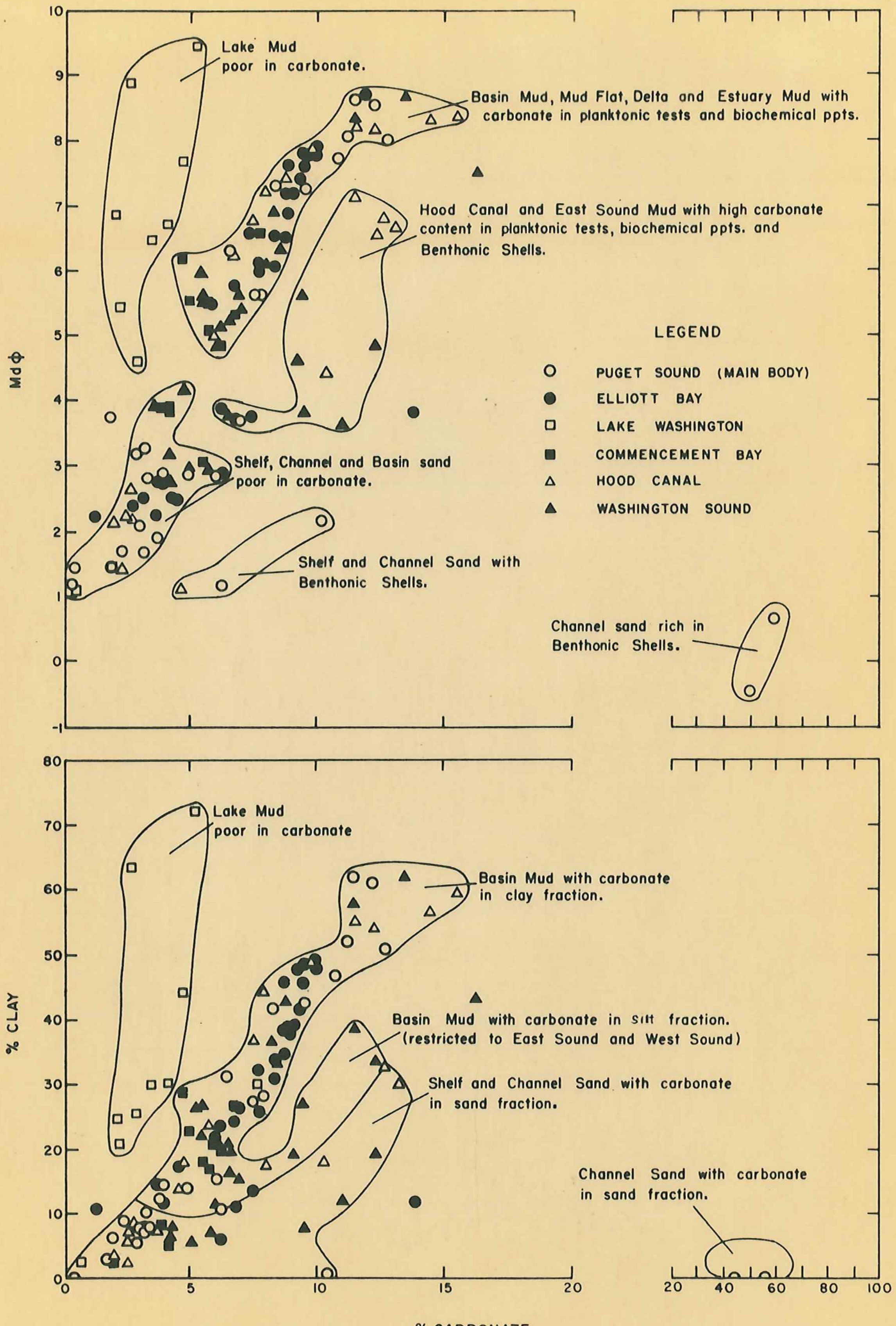

Figure 23. Relation of carbonate content to median diameter (Mdϕ) (upper), and clay content (lower) for Puget Sound, Washington Sound, and Lake Washington sediments.

ordinary channel sands are low in carbonate content, ranging from 0% to 10%, and also occur as sand-sized benthonic shell fragments (Figure 25).

Basin muds usually contain 8% to 16% carbonates, which occur chiefly as clay and fine silt-sized calcareous particles of uncertain origin. These particles may consist either of minute planktonic tests of partly calcareous composition, or of bio-chemical precipitates formed by phytoplankton photosynthesis[1] in sea water or by bacterial process.[2] In basin muds, benthonic shell fragments and benthonic foraminiferal tests are rare, generally comprising less than 1% of the sample.

Revelle and Shepard (1939, pp. 260-261) believe that shell fragments in sediments tend to be either dissolved and reprecipitated in interstitial water as fine calcareous particles, or broken down mechanically by mud-eating organisms. This process may be active also in the Puget Sound and Washington Sound sediments and thus account in part for the fine texture of calcareous matter.

Analytical data indicate that glacial deposits in Puget Sound are extremely low in carbonate content. It follows that materials

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[1]Trask, 1937, p. 276. Photosynthesis of phytoplankton which removes carbon dioxide from sea water for building organic compounds in their tissues, makes the surface water oversaturated with carbonate and consequently leads to carbonate precipitation.

[2]Twenhofel, 1950, pp. 571-572. By the process of ammonifying bacteria, nitrates in sea water are first reduced to nitrites and then to ammonia. Ammonia may react with carbon dioxide in sea water to form ammonium carbonate, which on reacting with calcium sulphate in sea water, forms calcium carbonate precipitates.

derived immediately from the parental glacial deposits by coastal erosion and streams are probably also low in carbonate content. Non-calcareous material derived from coastal erosion and stream discharge, which effectively dilutes the carbonate content of sediments, decreases progressively with increasing distance from shore. Consequently, the basin muds deposited in deep water usually contain more carbonate than shelf sands near shore, such as those in Elliott Bay (Figure 22). Because of average grain size of sediments and their carbonate content are both related to the rate of deposition of non-calcareous clastic materials, an indirect relationship exists between carbonate content and median diameter (Figure 23).

Solution of calcareous particles contained in bottom deposits can be considered only as a secondary modifying factor in determining carbonate distribution. For Washington Sound sediments, there is no definite trend of variation in carbonate content with depth in core. Emery and Rittenberg (1952, p. 776) found that delicate tests of benthonic and pelagic foraminifera in sediments show no evidence of solution. However, Bader (personal communication) believes that shells of certain forms are subjected to active solution, whereas shells of other forms are more or less insoluble.

5.8 SIZE FREQUENCY DISTRIBUTION

Sediment size distribution represented by cumulative frequency curves are used as the basis to evaluate the origin of a deposit.

Cumulative curves for all Puget Sound and Washington Sound sediments analyzed have been classified into twenty-nine types (Figure 9 and Table 8).

Cumulative curves drawn on arithmetic probability paper (Figure 10 and Table 11) have been used as a basis to ascertain the origin of deposits, including mechanical composition of materials supplied to transporting agents, manners of differentiation during transportation, and sizing of various sized sediment grains during deposition. Based on the selective process of transportation and deposition, the genetic significance of several types of cumulative curves are evaluated.

(1) T - Type Differentiation.

Based on analytical data of sediment load in transport and sediments deposited, Doeglas (1946, p. 30) concluded that materials transported either by traction or suspension, by any single agent of more or less uniform velocity, generally possess perfectly symmetrical size distribution which may be represented by a straight-line cumulative curve on arithmetic probability paper. It follows that a suspension-carrying current of this nature, on reaching an inert basin environment, will suddenly deposit its entire suspended load to form basin mud sediments. These consist of undifferentiated fine sand, silt, and clay, and are characterized by straight-line cumulative curves or symmetrical size distribution inherited from the original suspended load. The deposition of the entire suspended

TABLE 11

GENETIC TYPES OF CUMULATIVE SIZE DISTRIBUTION CURVES OF PUGET SOUND, WASHINGTON SOUND, AND LAKE WASHINGTON SEDIMENTS (REFER TO FIGURES 9 AND 10)

Curve shape on arithmetic probability paper	Size Distribution				
	Coarse sand abundant; no clay	Fine sand abundant; no clay	Fine sand and silt abundant; clay deficient	Silt abundant; clay deficient	Fine sand and silt, moderately abundant; clay deficient
3 straight-line segments connected by sharp bends	(A) Shelf sand, depositional channel sand R-type differentiation	(A_1) Residual channel sand R-type differentiation			
2 straight-line segments connected by sharp bend			(B_1), (E_2), (D_2) Shelf sand. (C_1) Depositional channel sand. (E) Slope sand and basin mud. (H_1) Basin mud rich in sand grains, lake mud. (D_1) Basin mud rich in sand grains. T + R type differentiation	(E_3), (F), (G_1). (H) Basin mud, glacial clay. (E_1) Mudflat sediments. (B_3) Basin mud rich in sand grains (F), (G), (F-G) Basin mud. T + R type differentiation	(C) Shelf sand, slope sand. (A_2), (B), (B_2) Shelf sand, channel sand. R-type differentiation

TABLE 11 (Continued)

	Size Distribution	
Single straight-line	(A_3) Dumped earth, refuse, and materials dredged from bottom, heterogeneous sediments slumped from slopes, residual channel gravel. (C_1), (D) Slope sand, basin sand with mud matrix.	Lack of differentiation (Symmetrical distribution of gravel, sand, silt, and clay)
	(F_1), (F_2), (G_2) Basin mud characterized by T-type differentiation (Symmetrical distribution of fine sand, silt, and clay.) (H), (Spe H) Basin mud and lake mud characterized by modified T-type differentiation (nearly symmetrical size distribution of fine sand, silt, and clay, except deficiency of fine silt).	

load has been defined by Doeglas (1946, pp. 26-27, p. 33) as T - type differentiation. (H)-type basin mud and lake mud are characterized by a special T-type differentiation, as there is a minor break in the straight-line cumulative curve (Table 11 and Figure 10) indicating a relative abundance of coarse silt and clay grades and a lack of fine silt grade in the size distribution. Similar to the T-type differentiation in shape of curve but differing genetically are dumped materials, heterogeneous sediments slumped from slopes, residual channel gravel of (A3) type, and slope and basin sand of (D) type (Table 11). These are also characterized by straight-line cumulative curves, indicating that the sediments consist of undifferentiated mixtures of gravel, sand, silt, and clay derived from various sources.

(2) S-Type Differentiation.

Shelf and channel sands of (A) and (A_1) types are characterized by cumulative curves consisting of three practically straight-line segments connected by rather sharp bends (Figure 10), with each straight-line segment representing a symmetrical size distribution of a narrow size range. The abundance of sand and deficiency in clay characterizing sediments of these types, as indicated by the slope of cumulative curves, are considered to result from a predominant deposition of sandy materials in the self and channel environment, or from the subsequent winnowing out of fine materials by continuous wave or current action. Doeglas (1946, p. 27 and p. 32) defined the deposition of predominantly course materials as R-type differentiation. Shelf and channel sands of (A2), (B), and (B2) types and shelf and slope sand of (C) type (Table 11), which are abundant in fine sand and silt and lack clay, are characterized by modified R-type differentiation.

(5) T + R Differentiation.

The majority of types of Puget Sound and Washington Sound sediments, including basin mud, shelf sand, channel sand, and slope sand, are characterized by cumulative curves consisting of two straight-line segments connected by a rather sharp bend, indicating that the sediments are deficient in clay (Table 11 and Figure 10). The predominance of fine sand and silt and the sparsity of clay in the sediments is evidently caused by an oceanward transport of clay materials out of the non-stagnant environment of Puget Sound and Washington Sound. Deposition of this nature resembles the T + R type differentiation defined by Doeglas (1946, p. 55), and includes characteristics of T-type differentiation for normal basin sedimentation and the R-type differentiation of the residual or reworking environment.

6. SEDIMENTATION BUDGET OF PUGET SOUND

(Supply, Deposition, and Seaward Transport)

6.1 WATER BUDGET OF PUGET SOUND AND TRANSPORTING POWER OF CURRENTS

The addition of fresh water to Puget Sound comes principally from runoff of rivers, with smaller amounts from ground water seepage, surface condensation and direct precipitation on the Sound surface (Collias, 1952). Because the local influx of fresh water is continuous, although variable, the average volume of out-flow on ebb tide exceeds the inflow on flood tide and ebb currents are generally stronger than flood currents. Puget Sound waters are but little less saline than those of the adjacent Pacific.

Collias (1952) estimated that 50 x 10^9 cubic meters of fresh water entered Puget Sound during the water year of 1947-1948. Assuming that all the water flowed through Admiralty Inlet at Point Wilson, the Puget Sound system would have a net discharge of about 1600 cubic meters per second, which would be equivalent to a 0.01 knot current setting seaward through Admiralty Inlet.

The ratio of transporting distances by flood currents to those by ebb currents during a tidal cycle (Figures 7 and 8) indicates that in mid-channel at the surface and intermediate depths in Puget Sound the water flows seaward for a longer distance on ebb than it flows landward on flood. Thus the Puget Sound ebb currents generally have greater transporting power than the flood currents. The configuration of Sound bars and spits along the western shore of Admiralty Inlet indicate that there is a net landward transport of water as well as sediments at the surface along the western shore by waves and flood currents. However, this is a minor alongshore feature and is considered negligible in comparison with the transport of the whole water mass at mid-channel. Based on continuous current measurements for several tidal cycles at fixed stations in Admiralty Inlet, R. G. Paquette (personal communication) states that bottom waters flow landward on flood for a slightly greater distance than they flow outward on ebb, and thus bottom currents on flood at many localities have slightly greater transporting power than those on ebb. Consequently, at the bottom there is probably a local net landward, mid-channel, tractional, transport of gravel and coarse sand.

Based on a current study of the water column from surface to bottom in Admiralty Inlet, Paquette further concluded that the whole water mass flows seaward for a greater distance on ebb than it flows landward on flood. Since the concentration of suspended fine sand, silt, and clay in a current with moderate turbulence is more or less uniform to within 1/2 meter of the bottom (Hjulstrom, 1939, p. 20), the predominating outflow of water mass through Admiralty Inlet, favors a net seaward transport of suspended sediments, chiefly fine sands, silts, and clays.

6.2 MINIMUM TRANSPORT DISTANCE

The distance from their source, to which suspended sediments of various size grades can be transported by currents, depends chiefly upon their settling velocities in water, the water depth, and the velocity of the transporting currents.

Calculated according to Stoke's law (Sverdrup, Johnson, and Fleming, 1946, pp. 956-957), the time required for sediments of various size grades, ranging from fine sand to coarse clay, to settle 100 meters in still water, varies from three hours to two months (Table 12). Assuming an average depth of 100 meters for Puget Sound and a 0.02 knot net ebb current, which is double the estimated net rate at Admiralty Inlet, sediments of various size grades would be transported from their sources seaward for distances ranging from 0.1 to 50 Km. Assuming a 0.2 knot net ebb current which is 20 times the estimated net rate of that at Admiralty Inlet, the transport distance for various sized sediments would range from 1 to 500 Km (Table 12). These distances of sediment transport are estimated minima, as eddies and turbulent motion caused by currents and waves tend to reduce the settling velocities, thus prolonging the settling time and increasing the transport distance. However, owing to flocculation of clay particles in sea water, the action of organisms in forming clay pellets, and the formation of larger clay flakes by organic slime (Kuenen, 1950, p. 257), small particles adhere to form larger units which settle in less time. Consequently the transport distance of clay materials is slightly reduced.

TABLE 12

MINIMUM TRANSPORT DISTANCE OF SEDIMENTS [a]

Size Grade	Diameter in mm.	Settling Velocity cm/sec.	Time for Settling 100 m.	Displacement by 10 cm/sec. or 0.19 Knot Current	Displacement by 1 cm/sec. or 0.02 Knot Current
Fine Sand	0.1	0.08	3 hours	1 km.	0.1 km.
Silt	0.06	0.35	8 hours	3 km.	0.3 km.
Coarse Clay	0.005	0.002	2 months	500 km.	50.0 km.

[a]Modified after Kuenen, 1950, p. 253.

According to the estimated minimum transport distance of sediments (Table 12), suspended sandy and silty materials introduced into relatively quiet and calm portions of Puget Sound, must have been deposited within a few miles of their source. On the other hand, those introduced into non-depositional tidal channels, such as Admiralty Inlet, would be completely carried away by the prevailing vigorous currents, either to the open sea or to protected embayments in the Sound.

Before deposition, clay particles can be transported seaward for several tens of kilometers from their source (Table 12), even assuming that the net transporting current ebbs at a velocity of only a hundredth of a knot. The extremely long transport distance of clay and silt particles is evidenced by the path of stream-discharged turbid surface waters which extend for many miles off river mouths during the flood season. As a result of the long distance of seaward transport, clay materials supplied to the Sound by streams and shoreline erosion are carried out through Admiralty Inlet at a rate nearly equal to the rate of supply. However, a small portion of these clays may have been carried back again by flood currents, generally at the bottom, and deposited in calm embayments within the Sound. The examination of cumulative curves of various types of Puget Sound sediments (Figure 10 and Table 11) reveals the deficiency of clay grade in their size distribution.

The relative abundance of materials of various size grades in Puget Sound (Figure 19), together with the genetic interpretation of cumulative curves of the Sound sediments (Table 11), indicates that most of the sediments supplied are deposited at one place or another within the Sound. It further indicates that the materials carried out of Puget Sound, comprising most of the clays and part of the silts, probably amounts to about one quarter of the total supply.

6.3 RATE OF SEDIMENTATION

Based on stream sediment load, water analysis data[1], and the total volume of water discharged per year, the annual supply of suspended and dissolved materials into Puget Sound by streams is estimated at 39.7×10^5 metric tons, of which 31.3×10^5 metric tons is carried in solution and 8.4×10^5 metric tons in suspension.

Considering the entire 11,077 square miles of Puget Sound Basin drainage area (University of Washington, Department of Oceanography, 1953 a, p. 87), each square mile contributes about 360 metric tons per year of dissolved and suspended materials to streams. On this basis the estimated overall rate of denudation of the whole drainage basin area is 1 inch of bedrock or 1.7 inches of soil for each 490 years, assuming an average density of 2.7 for bedrock and 1.6 for soil.

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[1]Van Winkle (1914). The mean suspended load in 1910-1911 for four Puget Sound streams (Skagit, Snohomish, Cedar, and Duwamish) is estimated at 16.16 parts per million. The mean quantity of dissolved solids is estimated at 60.67 parts per million.

Comparative study of subaerial and submarine profiles of portions of Puget Sound coast reveals a general retreat of shoreline, varying from insignificantly small to more than 200 feet. On this basis, the total amount of shoreline erosion in Puget Sound is estimated at 18.83×10^9 cubic meters or 37.66×10^9 metric tons of glacial outwash with an assumed density of 2.0. Assuming the duration of post-glacial time to be 15,000 years, it follows that the annual supply of sediments into the Sound from shoreline erosion is about 25.1×10^5 metric tons, or about three times the amount annually discharged by streams as suspended matter. The total quantity of solid matter supplied by streams and shoreline erosion amounts, therefore, to about 33.5×10^5 metric tons per year. Of this, about three-quarters is believed to be deposited in Puget Sound, and about one-quarter carried seaward out of the Sound.

Assuming that three-quarters of the total increment of solid materials has been evenly deposited in the 767.6 square nautical mile area of Puget Sound as bottom sediments with an assumed bulk density of 1.60 or 60% water content, the overall estimated rate of sedimentation is approximately 0.6 mm per year. Based on measurement of radium content of sediment cores, Blank (1950) arrived at a similar rate, approximately 0.58 mm per year for Skagit Bay sedimentation.

In addition to the suspended matter discharged from streams and the solid materials derived from shoreline erosion several minor sources also contribute materials to Puget Sound, and consequently may increase slightly the rate of sedimentation. Such minor sources of sediment supply are:

(a) Coarser materials transported into Puget Sound by streams as tractional load.

(b) Suspended and dissolved material supplied to Puget Sound by numerous ungaged small streams, un-named intermittent streams, and slope wash.

(c) Materials derived from submarine erosion of channels and banks in the Sound.

(d) Sea water nutrients carried into Puget Sound from the open sea and stream dissolved matter which may be partially secreted and precipitated as organic substances and other chemical constituents of sediments, such as carbonates, phosphates, and silicates.

7. SEDIMENT BY-PASSING AND SEDIMENTATION IN EPI-CONTINENTAL SEAS

7.1 SEDIMENT BY-PASSING AND SIZE VARIATION SERIES OF PUGET SOUND

7.1a General Statement

Eaton (1929, p. 714), has defined "by-passing" as the condition where one sedimentary particle passes another transported simultaneously by the same current or continues in motion after the other has come to rest. A progressive decrease in average grain size distribution following the direction of sediment transport, as frequently noted in sediments deposited by winds, streams, or currents in standing bodies of water, is termed "normal by-passing". Conversely, a progressive increase in sediment coarseness in the direction of sediment transport, as found in rare cases of sediments deposited by running water, is termed "reverse by-passing".

Typical cases of normal and reverse by-passing are illustrated by size variation series of sediment distribution in Hood Canal, mid-channels of the main portion of Puget Sound, and Possession Sound.

7.1b Size Variation Series of Hood Canal Sediments

Normal by-passing is illustrated by the sediment distribution in the southern section of Hood Canal between stations H-1 and H-5, with a progressive decrease in sediment coarseness from well-sorted silty fine sand to moderately sorted clayey silt (Figure 24), following the general direction of seaward transport of sediment.

Northward from station H-5 and following the same direction of sediment transport, the trend of sediment size variation in the central and northern sections of Hood Canal fulfills the requirements of reverse by-passing; i.e., characterized by a progressive increase in sediment coarseness from moderately sorted clayey silt to excellently sorted sand (Figure 24).

7.1c Size Variation Series in Puget Sound Mid-Channel

Sediments in the mid-channel of the main body of Puget Sound between Tacoma Narrows and Admiralty Inlet presents another example of reverse by-passing, as evidenced by an overall progressive increase in sediment coarseness from clayey silt at the southern end to gravel at the Inlet (Figure 25), following the general northerly direction of

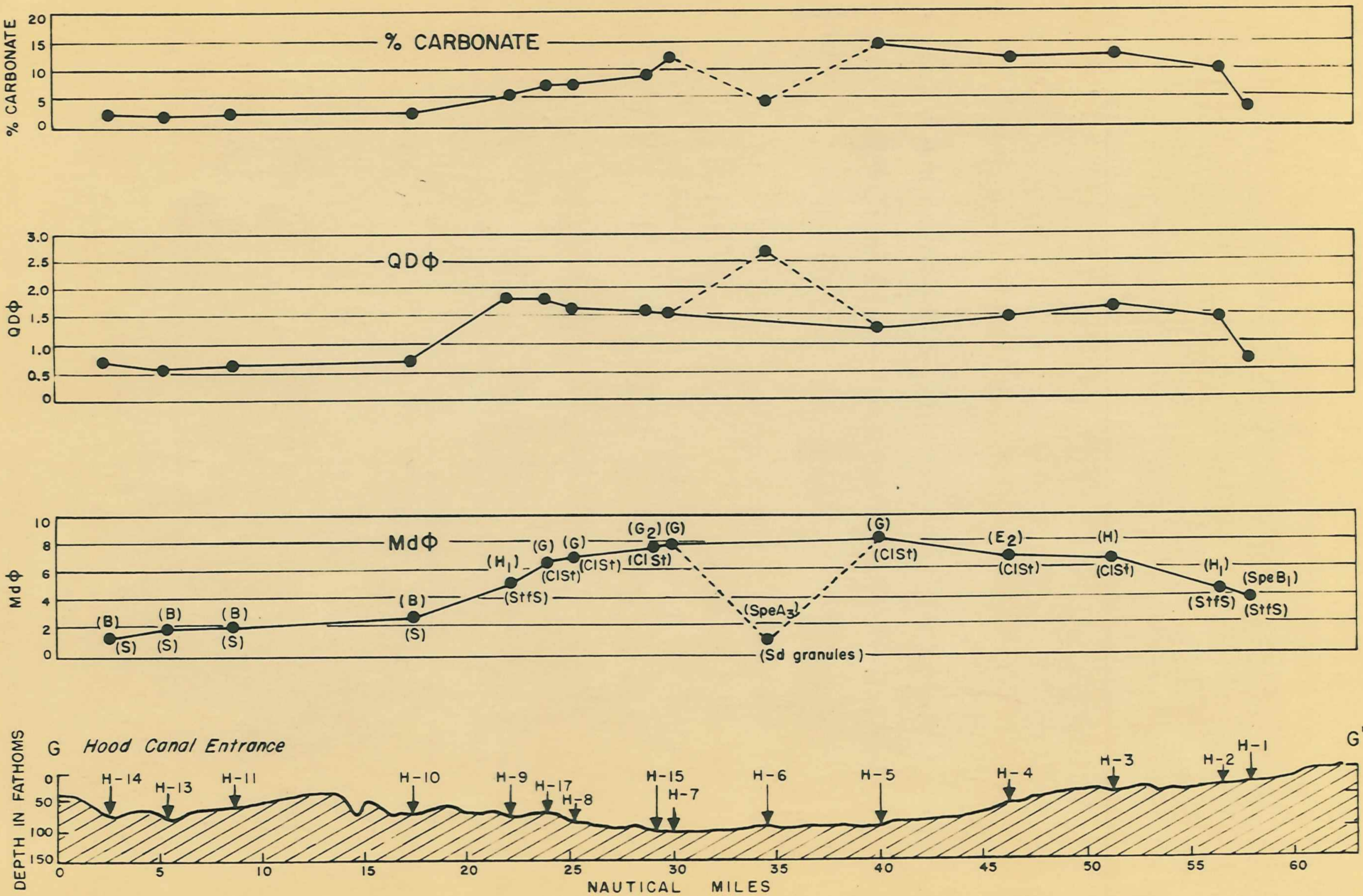

Figure 24. Carbonate content, sorting coefficient (QDϕ), and median diameter (Mdϕ) of sediments in Hood Canal.

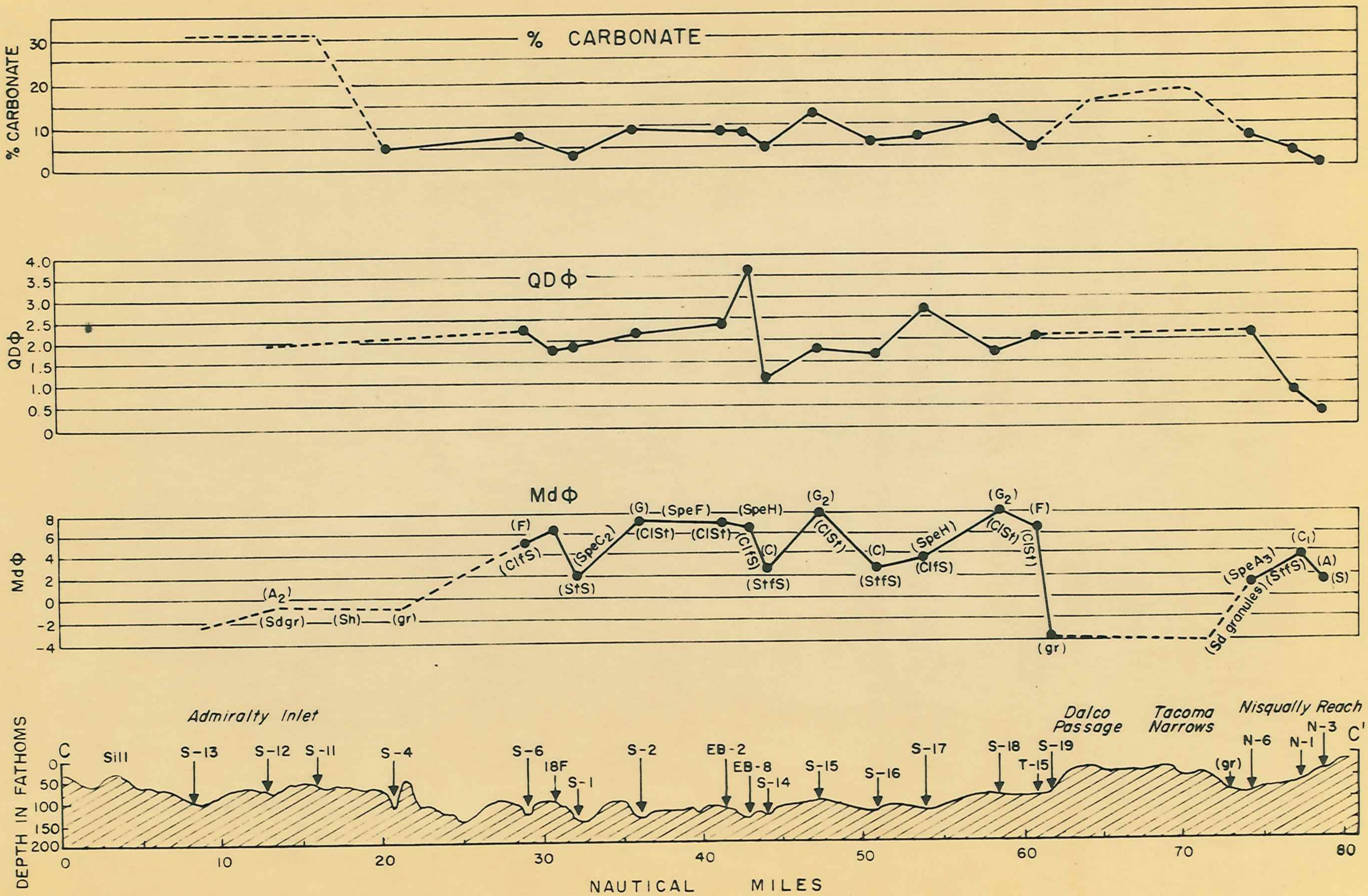

Figure 25. Carbonate content, sorting coefficient (QDϕ), and median diameter (Mdϕ) of sediments in Puget Sound.

sediment transport. From stations S-18 to S-6, the clayey silt of the "basin mud" sediments, occurring in deep holes and depressions, increases progressively in median diameter; i.e., decreases in phi-median diameter (Figure 25). In the same manner, silty fine sands (represented by samples S-1, S-14, and S-16) and clayey fine sands (represented by sample S-17), occurring in deep holes near steep slopes or in depressions with moderately strong bottom currents, also show a progressive increase in median diameter following the general direction of seaward transport.

7.1d Size Variation Series in Possession Sound Mid-Channel and Skagit Bay

Disregarding the coarse channel sands in Saratoga passage (represented by sample S-8), the "basin mud" sediments in Skagit Bay and the mid-channel of Possession Sound increase progressively in coarseness from clayey silt to clayey fine sand, following the southerly or seaward direction of sediment transport from stations S-10 to S-5 (Figure 26). This size variation series also appears to represent a case of reverse by-passing.

7.2 NORMAL BY-PASSING

It is generally believed that normal by-passing of sediments results chiefly from selective transportation of sediments, which depends on the nature and quantity of sediment supply and a progressive decrease in competency of the transporting agent. With progressive decrease and local fluctuations in competency of the transporting agent, the largest particles are moved only occasionally and therefore lag behind, whereas the smallest particles may be carried along even when the transporting energy is at its minimum. The tendency of the fine sediments to outrun

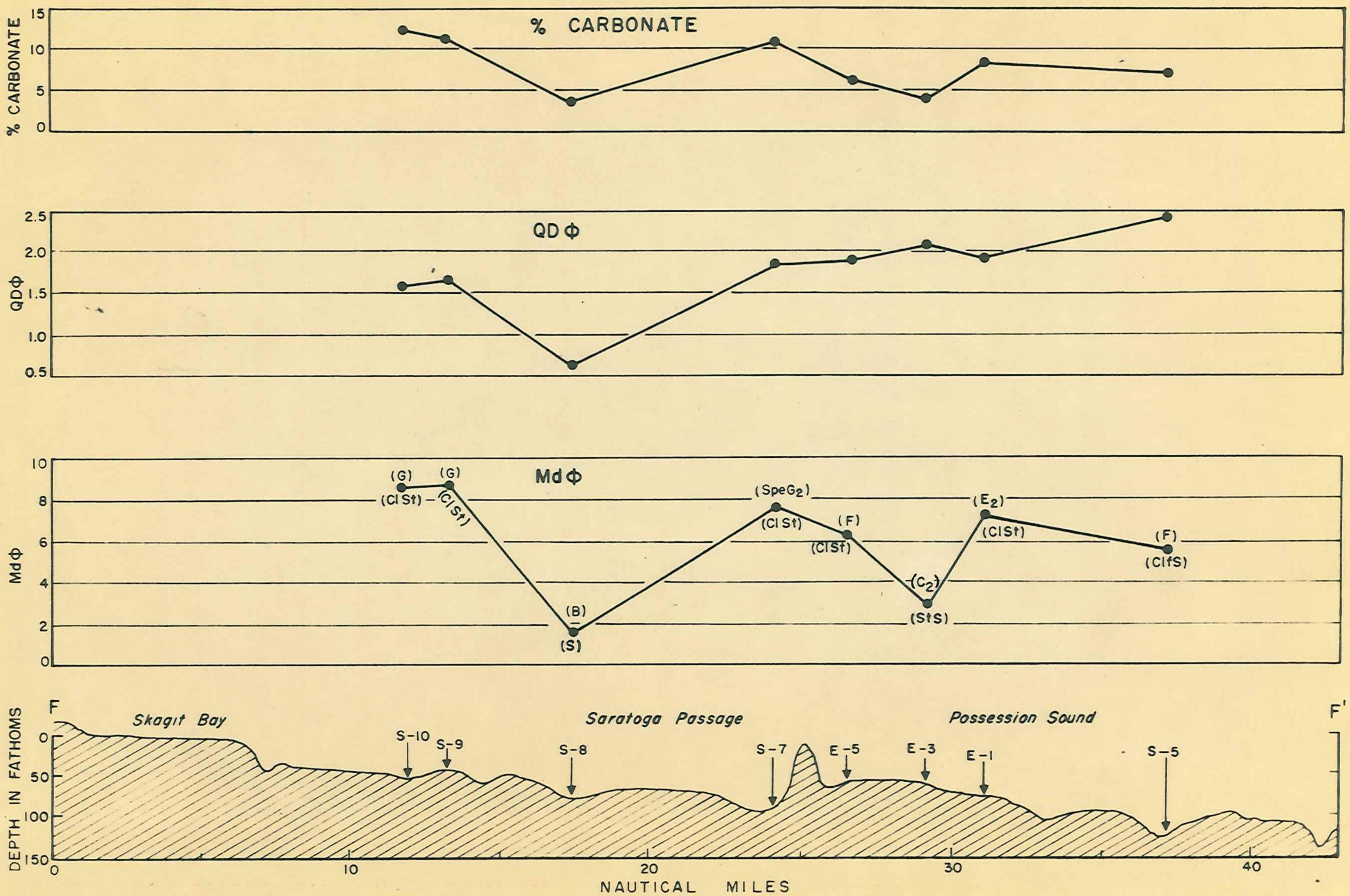

Figure 26. Carbonate content, sorting coefficient (QDΦ), and median diameter (MdΦ) of sediments in Possession Sound and Saratoga Passage.

the coarse in the direction of transport results in normal by-passing. Krumbein and Sloss (1951, p. 168) believe that perhaps 90% of the observed decrease in sediment coarseness is effected by selective transportation, and perhaps 10% by particle wear.

The normal by-passing of sediments in the southern section of Hood Canal can be explained by a progressive decrease of bottom wave action due to the progressive seaward increase in water depth.

7.3 REVERSE BY-PASSING

The reverse by-passing of Puget Sound sediments likewise can be explained by a progressive increase in competency of the transporting agents in a seaward direction of sediment transport.

Puget Sound surface currents for comparable channel widths become progressively stronger in a seaward direction, with velocities at the peak of greater daily tropic currents increasing from extremely weak or less than 0.2 knot at the southern ends of Hood Canal and Puget Sound proper to more than 5 knots in Admiralty Inlet (Figures 7 and 8). In Possession Sound and northward, the increase in current intensity in a seaward or southerly direction is less pronounced but still noticeable. Puget Sound bottom currents are also presumed to increase in intensity seaward (approaching Admiralty Inlet) and they are usually proportionally slower than surface currents (personal communication with C. A. Barnes).

According to the direct correlation between current velocity and size of particle deposited, as demonstrated by Hjulstrom's diagram, only sediment particles of a narrow size range are deposited when the current velocity reaches the lowest transporting velocity for particles of a given size; whereas all remaining finer particles are carried away (Hjulstrom, 1939, pp. 10-12). With a progressive seaward increase in bottom current intensity and a constant supply of shoreline erosion and stream-derived materials of all size grades into all portions of Puget Sound, sediments deposited should become progressively coarser in average grain size in a seaward direction, thus forming typical cases of reverse by-passing.

Reverse by-passing is also demonstrated by the size variation of beach sands at Cape Cod and by laboratory model studies. At Cape Cod, beach sands from a single source show a progressive increase in coarseness in the direction of transport (Schalk, 1938). By controlling the experimental conditions of the model, Straub (1940) developed a reversed size gradient, in which the moving load shows an increase in average grain size in the direction of transport. In a model beach study, Krumbein (1944) also developed residual deposits of finer grain size by abstracting coarse materials from original deposits and transferring them to the underwater part of the beach. The hydrodynamic explanation of the small-scale abstraction of well-sorted coarse sediments from poorly sorted deposits of mixed coarse and fine materials, as demonstrated both in nature and the laboratory, is still not fully understood.

The large scale reverse by-passing of Puget Sound sediments cannot be explained, however, by this hydrodynamic process because the sediments in different portions of the Sound have similar degrees of sorting.

7.4 STRATIGRAPHIC IMPLICATIONS (SEDIMENTATION OF EPI-CONTINENTAL SEAS)

Puget Sound and Washington Sound may be classed as a channel-shaped small epi-continental sea or a deep coastal embayment characterized by a humid climate. Doubtless, it is similar in some characteristics to many that have existed in the geologic past.

As a consequence of these environmental similarities, the sediment distribution in such ancient epi-continental seas may have resembled that of Puget Sound, with both normal and reverse by-passing of sediments controlled by lateral variation of tidal current intensity. Therefore, an understanding of Puget Sound sedimentation should help to reconstruct the sedimentary environments, under which some ancient neritic sediments were deposited, and to directly correlate sedimentary facies with environments.

8. SUMMARY AND CONCLUSIONS

The results and conclusions of this report are summarized below:

(1) A textural and nomenclatural classification of Clastic sediments, modified after Niggli's system, is presented. This classification is expressed also in terms of median diameter and sorting coefficient, assuming that the sediment size distribution is absolutely symmetrical.

(2) Nine sediment types, namely shelf sand, slope sand, depositional channel sand, residual channel sand, basin mud, basin mud rich in

sand grains and basin sand with mud matrix, lake mud, compacted glacial clay, and dumped materials, are recognized.

(3) The water content of unconsolidated sediments has an inverse relation to sediment texture. In the short cores studied, the water content is controlled more by sediment texture than by compaction. The salinity of interstitial water shows no regular variation with core depth.

(4) The deficiency of granules, coarse sand, and coarse silt in Puget Sound and Lake Washington sediments is explained on the basis of sediment transport and the composition of parental glacial deposits.

(5) The significance of the clay ratio, a measure of colloidal clay content, is somewhat obscure but it is undoubtedly related in part to the mechanical composition of suspended matter from which sediments settled and the degree of flocculation of suspended clay particles.

(6) The carbonate content of sediments depends on the rate of lime deposition, the rate of deposition of non-calcareous clastic materials, and rate of solution of carbonate deposited in sediments. Carbonate in the sediments occurs as benthonic shell fragments, foraminiferal tests, and very fine calcareous particles of uncertain origin.

(7) Based on study of cumulative frequency curves, the genetic significance of sediment size distribution for various sediment types is interpreted in terms of hydrodynamic principles of sediment transportation and deposition.

(8) In the mid-channel area of Puget Sound, ebb currents have greater transporting power than flood currents, resulting in a net oceanward transport of sediments in suspension.

(9) About 55.5 x 10^9 metric tons per year of solids enters Puget Sound, of which about 25% is discharged by streams, and 75% is derived by shoreline erosion.

(10) An estimated three-quarters of the total sediment supply is deposited in the Sound at an estimated rate of 0.6 mm per year, and about one-quarter chiefly in the form of clay and fine silt is carried seaward out of the Sound.

(11) The sediments of Puget Sound are characterized by both normal and reverse by-passing. These conditions are produced by lateral variations of current intensity. The distribution of sediments and the processes of sedimentation in Puget Sound and Washington Sound may well have their counterparts in ancient sediments deposited in a similar environment.

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APPENDIX

Basic Data for Samples and Cores from Puget Sound, Washington Sound and Lake Washington

The following explanations apply to all appendix tables.

1. The color descriptions of samples are based on the standards of the Rock Color Chart Committee, National Research Council (1948).

2. The notation PM indicates primary or principal modal diameter, and SM indicates secondary modal diameter.

3. An acid digestion method was used for the estimation of the carbonate content.

4. The abbreviations of sediment textures are as given in Fig. 12.

5. The abbreviations of type of samples are explained below:

   Grab means grab sample.
   Phlg 0-4" indicates surface section (0-4") of a Phleger (gravity type) core.
   Pist 18-24" indicates a section of a piston core taken at a depth of 18-24" from the sediment surface.

6. The total length of a piston core is occasionally shown by the depth of its deepest section.

7. Only representative sections of piston cores are listed in data appendix, whereas (additional) size analysis data for other core sections are on file at the Department of Oceanography, at the University of Washington.

Appendix 1. Data for Grab Samples from Elliott Bay

Sample Number	Sample Type	Collection Date	Location Lat. N 47°+	Location Long. W 122°+	Water depth (ft.)	Distance from shore (yards)	Carbonate Content	Texture
44-1	grab	Apr 4-'50	37'48"	23'31.5"	16	150		Sd
2	"	"	37'39"	23'37.5"	41	450		StSd
3	"	"	37'32"	23'45"	93	750	4.33	Sd
4	"	"	37'13"	23'53"	260	1400		Sd
5	"	"	36'43"	24'04"	618	2370		St
6	"	"	36'10"	23'57"	504	1330		ClSt
7	"	"	35'41"	23'46"	144	560		fS
8	"	"	35'32"	23'38"	8	200		fS
9	"	"	36'15"	23'09"	252	1040		StfS
10	"	"	35'36.5"	22'34"	300	250		StfS
11	"	"	35'17"	22'21.5"	171	290		StSd
12	"	"	35'21.5"	22'06.5"	234	530		StfS
13	"	"	35'26.5"	21'33"	186	450	6.30	StSd
14	"	"	35'26"	21'11"	192	380		StfS
15	"	"	35'32"	20'45"	106	370	6.84	StfS
16	"	"	35'37.5"	20'29"	17	100		StfS

Appendix 1. (continued)

Spl. No.	Spl. Type	Collection Date	Location Lat. N 47°+	Location Long. W 122°+	Water depth (ft.)	Distance from shore (yards)	Color Moist	Color Dry	Carbonate Content	Texture
44-17	grab	Apr 4-'50	35'14.5"	20'36"	16	120			5.97	StfS
18	"	"	34'50"	20'36"	40	120				St
19	"	"	34'25.5"	20'36"	33	90			7.46	StfS
20	"	"	36'04"	21'16"	48	1220				St
21	"	"	36'48"	21'15"	65	25				St
22	"	"	36'45"	21'36"	186	480				StfS
23	"	"	36'30"	21'50"	420	1050				StfS
24	"	"	36'23.5"	22'08"	288	1510				StfS
25	"	"	36'11"	22'37"	372	1080				ClSt
26	"	"	35'58"	22'45"	348	660				StfS
27	"	"	35'50"	23'08.5"	16	220				Sd
28	"	"	36'41"	23'04"	561	1426				StfS
29	"	"	36'48"	25'15"	624	2990				St
Ba-1	"	Dec 4-'51	38'12"	24'54"	48	420	olive dk gray 5Y 3/1	Lt olive gray 5Y 5/1		Sd
2	"	"	38'01"	24'38"	62	460	dk gray N 2.5	"		Sd
3	"	"	37'50.5"	24'43"	200	800	olive gray 5Y 3.5/1	lt olive gray 5Y 6/1	4.58	StSd

Appendix 1. (continued)

Spl. No.	Spl. Type	Collection Date	Location Lat. N 47°+	Location Long. W 122°+	Water depth (ft.)	Distance from shore (yards)	Color Moist	Color Dry	Carbonate Content	Texture
Ba-4	grab	Dec 4-'51	37'41"	23'39"	42	390	olive dk gray 5Y 3/1	olive gray 5Y 5/1		Sd
5	"	Dec 13-'51	37'46.5"	23'49"	25	300	dk gray N 3	olive gray N-5Y 4/1		Sd
6	"	"	37'29"	22'22"	62	400	olive dk gy 5Y 3/1	olive gray 5Y 5/1		StSd
7	"	"	37'07"	21'59"	198	500	"	lt olive gray 5Y 5.5/1	3.18	StSd
8	"	"	36'53"	21'34"	116	300	brownish dk gray 5YR 3/1			SdGr
9	"	"	36'33"	21'33"	300	770	olive dk gray 5Y 3/1	lt olive gray 5Y 6/1	6.72	StfS
10	"	"	36'26"	21'12"	312	650	"	"		ClSt
11	"	"	36'36.5"	20'51"	60	50	"	olive gray 5Y 5/1		StfS
12	"	"	36'08"	20'31"	100	340	"	lt olive gray 5Y 5.5/1		ClSt
13	"	"	35'36.5"	20'38"	132	300	olive dk gray 5Y 2.5/1	olive gray 5Y 5/1		StfS
14	"	"	35'35"	21'08.5"	198	620	olive dk gray 5Y 3/1	"		StfS
15	"	"	35'28"	21'50.5"	180	780	"	"		Sd
16	"	"	35'35"	21'58"	228	1040	olive dk gray 5Y 2.5/1	lt olive gray 5Y 5.5/1	13.86	StfS
17	"	"	35'37"	22'11"	276	920	olive dk gray 5Y 3/1	"		StfS
18	"	"	35'35"	22'32"	282	430	olive gray 5Y 3.5/1	"		StfS
19	"	"	35'48"	22'51.5"	130	250	olive dk gray 5Y 3/1	lt olive gray 5Y 5.5/1		fS

Appendix 1. (continued)

Spl. No.	Spl. Type	Collection Date	Location Lat. N 47°+	Location Long. W 122°+	Water Depth (ft.)	Distance from shore (yards)	Color Moist	Color Dry	Carbo-nate Con-Tent	Texture
Ba-20	grab	Dec 13-'51	36'23.5"	22'26.5"	408	1580	olive dk gray 5Y 3/1	lt olive gray 5Y 6/1		ClSt
21	"	"	36'14.5"	22'39.5"	414	1170	"	"		ClSt
22	"	"	36'01"	22'47"	360	680	"	"		ClSt
23	"	"	35'59"	23'09"	72	550	olive dk gray 5Y 3/1	lt olive gray 5Y 5.5/1		Sd
24	"	"	36'11"	23'19"	192	960	"	"	1.29	Sd
25	"	Apr 10-'52	37'36"	25'00"	500	1420	olive gray 5Y 3.75/1	lt olive gray 5Y 6/1	8.71	ClSt
26	"	"	37'17"	25'07.5"	552	2030	"	"		ClSt
27	"	"	36'57"	25'10"	582	2620	"	"		ClSt
28	"	"	36'22.5"	25'11"	624	3180	"	"	9.38	ClSt
29	"	"	36'05"	25'09"	588	2560	"	"		ClSt
30	"	"	35'30"	25'10"	552	1660	"	"		ClSt
31	"	"	35'11"	25'10"	360	1080	olive gray 5Y 4/1	lt olive gray 5Y 5.75/1	3.97	Sd
32	"	"	34'55.5"	25'11"	180	600	olive dk gray 5Y 3.5/1	lt olive gray 5Y 5.75/1		fS
33	"	"	35'11"	24'10"	108	380	olive dk gray 5Y 3.25/1			Sd
34	"	"	35'20.5"	24'10"	220	570	olive dk gray 5Y 3.5/1	lt olive gray 5Y 5.5/1	3.75	fS
35	"	"	35'28"	24'11"	324	740	olive gray 5Y 4/1	lt olive gray 5Y 5.75/1	6.26	StfS

Appendix 1. (continued)

Spl. No.	Spl. Type	Collection Date	Location Lat. N 47°+	Location Long. W 122°+	Water Depth (ft.)	Distance from shore (yards)	Color Moist	Color Dry	Carbonate Content	Texture
Ba-36	grab	Apr 10-'52	35'34.5"	24'13"	408	930	olive gray 5Y 3.75/1	lt olive gray 5Y 6/1	9.91	ClSt
37	"	"	36'09"	24'05"	480	1440	"	"		ClSt
38	"	"	36'37.5"	23'44"	612	1980	"	"	8.36	ClfS
39	"	"	37'04"	23'57"	450	1700	"	"	9.33	ClSt
40	"	"	37'12"	23'55"	324	1460	olive gray 5Y 4/1	lt olive gray 5Y 5.5/1	3.71	StSd
41	"	"	36'42"	23'15"	564	1960	olive gray 5Y 4.25/1	lt olive gray 5Y 6/1	8.38	ClfS
42	"	"	36'25"	22'46"	492	1440	olive gray 5Y 3.75/1	lt olive gray 5Y 6/1		ClSt
43	"	"	36'11"	22'13"	318	1400	"	"	8.82	ClSt
44	"	"	36'05"	21'51"	216	1700	"	"		StSd
45	"	"	35'37"	20'54"	160	640	dk gray N-5Y 3/1	lt olive gray N-5Y 6/1		ClSt
46	"	"	35'46"	20'48.5"	204	680	olive gray 5Y 3.75/1	lt olive gray 5Y 5.5/1		StfS
47	"	"	35'53.5"	21'11"	252	1240	olive dk gray 5Y 3.5/1	lt olive gray 5Y 5.75/1		ClSt
48	"	"	36'00"	21'40"	234	1700	olive gray 5Y 3.75/1	lt olive gray 5Y 5.75/1	7.73	ClfS
49	"	"	36'11.5"	22'21"	348	1320	olive gray 5Y 3.75/1	lt olive gray 5Y 6/1		ClSt

Appendix 1. (continued)

Sample Number	Statistical Measures								Phi Modal dia.	Type of Cumulative Curve	Remarks
	$P_{10\phi}$	$Q_{1\phi}$	Md_{ϕ}	$Q_{3\phi}$	$P_{90\phi}$	Qd_{ϕ}	Skq_{ϕ}	Kq_{ϕ}			
44-1	0.13	1.25	1.86	2.93	4.53	0.84	0.23	0.19			+ shell
2	-1.06	0.83	2.30	4.00	7.00	1.59	0.12	0.20			
3	1.60	1.87	2.50	3.50	7.40	0.82	0.19	0.14			
4	-0.38	1.40	2.31	3.82	7.14	1.21	0.30	0.16			
5											
6											
7	1.71	2.26	2.68	3.23	5.75	0.49	0.07	0.12	PM 3.1[1]	B	shell and cinder
8	1.86	2.21	2.55	2.78	3.25	0.29	-0.06	0.21			+ plants
9	1.94	2.60	3.40	5.96	8.95	1.68	0.88	0.24			+ andesite granules
10	1.50	2.60	3.98	6.95	9.20	2.18	0.80	0.28			+ wood
11	1.20	1.96	2.92	4.58	7.10	1.31	0.35	0.22			+ wood, etc.
12	1.15	2.12	3.34	5.22	8.20	1.55	0.33	0.22			+ wood
13	0.99	1.80	2.89	4.55	6.56	1.38	0.29	0.25			+ wood
14	2.00	2.60	3.68	5.22	7.80	1.31	0.23	0.23			+ shell
15	1.63	2.42	3.75	6.25	8.05	1.92	0.59	0.30			+ wood, dark color
16	2.10	3.10	4.38	6.15	7.94	1.53	0.25	0.26	PM 4.1	Spe D	+ wood, dark color

Appendix 1. (continued)

Sample Number	Statistical Measures								Phi Modal Dia.	Type of Cumulative Curve	Remarks
	$P_{10\phi}$	$Q_{1\phi}$	Md_{ϕ}	$Q_{3\phi}$	$P_{90\phi}$	Qd_{ϕ}	Skq_{ϕ}	Kq_{ϕ}			
44-17	2.40	3.27	5.49	7.72	9.60	2.23	0.01	0.31	PM 3.2	F	+ wood
18	3.80	4.98	6.45	8.00	9.66	1.51	0.04	0.26	PM 6.9	E_2	+ wood
19	1.71	2.33	3.78	6.72	8.60	2.20	0.75	0.32	PM 3.1	D	+ wood
20											
21	3.39	4.50	5.95	7.60	9.35	1.55	0.10	0.26	PM 5.9	F	
22	0.94	2.06	4.00	6.28	8.20	2.11	0.17	0.29	PM 2.2	D	
23	2.34	2.98	3.95	6.36	8.78	1.69	0.72	0.26	PM 3.9	D_1	
24	1.40	3.02	5.90	7.90	9.95	2.44	-0.44	0.29	PM 6.9 SM 3.1[2]	B_3	
25											
26	1.73	2.65	4.52	7.32	9.40	2.34	0.47	0.30	PM 3.1	Spe B_3	
27	1.55	1.95	2.30	2.60	2.82	0.33	-0.03	0.26			+ plants
28											
29											
Ba-1	1.25	1.54	1.85	2.18	2.68	0.32	0.01	0.22	PM 2.2	A	+ coal, shell and plants
2	1.40	1.80	2.16	2.49	2.98	0.35	-0.02	0.22	PM 2.9	A	
3	0.70	1.60	2.51	6.50	9.55	2.45	1.54	0.28	PM 2.5	C_2	+ pebble, coal and cinder

Appendix 1. (continued)

Sample Number	Statistical Measures								Phi Modal Dia.	Type of Cumulative Curve	Remarks
	$P_{10\phi}$	$Q_{1\phi}$	Md_{ϕ}	$Q_{3\phi}$	$P_{90\phi}$	Qd_{ϕ}	Skq_{ϕ}	Kq_{ϕ}			
Ba-4	0.84	1.52	2.03	3.06	6.55	0.77	0.26	0.14	PM 2.4	C	
5	1.30	1.58	1.86	2.11	2.65	0.27	-0.02	0.20	PM 2.4	A	2 pebbles discarded
6	0.86	1.78	3.25	5.89	8.75	2.06	0.59	0.26	PM 2.5	D	+ coal, cinder, wood, pssbly dmpd refuse
7	1.15	1.65	2.53	4.05	7.20	1.20	0.32	0.20	PM 2.5	C	
8	-3.86	-2.55	1.16	3.50	7.34	3.03	-0.69	0.27	PM 2.0 SM -3.5	A_3	Possibly dumped earth
9	2.23	3.88	5.79	7.92	10.50±	2.02	0.11	0.24	PM 6.0	F	
10	3.00	4.48	6.40	8.56	10.90±	2.04	0.12	0.26	PM 6.5	F	
11	3.15	3.99	5.58	7.39	9.70	1.70	0.11	0.26	PM 4.5	F	
12	2.84	4.40	6.17	8.10	10.30±	1.85	0.08	0.25	PM 6.5	Spe F	+ coal and cinder
13	1.49	2.20	3.77	6.68	9.20	2.24	0.67	0.29	PM 2.6	D	+ wood
14	1.70	2.40	3.72	5.93	8.60	1.77	0.45	0.26	PM 3.4	D	Coal and shale discd. in anal.
15	0.55	1.32	2.37	3.87	6.70	1.28	0.23	0.21	PM 2.5	C	+ wood
16	1.42	2.12	3.82	5.75	8.35	1.82	0.12	0.26	PM 2.5	D	
17	2.35	3.94	5.65	7.96	10.30±	2.01	0.30	0.25	PM 4.6	F	
18	2.04	3.55	4.88	7.39	10.00	1.92	0.59	0.24	PM 3.9	F	
19	1.90	2.55	3.28	3.95	7.24	0.70	-0.03	0.13	PM 3.5	Spe B_1	

Appendix 1. (continued)

Sample Number	Statistical Measures								Phi Modal Dia.	Type of Cumulative Curve	Remarks
	$P_{10\phi}$	$Q_{1\phi}$	Md_{ϕ}	$Q_{3\phi}$	$P_{90\phi}$	Qd_{ϕ}	Skq_{ϕ}	Kq_{ϕ}			
Ba-20	4.10	5.40	7.03	9.14	11.10±	1.87	0.24	0.27	PM 6.9	G	
21	3.65	5.20	6.87	9.05	11.70±	1.93	0.26	0.24	PM 6.8	E_2	
22	4.00	5.46	7.16	9.38	10.90	1.96	0.26	0.28	PM 6.9	E_2	
23	0.70	1.41	2.20	3.40	7.20	1.00	0.21	0.15	PM 2.5	B	+ Gr, shell and cinder
24	1.00	1.75	2.23	3.31	8.30	0.78	0.30	0.11	PM 2.6	C	+ shell, cinder
25	4.46	6.01	7.68	9.60	11.90±	1.80	0.13	0.24	PM 7.9	G_2	
26	5.00	6.22	7.81	9.83	12.00±	1.81	0.22	0.26	PM 7.1	G_2	
27	5.16	6.19	7.76	9.70	11.90±	1.76	0.19	0.26	PM 7.1	G_2	
28	5.10	6.29	7.84	9.73	11.90±	1.72	0.17	0.25	PM 7.1	G_2	+ shell, spines
29	5.22	6.41	7.98	9.96	12.05±	1.78	0.21	0.26	PM 7.2	G_2	+ wood
30	4.90	6.34	7.90	9.83	11.90±	1.75	0.19	0.25	PM 7.5	G_2	
31	0.73	1.76	2.80	3.78	8.55	1.01	-0.03	0.13	PM 3.1	C	+ shell, wood
32	1.25	2.03	2.60	3.68	8.20	0.83	0.26	0.12	PM 2.9	C	
33	0.95	1.62	2.08	2.60	3.39	0.49	0.03	0.20	PM 2.9	B	+ shell, wood
34	1.65	2.14	2.75	3.44	6.80	0.65	0.04	0.13	PM 3.1	B	cinder, shell, pebble discd.
35	2.21	2.95	3.90	7.78	10.20	2.42	1.47	0.30	PM 3.9	D_1	+ wood

Appendix 1. (continued)

Sample Number	Statistical Measures								Phi Modal Dia.	Type of Cumulative Curve	Remarks
	$P_{10\phi}$	$Q_{1\phi}$	Md_{ϕ}	$Q_{3\phi}$	$P_{90\phi}$	Qd_{ϕ}	Skq_{ϕ}	Kq_{ϕ}			
Ba-36	4.80	6.28	7.94	9.97	11.90±	1.85	0.19	0.26	PM 7.9	G_2	
37	5.26	6.45	7.95	9.85	11.86±	1.70	0.20	0.26	PM 7.9	G_2	
38	2.90	3.98	6.57	8.87	11.02	2.45	-0.15	0.30	PM 4.1 SM 7.1	F	
39	3.90	5.70	7.43	9.41	11.40±	1.86	0.13	0.25	PM 7.5	E_2	
40	0.05	1.37	2.25	5.70	9.04	2.17	0.29	0.24	PM 2.1	C_2	± cinder
41	1.42	2.76	6.10	8.50	10.85	2.87	-0.47	0.30	PM 2.5 SM 7.5	B_3	
42	4.23	5.42	7.20	9.24	11.10	1.91	0.13	0.28	PM 7.1	E_2	
43	4.68	5.80	7.24	9.15	11.30±	1.68	0.24	0.25	PM 7.1	E_2	
44	-2.00	1.22	4.50	7.50	9.78	3.14	-0.14	0.27	PM 7.1 SM 2.5	B_3	+ coal, shell, pssbly dmpd refuse
45	2.10	4.94	6.44	8.02	10.08	1.54	0.04	0.19	PM 7.1	E_2	+ wood, shell, bk M with kerosene smell
46	2.85	3.90	5.60	7.75	10.10	1.93	0.23	0.27	PM 4.1	F	+ wood
47	4.14	5.37	6.88	8.84	10.43	1.74	0.23	0.26	PM 6.9	E_2	+ wood, coal discarded
48	2.08	3.70	6.02	8.06	10.32	2.18	-0.14	0.27	PM 6.9	F	
49	4.60	5.72	7.31	9.20	10.98	1.74	0.15	0.27	PM 7.1	E_2	

1 PM primary modal diameter

2 SM secondary modal diameter

Appendix 1. (continued

Spl. No.	>8.00	8.00 -4.00	4.00 -2.00	2.00 -1.00	1.00 -.50	.50 -.25	.25 -.125	.125 -.0625	.0625 -.0312	.0312 -.0156	.0156 -.0078	.0078 -.0039	.0039 -.00195	.00195 -.00098	.00098 -.00049	<.00049
	% wt. of size grades (in mm)															
44-1		[a](Gr	6.5%)(			Sd	80.1%	)(		St	9.4%	)(		Cl	4.0%	)
2		(Gr	10.5%)(			Sd	64.4%	)(		St	21.1%	)(		Cl	4.0%	)
3			(			Sd	78.8%	)(		St	13.4%	)(		Cl	7.8%	)
4		(Gr	7.3%)(			Sd	68.7%	)(		St	17.2%	)(		Cl	6.8%	)
5[b]			(			Sd	22.0%	)(		St	54.2%	)(		Cl	23.8%	)
6[b]			(			Sd	14.4%	)(		St	47.3%	)(		Cl	38.3%	)
7					.88	16.02	51.06	19.05	1.96	1.47	1.96	2.20	1.71	1.69	1.00	.98
8			(			Sd	92.0%	)(		St	8.0%	)				
9			(			Sd	64.5%	)(		St	23.2%	)(		Cl	12.3%	)
10			(			Sd	50.5%	)(		St	33.5%	)(		Cl	16.0%	)
11			(			Sd	67.6%	)(		St	26.1%	)(		Cl	6.3%	)
12			(			Sd	61.7%	)(		St	28.1%	)(		Cl	10.2%	)
13			(			Sd	67.2%	)(		St	26.6%	)(		Cl	6.2%	)
14			(			Sd	55.2%	)(		St	35.6%	)(		Cl	9.2%	)
15			(			Sd	52.9%	)(		St	36.1%	)(		Cl	11.0%	)

[a] Brackets indicate broader divisions of size analysis where more detail analyses are not available.

[b] Questionable size analysis data.

Appendix 1. (continued)

Spl. No.	>8.00	8.00 -4.00	4.00 -2.00	2.00 -1.00	1.00 -.50	.50 -.25	.25 -.125	.125 -.0625	.0625 -.0312	.0312 -.0156	.0156 -.0078	.0078 -.0039	.0039 -.00195	.00195 -.00098	.00098 -.00049	<.00049
44-16				1.42	1.19	6.03	14.98	18.40	17.65	13.68	10.44	6.48	4.32	2.21	1.39	1.80
17					1.14	3.61	16.65	12.84	11.07	10.09	11.72	10.74	8.79	5.55	3.89	3.91
18						1.71	3.11	8.55	11.75	16.64	18.11	15.17	10.77	6.19	4.58	3.43
19				.85	1.13	13.83	25.50	10.71	6.98	8.29	10.47	8.72	5.67	3.80	2.31	1.74
20^b			(			Sd	9.1%		)(	St	67.3%	)(		Cl	23.6%	)
21						.91	6.13	10.64	15.60	17.76	16.46	12.13	8.23	5.44	3.66	3.03
22		3.27	1.44	1.70	4.30	13.35	12.83	13.36	12.02	10.06	9.22	7.27	5.03	2.80	1.39	1.96
23					.95	4.82	19.95	25.80	12.38	8.25	7.74	5.93	5.42	3.66	2.01	3.09
24			3.83	1.43	2.52	7.08	9.85	8.36	7.15	10.87	13.16	11.73	8.29	6.03	4.84	4.86
25^b			(			Sd	20.0%		)(	St	40.0%	)(		Cl	40.0%	)
26				.93	2.31	10.57	17.56	14.08	7.87	8.44	10.40	8.15	7.03	5.61	3.67	3.37
27^b			(			Sd	98.2%		)(	St	1.8%	)				
28^b			(			Sd	26.0%		)(	St	56.8%	)(		Cl	17.2%	)
29			(			Sd	15.0%		)(	St	66.0%	)(		Cl	19.0%	)
Ba-1			1.43	.70	1.95	56.98	33.58	1.93	.49	.49	.25	.73	.25	.25	.20	.78
2				.55	1.99	35.85	52.05	2.97	.83	.41	1.03	.83	1.03	.62	.84	1.02
3			4.95	2.40	5.49	21.90	22.95	7.91	2.71	4.64	4.64	5.03	5.03	4.25	3.80	4.32

Appendix 1. (continued)

Spl. No.	>8.00	8.00 -4.00	4.00 -2.00	2.00 -1.00	1.00 -.50	.50 -.25	.25 -.125	.125 -.0625	.0625 -.0312	.0312 -.0156	.0156 -.0078	.0078 -.0039	.0039 -.00195	.00195 -.00098	.00098 -.00049	<.00049
Ba-4				3.30	8.65	37.62	25.21	7.09	3.16	3.16	2.95	2.11	2.11	1.69	1.65	1.30
5				.68	2.08	61.80	29.57	2.96	.55	.55	.36	.18	.36	.36	.35	.20
6				6.15	5.03	18.12	18.41	13.81	6.71	7.61	6.71	4.47	4.02	3.13	2.63	3.19
7				2.92	4.59	27.16	28.60	11.44	4.84	5.11	4.57	2.96	2.42	1.35	.84	3.20
8	21.29[c]	7.29	4.26	5.36	9.59	15.25	9.72	6.27	2.72	2.93	4.19	3.56	2.93	1.68	.86	2.07
9					1.70	6.22	9.33	10.36	12.63	12.63	12.63	10.20	7.77	4.86	2.97	8.69
10						2.95	7.18	9.19	11.80	13.12	14.43	10.50	9.84	6.56	4.93	9.50
11					.77	1.07	6.25	17.29	15.40	15.99	14.21	9.48	6.51	4.15	3.38	5.50
12					4.11	2.46	4.11	9.51	12.17	15.09	15.09	11.19	9.25	5.84	3.88	7.31
13					3.08	16.96	21.63	12.01	8.22	7.47	8.22	6.72	4.86	4.11	3.32	3.40
14				1.91	2.08	11.71	24.32	18.72	9.02	7.74	6.45	4.73	5.16	1.29	1.37	5.51
15			4.48	2.26	10.53	24.97	20.72	15.05	5.89	3.54	3.54	2.36	2.36	1.57	.73	2.02
16				1.80	3.84	16.57	18.61	12.07	10.04	9.65	8.88	6.95	3.86	2.70	2.23	2.79
17				.67	1.69	5.60	6.81	11.38	14.70	13.79	11.57	9.34	7.12	5.78	4.55	7.02
18				2.53	2.01	5.27	8.82	18.75	13.91	10.93	9.94	6.96	5.96	4.97	3.95	5.99
19			1.25	.79	1.56	7.82	29.38	35.32	6.62	3.55	3.31	2.13	2.36	1.65	1.76	2.49

[c] 16.00 mm 7.67%, 16.00 - 8.00 mm 13.62%

Appendix 1. (continued)

Spl. No.	>8.00	8.00 -4.00	4.00 -2.00	2.00 -1.00	1.00 -.50	.50 -.25	.25 -.125	.125 -.0625	.0625 -.0312	.0312 -.0156	.0156 -.0078	.0078 -.0039	.0039 -.00195	.00195 -.00098	.00098 -.00049	<.00049
Ba-20						1.01	1.09	7.20	10.49	14.24	15.74	13.49	10.49	8.25	7.40	10.59
21						1.68	3.86	7.65	9.57	13.67	15.72	12.99	9.57	6.15	5.44	13.70
22						2.08	2.63	5.23	9.35	12.74	16.14	12.74	10.20	10.20	9.19	9.50
23		2.05	1.91	2.24	7.57	28.99	25.98	12.89	2.98	2.24	2.98	2.24	2.24	1.99	1.80	1.93
24		1.38	1.46	1.85	5.32	26.72	34.72	6.44	2.14	2.85	3.33	3.09	2.85	2.85	2.60	2.39
25						.49	1.23	5.93	8.06	10.19	14.00	15.70	14.00	10.00	6.55	14.85
26						.34	.73	.75	8.22	11.12	16.45	15.48	13.54	9.97	7.44	15.96
27						.09	.61	1.41	6.33	13.25	16.70	15.55	13.82	9.94	7.34	14.97
28						1.71	.63	1.45	5.26	11.57	16.30	15.77	14.20	10.71	7.69	14.72
29						.37	.99	2.13	4.80	10.66	16.00	15.46	14.40	10.69	7.97	16.53
30						.42	.90	3.23	6.46	9.45	15.41	15.91	14.42	10.40	7.99	15.41
31		2.35	2.32	2.29	5.36	16.87	28.76	18.67	2.87	2.26	3.02	3.47	3.17	2.79	1.89	3.92
32		.67	1.38	1.93	3.92	15.89	44.99	9.54	1.73	2.20	4.56	2.79	2.40	2.20	2.19	3.61
33	.50	3.39	1.79	1.39	3.33	33.84	41.63	6.94	1.16	.70	.70	1.16	.93	1.04	.58	.93
34			.48	.42	1.43	18.29	39.73	23.85	2.70	1.54	2.12	1.93	1.93	1.73	1.54	2.31
35					1.32	6.09	19.47	25.18	6.36	4.24	6.79	7.21	6.79	5.65	4.53	6.36
36						.23	.65	3.10	7.74	9.81	13.94	15.49	13.94	10.50	8.60	16.00

Appendix 1. (continued)

Spl. No.	>8.00	8.00 -4.00	4.00 -2.00	2.00 -1.00	1.00 -.50	.50 -.25	.25 -.125	.125 -.0625	.1625 -.0312	.0312 -.0156	.0156 -.0078	.0078 -.0039	.0039 -.00195	.00195 -.00098	.00098 -.00049	<.00049
Ba-37						.10	.31	1.33	6.14	10.75	15.35	16.89	14.84	10.79	8.15	15.35
38						2.34	8.29	14.88	8.33	9.26	12.03	11.57	9.26	7.34	6.54	10.18
39						4.10	2.55	3.88	7.50	10.72	14.47	15.00	12.86	8.72	7.35	12.86
40		1.90	3.87	3.90	7.71	24.79	20.58	7.38	2.53	3.80	4.30	4.81	4.30	3.33	2.75	4.05
41				1.72	4.45	10.64	9.92	6.62	7.45	8.28	9.94	10.35	9.94	6.69	4.49	9.52
42						2.77	1.91	3.32	11.70	12.76	14.89	13.83	11.70	8.92	7.56	10.64
43						.36	.86	2.54	9.98	14.78	17.17	16.37	11.58	8.36	6.42	11.58
44	4.90	5.01	5.39	3.81	4.42	8.36	9.09	6.70	5.65	7.37	10.07	8.35	7.12	4.76	3.10	5.89
45	3.22	0	0	.94	1.20	3.94	3.33	2.70	10.55	14.36	22.56	12.01	8.79	6.05	3.91	6.45
46					1.19	2.62	7.83	15.66	14.54	13.57	12.12	9.69	6.79	5.49	4.69	5.82
47						1.09	1.34	4.84	12.63	14.60	17.76	13.81	10.66	7.77	6.04	9.47
48				2.18	1.67	5.58	9.15	9.31	9.96	12.02	13.39	10.99	8.24	6.01	4.64	6.87
49						.50	1.13	2.96	10.40	14.02	17.18	14.92	11.76	9.93	7.25	9.95

Appendix 2.

Data for Core Samples from Elliott Bay

Spl. No.	Spl. Type	Collection Date	Location Lat. N 47°+	Location Long. W 122°+	Water depth (ft.)	Distance from shore (yards)	Color Moist	Color Dry	Water Content Wet Basis	Carbonate Content	Texture
14-2B1	piston 0-8"	Feb 14-'51	35'09"	22'17"	217	400					StSd
2B2	piston 8-16"	"	"	"	"	"					"
2B5	piston 32-40"	"	"	"	"	"					"
2B10	piston 74-84"	"	"	"	"	"					"
26-3A1	piston 0-7"	Mar 26-'51	37'24"	20'50"	184	850					Sd
3C1	piston 0-6"	"	36'22"	20'47"	190	400	dk olive gray 5Y 3/1	lt olive gray 5Y 5.5/1	40.75		ClSt
3C2	piston 6-12"	"	"	"	"	"	olive gray 5Y 3.5/1	lt olive gray 5Y 6/1	42.25		St
3C3	piston 12-18"	"	"	"	"	"	"	"	40.07		"
3C4	piston 18-24"	"	"	"	"	"	"	"	40.84		ClSt
3C17	piston 96-104"	"	"	"	"	"	"	"	39.43		"
3D1	piston 0-6"	"	35'44"	21'26"	252	1150	olive gray 5Y 3.5/1	lt olive gray 5Y 6/1	43.24		StfS
3D6	piston 26-33"	"	"	"	"	"	"	"	30.29		StSd
3E1	piston 0-6"	"	35'16"	21'42"	52	460	dk olive gray 5Y 3/1	olive gray 5Y 5/1	25.39		Sd
3E2	piston 6-12"	"	"	"	"	"	"	lt olive gray 5Y 5.5/1	34.77		St
3E4	piston 18-28"	"	"	"	"	"	"	"	39.00		"
3E19	piston 112-121"	"	"	"	"	"	"	"	36.43		"

Appendix 2. (continued)

Spl. No.	Spl. Type	Collection Date	Location Lat. N 47°+	Location Long. W 122°+	Water depth (ft.)	Distance from shore (yards)	Color Moist	Color Dry	Water Content Wet Basis	Carbonate Content	Texture
6-6A1	piston 0-5"	June 6-'51	37'04"	22'42.5"	348	1330	olive medium dark gray 5Y-N4	lt olive gray 5Y 6.25/1			ClSt
6A21	piston 141-147"	"	"	"	"	"	olive gray 5Y 4/1	lt olive gray 5Y 6.5/1			"
12-31	piston surface section	Mar 12-'51	35'36"	22'38"	250±	320					SdGr
6-61	"	June 6-'51	37'04"	22'42½"	348	1330					ClSt
EB-1	Phleger 0-3½"	June 30-'52	37'11"	28'41"	300±	1060	olive gray 5Y 3.5/1	lt olive gray 5Y 5.5/1		2.82	Sd
2	Phleger 0-3½"	"	36'07"	27'34"	720±	2600	olive gray 5Y 3.75/1	lt olive gray 5Y 6/1		8.88	ClSt
3	Phleger 0-3½"	"	36'59.5"	27'46"	680±	2370	"	"		7.67	ClfS
4	Phleger 0-3½"	"	36'55"	26'49"	640±	3600	"	"		9.49	ClSt
5	Phleger 0-3½"	"	36'51"	25'54"	620±	3330	dk olive gray 5Y 3.5/1	"		10.03	"
6	Phleger 0-3"	"	36'40"	24'13"	610±	2390	olive gray 5Y 4/1	"		9.63	"
7	Phleger 0-3"	"	37'13"	23'02"	300±	1300	"	"		9.11	"
8	Phleger 0-3½"	Sept 11-'52	34'23"	26'37"	815±	2070	olive dk gray 5Y 3.25/1	lt olive gray 5Y 6.5/1		8.72	ClfS

Appendix 2. (continued)

Spl. No.	Statistical Measures								Phi Modal dia.	Type of Cumulative Curve	Remarks
	$P_{10\phi}$	$Q_{1\phi}$	Md_{ϕ}	$Q_{3\phi}$	$P_{90\phi}$	Qd_{ϕ}	Skq_{ϕ}	Kq_{ϕ}			
14-2B1	1.15	1.82	2.52	4.40	8.40	1.29	0.59	0.18	PM 2.9	C	
2B2	1.05	1.68	2.30	3.62	6.72	0.97	0.35	0.17	PM 2.3	C	
2B5	1.04	1.70	2.49	4.25	7.10	1.28	0.49	0.21	PM 2.4	C	
2B10	1.00	1.68	2.30	4.00	6.95	1.16	0.54	0.20	PM 2.3	C	
26-3A1	1.06	1.81	2.22	3.04	5.10	0.62	0.21	0.15	PM 2.9	B	
3C1	2.05	4.85	6.27	8.04	10.60	1.60	0.18	0.19	PM 6.5	E_2	+ coal and cinder
3C2	2.90	5.10	6.07	7.48	10.40	1.19	0.22	0.16	PM 6.3	E_2	+ coal and cinder
3C3	4.55	5.65	6.34	7.82	10.50	1.09	0.40	0.18	PM 6.7	E_2	
3C4	4.95	5.73	6.45	8.14	11.50±	1.21	0.49	0.18	PM 6.7	E_2	
3C17	4.90	5.60	6.59	8.28	11.00	1.34	0.35	0.22	PM 6.5	E_2	
3D1	-2.80±	2.29	4.93	7.05	9.65	2.38	-0.26	0.19	PM 6.3 SM 3.2	B_3	
3D6	-0.50	1.41	2.56	4.90	8.50	1.75	0.60	0.19	PM 2.6	Spe C	
3E1	-1.80	1.10	1.91	3.45	5.90	1.18	0.37	0.15	PM 2.2	Spe B	+ wood
3E2	1.60	4.05	5.22	6.85	9.50	1.40	0.23	0.18	PM 5.9 SM 4.1	Spe E	+ wood
3E4	3.30	4.15	5.11	6.16	8.16	1.01	0.05	0.21	PM 5.9	E_1	

Appendix 2. (continued)

Spl. No.	Statistical Measures $P_{10\phi}$	$Q_{1\phi}$	Md_{ϕ}	$Q_{3\phi}$	$P_{90\phi}$	Qd_{ϕ}	Skq_{ϕ}	Kq_{ϕ}	Phi Modal dia.	Type of Cumulative Curve	Remarks
26-3E19	3.68	4.44	5.36	6.48	8.75	1.02	0.10	0.20	PM 5.9	E_1	
6-6A1	5.10	6.02	7.25	9.10	11.30±	1.54	0.31	0.25	PM 6.8	G	+ charcoal
6A21	5.20	5.90	7.44	9.68	11.80±	1.88	0.35	0.29	PM 6.3	G	
12-31	-3.56	-3.05	-1.75	2.55	6.46	2.80	1.50	0.28	PM -1.9	A_3	+ cinder possibly dumped refuse
6-61	5.39	6.16	7.22	9.52	11.50±	1.68	0.62	0.28	PM 7.2	G	same locations as 6-6A
EB-1	1.65	1.97	2.42	3.15	6.85	0.59	0.14	0.11	PM 2.9	B	+ wood and sh
2	2.82	4.59	6.91	9.42	11.60±	2.42	0.10	0.28	PM 7.1	Spe F	
3	3.03	3.78	6.14	8.92	11.29±	2.57	0.21	0.31	PM 4.1	F	
4	4.71	5.97	7.63	9.84	11.95±	1.94	0.28	0.27	PM 7.1	G_2	Bk M + sh and spicules
5	4.96	6.18	7.84	9.94	12.00±	1.88	0.22	0.27	PM 7.1	G_2	Bk M
6	5.05	6.32	7.86	9.80	11.83±	1.74	0.20	0.26	PM 7.5	G_2	
7	3.99	5.71	7.24	9.23	11.50±	2.26	0.23	0.30	PM 7.2	E_2	+ wood and coal
8	1.40	2.68	6.54	8.93	11.10	3.13	-0.74	0.32	PM 7.1 SM 2.5	Spe H	

Appendix 2. (continued) % wt. of size grades (in mm)

Spl. No.	>8.00	8.00 -4.00	4.00 -2.00	2.00 -1.00	1.00 -.50	.50 -.25	.25 -.125	.125 -.0625	.0625 -.0312	.0312 -.0156	.0156 -.0078	.0078 -.0039	.0039 -.00195	.00195 -.00098	.00098 -.00049	<.00049
14-2B$_1$			.67	1.73	5.18	24.23	29.26	14.88	2.47	4.42	2.99	2.86	2.60	2.51	1.20	4.73
2B$_2$			.93	2.07	6.51	31.50	25.30	14.68	1.85	4.69	2.99	1.85	2.28	1.55	.80	3.06
2B$_5$			1.12	2.24	6.14	26.30	23.01	19.18	2.55	5.30	3.93	2.16	1.57	3.73	1.77	.98
2B$_{10}$			1.91	1.98	5.92	28.89	23.85	16.82	3.06	4.66	3.20	2.13	2.13	1.42	1.00	3.04
26-3A$_1$			6.45	.80	1.94	25.44	39.44	11.35	4.07	2.15	2.15	1.08	1.63	1.00	1.00	1.51
3C$_1$					5.47	4.33	3.09	7.29	7.61	17.12	17.60	11.88	9.04	4.57	3.00	9.07
3C$_2$					6.58	1.92	1.49	4.88	8.60	23.56	22.20	10.41	5.88	3.48	2.20	8.81
3C$_3$					1.24	2.18	1.61	4.69	6.10	22.79	26.04	11.80	6.92	4.83	3.00	8.87
3C$_4$						.40	.54	2.45	8.00	21.55	26.43	14.61	6.59	3.63	3.80	12.04
3C$_{17}$						.71	.58	4.35	5.79	22.80	24.87	13.29	7.50	6.11	4.00	10.00
3D$_1$		12.32	1.78	1.18	1.91	5.55	9.92	9.10	8.74	12.74	10.92	7.64	5.46	3.94	3.34	5.46
3D$_6$		4.44	3.52	4.26	7.66	18.48	19.92	14.36	2.88	3.84	4.56	4.32	3.60	2.56	2.24	3.36
3E$_1$			10.89	2.17	11.02	29.00	17.07	12.68	2.88	4.70	2.88	1.99	.91	1.31	.50	1.99
3E$_2$			1.28	1.04	3.07	6.74	4.46	15.74	13.80	18.28	12.08	6.90	4.48	3.63	2.80	5.65
3E$_4$					.84	2.39	3.93	25.54	15.02	24.65	12.02	5.11	2.70	1.00	.80	6.01
3E$_{19}$						1.17	2.71	23.32	14.84	25.28	13.70	6.46	2.89	1.83	1.30	6.50
6-6A$_1$							1.45	.94	6.75	15.58	21.29	16.10	11.94	7.75	6.27	11.94

Appendix 2. (continued)

Spl. No.	>8.00	8.00 -4.00	4.00 -2.00	2.00 -1.00	1.00 -.50	.50 -.25	.25 -.125	.125 -.0625	.0625 -.0312	.0312 -.0156	.0156 -.0078	.0078 -.0039	.0039 -.00195	.00195 -.00098	.00098 -.00049	<.00049
6-6A21							.20	2.56	4.86	19.89	15.47	15.47	11.05	8.05	6.98	15.47
12-31	26.12	20.68	11.31	6.76	3.94	3.78	4.50	4.38	3.22	3.83	3.02	2.22	1.81	1.41	1.12	1.90
6-61								1.34	4.13	14.45	26.83	14.04	9.91	8.26	7.04	14.01
EB-1				.40	.94	25.18	45.14	13.99	1.96	1.14	1.47	1.96	1.96	1.66	1.44	2.77
2						4.93	6.35	8.66	8.51	10.01	12.51	10.51	10.01	7.91	7.10	13.51
3						1.23	8.49	20.36	9.99	8.63	9.99	9.08	7.72	7.31	5.86	11.35
4						2.01	1.06	1.79	8.78	11.71	16.10	13.17	11.71	9.95	7.59	16.10
5							.99	2.47	6.85	12.32	15.06	14.38	13.01	10.42	8.07	16.43
6							.96	2.48	6.00	10.91	15.82	15.82	14.18	10.63	7.92	15.28
7						2.39	2.56	5.14	7.01	11.96	17.32	14.85	11.55	8.42	6.43	12.37
8				4.29	2.25	10.73	10.22	3.37	5.84	7.19	11.68	9.88	10.33	7.22	6.25	10.78

Appendix 3.

Data for Grab Samples and Cores from Nisqually Beach, Commencement Bay and Everett Harbor

Spl. No.	Spl. Type	Collection Date	Location Lat N	Location Long. W 122°+	Water depth (ft.)	Distance from shore (yards)	Color Moist	Color Dry	Carbonate Content	Texture
N-1	Phleger 0-4"	Sept 11-'52	47°07.95'	40.45'	432	1500	olive gray 5Y 3.75/1	lt olive gray 5Y 5.75/1	3.22	StfS
2	Phleger 0-5"	"	07.4'	41.9'	216	200	"	"	1.94	Sd
3	grab	"	07.1'	41.87'	216	800	dk brownish gray N-5YR 3/1	brownish dk gray 5YR-N3	0.41	Sd
4	"	"	06.7'	41.78'	24	1280	"	"	0.36	Sd
5	"	"	06.22'	41.68'	15	350	dk olive gray 5Y 3.5/1	lt brownish olive gray 5YR 5.25/1	1.82	fS
6	Phleger 0-4"	"	10.76'	38.35'	588	1600	olive gray 5Y 4.25/1	lt olive gray 5Y 6.25/1	6.20	sandy granules
7	"	"	12.25'	37.63'	540	1200	olive gray 5Y 4/1	lt olive gray 5Y 6/1	5.75	
T-1	"	Sept 20-'52	17'05"	28'32"	200	400	olive gray 5Y 3.75/1	lt olive gray 5Y 6.75/1	6.73	ClfS
2	"	"	17'16"	28'26"	440	800	"	"	5.52	StSd
3	"	"	16'38"	27'32"	200	200	"	"	4.99	StfS
4	"	"	16'43"	27'28"	420	360	"	"	5.92	St
5	Phleger 0-2"	"	16'56½"	27'14"	456	920	olive gray 5Y 4/1			St
6	Phleger 0-3½"	"	16'33"	26'19"	300	1100	olive dk gray 5Y 3.5/1	lt olive gray 5Y 6.75/1	5.73	St
7	Phleger 0-2½"	"	16'09½"	25'28"	4	20	"			StfS
8	grab	"	16'10½"	25'28½"	40	50	olive gray N-5Y 3.5/1	lt brownish olive gray 5YR-5Y 6/1	2.01	Sd
9	"	"	16'12"	25'30"	80	120	dark gray N 2.5	brownish olive gray 5YR-5Y 5/1	3.84	StfS

Appendix 3. (continued)

Spl. No.	Spl. Type	Collection Date	Location Lat. N	Location Long W. 122°+	Water depth (ft.)	Distance from shore (yards)	Color Moist	Color Dry	Carbonate Content	Texture
T-10	grab	Sept 20-'52	47°16'15½"	25'32"	100	230	dark gray N 2.5	brownish olive gray 5YR-5Y 5/1	4.28	StfS
11	"	"	16'24"	25'51½"	100	650	"	"	4.22	StfS
12	Phleger 0-3½"	"	17'50½"	26'29"	294	300	olive gray 5Y 4/1	lt olive gray 5Y 6/1	7.70	ClSt
13	Phleger 0-2½"	"	17'25"	26'49"	480	1250	"			StfS
14	Phleger 0-5"	"	18'01"	28'06"	552	2100	olive gray 5Y 2.75/1	lt olive gray 5Y 5.75/1	6.20	StfS
15	Phleger 0-2"	"	19'02"	27'58"	582	2300	"		4.69	ClSt
15a	2-5"	"	"	"	"	"	"	brownish olive gray 5YR-5Y 5/1		StfS
E-1	Phleger 0-3½"	July 17-'52	58.7'	17.22'	444	2900	olive gray 5Y 4/1	lt olive gray 5Y 6/1	8.35	ClSt
2	"	"	48°00.16'	16.52'	198	2250	olive gray 5Y 3.75/1	lt olive gray 5Y 5.5/1	2.34	Sd
3	Phleger 0-4"	"	00.3'	16.32'	330	2520	"	"	3.96	StSd
4	Phleger 0-3½"	"	00.5'	16.07'	120	2850	dk olive gray 5Y 3/1	med olive gray 5Y 5/1	2.88	fS
5	"	"	02.62'	18.35'	330	1700	olive gray 5Y 3.5/1	lt olive gray 5Y 6/1	6.46	ClSt

Appendix 3. (continued)

Sample Number	Statistical Measures								Phi Modal Dia.	Type of Cumulative Curve	Remarks
	$P_{10\phi}$	$Q_{1\phi}$	Md_{ϕ}	$Q_{3\phi}$	$P_{90\phi}$	Qd_{ϕ}	Skq_{ϕ}	Kq_{ϕ}			
N-1	2.38	2.80	3.30	4.20	8.10	0.70	0.20	0.12	PM 3.8	C_1	+ wood, shell
2	0.60	1.10	1.50	2.30	6.00	0.60	0.20	0.11	PM 1.9	B	stinky smell, + shell and worm
3	0.70	1.16	1.45	1.66	1.98	0.25	-0.04	0.20	PM 1.9	A	+ red Sd grains
4	0.50	0.91	1.20	1.67	2.30	0.38	0.09	0.21	PM 1.8	A	+ red Sd grains and shell
5	2.15	2.94	3.75	3.98	5.08	0.52	-0.29	0.18	PM 3.9	B_1	Bk Sd + wood and shell
6	-3.90	-1.55	1.20	2.78	8.20	2.17	-0.59	0.18	PM 1.9 SM -3.2	Spe A_3	stinky smell + rnded pebbles and shell Sd
7											
T-1	1.78	2.90	5.32	8.20	10.55	2.65	0.23	0.30	PM 3.5	Spe B_3	+ wood, gravel and shell
2	1.26	1.88	3.08	6.80	9.70	2.46	1.26	0.29	PM 2.5	D	+ wood
3	1.05	2.98	5.55	7.75	10.02	2.39	-0.19	0.27	PM 6.8	B_3	+ wood and coal
4	3.60	4.20	5.50	7.50	9.85	1.65	0.35	0.26	PM 4.9	E	+ wood and charcoal
5	3.58	4.09	5.57	7.68	10.15	1.80	0.32	0.27	PM 4.8	E	+ wood and charcoal
6	3.46	4.05	5.11	6.91	9.26	1.43	0.37	0.25	PM 4.8	E	+ wood and shell
7	2.96	3.60	4.10	5.60	7.28	1.00	0.50	0.23	PM 4.3	E_3	+ wood
8	0.50	1.05	1.47	2.05	3.30	0.50	0.08	0.18	PM 1.9	B	+ red Sd grains and wood
9	2.46	2.85	3.89	5.50	7.40	1.33	0.29	0.27	PM 3.4 SM 5.9	Spe E_3	Bk M + H_2s and wood

Appendix 3. (continued)

Sample Number	Statistical Measures $P_{10\phi}$	$Q_{1\phi}$	Md_{ϕ}	$Q_{3\phi}$	$P_{90\phi}$	Qd_{ϕ}	Skq_{ϕ}	Kq_{ϕ}	Phi Modal Dia.	Type of Cumulative Curve	Remarks
T-10	2.50	2.86	3.82	5.48	6.95	1.31	0.35	0.29	PM 3.4 SM 5.8	Spe E_3	Bk M + H_2S, wood and shell
11	2.78	3.25	3.89	4.94	6.35	0.85	0.21	0.24	PM 4.2	B_1	Bk M + H_2S and wood
12	4.30	5.30	6.62	8.50	10.90	1.60	0.28	0.24	PM 6.5	E_2	+ wood and shell
13	-1.85	2.20	4.84	7.13	9.82	2.47	-0.18	0.21	PM 6.1 SM -1.1	B_3	stinky smell + wood
14	2.45	3.46	4.84	7.27	9.88	1.91	0.53	0.26	PM 4.2	F	+ coal and wood
15	3.80	4.30	6.20	8.35	10.56	2.03	0.13	0.30	PM 4.7 SM 7.9	F	coal and wood discarded
15a	2.20	3.05	3.65	4.92	8.20	0.94	0.34	0.16	PM 3.9	C_1	coal and wood discarded
E-1	4.47	5.60	7.35	9.41	11.40±	1.91	0.16	0.28	PM 6.9	E_2	
2	-1.12	0.40	1.73	3.08	7.50	1.34	0.01	0.16	PM 2.3	B_2	
3	0.64	1.95	2.90	6.10	9.18	2.08	1.13	0.24	PM 2.9	C_2	glacial clay clumps on lower part of core discarded
4	2.38	2.69	3.19	3.92	5.75	0.62	0.12	0.18	PM 3.4	B_1	+ wood and shell
5	4.09	4.88	6.35	8.72	11.05	1.92	0.45	0.28	PM 5.5	F	

Appendix 3.

% wt. of size grades (in mm)

Spl. No.	>8.00	8.00 -4.00	4.00 -2.00	2.00 -1.00	1.00 -.50	.50 -.25	.25 -.125	.125 -.0625	.0625 -.0312	.0312 -.0156	.0156 -.0078	.0078 -.0039	.0039 -.00195	.00195 -.00098	.00098 -.00049	<.00049
N-1					.67	3.96	30.31	37.46	8.54	3.13	2.85	2.85	2.56	2.17	2.10	3.42
2		.49	.74	2.44	16.58	50.52	11.19	4.22	2.21	1.62	1.62	2.06	1.62	1.69	1.11	1.91
3				1.04	15.93	74.00	8.84	.18								
4			.88	2.00	28.46	52.87	13.07	1.72	.0625 .99							
5					1.49	7.12	17.96	49.68	13.37	4.38	2.07	.92	.69	.52	.63	1.15
6	18.34[a]	4.21	5.54	6.24	11.39	24.51	5.52	2.03	2.47	3.09	2.93	3.24	2.62	2.27	1.72	3.86
7																
T-1		.79	.85	1.61	2.99	6.53	13.49	13.57	7.95	7.57	8.70	9.46	7.95	5.79	4.81	7.95
2			.76	1.37	4.79	21.57	20.87	7.93	6.27	5.67	7.17	5.67	5.37	3.71	3.16	5.67
3		.74	1.46	2.58	4.70	7.51	8.04	9.90	9.26	10.85	12.43	10.05	7.41	4.97	4.03	6.08
4				.57	.76	1.43	1.49	15.89	21.92	14.88	13.31	9.00	6.65	4.85	3.76	5.48
5						1.38	4.04	16.67	19.00	15.20	13.30	7.60	6.65	5.56	4.89	5.70
6					.87	1.01	3.46	18.41	24.19	16.46	11.42	7.39	5.71	3.63	2.75	4.70
7				.22	.20	.83	9.12	33.77	22.35	13.85	8.04	4.92	2.68	1.17	.62	2.24
8		.30	.66	3.53	18.02	51.26	14.88	2.27	1.36	2.27	1.97	1.06	.91	.46	.15	.91
9					.33	3.55	26.33	21.92	12.23	20.55	3.64	3.38	1.82	1.70	1.42	3.12

[a] one pebble 16.00 mm 8.54%, 16.00 - 8.00 mm 9.80%

Appendix 3. (continued)

Spl. No.	>8.00	8.00 -4.00	4.00 -2.00	2.00 -1.00	1.00 -.50	.50 -.25	.25 -.125	.125 -.0625	.0625 -.0312	.0312 -.0156	.0156 -.0078	.0078 -.0039	.0039 -.00195	.00195 -.00098	.00098 -.00049	<.00049
T-10				.12	.34	3.26	26.86	22.07	12.75	21.59	2.86	2.86	1.82	1.47	1.39	2.60
11					.52	1.80	13.95	37.58	22.28	11.64	4.93	1.97	1.38	.95	.82	2.17
12						.28	.81	5.55	13.40	18.03	18.49	13.40	8.78	6.51	5.51	9.24
13	5.21	3.94	5.13	3.91	2.41	3.33	7.73	9.38	10.72	11.49	10.72	6.89	5.36	4.53	3.89	5.36
14				1.10	1.56	3.34	11.13	18.40	16.89	11.26	9.01	7.60	6.19	4.02	3.30	6.19
15							2.99	15.06	17.34	12.61	11.03	12.61	9.46	6.05	4.98	7.88
15a						8.12	15.73	39.74	12.04	5.25	4.63	4.01	3.09	2.36	1.96	3.09
E-1						.57	.92	3.79	11.48	13.78	14.93	13.20	12.06	9.27	7.38	12.63
2	.91	3.34	6.73	9.55	13.16	22.86	17.72	7.10	2.96	2.12	2.54	2.12	2.54	2.15	1.66	2.54
3			2.32	3.63	6.91	13.15	26.29	11.94	5.11	5.11	5.34	5.11	4.01	3.23	2.97	4.38
4				.29	.56	3.28	37.26	35.44	9.31	4.98	1.95	1.52	1.51	1.30	.87	1.73
5						.13	.85	7.96	18.64	17.57	13.31	10.65	7.99	6.70	6.08	10.12

Appendix 4.

Data for Grab Samples and Cores from Main Body of Puget Sound and Possession Sound

Spl. No.	Spl. Type	Collection Date	Lat. N	Long. W 122°+	Water depth (ft.)	Distance from shore (yards)	Color Moist	Color Dry	Carbonate Content	Texture
S-1	Phleger 0-3½"	June 30-'52	47°44.9'	25.7'	912	3150	dk olive gray 5Y 3.5/1	lt olive gray 5Y 6/1	3.81	StSd
2	Phleger 0-3½"	"	41.1'	27.65'	840	3500	olive gray 5Y 4/1	lt olive gray 5Y 6/1	9.62	ClSt
3	Phleger 0-4"	July 17-'52	48°05.4'	44.5'	16	800	dk olive gray 5Y 3.5/1	lt olive gray 5Y 5.5/1	3.37	fS
4	grab	"	47°55.5'	29.6'	660	3000				Gr sub-rounded
5	Phleger 0-3"	"	53.8'	21.35'	780	2000	olive gray 5Y 3.75/1	lt olive gray 5Y 6/1	7.50	ClfS
6	Phleger 0-3"	"	47.85'	24.8'	744	1700	olive gray 5Y 4/1	lt olive gray 5Y 6/1	7.82	ClfS
7	Phleger 0-4"	July 29-'52	48°02.46'	21.7'	582	1400	"	"	10.75	ClSt
8	Phleger 0-4"	"	06.32'	29.4'	420	1100	dk olive gray 5Y 3.5/1	lt olive gray 5Y 5.75/1	3.26	Sd
9	Phleger 0-4"	"	09.86'	32.5'	276	1300	olive gray 5Y 4/1	lt olive gray 5Y 6/1	11.51	ClSt
10	Phleger 0-4"	"	11.0'	33.47'	300	1800	"	"	12.21	ClSt
11	grab	Aug 2-'52	47°58.38'	35.5'	384	3350	"		high	
12	"	"	48°01.24'	37.12'	450	1600			high	calc SdGr
13	"	"	05.5'	38.6'	620	2950			high	
14	Phleger 0-4"	Sept 11-'52	47°33.0'	26.36'	840	3400	olive dk gray 5Y 3/1	lt olive gray 5Y 5.75/1	4.94	StfS
15	Phleger 0-3½"	"	29.82'	24.68'	630	2300	olive gray 5Y 3.5/1	lt olive gray 5Y 6.25/1	12.73	ClSt
16	Phleger 0-3½"	"	26.3'	23.6'	816	1850	dk olive gray 5Y 3/1	lt olive gray 5Y 6/1	6.05	StfS

Appendix 4. (continued)

Spl. No.	Spl. Type	Collection Date	Location Lat. N	Location Long. W 122°+	Water depth (ft.)	Distance from shore (yards)	Color Moist	Color Dry	Carbonate Content	Texture
S-17	Phleger 0-4½"	Sept 11-'52	47°23.82'	21.61'	720	1400	olive dk gray 5Y 3.25/1	lt olive gray 5Y 6.25/1	6.91	ClfS
18	Phleger 0-3½"	"	20.65'	25.68'	600	1850	olive gray 5Y 3.75/1	lt olive gray 5Y 6.25/1	11.21	ClSt
19	grab	"	18.86'	29.58'	480	1700				Gr sub-angular
20	Phleger 0-4"	Sept 20-'52	22.09'	31.8'	270	760	olive dk gray 5Y 3/1	olive gray 5Y 4.25/1	58.81	sandy granules
21	grab	"	26.11'	31.23'	432	820	olive dk gray 5Y 2.5/1	brownish olive gray 5YR-5Y 3.75/1	10.22	Sd
22	Phleger 0-7"	"	29.3'	29.8'	312	1200	dark gray N 2.5	lt olive gray 5Y 5.75/1	3.06	Sd

Appendix 4. (continued)

Sample Number	Statistical Measures $P_{10\phi}$	$Q_{1\phi}$	Md_{ϕ}	$Q_{3\phi}$	$P_{90\phi}$	Qd_{ϕ}	Skq_{ϕ}	Kq_{ϕ}	Phi Modal dia.	Type of Cumulative Curve	Remarks
S-1	-0.01	1.04	1.89	4.86	8.84	1.91	1.06	0.22	PM 1.9	Spe C_2	
2	4.20	5.46	7.28	9.75	11.80±	2.15	0.33	0.28	PM 6.9	G	
3	2.21	2.48	2.82	3.58	6.80	0.55	0.21	0.12	PM 3.2	B	
4					-3.35						+ shell
5	2.23	3.40	5.66	8.35	10.90	2.48	0.22	0.29	PM 3.8 SM 6.9	F	
6	3.03	3.86	5.65	8.40	10.40	2.27	0.48	0.31	PM 4.3	F	
7	3.91	6.00	7.76	9.75	11.85±	1.88	0.12	0.23	PM 7.9	Spe G_2	
8	0.44	1.06	1.70	2.30	5.40	0.62	-0.02	0.13	PM 1.9	B	
9	5.88	7.17	8.65	10.55	12.15±	1.69	0.21	0.27	PM 8.8	G	
10	5.88	7.15	8.60	10.34	11.70±	1.60	0.15	0.27	PM 8.8	G	
11											completely shell
12	-4.00	-2.90	-0.40	0.98	1.62	1.94	0.56	0.35	PM 1.5 SM -2.5	A_2	+ shell and angular rock fragments
13											a brachiopod
14	2.07	2.35	2.90	4.75	9.05	1.20	0.65	0.17	PM 3.2	C	+ pebble and wood
15	5.32	6.44	8.05	9.98	11.60±	1.77	0.16	0.28	PM 7.2	G_2	
16	1.86	2.39	2.83	5.70	9.40	1.66	1.22	0.22	PM 3.1 SM 7.5	C	

Appendix 4. (continued)

Sample Number	Statistical Measures								Phi Modal dia.	Type of Cumulative Curve	Remarks
	$P_{10\phi}$	$Q_{1\phi}$	Md_{ϕ}	$Q_{3\phi}$	$P_{90\phi}$	Qd_{ϕ}	Skq_{ϕ}	Kq_{ϕ}			
S-17	2.22	2.79	3.68	8.15	10.50	2.68	1.79	0.32	PM 3.5 SM 8.8	Spe H	
18	4.96	6.40	8.10	9.97	11.60±	1.79	0.09	0.27	PM 8.8	G_2	
19			-4.00	-3.70	-3.08				PM -3.8		
20	-2.67	-1.37	1.19	1.78	1.97	1.58	-0.99	0.34	PM 1.9 SM -1.2	A_1	+ shell foul odor
21	-2.22	1.20	2.21	2.43	2.70	0.62	-0.40	0.13	PM 2.9 SM -1.5	A_1	+ shell
22	0.65	1.52	2.10	2.68	6.80	0.58		0.09	PM 2.7	B	+ shell

Appendix 4. (continued) % wt. of size grades (in mm)

Sample Number	>16.00	16.00 -8.00	8.00 -4.00	4.00 -2.00	2.00 -1.00	1.00 -.50	.50 -.25	.25 -.125	.125 -.0625	.0625 -.0312	.0312 -.0156	.0156 -.0078	.0078 -.0039	.0039 -.00195	.00195 -.00098	.00098 -.00049	<.00049
S-1			2.06	2.21	5.78	14.51	27.46	10.42	7.77	5.60	4.48	3.81	3.58	2.91	2.71	2.22	4.48
2								1.20	6.57	12.00	11.37	15.16	11.37	10.74	8.59	7.83	15.16
3					.19	.41	5.47	53.77	20.97	4.24	3.03	2.22	2.02	1.82	1.66	1.17	3.03
4	84.26	7.23	1.13	4.00 7.38													
5							6.64	13.91	15.26	8.23	9.88	10.43	8.23	6.58	5.69	5.83	9.33
6						1.04	1.36	7.19	21.50	12.40	10.41	9.92	7.93	7.44	7.66	8.21	4.96
7							.78	2.78	7.18	7.76	6.47	13.58	14.88	13.58	10.14	7.32	15.52
8				.47	2.49	20.13	44.59	15.97	4.85	.93	.74	.93	1.67	1.85	1.38	1.59	2.41
9								.11	1.20	3.77	6.03	11.30	15.82	18.08	12.86	10.49	20.34
10								.18	1.43	3.68	5.52	11.95	16.55	17.47	14.12	11.63	17.47
11																	
12	10.68	12.63	12.98	8.73	9.69	20.90	18.73	3.72	.65	.23	.14	.19	.18	.18	.12	.11	.14
13																	
14					1.84	.54	5.71	45.60	19.13	2.63	3.21	3.80	3.80	3.51	3.08	2.18	4.97
15								.58	1.23	5.78	10.83	15.88	15.16	14.44	11.40	9.54	15.16
16					.69	1.83	10.35	47.35	12.16	1.53	2.15	4.30	4.30	3.99	3.30	3.15	4.91

Appendix 4. (continued)

Sample Number	>16.00	16.00 -8.00	8.00 -4.00	4.00 -2.00	2.00 -1.00	1.00 -.50	.50 .25	.25 -.125	.125 -.0625	.0625 -.0312	.0312 -.0156	.0156 -.0078	.0078 -.0039	.0039 -.00195	.00195 -.00098	.00098 -.00049	<.00049
S-17						2.05	4.79	23.94	22.84	3.37	3.80	6.33	6.75	7.59	6.14	4.40	8.01
18								1.56	2.77	6.07	9.87	13.67	14.43	15.95	11.03	9.47	15.19
19	51.42	39.88	8.70														
20		6.82	10.05	12.58	7.29	9.88	45.85	6.29	.59	.21	.0312 .43						
21	3.94	0	7.39	5.90	2.81	2.64	16.68	55.66	3.11	.17	.17	.17	.17	.34	.15	.19	.51
22				.95	4.22	8.89	30.96	36.41	5.18	1.18	.92	1.58	1.97	2.10	1.79	1.10	2.76

Appendix 5.

Data for Grab Samples and Cores from Hood Canal

Spl. No.	Spl. Type	Collection Date	Location Lat. N 47°+	Location Long. W	Water depth (ft.)	Distance from shore (yards)	Color Moist	Color Dry	Carbonate Content	Texture
H-1	Phleger 0-3½"	July 16-'52	25.13'	122°52.87'	19	820	dk olive gray 5Y 3/1	lt olive gray 5Y 5.5/1	3.66	StfS
2	Phleger 0-3½"	"	24.42'	54.4'	42	1100	olive gray 5Y 3.5/1	"	10.29	"
3	Phleger 0-3½"	"	21.82'	123°00.82'	126	400	"	"	13.12	ClSt
4	Phleger 0-3½"	"	22.32'	07.8'	252	1500	"	lt olive gray 5Y 6/1	12.60	"
5	Phleger 0-3½"	"	28.17'	04.56'	498	1200	"	"	14.42	"
6	Phleger 0-8"	"	32.94'	00.55'	490	1200	dk olive gray 5Y 3/1	"	4.58	sandy granules
7	Phleger 0-3½"	"	36.6'	122°56.57'	540	2080	olive gray 5Y 3.5/1	"	12.22	ClSt
8	Phleger 0-3½"	"	39.9'	51.9'	486	2130	dk olive gray 5Y 3/1	"	7.87	"
9	Phleger 0-3½"	"	40.62'	47.7'	408	1100	"	"	5.80	StfS
10	Phleger 0-3½"	"	44.6'	44.85'	396	1000	dk olive gray 5Y 2.5/1	lt olive gray 5Y 5.5/1	2.59	Sd
11	Phleger 0-4"	"	51.45'	37.6'	318	1300	dk olive gray 5Y 2.5/1	lt olive gray 5Y 5.5/1	2.49	"
12	Phleger 0-4"	"	50.54'	34.5'	54	680	"	"	2.73	"
13	Phleger 0-4"	"	53.72'	36.15'	432	1120	"	"	1.95	"
14	Phleger 0-4"	"	56.1'	38.0'	384	1200	"	"	2.43	"
15	Phleger 0-3½"	July 31-'52	37.65'	55.7'	540	1200	olive gray 5Y 3.75/1	lt olive gray 5Y 6/1	9.74	ClSt

Appendix 5. (continued)

Spl. No.	Spl. Type	Collection Date	Location Lat. N 47°+	Location Long. W	Water depth (ft.)	Distance from shore (yards)	Color Moist	Color Dry	Carbonate Content	Texture
H-16	Phleger 0-4"	Aug 1-'52	46.35'	122°50.3'	552	900	olive gray 5Y 3.75/1	lt olive gray 5Y 6/1	11.46	ClSt
17	Phleger 0-3½"	"	40.8'	50.35'	320	1500	"	"	7.38	ClSt
18	Phleger 0-4"	Aug 2-'52	44.8'	50.15'	600	1280	olive gray 5Y 4/1	"	15.56	ClSt

Appendix 5. (continued)

Sample Number	Statistical Measures								Phi Modal dia.	Type of Cumulative Curve	Remarks
	$P_{10\phi}$	$Q_{1\phi}$	Md_{ϕ}	$Q_{3\phi}$	$P_{90\phi}$	Qd_{ϕ}	Skq_{ϕ}	Kq_{ϕ}			
H-1	2.68	3.34	3.90	5.42	7.29	1.04	0.48	0.23	PM 3.9	Spe B_1	+ H_2S and wood
2	3.18	3.78	4.44	7.27	9.15	1.75	1.09	0.29	PM 4.2 SM 7.2	H_1	foul odor, no H_2S, + granules
3	3.80	4.70	6.70	8.48	10.55	1.89	-0.11	0.28	PM 4.5 SM 7.2	H	foul odor
4	4.02	5.39	6.88	8.68	10.48	1.65	0.16	0.26	PM 7.2 SM 5.5	E_2	foul odor
5	5.68	6.88	8.34	9.85	11.30±	1.49	0.03	0.26	PM 8.6 SM 6.5	G	
6	-2.97	-1.70	1.14	3.95	8.90	2.83	-0.02	0.24	PM -2.1 SM 3.9	Spe A_3	+ subrounded gravels
7	5.45	6.75	8.21	10.25	12.10±	1.75	0.29	0.34	PM 8.1	G	
8	4.48	5.68	7.25	9.46	11.50±	1.89	0.32	0.27	PM 7.1	G	
9	3.12	3.85	5.05	7.83	10.68	1.99	0.79	0.26	PM 4.2	H_1	+ wood
10	1.35	1.88	2.67	3.58	6.40	0.85	0.06	0.17	PM 2.8	B	+ shell, sediments become finer with depth of core.
11	1.33	1.60	2.23	3.15	5.50	0.78	0.15	0.19	PM 2.3	B	+ shell and wood
12	1.68	1.98	2.19	2.90	7.46	0.46	0.25	0.08	PM 2.8	C	+ shell and wood
13	1.24	1.58	2.12	2.87	4.35	0.65	0.11	0.21	PM 2.4	B	+ tube worms
14	-0.38	0.48	1.40	2.10	3.25	0.81	-0.01	0.22	PM 1.8	B	foul odor, no H_2S + shell and tube worms

Appendix 5. (continued)

Sample Number	Statistical Measures								Phi Modal dia.	Type of Cumulative Curve	Remarks
	$P_{10\phi}$	$Q_{1\phi}$	Md_{ϕ}	$Q_{3\phi}$	$P_{90\phi}$	Qd_{ϕ}	Skq_{ϕ}	Kq_{ϕ}			
H-15	5.12	6.30	7.92	9.78	11.35±	1.74	0.12	0.28	PM 7.5	G_2	
16	5.90	6.96	8.25	9.88	11.80±	1.46	0.17	0.25	PM 8.2	G	
17	4.05	5.22	6.80	9.18	11.55±	1.98	0.40	0.26	PM 6.8	G	
18	6.00	7.13	8.42	9.81	11.52±	1.34	0.05	0.24	PM 8.8	G	

Appendix 5. (continued)

% wt. of size grades (in mm)

Spl. No.	>8.00	8.00 -4.00	4.00 -2.00	2.00 -1.00	1.00 -.50	.50 -.25	.25 -.125	.125 -.0625	.0625 -.0312	.0312 -.0156	.0156 -.0078	.0078 -.0039	.0039 -.00195	.00195 -.00098	.00098 -.00049	<.00049
H-1					.70	2.38	13.52	43.15	10.86	10.22	7.98	3.83	2.56	1.65	1.22	1.92
2					2.22	3.21	3.91	33.00	13.25	4.64	11.93	9.94	7.29	3.61	2.35	4.64
3						.75	.55	17.97	8.46	11.07	16.93	14.32	9.77	6.68	6.34	7.16
4							.30	9.51	11.27	10.52	21.80	14.28	10.52	8.40	6.63	6.76
5							.23	1.52	2.76	10.10	11.94	17.45	18.37	14.53	10.26	12.86
6	[a]9.45	12.47	8.67	9.06	9.38	7.94	7.38	11.23	2.71	1.73	2.96	3.45	3.95	3.42	2.25	3.95
7							.25	.50	5.96	7.94	14.89	16.87	15.88	10.51	8.35	18.86
8							.33	5.12	10.77	13.17	16.76	13.76	10.77	8.82	7.34	13.17
9					.16	1.64	6.61	29.19	11.73	11.26	8.44	7.50	5.63	5.09	3.82	8.91
10			.34	.37	2.79	24.70	39.74	13.72	4.59	2.75	2.52	1.38	1.60	1.50	1.25	2.75
11			.65	.23	4.02	36.19	31.93	12.58	3.30	2.26	1.73	1.56	1.21	1.29	.97	2.08
12				.29	1.45	26.56	48.19	4.27	2.24	2.68	3.13	2.46	2.46	1.97	1.83	2.46
13			.28	.89	5.14	36.90	34.83	10.81	2.10	2.10	1.29	1.13	.97	.81	.81	1.94
14	4.54	1.47	.93	7.68	22.96	35.43	15.63	4.58	1.62	.81	.81	.81	.65	.33	.64	1.13

[a] 16.00 mm .48%, 16.00 - 8.00 mm 8.97%

Appendix 5. (continued)

Spl. No.	>8.00	8.00 -4.00	4.00 -2.00	2.00 -1.00	1.00 -.50	.50 -.25	.25 -.125	.25 -.0625	.0625 -.0312	.0312 -.0156	.0156 -.0078	.0078 -.0039	.0039 -.00195	.00195 -.00098	.00098 -.00049	<.00049
H-15							.49	1.89	6.56	11.49	15.59	15.59	13.95	11.84	9.49	13.13
16							.15	1.12	2.04	8.14	14.25	19.34	18.32	12.94	8.43	15.27
17							.48	8.22	13.32	15.22	15.85	10.15	10.15	7.91	6.04	12.68
18							.64	1.55	2.57	5.15	12.87	18.02	21.88	14.32	8.85	14.16

Appendix 6.

Data for Grab Samples from West Sound

Sample Number	Sample Type	Collection Date	Location Lat. N 48°+	Location Long. W 122°+	Water depth (ft.)	Distance from shore (yards)	Carbonate Content	Texture
286-5	grab	June 28-'50	35.87'	56.95'	82	100		Sd
6	"	"	35.90'	57.28'	135	550	5.83	fS
7	"	"	35.91'	57.81'	174	500		ClSt
8	"	"	35.91'	58.19'	132	600	4.20	fS
9	"	"	35.96'	58.48'	66	200	4.25	"
10	"	"	36.78'	58.53'	33	100		"
11	"	"	36.72'	58.25'	144	500		StfS
12	"	"	36.64'	57.92'	148	1000	6.03	St
13	"	"	36.55'	57.48'	94	500		St
14	"	"	36.48'	57.23'	39	100		"
15	"	"	37.26'	57.37'	66	150		"
16	"	"	37.33'	57.79'	66	750	6.83	"
17	"	"	37.52'	58.41'	66	700	6.61	"
18	"	"	37.64'	58.88'	59	250		"
19	"	"	37.94'	58.66'	56	500	7.95	"

Appendix 6. (continued)

Sample Number	Sample Type	Collection Date	Location Lat. N 48°+	Location Long. W 122°+	Water depth (ft.)	Distance from shore (yards)	Carbonate Content	Texture
286-20	grab	June 28-'50	38.22'	58.88'	49	380	7.95	St
21	"	"	38.48'	58.98'	36	250		fS
22	"	"	37.05'	58.13'	72	780		St
23	"	"	36.30'	57.73'	105	680		StfS

Appendix 6. (continued)

Sample Number	Statistical Measures								Phi Modal dia.	Type of Cumulative Curve	Remarks
	$P_{10\phi}$	$Q_{1\phi}$	Md_{ϕ}	$Q_{3\phi}$	$P_{90\phi}$	Qd_{ϕ}	Skq_{ϕ}	Kq_{ϕ}			
286-5	-2.72	-0.25	1.18	2.90	5.45	1.58	0.15	0.19	PM 0.8	B_2	+ shell
6	2.16	2.60	2.94	3.98	7.04	0.69	0.35	0.14	PM 3.3	Spe B_1	+ shell
7	2.00	5.00	6.43	8.28	11.50±	1.64	0.21	0.17	PM 7.1	Spe E_2	
8	1.60	2.23	2.74	3.35	6.15	0.56	0.05	0.12	PM 3.3	B	+ shell
9	2.20	2.82	3.19	3.95	5.90	0.57	0.20	0.15	PM 3.8	B_1	
10	1.85	2.48	2.85	3.09	4.40	0.31	-0.07	0.12	PM 3.4	B	
11	3.20	3.65	4.32	5.71	7.94	1.03	0.36	0.22	PM 4.4	E_3	
12	3.58	4.13	4.86	6.23	8.27	1.05	0.32	0.22	PM 5.2	E	
13	3.72	4.24	5.02	6.70	8.88	1.23	0.45	0.24	PM 5.1	E	
14	3.08	4.05	5.15	6.75	8.64	1.35	0.25	0.24	PM 5.3	E	
15	4.10	4.68	5.49	6.83	8.75	1.08	0.27	0.23	PM 5.5	E_1	
16	4.16	4.91	5.68	7.02	8.90	1.06	0.29	0.22	PM 5.9	E_1	
17	4.16	4.43	6.26	7.50	9.38	1.54	-0.30	0.29	PM 5.1 SM 7.2	H	+ mud worm
18	4.65	5.66	6.66	7.98	9.95	1.16	0.16	0.22	PM 6.9	E_2	+ wood
19	3.63	5.11	6.11	7.35	9.18	1.12	0.12	0.20	PM 6.3	E_2	+ shell

Appendix 6. (continued)

Sample Number	Statistical Measures								Phi Modal dia.	Type of Cumulative Curve	Remarks
	$P_{10\phi}$	$Q_{1\phi}$	Md_ϕ	$Q_{3\phi}$	$P_{90\phi}$	Qd_ϕ	Skq_ϕ	Kq_ϕ			
286-20	3.60	5.11	6.16	7.40	9.10	1.15	0.10	0.21	PM 6.4	E_2	+ mud worm and shell
21	1.87	2.28	2.72	3.96	7.57	0.84	0.40	0.15	PM 3.1	C	
22	3.99	4.55	5.40	6.74	9.03	1.10	0.25	0.22	PM 5.4	E_1	
23	3.45	3.80	4.38	5.52	7.67	0.86	0.28	0.20	PM 4.6	E_3	+ mud worm

Appendix 6. (continued)

Spl. No.	>8.00	8.00 -4.00	4.00 -2.00	2.00 -1.00	1.00 -.50	.50 -.25	.25 -.125	.125 -.0625	.0625 -.0312	.0312 -.0156	.0156 -.0078	.0078 -.0039	.0039 -.00195	.00195 -.00098	.00098 -.00049	<.00049
286-5	9.00	3.15	3.55	13.75	17.73	15.24	13.41	7.33	5.13	3.24	2.43	1.89	1.62	.94	1.62	
6				.49	.79	5.49	50.40	18.20	7.27	4.93	2.35	3.05	2.58	1.41	3.05	
7				2.41	3.09	4.39	3.83	3.35	7.93	8.59	30.39	9.25	5.62	4.63	16.52	
8				1.83	2.71	11.31	53.03	13.15	5.03	2.39	2.39	1.92	1.92	1.68	2.63	
9			4.12	.12	.38	2.54	30.33	38.56	9.58	4.79	2.16	1.92	1.44	1.68	2.39	
10				.27	.64	12.14	59.28	17.00	1.46	1.46	1.46	1.70	1.46	1.21	1.94	
11				1.48	.33	.70	5.34	34.15	22.79	13.61	6.81	5.03	2.96	2.37	4.44	
12					.91	.50	2.36	16.00	33.41	19.36	9.37	6.87	3.75	2.81	4.68	
13							1.66	16.83	31.08	17.96	10.36	7.60	5.18	3.45	5.87	
14			4.81	.23	.17	.36	3.69	14.62	22.18	20.68	10.79	8.99	5.10	3.60	4.80	
15						.33	1.54	6.82	26.84	25.86	15.71	9.16	4.91	3.93	4.91	
16							1.08	6.36	20.30	30.28	16.86	9.98	5.50	3.10	6.54	
17							.23	2.64	35.95	5.74	22.94	13.00	7.65	3.82	8.03	
18						4.49	.78	2.16	5.99	19.55	24.34	17.96	9.58	5.59	9.58	
19					3.67	.27	1.51	5.85	10.88	25.15	21.75	13.58	6.46	3.40	7.48	
20						4.11	1.65	5.05	11.38	23.49	22.39	14.68	6.61	4.40	6.24	

Appendix 6. (continued

Spl. No.	>8.00	8.00 -4.00	4.00 -2.00	2.00 -1.00	1.00 -.50	.50 -.25	.25 -.125	.125 -.0625	.0625 -.0312	.0312 -.0156	.0156 -.0078	.0078 -.0039	.0039 -.00195	.00195 -.00098	.00098 -.00049	<.00049
286-21				.52	.99	10.48	48.27	14.80	2.32	4.93	4.93	4.64	3.19	1.74	3.19	
22						.13	.42	9.75	27.75	26.23	13.68	8.36	4.56	3.42	5.70	
23						.23	3.31	29.96	32.75	13.90	6.62	4.30	3.31	1.99	3.64	

Appendix 7.

Data for Core Samples from Washington Sound

Spl. No.	Spl. Type	Collection Date	Location Lat. N 48°+	Location Long. W 122°+	Water depth (ft.)	Distance from shore (yards)	Color Moist	Color Dry	Water Content Wet Basis	Carbonate Content	Texture
19-6A_1	piston 0-5"	June 19-'50	33.36'	55.93'	50	470	dk olive gray N-5Y 3/1	lt brownish olive gray 5YR-5Y 5.75/1	25.38	5.00	fS
6A_2	piston 5-11"	"	"	"	"	"	"	"	15.30		SdGr
6A_4	piston 16-21"	"	"	"	"	"	"	lt olive gray 5Y 5.75/1	28.65	11.06	StfS
6A_{14}	piston 66-71"	"	"	"	"	"	"	"	44.63	9.58	"
6B_1	piston 5-11"	"	35.14'	51.30'	90	1730	olive gray 5Y 3.5/1				StfS
6B_{19}	piston 116-125"	"	"	"	"	"	"				St
6C_1	piston 0-3"	"	35.71'	50.50'	124	1200	olive gray 5Y 3.5/1				StfS
6C_2	piston 3-9"	"	"	"	"	"	olive gray 5Y 3/1				St
6C_8	piston 37-42"	"	"	"	"	"	olive gray 5Y 3.5/1				ClSt
6D_1	piston 0-10"	"	36.20'	57.68'	105	720					StfS
21-7A_1	piston 0-3"	July 21-'50	29.08'	50.98'	158	380	olive gray 5Y 3.5/1	lt olive gray 5Y 6/1	43.2	11.46	ClSt
7A_2	piston 3-9"	"	"	"	"	"	"	"	40.8	8.83	"
7A_7	piston 29-32"	"	"	"	"	"	"	"	40.2	9.36	"
7B_1	piston 0-5"	"	34.98'	51.21'	99	2100	dk olive gray 5Y 3/1	lt brownish olive gray 5YR-5Y 6/1	41.8	9.08	StfS
7B_2	piston 5-10"	"	"	"	"	"	"	lt olive gray 5Y 6/1	46.8	8.54	ClSt

Appendix 7. (continued)

Spl. No.	Spl. Type	Collection Date	Location Lat. N 48°+	Location Long. W 122°+	Water depth (ft.)	Distance from shore (yards)	Color Moist	Color Dry	Water Content Wet Basis	Carbonate Content	Texture
21-$7B_7$	piston 30-36"	July 21-'50	34.98'	51.21'	99	2100	dk olive gray 5Y 3/1	lt olive gray 5Y 6/1	38.6	12.26	StfS
26-$7A_1$	piston 0-5"	July 26-'50	41.24'	53.87'	76	400	lt olive black 5Y 2.5/1	lt brownish olive gray 5YR-5Y 5.75/1	68.8	11.42	ClSt
$7B_1$	piston 0-5"	"	40.00'	53.75'	92	1100	lt dark gray N 3.5	lt brownish olive gray 5YR-5Y 6/1	70.0	13.49	"
2-$8A_1$	piston 0-6"	Aug 2-'50	38.62'	52.75'	82	460	dk gray N 3	lt olive gray 5Y 6/1	68.8	16.24	"
$8B_1$	piston 0-7"	"	37.14'	51.30'	89	800	dk olive gray N-5Y 3.5/1	"	60.5	12.29	"
$8B_{21}$	piston 130-139"	"	"	"	"	"	olive gray 5Y 3.5/1	"	52.4	8.26	"
$8C_1$	piston 0-6"	"	35.71'	50.85'	76	1730	dk olive gray 5Y 3/1	"	43.4	6.12	St
$8C_{17}$	piston 111-114"	"	"	"	"	"	dk gray N 3.5	"	34.3		"
$8D_1$	piston 0-6"	"	33.67'	50.42'	131	950	dk olive gray 5Y 3/1	lt brownish olive gray 5YR-5Y 6/1	32.7	6.45	StfS
$8D_3$	piston 12-18"	"	"	"	"	"	"	lt olive gray 5Y 6/1	32.2	6.50	"
$8D_{14}$	piston 78-84"	"	"	"	"	"	med dk gray N 4	"	33.4	5.41	St
12-$8A_1$	piston 0-8"	Aug 12-'50	30.80'	51.18'	30	1020	dk gray N 3.5	lt brownish olive gray 5Y 5.75/1	48.6	5.50	ClSt
$8A_6$	piston 37-44"	"	"	"	"	"		"	46.1		St
$8A_{18}$	piston 128-135"	"	"	"	"	"	dk olive gray 5Y 3/1	lt brownish olive gray 5Y 6/1	40.1	5.31	ClSt

Appendix 7. (continued)

Spl. No.	Spl. Type	Collection Date	Location Lat. N 48°+	Location Long. W 122°+	Water depth (ft.)	Distance from shore (yards)	Color Moist	Color Dry	Water Content Wet Basis	Carbonate Content	Texture
12-8B1	piston 0-7"	Aug 12-'50	28.86'	50.58'	54	660	dk olive gray N-5Y 3.5/1	lt olive gray 5Y 6.25/1	50.0	7.01	ClfS
8B6	piston 38-46"	"	"	"	"	"		lt olive gray 5Y 6/1	37.1	[illegible]	StfS
8B21	piston 160-169"	"	"	"	"	"	dk olive gray N-5Y 3.5/1	"	34.1	4.68	"
8D1	piston 0-6"	"	36.66'	58.36'	57	300	olive gray 5Y 3.5/1				ClSt
8D5	piston 24-30"	"	"	"	"	"	dk olive gray 5Y 3/1				StfS
8C	piston failed	"	31.98	49.6'	160+						

Appendix 7. (continued)

Spl. No.	Statistical Measures $P_{10\phi}$	$Q_{1\phi}$	Md_{ϕ}	$Q_{3\phi}$	$P_{90\phi}$	Qd_{ϕ}	Skq_{ϕ}	Kq_{ϕ}	Phi Modal dia.	Type of Cumulative Curve	Remarks
19-6A1	2.06	2.65	2.95	3.76	5.50	0.56	0.26	0.16	PM 3.3	B	+ few sh
6A2	-4.20	-3.10	2.73	3.55	5.35	3.33	-2.51	0.35	PM 3.4 SM -3.1	A_2	+ Gr, sh and wood
6A4	-1.50	2.80	3.66	5.05	8.70	1.13	0.27	0.11	PM 3.9	D_2	+ rock fragments and few shells
6A14	2.12	2.99	3.85	4.32	7.10	0.67	-0.20	0.13	PM 3.9	Spe D_2	+ sh and sand-stone fragments
6B1	3.46	3.94	4.94	7.06	9.96	1.56	0.56	0.24	PM 4.6	E	+ few sh
6B19	3.40	4.12	5.06	7.01	9.65	1.45	0.51	0.23	PM 4.9	E	+ few sh
6C1	1.77	2.48	4.77	7.08	9.71	2.30	0.01	0.29	PM 2.8 SM 5.9	Spe D	+ few small sh and a rock fragment
6C2	4.17	4.94	5.83	7.80	10.70	1.43	0.54	0.22	PM 5.8	Spe E_2	+ few small sh
6C8	2.57	4.22	6.05	8.25	10.60	2.02	0.19	0.25	PM 6.1	E_2	+ few small sh
6D1	3.20	3.58	4.28	6.35	10.50	1.39	0.69	0.19	PM 4.1	E	+ few sh
21-7A1	3.00	5.45	7.18	9.40	11.40±	1.98	0.25	0.24	PM 7.1	E_2	a large sh and twig discarded
7A2	4.80	5.91	7.45	9.80	11.26	1.95	0.41	0.30	PM 7.1	E_2	traces of sh
7A7	4.32	4.48	5.65	8.25	10.80	1.89	0.72	0.29	PM 5.2	Spe E	traces of sh
7B1	3.40	3.86	4.65	6.86	10.20	1.50	0.71	0.22	PM 4.4	E	+ few sh, no H_2S
7B2	3.94	4.77	6.35	9.00	11.60	2.12	0.54	0.28	PM 5.5	F	+ few sh, no H_2S
7B7	3.12	3.82	4.87	7.05	9.64	1.62	0.57	0.25	PM 4.5	E	+ few sh strong H_2S
26-7A1	4.70	6.76	8.38	10.22	11.55	1.78	0.11	0.26	PM 8.8	G	
7B1	5.20	7.07	8.70	10.57	11.80±	1.75	0.12	0.27	PM 8.9	I	

Appendix 7. (continued)

Spl. No.	Statistical Measures $P_{10\phi}$	$Q_{1\phi}$	Md_{ϕ}	$Q_{3\phi}$	$P_{90\phi}$	Qd_{ϕ}	Skq_{ϕ}	Kq_{ϕ}	Phi Modal dia.	Type of Cumulative Curve	Remarks
2-8A1	4.30	5.90	7.52	9.52	10.80	1.81	0.19	0.28	PM 7.5	G_2	moderate H_2S
8B1	4.50	5.20	6.57	8.94	10.80	1.87	0.50	0.30	PM 6.2	F-G	moderate H_2S + sh
8B21	4.75	5.55	6.95	9.30	11.70±	1.88	0.48	0.27	PM 6.3	F-G	weak H_2S
8C1	3.62	4.05	5.15	7.35	10.40	1.65	0.55	0.24	PM 4.8	E	+ sh, no H_2S
8C17	3.75	4.05	4.93	6.50	10.05	1.23	0.35	0.19	PM 4.8	E	
8D1	1.90	2.46	3.80	6.35	9.70	1.95	0.61	0.25	PM 3.2	D	rich in sh
8D3	3.04	3.80	5.25	7.35	10.70	1.78	0.33	0.23	PM 4.2 SM 5.9	F_1	
8D14	2.96	4.06	5.53	7.60	11.00	1.77	0.30	0.22	PM 5.5	F_1	
12-8A1	3.88	4.30	5.68	8.25	10.90	1.98	0.60	0.28	PM 4.5	F_2	no H_2S
8A6	4.10	4.80	5.85	7.98	10.85	1.59	0.54	0.24	PM 5.5	F_2	moderate H_2S
8A18	4.07	4.75	5.97	8.06	11.20±	1.66	0.44	0.30	PM 5.4	F_2	
8B1	2.80	3.80	5.42	8.20	10.80	2.20	0.58	0.28	PM 4.3	F	
8B61	2.38	2.78	3.80	5.70	8.80	1.46	0.44	0.23	PM 3.4	D_1	+ one big sh and wood
8B21	2.53	3.01	4.15	6.87	10.40	1.93	0.78	0.25	PM 3.5	D_1	
8D4	3.90	4.67	6.19	8.35	10.60	1.84	0.32	0.28	PM 5.8	F	
8D5	1.20	3.25	5.18	7.61	10.60	2.18	0.25	0.23	PM 4.5	Spe F	+ sh and rock fragments
8C	---	---	---	---	---	---	---	---	----	---	recovered small amount of sand and gravel

Appendix 7. (continued) % wt. of size grades (in mm)

Spl. No.	>8.00	8.00 -4.00	4.00 -2.00	2.00 -1.00	1.00 -.50	.50 -.25	.25 -.125	.125 -.0625	.0625 -.0312	.0312 -.0156	.0156 -.0078	.0078 -.0039	.0039 -.00195	.00195 -.00098	.00098 -.00049	<.00049
19-6A1					1.55	7.50	44.55	29.06	5.76	3.08	1.78	1.23	1.12	1.18	1.20	1.99
6A2	25.39[a]	2.39	1.08	1.17	1.26	4.78	26.23	20.40	5.97	3.09	1.65	1.44	1.24	1.31	.96	1.65
6A4		9.86	.30	.34	.69	2.90	18.12	29.52	13.23	6.47	4.71	2.35	2.35	2.06	1.90	5.16
6A14				4.86	.60	3.11	16.71	45.50	9.73	5.79	3.48	2.55	1.85	2.08	2.34	1.36
6B1					.61	.81	3.50	22.06	24.32	14.73	8.48	6.27	4.43	5.16	3.63	5.96
6B19					1.40	.58	3.15	17.79	26.23	16.64	9.17	7.08	5.42	3.75	3.39	5.36
6C1				1.21	.71	12.21	17.83	10.05	10.13	12.30	9.78	6.16	4.70	3.98	9.54	1.33
6C2					.87	1.42	2.54	3.63	19.37	24.71	14.85	9.07	5.36	4.53	4.65	8.95
6C8				2.20	2.04	2.04	7.94	8.77	11.00	15.49	13.85	9.78	6.93	6.11	5.65	8.20
6D1				1.10	.43	.82	3.89	40.05	13.15	12.46	7.47	3.56	4.27	2.00	1.60	9.03
21-7A1				1.89	2.18	2.63	3.43	3.23	6.73	13.02	14.81	13.92	9.88	8.08	7.20	13.00
7A2						1.31	1.15	2.28	7.67	14.00	16.25	14.90	9.48	9.94	10.02	12.99
7A7						1.17	.79	1.08	41.85	8.44	10.64	9.18	7.34	5.13	5.18	9.14
7B1				1.70	.18	.54	1.97	27.59	23.59	13.14	7.25	4.99	4.08	4.08	3.19	7.69
7B2						.35	1.52	9.83	17.04	17.04	11.55	9.73	7.90	6.08	5.56	13.31
7B7				5.46	.26	.33	2.78	21.32	22.08	14.14	8.56	5.93	3.95	3.62	9.07	2.56
26-7A1						3.55	3.01	1.77	2.96	5.91	10.84	14.78	17.74	11.83	10.81	16.79

[a] 16.00 mm 12.95%, 16.00 - 8.00 mm 12.44%

Appendix 7. (continued)

Spl. No.	> 8.00	8.00 -4.00	4.00 -2.00	2.00 -1.00	1.00 -.50	.50 -.25	.25 -.125	.125 -.0625	.0625 -.0312	.0312 -.0156	.0156 -.0078	.0078 -.0039	.0039 -.00195	.00195 -.00098	.00098 -.00049	<.00049
26-7B1							5.11	2.99	1.46	2.92	11.67	14.59	16.05	13.13	12.08	20.01
2-8A1							5.33	3.38	5.93	11.86	15.41	15.41	11.86	11.86	10.96	8.01
8B1							3.46	2.05	13.39	20.47	17.32	11.02	7.87	7.87	7.55	8.99
8B21							1.57	2.48	9.37	20.40	17.06	12.68	9.37	6.62	5.75	14.65
8C1						.80	2.65	18.62	25.38	15.14	9.35	7.13	4.90	4.45	3.58	8.00
8C17							.97	22.18	29.37	17.49	8.75	5.00	3.12	3.12	2.00	8.00
8D1			3.31	.52	.66	6.96	28.63	18.25	6.74	7.71	6.50	4.82	3.85	3.13	2.92	5.99
8D3						1.49	8.18	21.80	13.88	15.90	11.20	7.17	4.25	4.03	3.10	8.99
8D14						.62	9.96	13.44	16.94	16.94	12.36	7.78	4.58	3.66	2.72	11.01
12-8A1							.73	17.43	18.12	16.95	12.28	8.18	5.85	5.26	2.70	12.50
8A6							.76	7.76	22.64	21.25	13.86	8.78	6.01	4.74	4.96	9.24
8A18							.40	7.73	21.85	20.64	14.16	9.71	6.07	4.86	3.78	10.79
8B1						4.65	8.01	18.81	13.09	11.79	9.17	8.29	6.98	5.24	4.47	9.50
8B6				2.33	.17	1.59	27.98	22.56	13.91	8.61	5.63	3.97	3.97	1.08	.58	7.62
8B21					.21	.98	23.64	22.95	12.21	8.86	7.33	5.80	3.97	3.05	2.30	8.69
18-8D1							1.44	10.90	16.91	18.16	13.77	11.27	6.89	6.89	4.77	9.00
12-8D5				7.09	2.40	4.28	7.31	13.72	12.82	12.26	10.03	7.80	5.29	4.46	3.74	8.80
8C				---	---	---	---	---	---	---	---	---	---	---	---	---

Appendix 8.

Data for Grab Samples and Cores from Lake Washington

Spl. No.	Spl. Type	Collection Date	Location Lat. N 47°+	Location Long. W 122°+	Water depth (ft.)	Distance from shore (yards)	Color Moist	Color Dry	Water Content Wet Basis	Carbonate Content	Texture
16-21	grab	Feb 16-'51	38'39"	16'24"	100	340	med gray N 5.5	lt gray N 7.5		0.67	SdGr
Lu-51	"	Jan - '51	38'33"	19'49"	54	170	olive gray 5Y 3.5/1	lt olive gray 5Y 5.75/1	very low	2.75	ClSt
Lk-1	Phleger 0-4"	July 1-'52	39'51"	14'44"	200	1000	brownish olive gray 5YR-5Y 5/1	lt olive gray 5Y 6.5/1		4.75	"
2	"	"	39'50"	13'35"	169	1530	brownish olive gray 5YR-5Y 4/1	lt olive gray 5Y 6/1		2.86	ClfS
3	"	"	39'49"	12'51"	140	600	med gray N 5	lt gray N 6.5	very low	2.25	St
4	"	"	42'11"	15'28"	140	900	brownish olive gray 5YR-5Y 4/1	lt olive gray 5Y 6.5/1		4.11	ClSt
16-2A1	piston 0-8"	Feb 16-'51	38'40"	16'15"	177	500	dk brownish gray 5YR 3.5/1		very low		"
2A12	piston 88-92"	"	"	"	"	"	"		very low		"
7-3A1	piston 3-10"	Mar 7-'52	39'18"	13'24"	92	530	brownish dk gray 5YR 3/1	lt olive gray 5Y 6/1	85.14	2.15	StfS
3A3	piston 15-21"	"	"	"	"	"	"	lt olive gray 5Y 5.5/1	76.54		"
3A4	piston 21-25"	"	"	"	"	"	med gray N 4.5	med lt gray N 6	33.59	3.55	ClSt
3A19	piston 154-160"	"	"	"	"	"	med gray N 5	"	39.03	5.20	"

Appendix 8. (continued)

Spl. No.	Statistical Measures $P_{10\phi}$	$Q_{1\phi}$	Md_{ϕ}	$Q_{3\phi}$	$P_{90\phi}$	Qd_{ϕ}	Skq_{ϕ}	Kq_{ϕ}	Phi Modal dia.	Type of Cumulative Curve	Remarks
16-21	-4.20	-3.30	1.05	2.06	3.20	2.68	-1.67	0.36	PM 2.2 SM -3.2	A_2	+ subangular pebble and concrete fragment, possibly dumped refuse.
Lu-51	5.27	7.00	8.90	10.78	12.00±	1.89	-0.01	0.28	PM 9.1 SM 6.1	I	possible glacial clay
Lk-1	3.95	4.35	7.66	9.24	11.10	2.45	-0.86	0.34	PM 4.7 SM 8.5	H	
2	3.88	3.96	4.61	8.02	9.98	2.03	1.38	0.33	PM 4.3 SM 8.8	H_1	
3	3.90	4.30	5.42	7.45	9.68	1.58	0.46	0.27	PM 5.2	F	pebble and cinder discarded, possible glacial clay.
4	3.98	4.46	6.73	8.46	10.35	2.00	-0.27	0.31	PM 4.9 SM 7.9	H	
16-2A1	5.49	6.54	7.81	9.27	10.93	1.37	0.09	0.25	PM 8.2	G_1	possible glacial clay
2A12	5.51	6.20	7.50	8.97	10.66	1.39	0.08	0.27	PM 7.9 SM 6.5	G_1	"
7-3A1	2.69	3.68	6.89	8.00	9.25	2.16	-1.05	0.33	PM 7.8 SM 3.9	Spe H	dominantly plant tissue
3A3	2.80	3.90	5.45	7.20	9.10	1.65	0.10	0.26	PM 5.5	F	"
3A4	4.63	5.25	6.50	8.45	10.60	1.60	0.35	0.27	PM 6.1	E_2	possible glacial clay
3A19	5.96	7.71	9.45	11.10	12.20±	1.70	-0.05	0.27	PM 9.5	I	possible glacial clay

Appendix 8. (continued) % wt. of size grades (in mm)

Spl. No.	>8.00	8.00 -4.00	4.00 -2.00	2.00 -1.00	1.00 -.50	.50 -.25	.25 -.125	.125 -.0625	.0625 -.0312	.0312 -.0156	.0156 -.0078	.0078 -.0039	.0039 -.00195	.00195 -.00098	.00098 -.00049	<.00049
16-21	[a] 28.06	4.91	4.21	4.46	7.56	24.02	15.64	3.90	1.65	.82	.99	1.15	.99	.74	.41	.49
Lu-51							.46	1.78	5.00	10.78	6.93	11.55	15.01	13.19	13.36	21.94
Lk-1							.04	13.89	18.83	1.79	6.28	15.24	15.24	11.24	6.69	10.76
2							.50	29.25	25.20	5.35	7.64	6.87	9.16	6.13	4.56	5.35
3							2.34	12.83	25.41	19.69	10.38	8.59	6.80	5.81	4.93	3.22
4							.05	10.59	23.03	7.37	12.90	15.66	11.05	7.35	5.55	6.45
16-2A_1							1.34	2.51	1.73	11.26	15.59	21.65	17.32	11.75	7.31	9.53
2A_{12}							.62	2.19	1.37	17.80	16.43	21.90	15.06	10.10	6.33	8.21
7-3A_1					1.43	3.34	8.88	15.66	1.91	3.82	19.10	21.01	13.37	4.48	3.16	3.82
3A_3						1.60	10.49	13.38	16.73	16.73	13.69	10.65	6.08	4.30	3.30	3.04
3A_4							2.03	.86	15.85	22.75	16.25	12.19	9.75	6.67	5.11	8.53
3A_{19}								1.43	2.82	6.10	7.98	9.86	15.02	15.39	15.12	26.28

[a] 16.00 mm 12.31%, 16.00 - 8.00 mm 15.75%

VITA

Feng-Hui Wang, known also as Frank Wang, was born on March 21, 1924, at Paoting, Hopeh Province, China, Son of Shu-Lan and Wen-Chaun Wang. He attended the Provincial Second Grade School from 1929 to 1935, graduated from National Seventh High School in 1941, and graduated from National Southwest Associated University in 1945 with the degree of B. S. in Geology.