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J. R. Schubel, Director

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Introduction

Surficial sand reserves on the inner and middle continental shelf south of Long Island, NY are characterized by shore-subparallel ridges and swales, approximately northwest to southeast in orientation (Figure1). They can be classified as either nearshore ridges or mid-shelf ridges depending on distance from shore, water depth and morphology (Stubblefield *et al.*, 1984). The nearshore ridges are generally attached to shore, and the ridge axes of these features maintain a constant angular relationship of about 15-30° to the shoreline, regardless of the orientation of the shoreline (Duane, *et al.*, 1972). Mid-shelf ridges differ in that their axes maintain a more nearly shore-parallel trend regardless of shoreline orientation (Rine *et al.*, 1991). These large scale bedforms of the inner and mid-shelf are predominantly Holocene age fine to medium sands, and the sediment is classified as a clean palimpsest deposit winnowed and reworked by modern marine processes (Type III, Williams, 1976). As a result, these features may constitute important sand reserves for beach nourishment, construction aggregate or fill along the New York coast.

In order to better understand the composition, subbottom extent and origin of these features, an intensive, shallow seismic reflection survey was conducted over a small area to produce high resolution data for a representative portion of the inner shelf. The study area not only includes ridge and swale structures but also potentially contains fragments of relict ebb tidal deltas of the ancestral Fire Island inlet. A study area was chosen covering 200 square nautical miles (364 square kilometers) south and east of Fire Island inlet extending from the 3-nautical-mile limit to the 40-meter depth contour, approximately 23 nautical miles (42 kilometers) offshore (Figure 2). Ten seismic lines, 1 nautical mile (1.85 kilometers) apart, were run normal to the ridge crests, and two lines were run parallel to ridge crest orientation, and a total of 200 linear nautical miles (400 kilometers) of high quality seismic records were collected (Figure 3 and Table I).

TABLE I Location of seismic tracts

15 June 1993	
1018 start Line I	(40°32.28', 73°17.38')
1330 end Line I	(40°21.69', 73°15.09')
1347 start Line II	(40°21.80', 73°13.94')
1615 end Line II	(40°34.28', 73°16.69')
16 June 1993	
0845 start Line X	(40°35.45', 73°05.99')
1215 end Line X	(40°17.85', 73°02.40')
1227 start Line IX	(40°16.94', 73°02.60')
1614 end Line IX	(40°36.04', 73°07.99')
17 June 1993	
0856 start Line VIII	(40°35.49', 73°09.56')
1247 end Line VIII	(40°16.36', 73°04.89')
1256 start Line VII	(40°15.78', 73°05.78')
1611 end Line VII	(40°34.99', 73°10.19')
18 June 1993	
0830 start Line VI	(40°34.80', 73°11.49')
1157 end Line VI	(40°15.66', 73°07.31')
1239 start Line A	(40°17.44', 73°01.99')
1356 end Line A	(40°16.23', 73°11.45')
1415 start Line III	(40°14.91', 73°11.32')
1722 end Line III	(40°34.39', 73°15.50')
23 June 1993	
0934 start Line IV	(40°34.25', 73°14.07')
1143 start Line B	(40°24.97', 73°16.01')
1337 end Line B	(40°26.37', 73°03.45')
1606 end Line IV	(40°15.11', 73°09.98')

1618 start Line V	(40°15.41', 73°08.45')
1942 end Line V	(40°34.67', 73°12.73')

Previous Work

There are three major sedimentary geologic units lying above the bedrock on the Long Island inner and middle continental shelf that are distinguishable seismically and/or in cores:

Directly overlying the bedrock are semi-consolidated Coastal Plain strata of upper Cretaceous or lower Tertiary age consisting chiefly of stratified fine to medium quartz sands interbedded with lenses of silt and clay (Williams, 1976). This unit dips to the southeast at 50 feet per mile (10 meters per kilometer) and progressively thickens to the southeast (Williams, 1976). The strata are about 1,800 feet (549 meters) thick under Fire Island Beach, and the upper surface is of high relief due to the removal of material by erosion, especially in the vicinity of ancestral stream channels (Williams, 1976). In the study area, this unit is interpreted to be the Cretaceous age, upper Magothy Formation, which is non-marine in origin. Above the Magothy Formation lies a blanket of Pleistocene and Holocene sediments which are seismically indistinguishable from each other since the Holocene sediments are mostly reworked Pleistocene sediments (Williams, 1976).

The Pleistocene sediments are composed of sand, gravel, cobbles, silt and clay from ground and terminal moraines, and the layer is typically 100 feet (30 meters) thick, except where ancestral river channels exist. In these channels, Pleistocene sediments can be more than 300 feet (91 meters) thick (Williams, 1976). Sediments collected at the top of the Pleistocene layer are typically slightly compacted, oxidized, medium to coarse sands with varying amounts of gravel (Williams, 1976). On some seismic records, relatively symmetrical, concave features have been found to indent the upper Pleistocene surface and are interpreted to be relict Holocene tidal-inlet-filled channels (Pantageotou and Leatherman, 1986). The relief of these channels ranges from 3 to 10 meters, with widths ranging from 40 to 150 meters (Pantageotou and Leatherman, 1986).

The Holocene portion of the sediment blanket includes quartzose beach and dune sands and fine-grained lagoonal sediments (Williams, 1976). The Holocene sand blanket is generally coarser than the Pleistocene blanket, partly because the fine sediments have been winnowed from it, and partly because it is composed of fluvial sands which were deposited at the heads of estuaries before sea-level rise (Swift, *et al.*, 1972). Maximum thickness of Holocene sediments (except where tidal inlets or linear shoals exist) is 3 meters, where back-barrier deposits directly overly Pleistocene sediments, and they gradually thin seaward and eastward from Fire Island (Pantageotou and Leatherman, 1986). Minimum thickness of Holocene sediments is 1 meter and are found where modern marine sands directly overly Pleistocene sediments (Pantageotou and Leatherman, 1986). Radiocarbon-dates of Holocene peat deposits recovered from the inner shelf of the south shore of Long Island range from 3,585 ± 80 to 7,750 ± 125 years before present (Pantageotou and Leatherman, 1986). Where tidal inlets and linear bedforms exist, Holocene sediments can be up to 10 meters thick (Pantageotou and Leatherman, 1986).

The Holocene, linear sand ridges off the New York coast are similar in morphology to those off the New Jersey coast where much work has been done to determine the origin and history of the bedforms. Nearshore ridges off the New Jersey coast average 14 feet (4.2 meters) in height, 4.5 nautical miles (8.0 kilometers) in width and 6.3 nautical miles (11.5 kilometers) in wavelength (Rine *et al.*, 1991). Mid-shelf ridges have average heights and widths that are slightly larger than nearshore ridges, and mid-shelf ridges have slightly smaller average wavelengths of 4.3 nautical miles (7.8 kilometers) than the nearshore ridges (Rine *et al.*, 1991). Vibratory core data has shown that Holocene sediment texture in the offshore linear ridges is nearly uniform in the nearshore ridges with the coarsest sands on the shoreward flank and the finest sands on the seaward flank (Rine *et al.*, 1991). Sediments in the mid-shelf ridges tend to coarsen upward with the coarsest sands on the upper shoreward flank (Rine *et al.*, 1991). Nearshore ridges and mid-shelf ridges are steepest on their seaward sides, but the mid-shelf ridges have a more pronounced asymmetry than those nearshore (Rine *et al.*, 1991). Shelf processes dominant in shaping the linear shoals are storm currents and their associated wave trains, and winter storms are most significant on the Mid-Atlantic shelf (Duane *et al.*, 1972). Breakdown of thermal stratification due to cold temperatures allows the bottom to become affected during the strong northeast, winter winds (Rine *et al.*, 1991).

Rine *et al.* (1991) hypothesize that the sand ridges off the New Jersey coast were formed at or near their present day positions. Nearshore ridges originated on the shoreface as a result of strong winter storms and are presently being modified by storm processes. Rine *et al.* (1991) contrast previous hypotheses and explain that Mid-shelf ridges are not relict features but were formed in a mid-shelf environment. During an early Holocene (8,000 to 14,000 years BP) stillstand in sea level, sand was concentrated into prograding or transgressive barriers at the present mid-shelf position. As sea level rate increased, these barriers were altered to the point where they were completely or almost completely removed. Reworking and redeposition of the barriers at or near present day sea level has produced mid-shelf ridges above the inactive barrier roots, indicating a dynamic mid-shelf environment of deposition.

Methods

The field work was carried out over a 5-ship-day period aboard the R/V Onrust using a high resolution continuous seismic profiler system known as a GeoPulse®. The GeoPulse® system consists of a power supply, receiver, towed acoustic source, graphic recorder and a towed hydrophone array. With the intent to focus on the upper 40 meters of sediment, the power supply was adjusted to release a 280-Joule pulse to the acoustic source, and the receiver was programmed to fire the pulse every 0.48 second.

After the returned pulse was detected by the hydrophones, it was amplified, and the raw signal was recorded with a digital audio tape recorder (DAT) for post processing. At the same time, a second circuit of the signal was band pass filtered between 500 Hertz and 5,000 Hertz and graphically recorded with a 120-ms sweep speed and 210-lines-per-inch chart speed. Deep sediment layers were resolved on the graphic records through the use of a Time-Varying-Gain (TVG) on the GeoPulse® receiver. The TVG was set to amplify the later arriving signals to the strength of the bottom return signal, and the ramp was started at the bottom return by using a bottom tracking feature on the GeoPulse® receiver. Depending on the quality of the records as they were being collected aboard the ship, it was useful to record the full trace of the returned signal at times and a single polarity of the returned signal at other times. Figure 4 shows a typical graphic printout where both the positive and negative traces of the signal were recorded, and figure 5 shows a typical graphic printout where only the negative traces were recorded. Figure 5 shows that higher quality records are produced by recording only the negative trace. The reflecting layer (labeled G.C. on figure 5) is interpreted as the Gardiners Clay and represents the base of the Pleistocene when present. Position and speed of the survey vessel were attained by logging latitude and longitude from a Loran-C unit to a computer disk at one-minute intervals (Figure 6). Figure 3 is a plot of those positions. Navigation fixes were keyed to the graphic records at 5-minute intervals and to the digital audio tapes at 10-minute intervals using an event mark so that the shipboard graphs could be correlated with the replayed versions. Real time, tape time and water depth were marked on the records at these intervals.

The shipboard records were used to determine the thickness, extent and distribution of sedimentary deposits so that deposits could be correlated with data from previous work, and geologic ages could be assigned to the sediments. When analyzing the records, the speed of sound in water was considered a constant 1500 m/sec, and the speed of sound in shelf sediments was considered a constant 1650 m/sec. In some cases, the records were not clear enough to resolve the boundaries between sediment layers, and they were replayed filtering a more narrow frequency range then the shipboard records. The filter range for replayed records was typically between 700 Hertz and 2,000 Hertz. Apparent ripple features resulted on some shipboard records due to wave swell during high sea-states (Figure 7), and elimination of these apparent features was tried during play-back of the records by using a Swell Filter option.

In order to improve the resolution of the Holocene sediment structure and to determine the possible evolution and maintenance of the Holocene sand ridges, Portions of the DAT records were played back and digitized using a digital acquisition processor (DAP 1200) from Microstar Laboratories. Various frequencies of these pieces were filtered and the resulting digitized graphs were manipulated using the NASA sponsored computer image display program called Planetary Data Systems v.5.6 from the California Institute of Technology.

Results

The elimination of apparent ripples caused by wave swell was unsuccessful due to a malfunction of the Swell Filter option, and recognition of small-scale structures in the upper parts of the Holocene sand ridges was impossible. On the records collected during calm sea-states, small-scale structures were masked by the reverberation of the bottom return signal, regardless of the sea-state. Reverberation removal was attempted with the DAP processor and computer image display program, but the software was not sufficient to discern the small-scale structures likely to be found in the Holocene ridges. One problem with this particular software was that the digital filter did not achieve a clean band-pass of frequencies, and unwanted low-frequency-ship-noise was superimposed on the records.

All records were used to generate a preliminary isopach map of the uppermost sediments, which have been interpreted to be Pleistocene and Holocene in age (Williams, 1976; Figure 8). The isopachs in Figure 8 show a region of the Pleistocene and Holocene sediments filling in the deeply eroded Cretaceous sediments approximately 20 nautical miles (37 kilometers) from shore. The 5-nautical-mile wide deposit is oriented parallel to shore and sediment thickness can exceed 40 meters in places. Nearer to shore, Williams (1976) found ancient channels oriented perpendicular to shore, which he ascertained were Pleistocene outwash channels or ancestral river channels, depending on the sizes of the features. The shore-subparallel structure found further offshore in this study may represent an ancient river channel which meandered shore-parallel or a buried shore erosional feature such as a relict tidal inlet in a barrier island system. The data is insufficient to decide which of these is correct since no east-west seismic lines were run in this area. Shoreward and landward the blanket of sediment overlies less deeply eroded Cretaceous sediment and is more uniform between 10 and 20 meters thick. It may be more uniform shoreward due to the erosion, and consequently, the erasure of deep features on the Cretaceous sediments during the relatively slow rise in sea-level during the past 7,000 years.

Possible Future Work

A follow-up seismic reflection profiling cruise is planned to run more closely spaced ship-tracts in some of the portions of the study area where information is limited and large-scale geologic structures appear to persist. One important area is the shore-subparallel linear feature found on the isopach map. Several east-west ship-tracts in this region should give a better understanding of the nature and origin of the deposit, especially if during post-processing, sedimentary structures are identified which would indicate flow direction or channel migration. Another division of the expected cruise will be to run more seismic profiling transects in the inshore region, inside the 3-nautical-mile-limit. Transects will be run to meet with Suffolk County water well borings (well numbers S1532 and S1533) in order to correlate acoustic horizons with sediment horizons on well logs. Sediment cores and grabs are to be taken during the next seismic cruise to verify some of the sediment sizes and compositions reported in the literature and to identify upper sedimentary structures. Box cores will be taken at several locations which will be analyzed for minute sedimentary structures using a Rohé Company 3.8 Mega-hertz Rohnar 7000 ultrasound profiler in conjunction with other techniques, such as X-ray radiography and/or epoxy peels.

As pointed out by Rine (personal communication), dating of the sediments in the nearshore and mid-shelf ridges using foraminiferan tests would be a valuable tool for comparing Long Island south shore ridges with those of the New Jersey shelf. The relative change in age with depth in the Holocene sand ridges is a good indication of the mechanisms of formation of the ridges.

The Swell Filter option on the GeoPulse® has recently been repaired, and elimination of wave swell on some of the records taken in rough seas will be completed in the future in order to resolve structures in the Holocene ridges which may be the result of ridge evolution or migration. It will also be necessary to remove more of the low-frequency-ship-noise as well as reverberation from the records if fine details are to be resolved. Plans are underway to acquire the latest petroleum industry software package, Seistrix 3® from Interpex Limited, which features high quality filtering, migration and deconvolution technology. Computer enhancement using this package should improve graphic record resolution.

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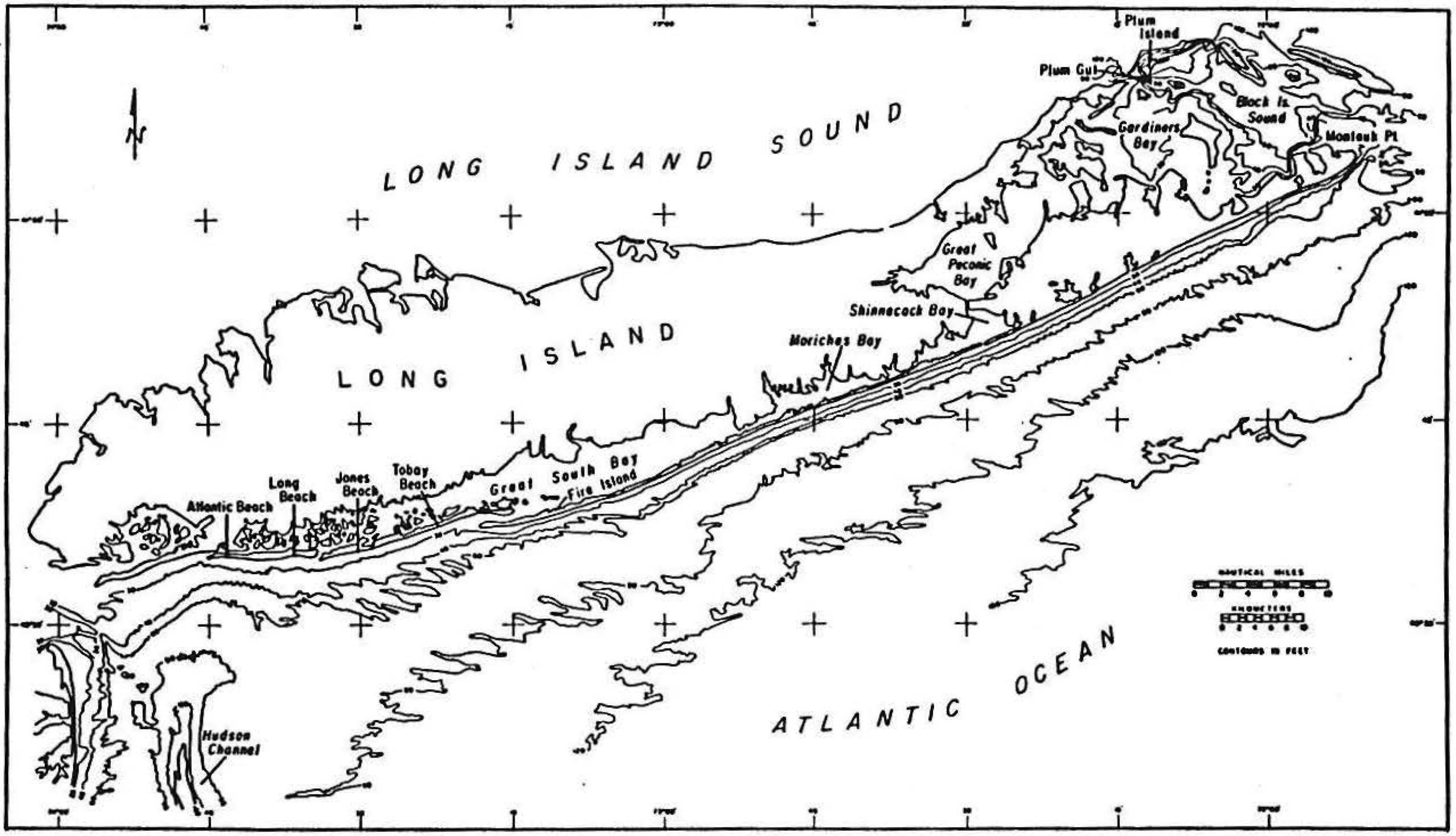

Figure 1. Bathymetric chart of the Long Island continental shelf showing the 60-foot (18-meter), 90-foot (27-meter) and 120-foot (37-meter) depth contours.

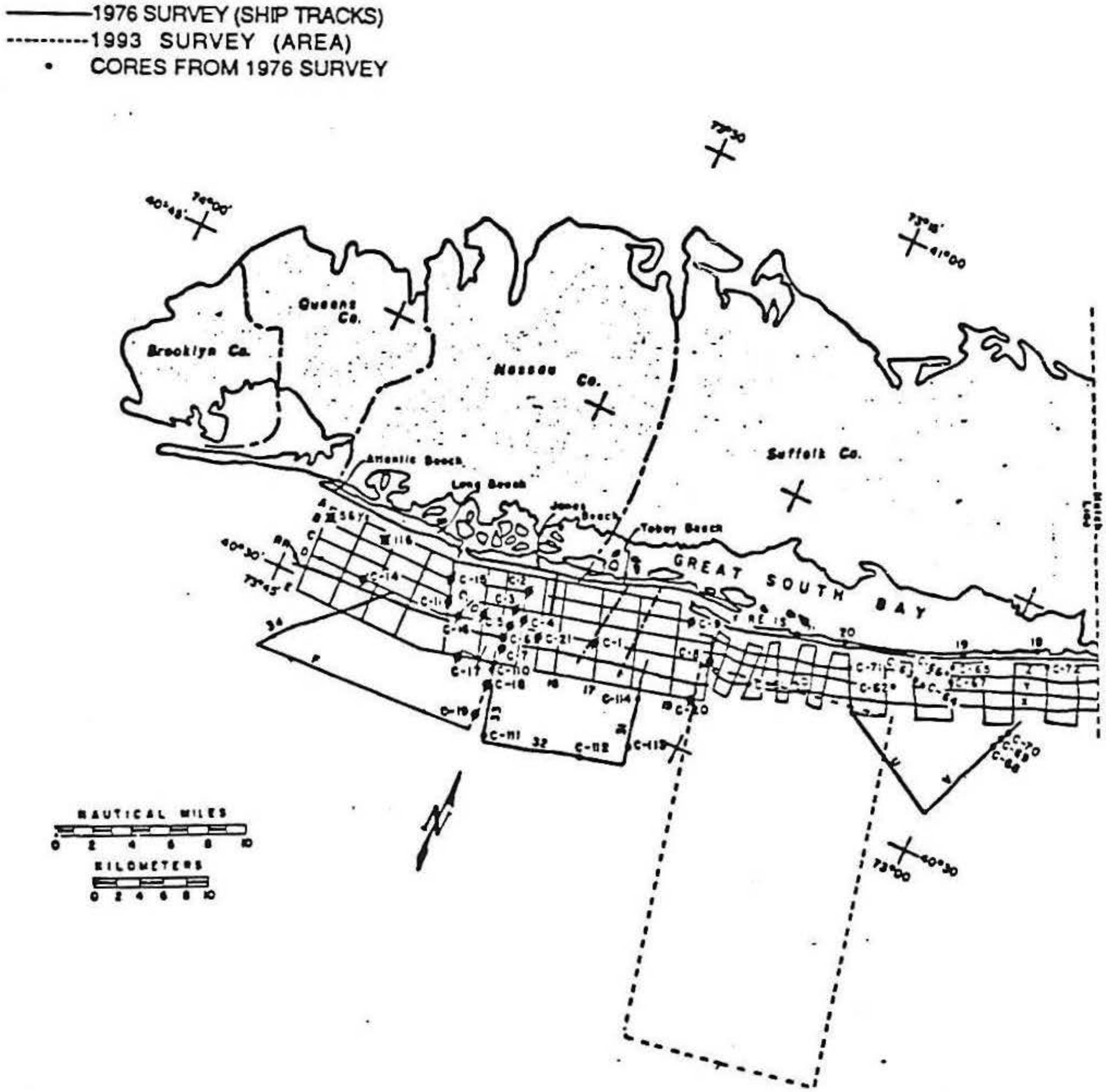

Figure 2. Study area of the 1993 seismic reflection survey off the south shore of Long Island compared with the 1976 survey completed by Williams.

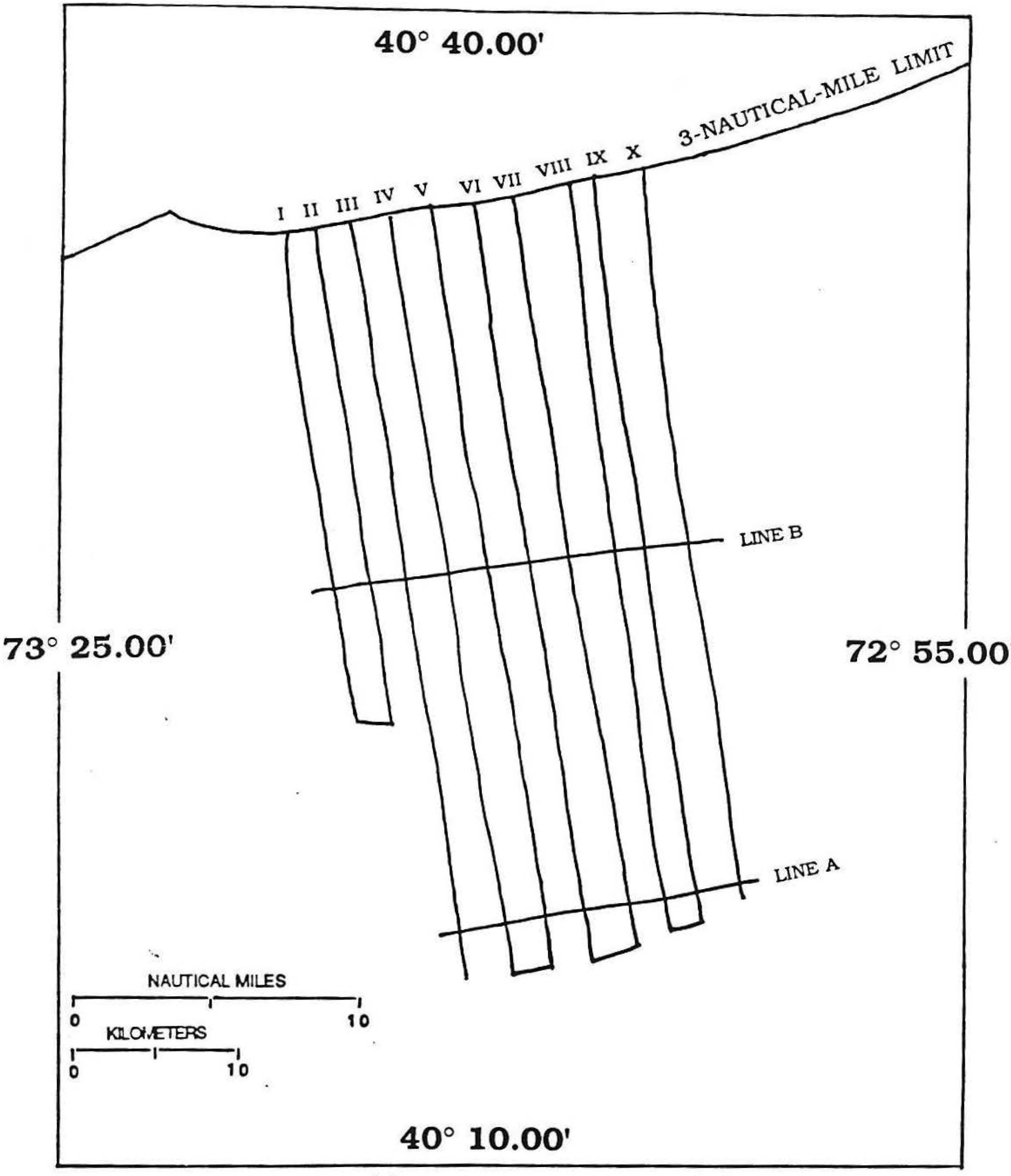

Figure 3. Long Island south shore seismic profiling ship tracts containing quality seismic records.

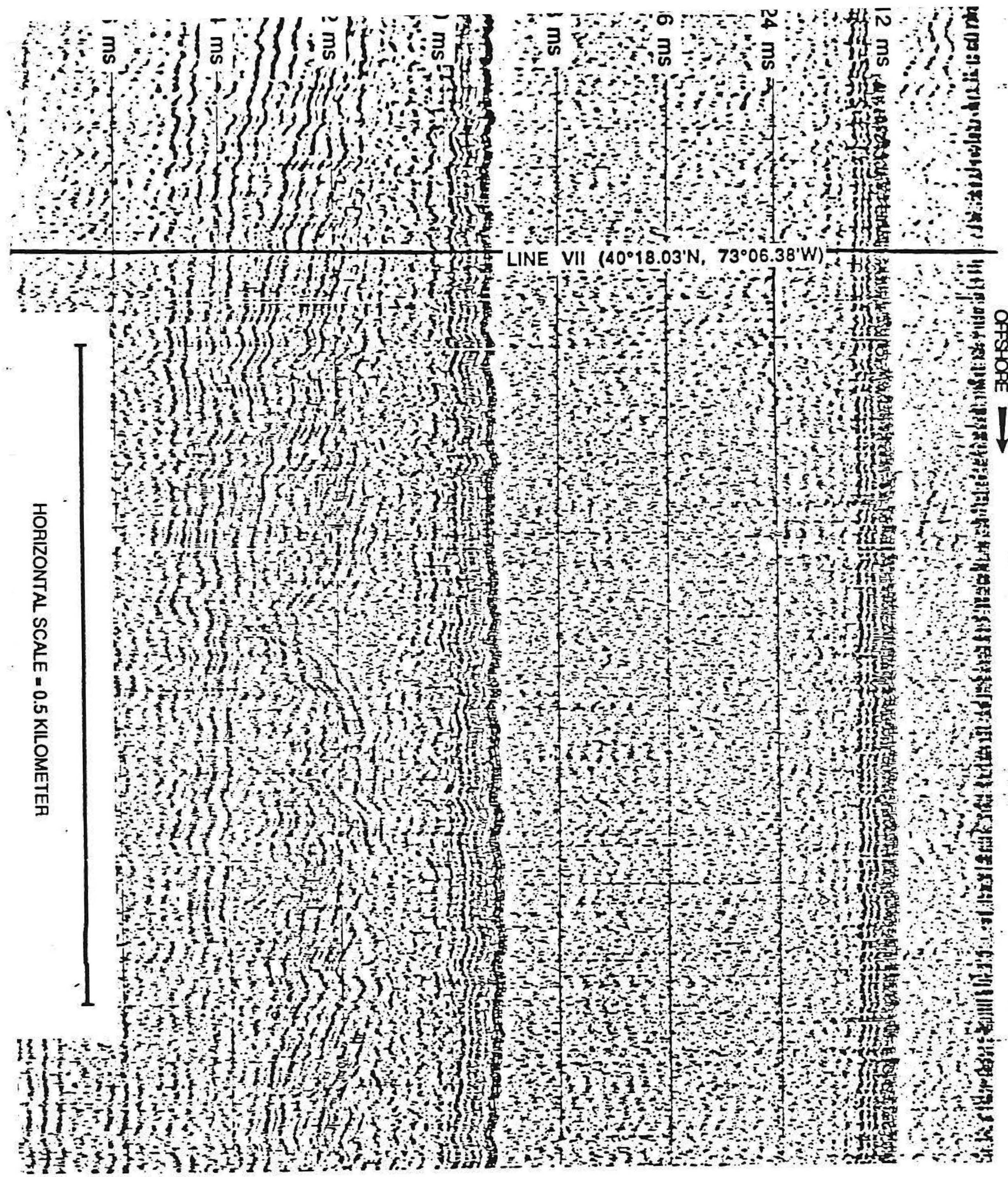

Figure 4. Seismic profile record in which both the positive and negative traces of the echoed signal were recorded.

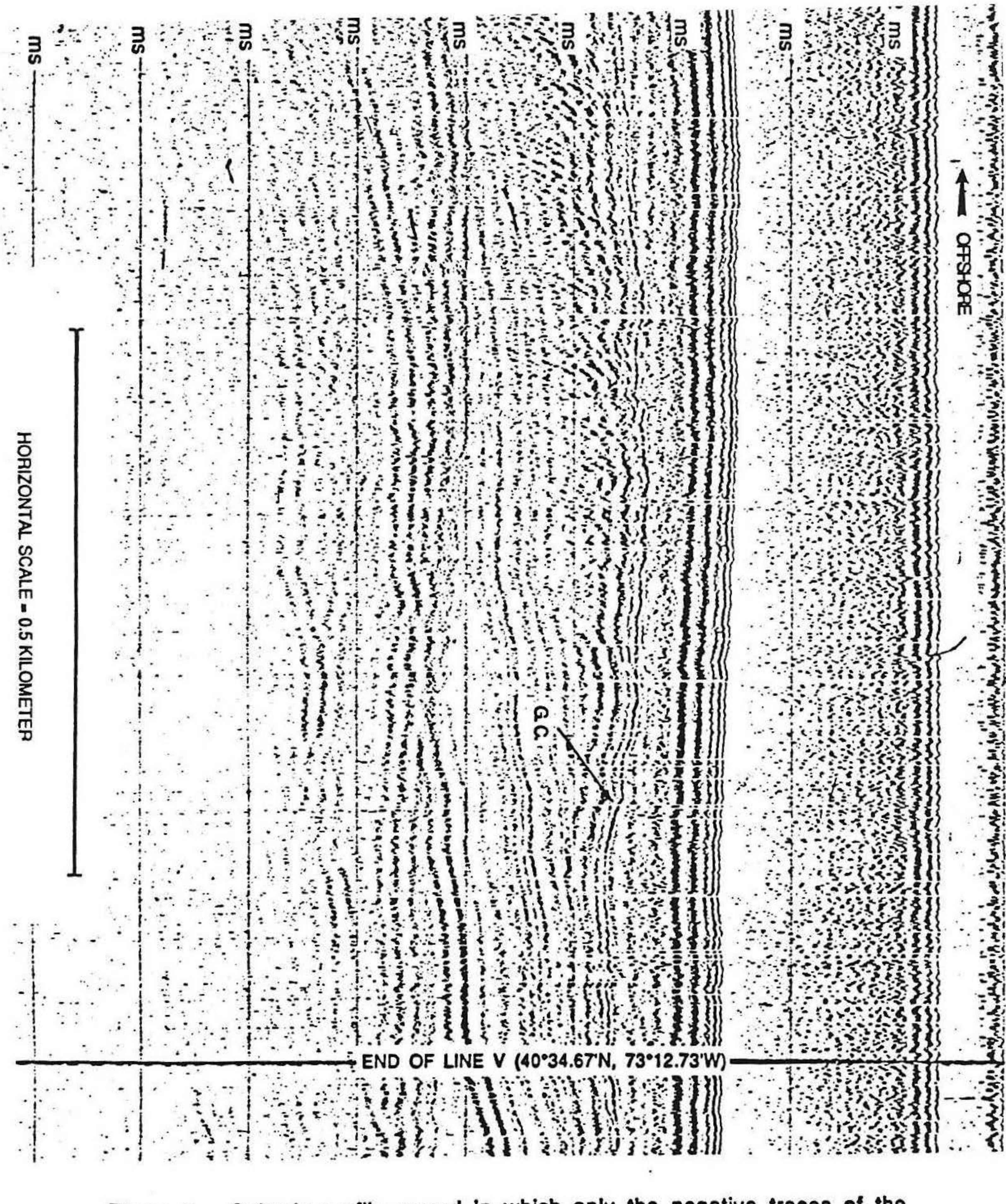

Figure 5. Seismic profile record in which only the negative traces of the echoed signal were recorded.

07:15:18 06-23-1993

09:34:01	40	34.25	N	073	14.07	W	161	T	04.4	KT	26644.0	43724.8	A	A
09:35:01	40	34.14	N	073	14.05	W	170	T	05.9	KT	26643.6	43723.7	A	A
09:36:01	40	34.02	N	073	14.03	W	171	T	06.5	KT	26643.2	43722.6	A	A
09:37:01	40	33.90	N	073	14.01	W	169	T	06.6	KT	26642.7	43721.5	A	A
09:38:00	40	33.78	N	073	13.98	W	171	T	07.1	KT	26642.2	43720.4	A	A
09:39:01	40	33.67	N	073	13.96	W	169	T	06.9	KT	26641.8	43719.3	A	A
09:40:01	40	33.55	N	073	13.93	W	171	T	06.6	KT	26641.3	43718.2	A	A
09:41:00	40	33.44	N	073	13.90	W	168	T	07.2	KT	26640.8	43717.1	A	A
09:42:00	40	33.35	N	073	13.87	W	169	T	06.8	KT	26640.4	43716.2	A	A
09:43:00	40	33.24	N	073	13.85	W	169	T	06.5	KT	26640.0	43715.2	A	A
09:44:00	40	33.12	N	073	13.83	W	170	T	06.6	KT	26639.6	43714.1	A	A
09:45:00	40	33.03	N	073	13.81	W	171	T	06.1	KT	26639.2	43713.2	A	A
09:46:00	40	32.91	N	073	13.78	W	169	T	06.6	KT	26638.7	43712.1	A	A
09:47:00	40	32.80	N	073	13.77	W	173	T	06.7	KT	26638.4	43711.1	A	A
09:48:00	40	32.70	N	073	13.75	W	173	T	06.6	KT	26638.0	43710.1	A	A
09:49:00	40	32.59	N	073	13.72	W	170	T	06.7	KT	26637.5	43709.1	A	A
09:50:00	40	32.50	N	073	13.69	W	172	T	06.3	KT	26637.1	43708.2	A	A
09:51:00	40	32.38	N	073	13.68	W	169	T	06.5	KT	26636.7	43707.1	A	A
09:52:00	40	32.27	N	073	13.65	W	172	T	06.3	KT	26636.3	43706.0	A	A
09:53:00	40	32.17	N	073	13.63	W	170	T	06.4	KT	26635.9	43705.1	A	A
09:54:00	40	32.06	N	073	13.61	W	169	T	06.3	KT	26635.5	43704.0	A	A
09:55:00	40	31.96	N	073	13.59	W	170	T	06.3	KT	26635.1	43703.1	A	A
09:56:00	40	31.86	N	073	13.57	W	173	T	06.2	KT	26634.7	43702.1	A	A
09:57:00	40	31.74	N	073	13.55	W	170	T	06.3	KT	26634.3	43701.0	A	A
09:58:00	40	31.63	N	073	13.53	W	173	T	06.3	KT	26633.9	43700.0	A	A
09:59:00	40	31.52	N	073	13.51	W	173	T	06.2	KT	26633.5	43698.9	A	A
10:00:00	40	31.41	N	073	13.48	W	171	T	06.6	KT	26633.1	43697.9	A	A
10:01:00	40	31.31	N	073	13.46	W	173	T	06.6	KT	26632.7	43696.9	A	A
10:02:00	40	31.20	N	073	13.44	W	173	T	06.2	KT	26632.3	43695.9	A	A
10:03:00	40	31.11	N	073	13.42	W	171	T	06.8	KT	26631.9	43695.0	A	A
10:04:00	40	30.99	N	073	13.40	W	169	T	06.2	KT	26631.5	43693.9	A	A
10:05:00	40	30.89	N	073	13.36	W	168	T	06.2	KT	26631.0	43692.9	A	A
10:06:00	40	30.79	N	073	13.34	W	169	T	06.1	KT	26630.6	43692.0	A	A
10:07:00	40	30.68	N	073	13.32	W	169	T	06.2	KT	26630.2	43691.0	A	A
10:08:00	40	30.57	N	073	13.30	W	171	T	06.5	KT	26629.8	43689.9	A	A
10:09:00	40	30.46	N	073	13.28	W	171	T	06.5	KT	26629.4	43688.8	A	A
10:10:00	40	30.35	N	073	13.24	W	172	T	06.4	KT	26628.9	43687.8	A	A
10:11:00	40	30.25	N	073	13.22	W	170	T	06.0	KT	26628.5	43686.8	A	A
10:12:00	40	30.13	N	073	13.20	W	173	T	06.8	KT	26628.1	43685.7	A	A
10:13:00	40	30.04	N	073	13.18	W	168	T	06.4	KT	26627.7	43684.8	A	A
10:14:00	40	29.92	N	073	13.16	W	170	T	06.3	KT	26627.3	43683.7	A	A
10:15:00	40	29.81	N	073	13.14	W	171	T	06.3	KT	26626.9	43682.7	A	A
10:1[illegible]00	40	29.71	N	073	13.11	W	171	T	06.3	KT	26626.5	43681.7	A	A
10:17:00	40	29.60	N	073	13.09	W	172	T	06.6	KT	26626.1	43680.7	A	A
10:18:00	40	29.50	N	073	13.07	W	171	T	06.2	KT	26625.7	43679.7	A	A
10:19:00	40	29.38	N	073	13.05	W	172	T	06.5	KT	26625.3	43678.6	A	A
10:20:00	40	29.29	N	073	13.01	W	171	T	06.1	KT	26624.8	43677.7	A	A
10:21:00	40	29.17	N	073	12.99	W	172	T	06.5	KT	26624.4	43676.6	A	A
10:22:00	40	29.07	N	073	12.97	W	172	T	06.3	KT	26624.0	43675.6	A	A

Figure 6. Computer loggings of the ship track showing latitude, longitude, true bearing, ship speed over ground and Loran time delays at 1-minute intervals from a Loran-C unit.

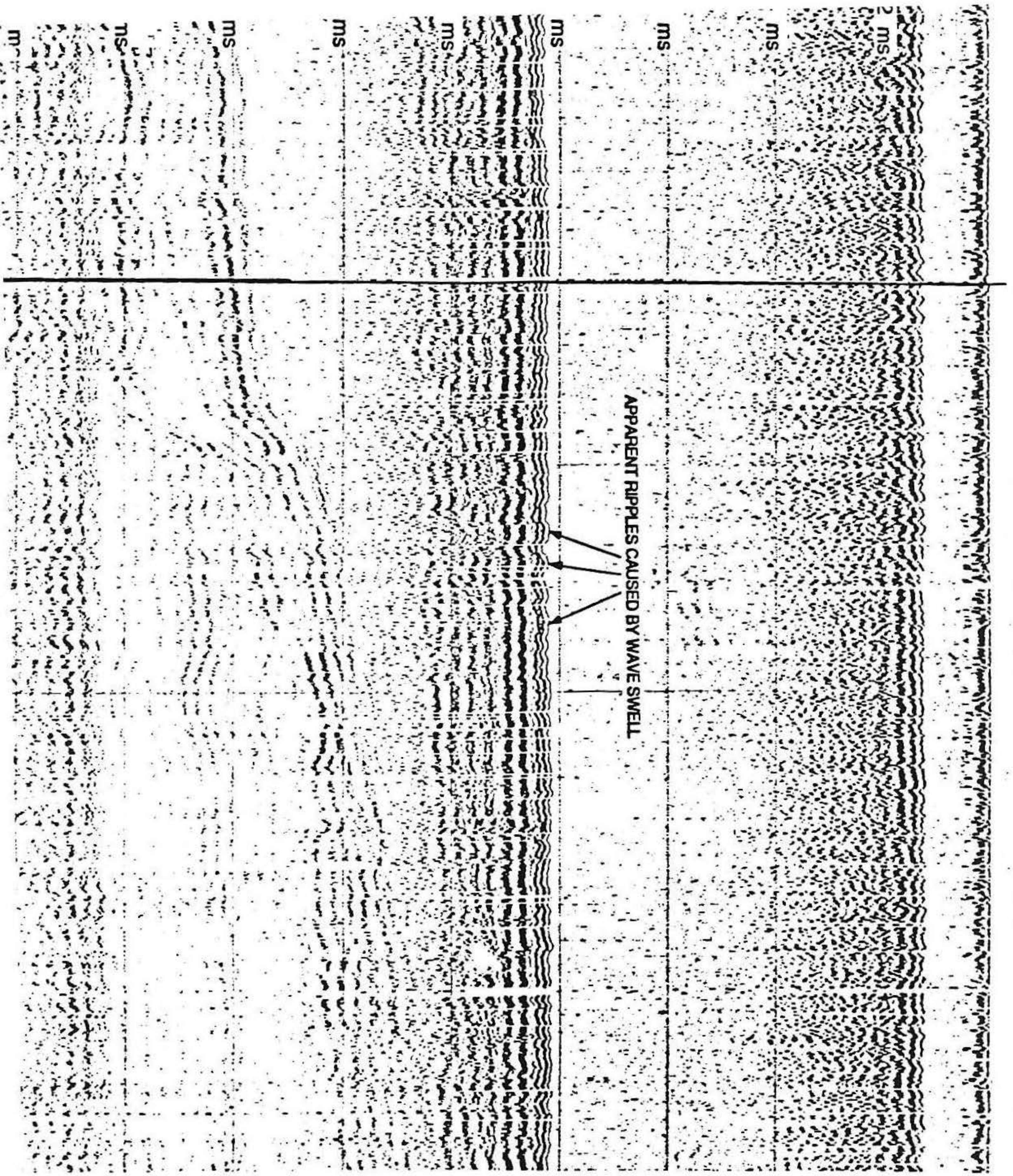

Figure 7. Apparent ripple marks due to wave swell during heavy seas.

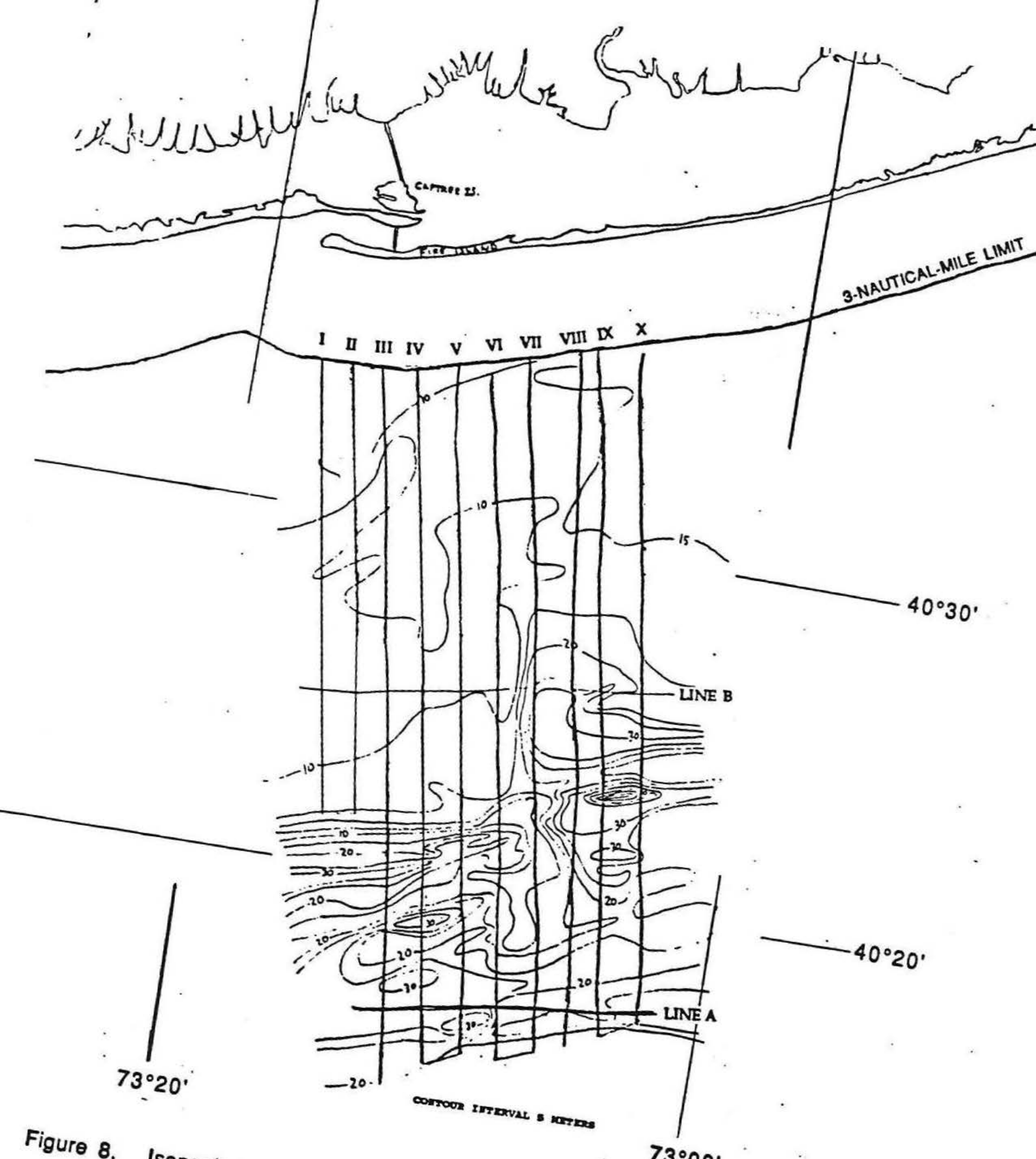

Figure 8. Isopach map of the Pleistocene and Holocene sediments off the south shore of Long Island.