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Mineral Composition and Sediments in Eastern Long Island Sound, New York*

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Introduction

The area of this investigation lies in eastern Long Island Sound. It is located between 72°04'W to 71°50'W and 41°20'N to 41°15'N. The area is about 78 square km in extent (Fig. 1). The adjacent Connecticut coastal region consists of Paleozoic and Precambrian metamorphic rocks that from the bedrock of eastern Connecticut. There are sporadic occurrences of granitic intrusions (Rodgers *et al.*, 1956). The bedrock is extensively covered by glacial material including huge erratic boulders, best exemplified in Stonington and Mystic areas, and tills ranging in thickness from less than 1 m to 10 m with a few exceptions of about 65 m. South of the Sound is Fishers Island, which forms part of the continuous chain of islands aligned east-west and extending from Long Island to Nantucket Island, Massachusets. These islands mark the sites of the terminal moraine of the Wisconsin stage glaciation along the New England coast (Fuller, 1914; Woodworth and Wiggleworth, 1934; Pratt and Schlee, 1969). Surficial reconnaissance of Fishers Island and the immediate Connecticut shoreline provided data that were useful in interpreting the mineralogy and sediment movement in the Sound. At Station 84 (a 3-m excavation site for a new home) details of the textural compositional and surficial sedimentary character of the Island were revealed. Further observation at Station 85 and 86 and throughout the Island showed that the surficial material on Fisher Island is composed of loosely to moderately compact sandy, gravelly and bouldery till, which is as thick as 10 m in some areas. Fuller (1914) reported a thickness of 13 m at Clay Point.

No previous study of the mineralogy and sedimentology of eastern Long Island Sound has been made. However, a general description of sediment size distribution in surrounding areas has been published by McCrone *et al.* (1961), and Buzas (1965). Schlee (1968) and Uchupi (1968) recorded sediment types in the adjacent area. The objective of this study is to determine: (1) the mineral composition, (2) distribution of sediment size, (3) dominant paths of sediment movement, and (4) sedimentation rate in the area.

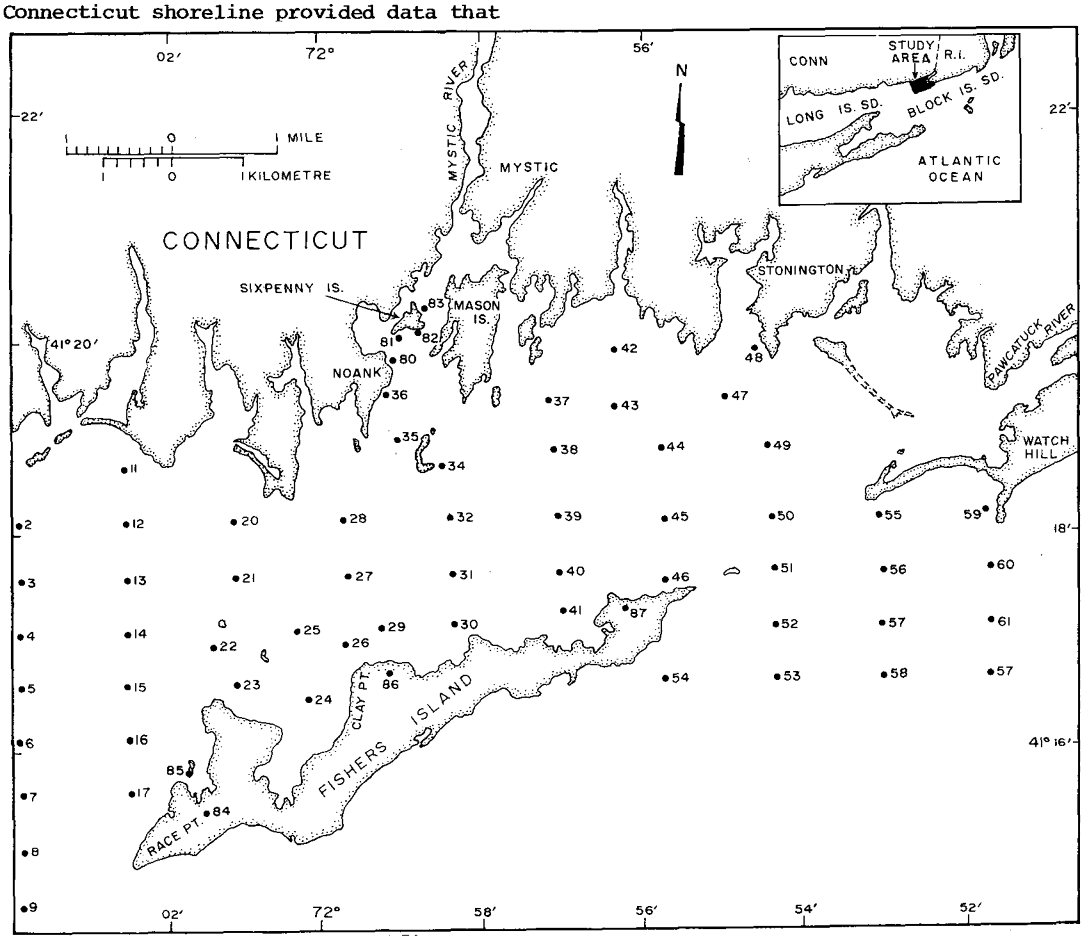

Fig. 1. Index map of study area and station locations.

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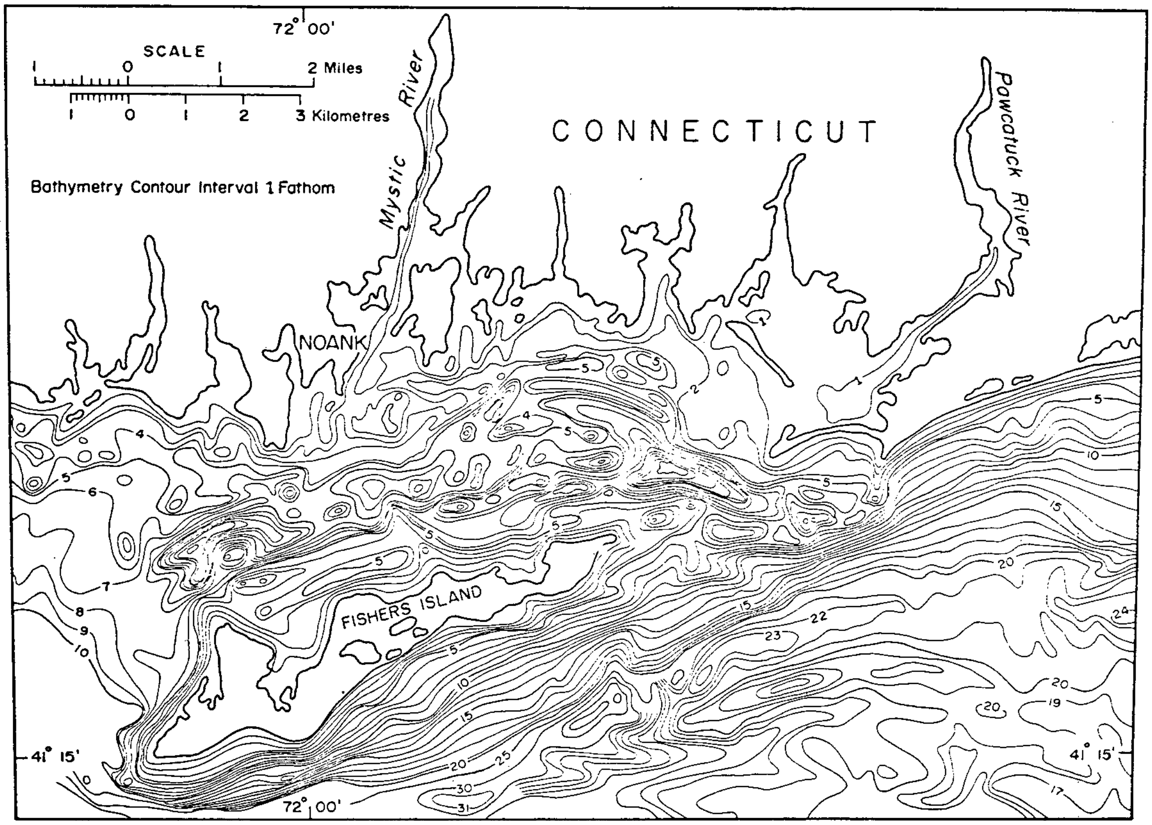
72° 00'
SCALE
2 Miles
3 Kilometres
Bathymetry Contour Interval 1 Fathom
Mystic River
CONNECTICUT
Pawcatuck River
NOANK
FISHERS ISLAND
41° 15'
72° 00'

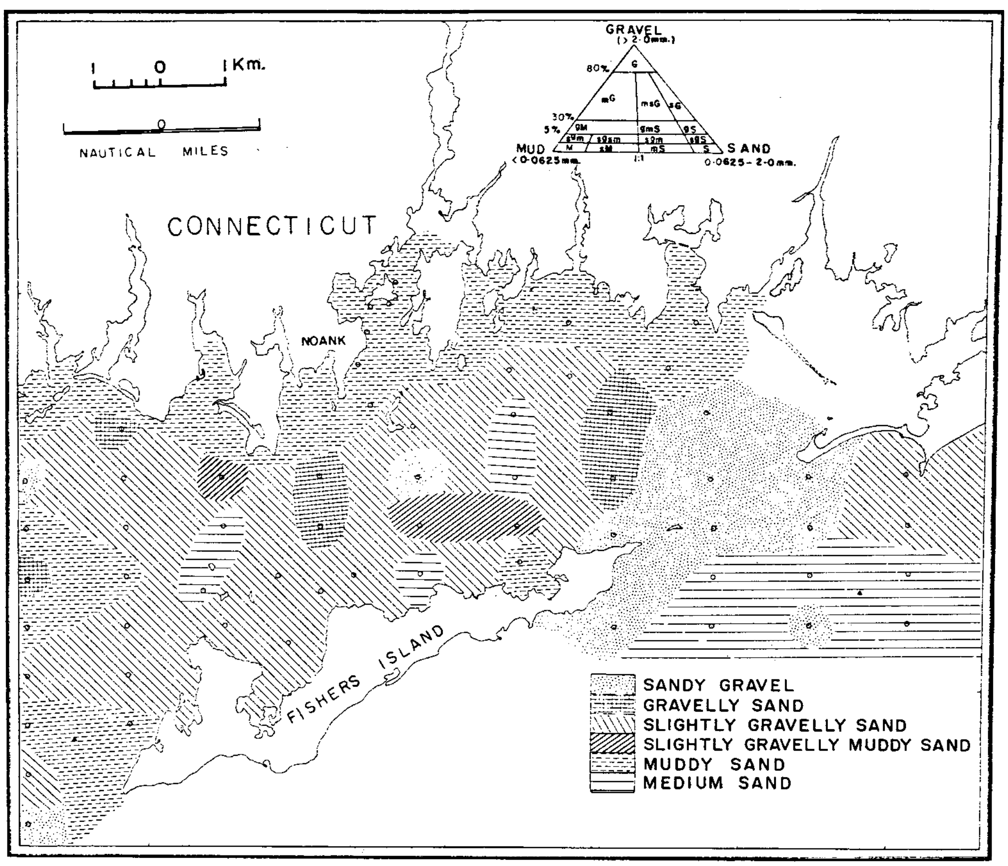
GRAVEL (> 2·0mm.)
MUD < 0·0625mm.
SAND 0·0625 - 2·0mm.
1 0 1 Km.
NAUTICAL MILES
CONNECTICUT
NOANK
FISHERS ISLAND
SANDY GRAVEL
GRAVELLY SAND
SLIGHTLY GRAVELLY SAND
SLIGHTLY GRAVELLY MUDDY SAND
MUDDY SAND
MEDIUM SAND

Fig. 2. Bathymetry of Eastern Long Island Sound. Contour interval one fathom (From U.S. Coast and Geodetic Survey No. 08084 N-53, 1967).

Fig. 3. Textural Types (After Folk, 1954).

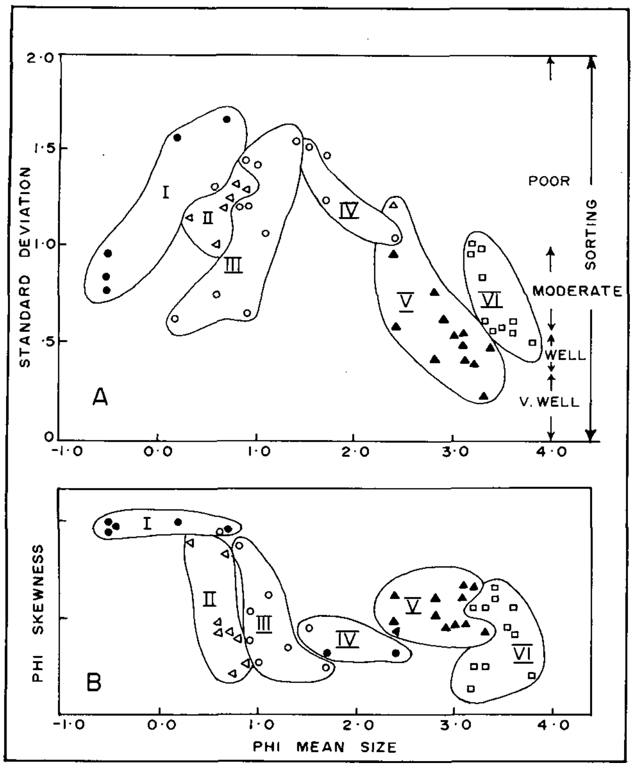

Fig. 4. Sediment groups based on plots of A: Phi standard deviation vs. mean grain size; B: Phi skewness vs. mean grain size. Group 1 represents sandy gravel; 11, gravelly sand; 111, slightly gravelly sand; 1V, slightly gravelly muddy sand; V, fine sand; V1, muddy sand.

Methods of Study

The research vessel, UCONN, of the University of Connecticut Marine Laboratory was used for the study. A total of 110 Phleger core samples were collected from 53 stations in eastern Long Island Sound (Fig. 1). The top 1-cm layer of the core samples (each about 25 cc) were used for the study. Traverses spaced 1.9 km apart were made and stations were spaced at 0.9-km intervals. Bottom photographs of stations in the Sound were taken with an underwater camera. Sediment color, texture, structure, and the presence of hydrogen sulfide odor were recorded for each sample station. The pH of sediments was taken with an on-board pH meter seconds after they were collected.

The samples were dried at 103°C, disaggregated with a rubber stopper and about 15-g used for grain-size analysis following the method of Folk (1954). A size interval of ¼ phi (ϕ) units was used for all samples. A size fraction of 125-88 micron was selected for heavy and light mineral study. Light and heavy minerals were separated by means of the standard bromoform method. Light minerals were mounted in Canada balsam, thin-sectioned and the percentage of potash and plagioclase feldspars studied according to the method of Hayes and Klugman (1959).

A size fraction of 0.5 to 1.0 mm of each sample was wetted, and 200 counts were made on the relative amount of iron-staining on quartz grains. Organic and carbonate carbon were determined using a Leco carbon analyser. Organic-carbon value was obtained by the difference between the total carbon and carbonate carbon whose values were then recalculated as calcium carbonate.

Results

Bathymetry

The bathymetry for this area is quite irregular, being characterized by depressions and shoals (Fig. 2). The area may be classified into three bathymetric zones: (1) the Mystic and Pawcatuck estuaries, which are shallow, constricted and 4 to 6 m deep; (2) Central sound waters with depths ranging from 0 to 38 m and with a chain of shoals at the eastern end; and (3) western and eastern sound entraces with depths greater than 40 m.

Texture

Sand sizes form the dominant textural groups in the area (Fig. 3). The sediments consist of mud-sand-gravel admixtures, occasionally intermingled with bivalve and gastropod shell fragments and varying amounts of organic materials. Bottom samples collected from the Mystic estuary and adjacent area consist of olive black (5Y2/1), gelatinous, organic rich, muddy sediments with strong hydrogen sulfide odors. Six types of textural sedimentary groups are distinguished (Fig. 4). The computed sedimentary parameters in phi units (ϕ) and per cent organic content are shown in Table 1.

The mean grain sizes range from 3.73 to 0.5 ϕ, with an average of 1.7 ϕ; standard deviations arrange from 1.97 to 0.36 ϕ. Well sorted sands (Folk, 1954) are sporadically distributed, and a moderately sorted group (0.5 to 1.0 ϕ) surround a poorly sorted (1.0 to 2.0 ϕ) member occurring along the central axis of the Sound and Mystic estuary. Approximately half of the areal distribution of the sediment is negative skewed.

Heavy Minerals

Hornblende, garnet, and epidote form 71% of the grant total of the heavy mineral assemblages in the area. Hornblende is the most abundant and ubiquitous single mineral with an average of 34% of the total. A large proportion of the mineral is found in sediments with mean grain size greater than 2 ϕ (Tables 1 and 2). Garnet which comprises about 21% of the total heavies has a high correlation between its distribution and the ϕ mean size, as well as the water depth. The relative percentage of this mineral decreases progressively away from the shore and toward deep water. Epidote has an average concentration of 16% occurring between 0.5 to 1.0 and 3.0 to 3.5 ϕ mean size (Tables 1 and 2).

The non-opaque, non-micaceous heavy minerals constitute 51 to 81% of the total heavy mineral suite. Other heavies of significance include the brown variety of staurolite and tourmaline (including brown, green-blue, pink species). Kyanite occurs to the average extent of less than 2% of the total heavy minerals; pyroxene, zircon, sillimanite, and andalusite have individually an average of about 2%. Sphene, hypersthene, rutile, and zoisite which occur as traces are listed as miscellaneous (Tables 2 and 3). Biotite and muscovite range from 1 to 36% and, the opaque minerals (hematite, magnetite, and ilmenite) range from 3 to 45%.

Light Minerals

The average abundances of the light minerals are quartz (64%), plagioclase (22%), and potash feldspar (13%). Most quartz grains are very angular, chipped, pitted, and coated with red iron stain. The feldspars are generally subrounded and show very little alteration. The quartz grains show mostly straight extinction.

Coarser sediments yielded mineral aggregates, rock fragments, and pebbles of quartz, granite, granodiorite, schist, gneiss and metaquartzite. Cursory observations along the shores of Fishers Island and opposite Connecticut coast show the two areas to have the same fragmental rock composition, dominated by metamorphics.

Sediment Transport

The occurrence of iron-stained quartz in the study area is an important tool in mapping patterns of sediment movement (Figs. 5 and 6). The present study shows a progressive increase in the amount of the ocherous hematite-stained minerals from eastern Long Island Sound toward Block Island Sound (Fig. 6). There is marked decrease in the relative amount of iron-stained quartz shoreward, but offshore this staining condition increases. This suggests that the continental shelf is the source of the stained quartz and that, although recent sediments are ebing deposited in the Sound, offshore sediments move landward. It was also observed that quartz grains, pebbles, and rock fragments from Fishers Island (Stations 84, 85, 86) and the Sound have an identical, characteristic iron stain that suggests similar modes of origin.

The eastern and western entrances of the Sound

TABLE 1

Sedimentary Parameters in Phi Units and Percentages of Calcium Carbonate and Organic Carbon

Stations	Mzϕ	$\sigma\phi$	Skϕ	Kqϕ	% Organic Carbon	% Calcium Carbonate	Depth (m)
2	0.65	1.66	0.89	0.74	1.97	2.12	11
3	3.57	0.63	-0.19	0.71	2.31	2.60	14
4	0.77	1.32	-0.26	0.82	0.67	1.34	12
5	3.55	0.56	0.09	0.72	0.65	2.72	17
6	3.13	0.43	0.13	1.16	0.73	2.30	21
7	3.30	0.83	0.10	1.58	1.71	2.95	25
8	2.75	0.75	0.00	1.16	0.74	0.98	26
9	0.58	1.97	0.89	2.51	--	--	42
11	0.68	1.19	-0.13	0.84	0.97	1.13	9
12	2.42	1.22	-0.18	0.89	0.48	0.20	10
13	3.17	0.38	0.33	1.53	0.61	0.57	16
14	3.20	0.92	0.11	0.91	0.79	0.79	18
15	3.05	0.54	0.16	1.04	0.88	0.44	16
16	3.29	0.36	0.21	1.38	0.51	0.11	12
17	3.43	0.55	0.25	0.75	0.31	0.21	14
20	1.53	1.51	-0.08	0.82	1.16	0.52	11
21	1.30	1.53	-0.19	0.65	1.05	0.58	18
22	0.90	1.44	0.05	1.79	1.38	2.55	19
23	2.88	0.60	0.09	1.22	0.48	0.07	6
24	3.37	0.49	0.23	1.88	0.53	0.79	6
26	0.57	1.50	-0.03	0.77	0.30	0.05	10
27	0.92	1.30	-0.43	1.16	0.95	1.31	20
29	2.98	0.54	0.10	0.99	0.39	0.37	12
30	1.12	1.07	0.23	1.35	0.92	3.66	9
31	1.66	1.23	-0.37	1.32	0.52	0.54	17
32	0.17	1.57	1.00	0.57	0.30	0.22	17
34	3.08	0.51	0.26	1.23	0.52	1.63	6
35	3.20	0.89	-0.53	1.39	3.20	5.31	6
36	3.33	0.92	-0.49	1.09	3.42	5.28	4
37	2.35	0.93	0.24	1.04	0.39	0.11	8
38	1.00	1.41	-0.38	1.41	0.53	0.59	13
39	0.13	0.61	-0.17	1.05	0.50	1.51	15
40	2.42	1.04	-0.32	1.30	0.35	0.45	13
41	3.14	0.58	-0.75	0.88	3.31	6.72	8
42	3.73	0.50	-0.56	1.14	0.85	0.41	6
43	2.80	0.42	0.20	1.08	0.19	0.16	8
44	0.73	1.28	-0.59	0.72	0.95	0.43	13
45	0.73	1.62	1.00	0.61	1.66	1.59	12
50	-0.48	0.96	1.00	1.27	1.68	3.77	20
52	0.63	0.77	-0.06	0.97	0.73	1.51	14
53	0.93	1.36	-0.26	0.94	1.11	0.87	22
54	-0.48	0.83	1.00	1.91	0.94	1.83	17
56	-0.50	0.76	1.00	1.06	1.20	2.25	12
57	0.87	0.63	0.09	1.41	0.31	0.13	20
58	0.60	1.30	0.93	0.53	1.03	0.73	33
59	2.39	0.59	-0.18	0.99	0.77	0.36	8
61	1.67	1.47	-0.47	1.12	1.19	1.21	29
67	0.79	1.23	-0.20	0.73	0.78	1.90	36
80	0.27	1.18	-0.06	0.80	5.17	3.23	4
81	-0.33	0.85	0.83	1.08	0.51	0.56	1
82	0.70	1.23	-0.75	0.69	0.47	0.45	1
83	0.20	1.57	-0.11	0.59	0.48	0.49	1

TABLE 2

Heavy Mineral Percentages

Stations	Wt%	Hbd	Ep	G	St	Tou	Ap	Ky	Py	Zi	Sil	And	Mic	Op	Alt	Mis
2	.38	11	12	43	1	6	2	0	1.5	6.5	3	0	2	11.5	.5	0
3	.01	31.5	8	9	2.5	10.5	8	2	2	3.5	5	1	1	15	1	.5
4	.87	24	9.5	41	1.5	3	1	0	1	3	2.5	1	3	6	1.5	2
5	.52	35	20	9	1	7	1.5	2	3.5	3.5	6	0	2.5	4	3	2
6	.60	36	18	7	1.5	6.5	2.5	2	4.5	3	6.5	.5	2.5	4.5	4	1
7	.07	35	14.5	6.5	2	8.5	.5	2	1.5	4	6	2	5.5	4	1.5	.5
8	.50	27.5	4	29	1	8	1.5	.5	1.5	1.5	4	.5	5.5	9.5	0	1
9	.44	40	16	13	0	3.5	3	0	1.5	6	3	1	2.5	7.5	1	1
11	.33	40.5	16	13	1.5	1.5	3	4	1.5	4	1.5	.5	5	7	.5	0
12	.23	41.5	11	10	5.5	9	2.5	2	1.5	2.5	4	.5	1	8	.5	.5
13	.75	37.5	14.5	6	4	4	2	.5	.5	4	4	2	10	9.5	1.5	.5
14	.10	29.5	10.5	24	1	7	1	.5	1	5.5	3	.5	7.5	5.5	1.5	2
15	1.33	30.5	19	5	2	4.5	9	1	2	1	4	1	8	8.5	3.5	1.5
16	.12	37	11.5	7	4.5	8	4	2	1.5	2	4.5	0	10.5	4	2.5	1
17	1.21	47.5	8	9.5	2.5	7.5	1.5	1	1.5	2.5	5	1.5	4	4.5	1.5	2
20	.7	36	11	21	.5	5	.5	0	1	2	3	0	1.5	14	1.5	3
21	.62	37	13	22	1	5	.5	.5	.5	1	2	1	2.5	13	2	1
22	.18	24	14	16	2	3	9	1.5	3	1.5	2.5	3.5	3.5	11	3.5	2
23	.13	41	17	7	1	2.5	7.5	.5	2	1	1	.5	9	4.5	2.5	1
24	.30	40	15	4.5	1	2	9.5	2	2.5	1	1	1.5	10	4.5	3.5	2
26	.01	24.5	10.5	17.5	3.5	6	10	.5	1	1.5	3.5	0	6.5	12.5	2.5	.5
27	.40	16.5	11	31.5	2	.5	5	0	2	3.5	3.5	.5	2	18.5	3	.5
29	.45	18	11	20	1.5	3.5	10	1.5	1.5	8	2	.5	4.5	14	2	2
30	.54	19	10	21.5	1.5	4	10.5	.5	2	9	1	.5	3	13	1	3
31	1.21	34	12	26.5	1.5	4.5	1	.5	2	2	1	1	2	9.5	1.5	1
32	.01	11.5	9.5	23.5	1.5	2	8.5	1	2	11	1.5	.5	7.5	16.5	2.5	1
34	1.29	37	9.5	11	0	4.5	4.5	1	2	3	5.5	2	12.5	3	3	1.5
35	.65	25	11	3.5	.5	2	9	.5	.5	.5	1	.5	36	.5	2	1
36	.14	25	11	3.5	0	2.5	10	1	1	0	1.5	1	35	4	3	.5
37	.07	24	14.5	15.5	3.5	5	3.5	0	1.5	3	7	0	7.5	11.5	1	2.5
38	1.26	22	13	16	3.5	4	3	.5	1	2.5	6	0	8	9.5	.5	2
39	1	35	18	19	3	3	1	0	1	.5	.5	0	5	10	.5	3.5
40	1.22	29.5	3	34.5	3	9	1.5	0	1	2	2.5	0	3	8.5	.5	2
41	.65	35	14	12	2	2.5	3.5	.5	2	3	3.5	1.5	10	5.5	3.5	1
42	.10	30.5	17.5	9	1.5	2.5	7	1	1.5	2	2	2	11.5	6.5	5.5	1.5
43	.01	33	20	9	3	4	6	1	2.5	6	1	0	5	8	.5	1
44	.12	19	12	10.5	.5	.5	6	1.5	2.5	2.5	2	2.5	1	35	3.5	1
45	1.27	29.5	17.5	14	.5	3.5	2	0	3.5	2	2	2	2.5	14	2	.5
50	.03	22.5	22.5	7	1.5	1.5	12	2	2.5	2.5	4	2	5	9	5	1
52	.12	30.5	16	16	2.5	1.5	2.5	0	3	0	1.5	0	12	9	4	1.5
53	.72	21.5	11.5	22.5	1.5	2	.5	0	1.5	4.5	2	1	7.5	21	1	2
54	1.68	20	19.5	25	1	2	10.5	.5	1.5	0	1	0	4.5	15.5	3.5	1
56	.52	13	5	17	4	4	4	1	1.5	0	0	0	5	45	.5	0
57	.03	31	21.5	11.5	2.5	6.5	1	0	2	1.5	2	0	5.5	15	.5	.5
58	.11	34	14	9	1	2	5.5	1	1.5	1.5	.5	0	3.5	18.5	4.5	.5
59	.81	18	19.5	17.5	.5	4	4	.5	4	3	.5	1	2	21.5	3	1
61	1.28	24.5	13	14.5	2	8.5	0	0	1.5	4.5	2	1.5	4	23.5	0	.5
67	.20	28.5	14	9	0	4	3	0	2	4.5	3.5	.5	5	22.5	2	.5
80	.01	15	4.5	32.5	2.5	6	9	0	2	4	3	0	3	16.5	1.5	1
81	.07	14	5	38	1	3	7	0	2	3	2.5	.5	6	17	1	0
82	.11	16	5	34	3	1.5	6.5	.5	1	1.5	3	0	7	19	1.5	.5
83	.15	16.5	5	32.5	2	5.5	5	0	1.5	4	2.5	.5	4.5	17.5	1	1.5

NOTE:
Wt% = Weight per cent of heavy minerals
Hbd = Hornblende
Ep = Epidote
G = Garnet
St = Staurolite
Tou = Tourmaline
Ap = Apatite
Ky = Kyanite
Py = Pyroxene
Zi = Zircon
Sil = Sillimanite
And = Andalusite
Mic = Micas
Op = Opaques: magnetite, illmenite, hematite
Alt = Alterites: altered pyroxene, hornblende
Mis = Rare heavy minerals: sphene, hypersthene, rutile, zoicite

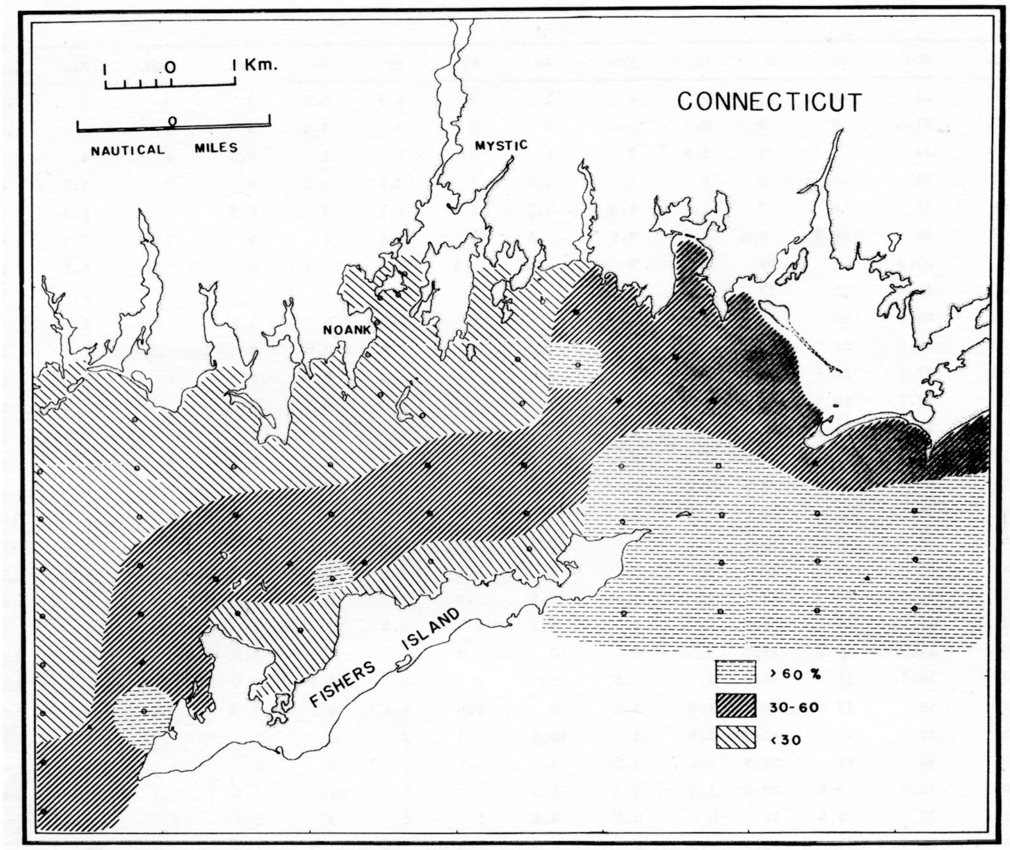

Fig. 5. Distribution of iron-stained quartz in percent of the sample.

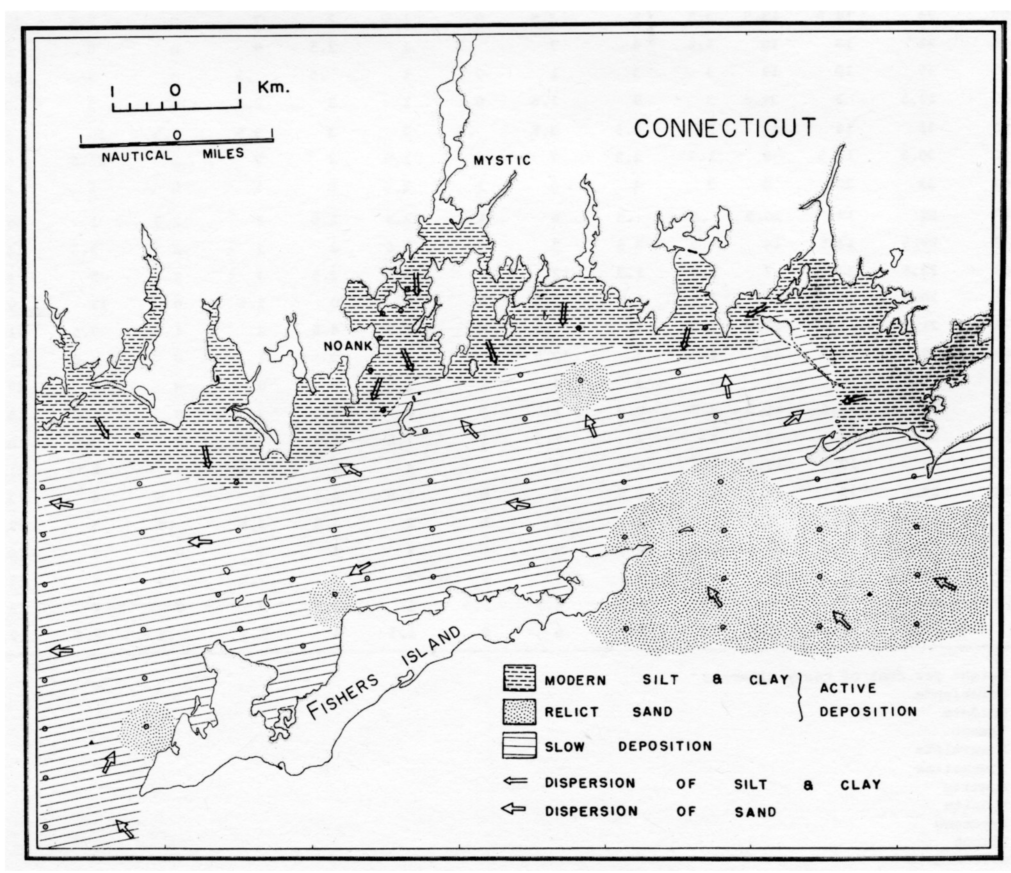

Fig. 6. Sediment Source and dispersal.

TABLE 3

Relative % Abundance of Nonopaque and Nonmicaceous Heavy Minerals

Stations	Hbd	Ep	G	St	Tou	Ap	Ky	Py	Zi	Sil	And	Mis	Alt
2	13	13	50	1	6	4	0	2	7	3	0	1	0
3	38	10	11	3	12	10	2	2	4	5	1	1	1
4	28	12	45	1	3	1	0	1	3	2	1	2	1
5	37	18	9	2	8	2	3	4	4	7	1	2	2
6	38	19	8	2	7	3	2	5	3	7	2	1	3
7	39	16	10	3	9	3	2	2	4	7	2	1	2
8	32	10	34	1	9	2	1	2	2	5	1	1	0
9	32	16	13	0	5	4	1	2	7	4	2	2	1
11	43	17	11	2	2	3	6	2	6	2	1	2	3
12	45	12	11	6	9	3	2	2	3	4	1	1	1
13	46	18	8	5	5	2	1	1	5	5	2	1	1
14	35	12	29	1	8	1	0	1	6	3	1	2	1
15	36	23	7	2	6	10	1	2	2	4	1	1	4
16	43	14	8	5	9	5	2	2	2	5	0	1	2
17	51	9	10	3	8	2	1	2	3	6	2	2	1
20	42	13	24	1	6	1	0	1	2	4	0	4	2
21	40	14	24	2	7	1	1	1	2	3	2	3	1
22	29	17	21	3	3	10	1	3	1	2	4	2	4
23	45	19	8	2	3	9	1	3	2	1	1	3	3
24	47	18	7	1	2	11	2	2	1	2	1	2	4
26	30	13	22	4	7	12	1	1	2	4	0	1	3
27	22	15	39	3	0	7	0	2	4	4	0	1	3
29	24	11	28	1	4	12	2	2	10	1	1	2	1
30	23	12	26	2	5	13	1	2	10	1	1	2	2
31	39	14	30	2	4	1	1	2	2	1	1	1	2
32	16	13	31	2	2	11	1	3	14	2	1	1	3
34	44	12	14	0	5	5	1	3	3	6	2	2	3
35	41	20	9	2	3	15	1	1	1	2	1	1	3
36	41	20	9	0	4	16	2	1	0	2	1	0	4
37	37	16	18	4	6	4	0	1	3	8	0	2	1
38	21	14	38	3	0	6	0	3	5	3	1	1	4
39	39	20	22	4	4	2	0	2	1	1	0	1	4
40	34	3	39	3	10	2	0	1	2	3	0	2	1
41	40	17	14	2	4	5	1	2	4	5	2	1	3
42	38	22	11	2	4	8	1	1	2	2	2	1	6
43	37	22	10	3	5	8	1	3	8	1	0	1	1
44	30	18	17	1	2	9	2	3	6	3	3	1	5
45	36	22	18	2	4	5	0	4	2	2	2	1	2
50	27	26	12	2	3	13	2	2	2	4	2	1	4
52	40	20	21	3	2	3	0	2	0	2	0	2	5
53	30	16	32	2	3	1	0	2	6	3	1	3	1
54	24	24	31	1	2	12	0	0	1	1	0	1	3
56	26	10	34	8	8	8	2	8	0	0	0	0	1
57	39	27	k4	3	8	1	0	2	1	2	0	1	1
58	44	19	12	1	3	7	1	2	2	1	0	1	6
59	24	26	23	1	5	5	1	5	4	1	1	1	3
61	34	18	20	3	11	0	0	2	6	3	2	0	1
67	39	19	13	0	6	4	0	3	6	5	1	3	1
80	19	6	40	3	7	11	0	2	5	4	0	2	1
81	17	8	39	2	6	12	0	3	3	5	1	3	1
82	18	7	40	3	7	10	1	2	4	3	1	2	2
83	19	5	38	4	6	11	1	2	.5	4	2	1	2

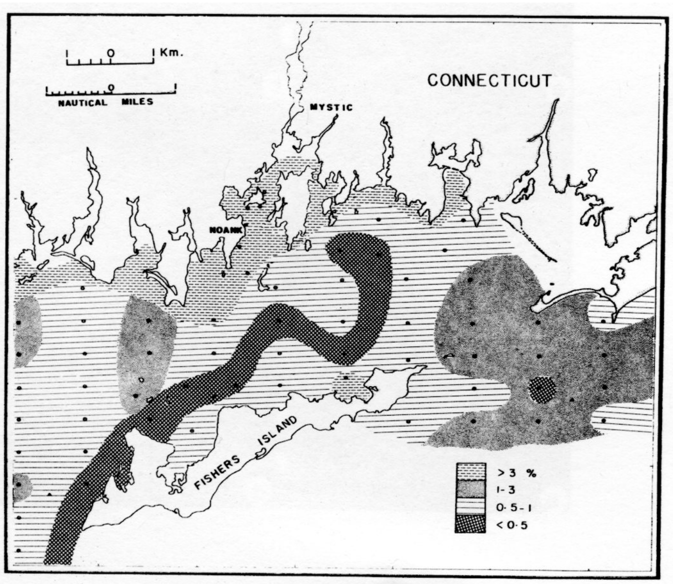

Fig. 7. Percent Organic carbon.

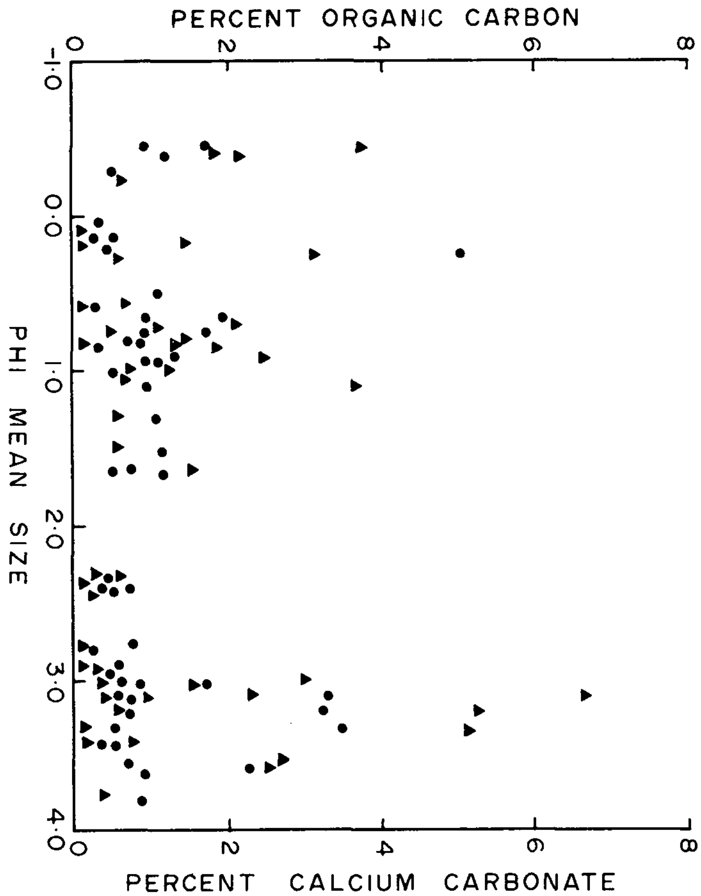

Fig. 8. Scatter diagram of organic carbon (dot) and calcium carbonate (triangle) percentages vs. phi mean grain size.

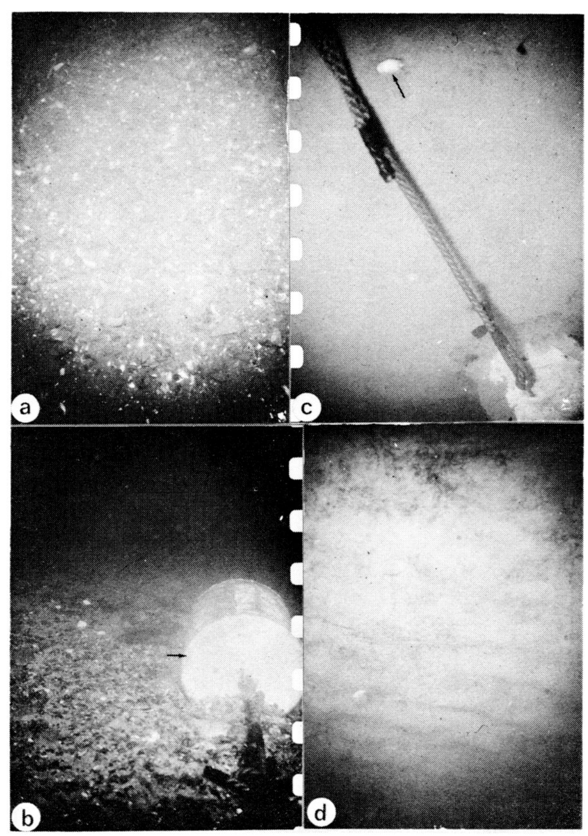

Fig. 9. Bottom photographs taken with an EG & G underwater camera set. a) High concentration of shell fragments, mostly bivalves in gravelly sand, at Station 27, 20 m depth. b) Coarse till-like, gravel-mud mixturead with large shell fragment, at station 45, 12 m depth, (camera weight, 25cm in diameter, gives scale) c) Station 39, 15 m depth, shows medium sand covering bottom, note unbroken gastropod shell. d) Oscillation ripple marks partially covered by algae, at Station 59, 8 m depth.

TABLE 4

Living Foraminifera Population in Per Cent of Total Population

Station	Living	Total	L/T x 100
2	146	947	15
3	297	811	37
4	58	174	33
5	936	1996	47
6	127	620	20
7	239	1789	13
8	188	625	30
9	20	94	21
11	23	102	23
12	108	326	33
13	294	1183	25
14	37	92	40
15	153	1270	12
16	272	661	41
17	705	1966	36
20	138	284	49
21	323	2069	16
22	162	1158	14
23	335	1267	26
24	49	363	13
26	309	939	33
27	97	547	18
29	184	1472	13
30	147	793	19
31	150	1340	11
32	207	1275	16
34	132	378	35
35	380	907	42
37	99	379	26
38	77	187	41
39	75	135	56
40	325	986	33
41	366	1091	34
42	123	242	51
43	72	350	21
44	66	150	44
45	116	714	16
50	455	1259	36
52	56	198	28
53	294	551	53
54	51	563	9
56	238	607	39
57	62	131	47
58	112	233	48
59	16	52	31
61	59	145	41
67	241	366	66
80	8	20	40
81	27	77	35
82	29	50	58
83	34	53	64

(Fig. 1) are influenced by strong tidal currents that generally reach 12 knots (United States Coast and Geodetic Survey No. 00084 N-53, 1967). Here, more than 75% of the foraminiferal fauna are composed of attached forms characterized by *Poroeponides lateralis (Terquem)*, *Cornuspira planorbis* Schultz, *Cibicides lobatulus* (Walker and Jacob), *Rosalina columbiensis* (Cushman). *Quinqueloculina subrotunda* (Montagu). *Poroeponides lateralis* is the most abundant species here than in other parts of the Sound (Akpati, 1970). Also associated with the attached foraminifera are encrusting bryozoa on pebbles, shell fragments, and other objects. The presence of encrusting bryozoa and attached foraminifera indicate that very little sediment is being deposited or transported shoreward in more recent time. The writer thus shares the opinion of Meade (1969) that large, landward, sediment transport in such an estuarine regime is mostly accomplished by storms.

Organic Matter

Values obtained from organic-carbon analyses range from 0.25 to 5.17% by weight (Table 1), and show a distinct distribution pattern. Maximum concentrations occur in the Mystic estuary area and Station 41, away from which the amount decreases toward the centre of the Sound (Fig. 7). A plot of the per cent organic carbon versus mean grain size (Fig. 8) shows a bimodal size distribution with high amount of organic carbon occurring between 0.0 to 1.5 ϕ and 2.5 to 3.5 ϕ. The areas with the highest organic carbon content (Stations 35, 36, 80) have the lowest pH (6.5) in the area and are characterized by such foraminiferal species as *Trochammina inflata*, *T. lobata*, and *Miliammina fusca* (Akpati, 1970). Although *Elphidium clavatum* and *Burcella frigida* are present, they have symbiotic algae (zoozanthellae) in their protoplasm (this may probably be advantageous to organism living in a low-oxygen environment). The writer's 1970-study of the area shows that organic content of the sediments is of secondary importance in the distribution of foraminiferal populations.

Visual examination of the samples, together with the underwater photographs (Fig. 9) taken along the central axis of the Sound clearly show that the calcium carbonate content of the sediments consists essentially of shell fragments, comprising mostly gastropods, bivalves, and bryozoans. The carbonate content in the area ranges from less than 0.1 to 6.72% by weight. The distribution pattern of calcium carbonate is similar to that of organic carbon (Fig. 7). The low carbonate content in the size range of 1 to 3 ϕ may be indicative of an absence of shell fragments in this size fraction, or lack of them through the effect of sorting.

It is curious to observe that the muddy sediment of Station 41 and those sediments occurring in the northern and western parts of the Sound typically contain finer shell fragments than those in the central and eastern areas. Stewart and Gorsline (1963) have recorded similar shell-fragment features in St. Joseph Bay, Florida. They attributed the finely macerated shells to the action of skates or rays that crush resident organisms in quiet water.

Sedimentation Rate

The rate of sediment accumulation in the area was estimated by using the live/total (L/T) foraminiferal population-ratio method described by Phleger (1960, 1964). The samples have L/T ratios ranging from 9 to 67% (Table 4). Relatively more rapid sedimentation occurs in Mystic estuary complex and the eastern end of the Sound (Fig. 10). Toward the eastern end of the Sound, the L/T ratios are quite variable, but away from the chain of shoals there is a discrete area of relatively higher rates of deposition ranging from 41 to 67%. The high L/T ratios in the northern part of the area are belived to be due to fast accumulation of river-borne detritus caused by the salt-wedge effect discussed by Pearcy and Richards (1962) and Meade (1969). Here the L/T ratios range between 40 and 64%. The lowest values (11 to 19%) occur almost in the region of the central Sound channel, trending westward.

Discussion

Grain size distribution and sorting appear to be related to the bottom topography of the area. Poorly sorted sediments which are generally muddy, gravelly sand dominate depressions in the Sound.

The dominant heavy minerals comprise hornblende, garnet and epidote. Compared with other major heavy minerals discussed, hornblende appears to have ubiquitous distribution; a condition that may be attributed both to its abundance and its relative low specific gravity (2.9 to 3.5) which allows relatively easy current transportation. There is a high correlation between the distribution of garnet and the ϕ-mean size as well as the water depth. With a specific gravity of 4, garnet probably accumulates as lag deposits near the shore and shallow water areas.

Quartz is the most abundant light mineral in the area. Less than 5% (including the polychrystalline forms) show undulose extinction. Although strained quartz can occur in both igneous and metamorphic rocks (Blatt and Christie, 1963), the preponderance of blue-green hornblende, garnet, epidote, staurolite and sillmanite in this area indicate a metamorphic-source terrain. The mineralogical suite recorded in this study is quite comparable to that from the western North Atlantic reported by Hubert and Neal (1967).

The occurrence of iron-stained quartz in the N.W. Atlantic was reported from Sable Island, Nova Scotia, by James and Stanley (1967, 1968) and from Nantucket Bay by Lidz (1965). In a recent study of iron-stained quartz on the southeastern United States Atlantic shelf, Judd *et al.* (1970) observed that the percentage of iron-stained quartz grains in the beach environment was similar to or higher than that in the shelf sediments. They therefore suggested that abrasion was not an effective process in removing iron-staining in the area. On the contrary, the writer noted a general decrease in the percentages of stained-quartz shoreward in the study area. The landward decrease in the degree of staining may be attributed to dilution by unstained quartz grains discharged from the Mystic and other rivers in the area. It is interesting to note that stations close to the shore contained vastly higher proportions of angular amethyst grains grains than those away from it. An alternative suggestion is that the landward decrease in the amount of stained quartz indicates an offshore source. The sands are transported shorewards by bottom currents and during storms (Meade, 1969).

The origin of iron-stained beds (red beds) has been a much disputed topic among geologists for many decades due to the fact that the mode of formation of hematitic stain in modern sediments is not well understood. A comprehensive study of the origin and mechanism of staining in the area is beyond the scope of this study. However, some workers (James and Stanley, 1967, 1968) believe that the staining of grains in Nova Scotia originated under subaerial condition during low stands of sea level.

A plot of the percentage of organic carbon versus mean size shows high organic carbon occurring in sediments between 0.0 to 1.5 ϕ and 2.5 to 3.5 ϕ. The size range 1 to 3 ϕ (medium-fine sand) has minimal organic carbon content, a factor that may be attributed to better sorting characteristics of this sediment size. Well sorted sands are permeable and thus not conducive to the prevention of odixation which is necessary for the preservation of organic carbon. However, the significance of a high concentration of organic carbon in the size range of 0.0 to 1.5 ϕ is not clear to the writer.

It may be said from mineralogical evidence that the Sound receives sediments both from offshore and the proximate landmass, but the volumetric amounts derived from each provenance are beyond the scope of this study. The relative rate of sedimentation (Fig. 10) based on foraminiferal Live/Total (L/T) ratios is comparable to the dominant sediment movement shown in Figure 6. The high sediment accumulation in the northern part of the area is believed to be a result of fast deposition of river-borne detritus caused by a salt-wedge effect. Here, the L/T ratios range between 40 and 64%. Toward the eastern end of the Sound, the L/T ratios are quite variable, but away from the chain of shoals there is a discrete area of relatively higher rates of deposition ranging from 41 to 67% L/T. Nevertheless, the significance of the lowest value of 9% at Station 54 is not clear to the writer. It is possible that this may be the result of mixing of the top sediment layer and the one vertically below, resulting in an increased dead population or the loss of the fauna from the surface sediment during sampling, and also a high proportion of dead test being washed in.

The preponderance of such attached foraminiferal species a *Poroeponides lateralis* and *Cornuspira planorbis* in the entrances of the Sound where the currents are strongest, is a matter of geologic significance. This relationship suggests that benthonic foraminifera might be useful to sedimentologists in reconstructing paleocurrents and sediment transport in regions where rocks lack other sedimentary structures.

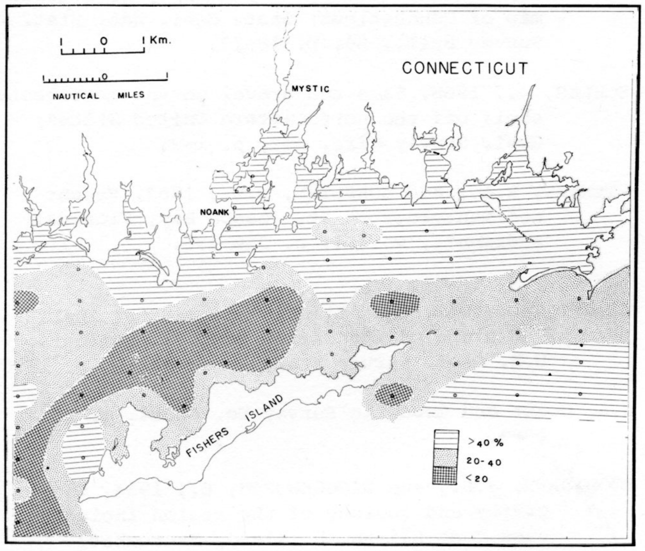

Fig. 10. Living population in percent of total population relative rate of sedimentation is indicated by L/T foraminifera ratios.

Conclusion

Hornblende, garnet, and epidote form the dominant non-opaque and non-micaceous heavy mineral assemblages in eastern Long Island Sound. Other heavies of significance include staurolite, tourmaline, pyroxene, sillimanite, andalusite and zircon.

Quartz grains with characteristic ocherous hematite stains, dominate the offshore sands in the area. The stains decrease landward and this may be attributed to dilution by unstained quartz grains in modern sediments from the adjacent landmass. An alternative suggestion would be that the shoreward decrease in stained quartz indicates an offshore source of this mineral, and that it is transported in the Sound by the prevalent landward bottom current.

Both the grain-size distribution and sorting reflect the effect of bottom topography of the Sound. Sorting is generally poor and muddy sediments predominate along the estuarine complex and eastern part of the Sound.

The relative rate of sedimentation based on living to total (L/T) foraminiferal population ratios suggests that deposition of sediments is more rapid around the Mystic estuarine complex than in the central channel, and eastern and western entrances of the Sound. This conclusion is essentially in agreement with observations based on the sediment source and dispersal, and also on the common occurrences of encrusting bryozoans and attached foraminifera on pebbles, shell fragments and other objects in the Sound. It indicates that the bottom current in this area is gentle, despite the strong surface water movement, and also that little of the bottom sediment in the Sound is being transported or deposited to a great extent at the present time.

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References

AKPATI, B.N., 1970, Sedimentation and foraminiferal ecology in eastern Long Island Sound, New York, Univ. Pittsburgh Ph.D. thesis.

BLATT, H., and Christie, J.M., 1963, Undulatory extinction in quartz of igneous and metamorphic rocks and its significance in provenance studies of sedimentary rocks; J. Sed. Petrol., v. 33, p. 599-579.

BUZAS, M.A., 1965, The distribution and abundance of foraminifera in Long Island Sound; Smithsonian Misc. Colls. 4604, 149, p. 1-89.

FOLK, R.L., 1954, The distinction between grain size and mineral composition in sedimentary rock nomenclature; J. Geol., v. 62, p. 344-359.

FULLER, M.L., 1914, The Geology of Long Island, New York; U.S. Geol. Survey Prof. Paper 82, p. 58-102.

HAYES, J.R., and KLUGMAN, M.A., 1959, Feldspar staining methods; J. Sed. Petrol., v. 29, p. 227-232.

HUBERT, J.E., and NEAL, W.J., 1967, Mineral composition and dispersal patterns of deep-sea sands in the western North Atlantic petrologic province; Geol. Soc. Am. Bull., v. 78, p. 749-772.

JAMES, N.P., and STANLEY, D.J., 1967, Sediment transport on Sable Island, Nova Scotia; Smithsonian Misc. Colls. 4723, 152, p. 1-33.

________________, 1968, Sable Island Bank off Nova Scotia: Sediment dispersal and recent history; Am. Assoc. Petrol. Geol., v. 52, p. 2208-2230.

JUDD, J.B., SMIT, W.C., and PILKEY, O.H., 1970, The environmental significance of iron-stained quartz grains on the southeastern U.S. Atlantic shelf; Mar. Geol., p. 355-362.

LIDZ, L., 1965, Sedimentary environment and foraminiferal parameters, Nantucket Bay, Massachusetts; Limnol. and Oceanogr., v. 10, p. 392-402.

MCCRONE, A.W., ELLIS, B.F., and CHARMATZ, R., 1961, Preliminary observations on Long Island Sound sediments; New York Acad. Sci. Trans., v. 24, p. 119-129.

MEADE, R.H., 1969, Landward transport of bottom sediments in estuaries of the Atlantic coastal plain; J. Sed. Petrol., v. 39, p. 222-234.

PEARCY, W.C., and RICHARDS, S.W., 1962, Distribution and ecology of fishes of the Mystic River estuary, Connecticut; Ecology, v. 43, p. 248-259.

PHLEGER, F.B., 1960, Sedimentary patterns of microfaunas in northern Gulf of Mexico, in Recent Sediments Northwest Gulf of Mexico; Bull. Am. Assoc. Petrol. Geol. Pub., p. 267-301.

__________, 1964, Patterns of living benthonic foraminifera, Gulf of California: A symposium on marine geology of the Gulf of California; Am. Assoc. Petrol. Geol. Mem. 3, p. 1-392.

PRATT, R.M., and SCHLEE, J., 1969, Glaciation on the continental margin off New England; Geol. Soc. Am. Bull., v. 80, p. 2335-2342.

RODGERS, J., GATES, R.M., and ROSENFELD, J.L., 1956, Explanatory text for preliminary geological map of Connecticut; State Geol. Nat. Hist. Survey Bull., 84, p. 18-27.

SCHLEE, J., 1968, Sand and gravel on the continental shelf off the northeastern United States; Geol. Survey Circ. 602, p. 1-9.

STEWART, R.A., and GORSLINE, D.S., 1963, Recent sedimentology of St. Joseph Bay, Florida; Sediment., vol. 1, p. 256-286.

UCHUPI, E., 1968, The Atlantic continental shelf and slope of the United States: physiography; U.S. Geol. Survey Prof. Paper 529-C, p. 1-30.

U.S. Coast and Geodetic Survey No. 08084, N. 53, 1967.

WOODWORTH, J.B., and WIGGLEWORTH, E., 1934, Geography and geology of the region including Cape Cod, Elizabeth Island, Nantucket, Martha's Vineyard, No Mans Land and Block Island; Harvard Mus. Comp. Zoology Mem. V, III, p. 4-8.