CRUISE REPORT 89-009
PHASE A - HALIFAX INLET
F.R.V. NAVICULA

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CRUISE SUMMARY SHEET

Cruise No.:	89-009 (Phase A - Halifax Inlet)	
Vessel:	F.R.V. Navicula	
Cruise Dates:	May 29th - June 18th, 1989	
Responsible Agency:	Atlantic Geoscience Centre, Geological Survey of Canada, Bedford Institute of Oceanography, Dartmouth, N.S., B2Y 4A2	
Area:	Halifax Harbour, Bedford Basin, Northwest Arm, Inner Scotian Shelf	
Ship's Master:	Captain Joe Bray	
Senior Scientist:	Robert O. Miller	
Scientific Personnel:	Andrea Adamson	Scientist, DFO
	Anthony S. Atkinson	Technician, AGC
	Darrell Beaver	Technician, AGC
	Bruce Bennett	Parks Canada
	Dale Buckley	Scientist, AGC
	Ray Cranston	Scientist, AGC
	André D'Entremont	Technician, Environment Canada
	Alice Dickinson	Acadia University
	Gordon Fader	Scientist, AGC
	R.A. Fitzgerald	Technician, AGC
	Shawna Heming	Saint Mary's University
	Ami Häkkinen	Scientist, Geological Survey of Finland
	G.F. Terry Lay	Scientist, TUNS
	Shawn Pecore	University of Waterloo
	Kok-Leng Tay	Scientist, Environment Canada

* Cover: Sidescan sonar image of the Governor Cornwallis. On December 22, 1944, this Halifax-Dartmouth ferry caught fire and was towed to its final seafloor resting place on the eastern side of Georges Island

NAVICULA CRUISE
89-009 (Phase A - Halifax Inlet)

ITINERARY:

DATE (1989)	TIME (GMT)	OPERATION
May 29, Julian Day 149	1100-1600	Set up geophysical equipment, dockside: 1) Huntec sea otter; 2) Klein 100 kHz sidescan; and 3) Datasonics bubble pulser.
	1600	Begin Survey by testing equipment in Bedford Basin.
	2120	Secured at BIO.
May 30, Julian Day 150	1100-1230	Set up geophysical equipment.
	1230	Deploy equipment in Bedford Basin
	1940	Recover equipment.
	2000	Secured at BIO.
May 31, Julian Day 151	1100-1130	Set up geophysical equipment.
	1140	Deploy equipment in Bedford Basin.
	1210	Return to BIO dock to work on navigation equipment.
	1315	Depart BIO and deploy equipment in Bedford Basin.
	1327	Lose sidescan tail section, with transducers (100 kHz Klein).
	1340	Secured at BIO.
	1710	Depart BIO with new sidescan tail section.
	1715	Deploy equipment in Bedford Basin.
	2250	Recover equipment.
	2305	Secured at BIO.
June 1, Julian Day 152	1100-1145	Set up geophysical equipment.
	1145	Depart BIO
	1230	Deploy anchored buoy on site of lost sidescan.
	1240	Deploy equipment in Bedford Basin.
	1410	Hose to gear box on Navicula breaks, recover equipment and return to BIO.
	1720	Depart BIO after repairing hose.
	1730	Tie up to DND dive tender (YDT 12).
	1735	Depart dive tender.
	1740	Deploy DND anchored buoy on side of lost sidescan.
	1749	Deploy equipment in Bedford Basin.
	2050	Recover equipment.
	2115	Secured at BIO.
June 2, Julian Day 153	1100-1330	Set up sampling equipment and deployment lines 1) modified, scaled-down Eckman dredge; and 2) Lehigh corer and van Veen grab sampler.
	1340	Sample in Bedford Basin and return to BIO with samples.
	1530	Depart BIO to sample in Bedford Basin and return to BIO with samples.
	1700	Depart BIO to sample in Bedford Basin and return to BIO with samples.
	1800	Secured at BIO.
June 3, Julian Day 154	1100-1150	Set up sampling equipment.
	1215	Sample in Bedford Basin.
	1400	Complete sampling (Station 1-9) in Bedford Basin.
	1415	Secured at BIO.
	1700	Depart BIO to resume survey in the Narrows.
	2000	Recover equipment.
	2010	Secured at BIO.

NAVICULA CRUISE
89-009

ITINERARY (Continued):

DATE (1989)	TIME (GMT)	OPERATION
June 4, Julian Day 155	1100-1200	Set up geophysical equipment.
	1200	Depart BIO to survey Narrows and area south to Point Pleasant.
	1930	Recover equipment.
	2000	Secured at BIO.
June 5, Julian Day 156	1100-1230	Set up geophysical equipment.
	1230	Depart BIO to survey Halifax Harbour.
	1850	Recover equipment.
	1930	Secured at BIO.
June 6, Julian Day 157	1100-1200	Place sampling equipment on board Navicula and set up.
	1200-1430	Sample in harbour: 1) Tufts Cove; 2) Duffus Street outfall; 3) Dartmouth Cove; and 4) North of Georges Island. Sampling equipment include: 1) modified, scaled-down Eckman dredge; 2) Lehigh corer; and (3) a medium van Veen grab sampler.
	1510	Secured at BIO and offload samples.
	1510-1615	Set up geophysical equipment.
	1615	Depart BIO.
	1650	Deploy equipment and survey the Northwest Arm.
	2000	Recover equipment.
	2015	Secured at BIO.
June 7, Julian Day 158	1100-1230	Set up geophysical equipment.
	1230	Depart BIO.
	1300	Deploy equipment and resume survey of outer harbour.
	1900	Recover equipment.
	1930	Secured at BIO.
June 8, Julian Day 159	1100-1200	Load new sidescan onboard Navicula for testing in Bedford Basin and the Narrows.
	1200	Depart BIO and deploy sidescan in Bedford Basin.
	1335	Recover sidescan.
	1345	Secured at BIO.
	1345-1500	Discuss merits of new sidescan fish to determine whether it yields suitable data to complete the Halifax Harbour survey.
	1500-1540	Dr. Kok-Leng Tay and André D'entremont (E.P.S.) load beam trawl onboard Navicula.
	1540	Depart BIO.
	1600	Commence trawls in: 1) Bedford Basin; 2) Narrows; 3) off Georges Island; and 4) Pleasant Shoal.
	2000	Recover beam trawl.
	2030	Secured at BIO.
June 9, Julian Day 160	1100-1400	Set up IKB Seistec boomer (as a replacement for the Huntec sea otter).
	1400	Depart BIO.
	1430	Deploy IKB Seistec boomer off of Point Pleasant to test system and set up towing configuration.
	1700	Resume survey with IKB Seistec boomer and new, shorter Klein sidescan and Datasonics bubble pulser.
	2030	Recover equipment.
	2100	Secured at BIO.

NAVICULA CRUISE
89-009

ITINERARY (Continued):

DATE (1989)	TIME (GMT)	OPERATION
June 10, Julian Day 161	1100-1330 1330 1345 1655 1715	Set up IKB Seistec boomer. Fender buoys are added for flotation. Depart BIO. Deploy IKB Seistec boomer for further test runs in Bedford Basin. All tests are in Bedford Basin due to inclement weather in the outer harbour. F.C.G. Smith line is run with Loran C only, for navigation. Recover IKB Seistec boomer. Secured at BIO.
June 11, Julian Day 162		Navicula at rest all day due to inclement weather.
June 12, Julian Day 163	1100-1315 1315 1345 2005 2100	Set up geophysical equipment: 1) IKB Seistec boomer; 2) Klein 100 kHz sidescan; and 3) Datasonics bubble pulser. Depart BIO. Deploy equipment except for Datasonics bubble pulser is deployed later. Survey between McNabs Island and Herring Cove. Recover equipment. Secured at BIO.
June 13, Julian Day 164	1100-1200 1200 1500	Set up sampling equipment. Depart BIO for morning of sampling: 1) Eastern Passage; and 2) Northwest Arm. Secured at BIO while modifications are made to geophysical equipment.
June 14, Julian Day 165	1125 1255 1955 2035	Depart BIO for Chebucto Head. Deploy geophysical equipment to survey mooring location site off Halifax Harbour for Whitman Benn and Associates Limited and then continue to survey the Harbour approaches. Recover equipment. Secured at BIO.
June 15, Julian Day 166	1130 1150 1235 2045 2135	Depart BIO to confirm correct buoy position over site of lost sidescan in Bedford Basin. Depart Bedford Basin for Herring Cove. Deploy geophysical equipment for survey between Herring Cove and Chebucto Head. Recover equipment Secured at BIO.
June 16, Julian Day 167		Navicula at rest all day to take on fuel, water and provisions.
June 17, Julian Day 168	1125 1215 2030 2120	Depart BIO. Deploy geophysical equipment off of Mars Rock for survey between Herring Cove and Chebucto Head. Recover equipment. Secured at BIO.
June 18, Julian Day 169	1140 1220 1920 1935	Depart BIO. Deploy geophysical equipment off of Maugher Beach for survey of outer harbour and approaches. Recover equipment. Secured at BIO.

Introduction

This cruise was carried out in support of a nearshore regional geological mapping program of the Geological Survey of Canada; it extended from May 29th to June 18th, 1989 and was multifaceted in nature and included collaborators from various departments of the Canadian Government

The main objective of the cruise was to collect geological and geophysical data in Halifax Inlet* (Fig. 1) with a 100 kHz Klein sidescan sonar set at 100 m range and a Datasonics Bubble Pulser, a Huntec Sea Otter (which was eventually replaced by an IKB Seistec boomer) and an Elac 30 kHz sounder. The study was intended to provide a regional assessment of geological conditions as background to the Halifax Harbour Cleanup Project (sewage management system). In addition, the data was collected to assess the aggregate potential of the Halifax Harbour and Approaches area.

Sidescan sonar data were used to identify and map surface attributes whether of natural origin such as bedforms and bedrock or of anthropogenic origin such as ship wrecks, anchor drag marks, dredge spoils, sewage banks, cables, etc.

Because of its lower frequency, data collected with the Datasonics Bubble Pulser was used to delineate the subseabed bedrock surface. These data, together with profiles collected with the Huntec Sea Otter and the IKB Seistec boomer were used to interpret the subsurface Quaternary geology and to identify locations for biological (Department of Fisheries and Oceans) and geochemical samples (Fig. 2). The preliminary findings of these studies are included (see Appendix I and II).

* Halifax Inlet is herein defined as that body of water extending north of a line from Hartlen Point to Chebucto Head and includes Halifax Harbour, Northwest Arm, Eastern Passage, the Narrows, Bedford Basin, Bedford Bay as well as many other smaller bays and coves within these general boundaries.

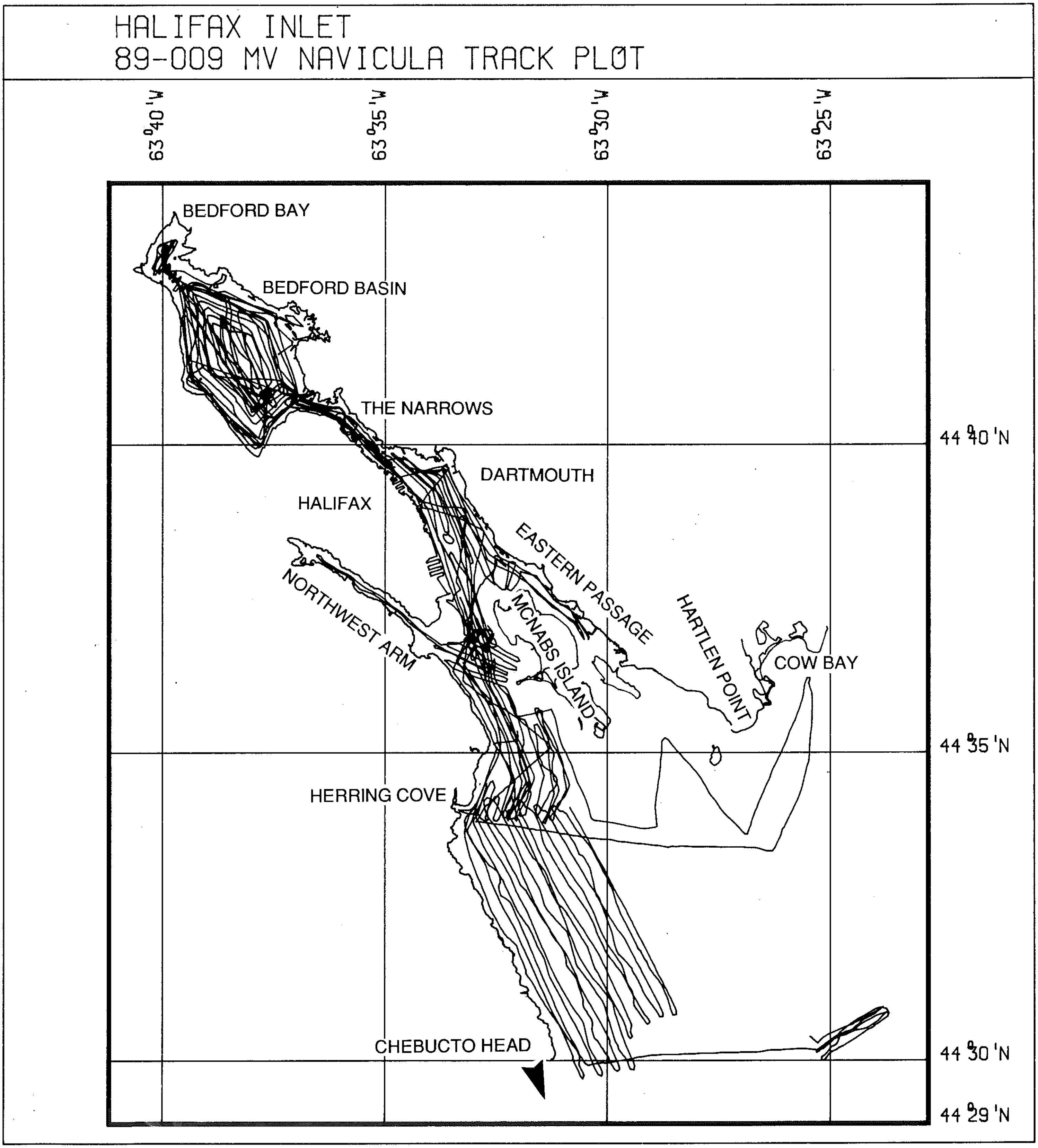

Figure 1. Trackplot for Navicula 89-009 (Phase A) in Halifax Inlet.

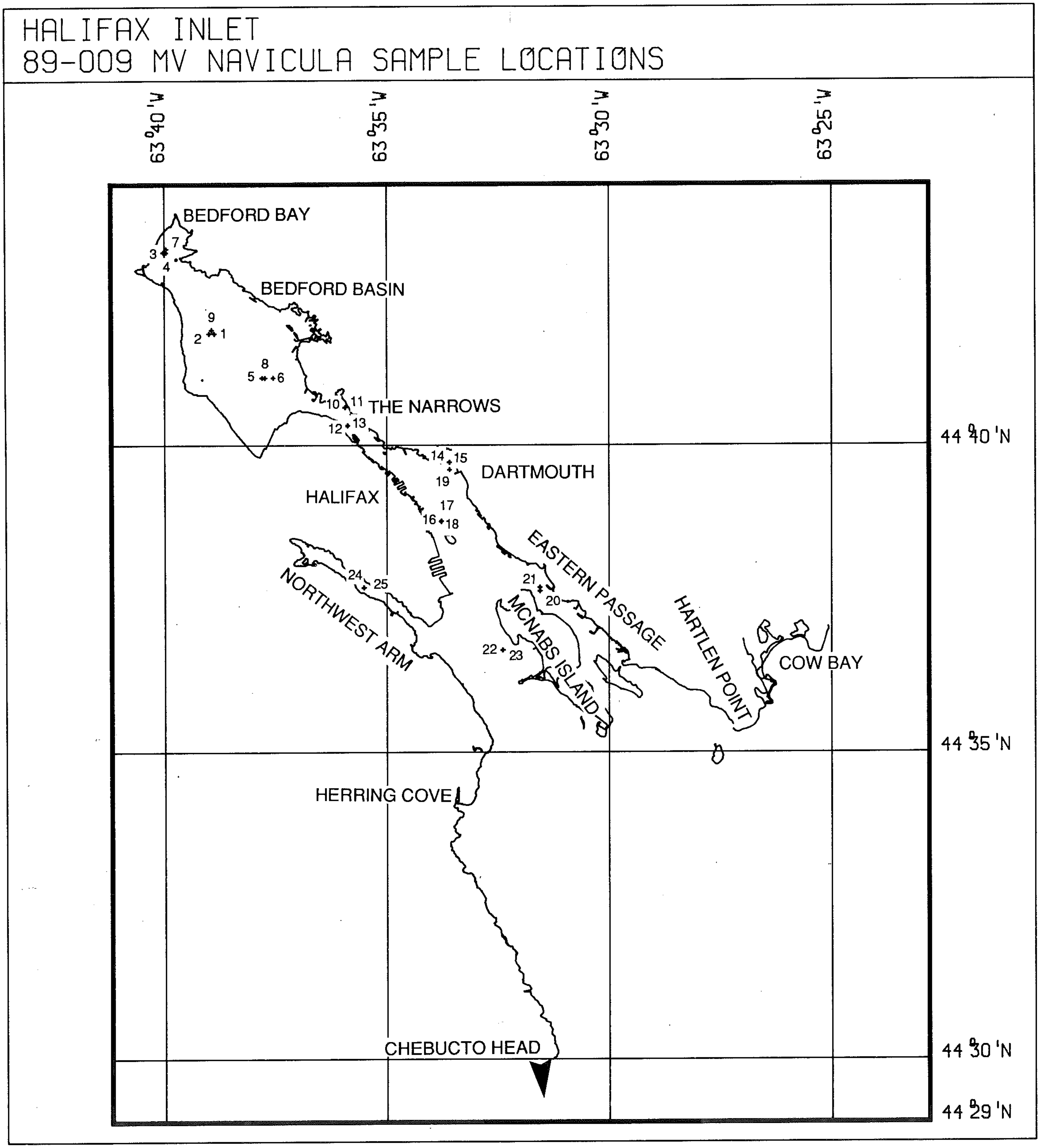

Figure 2. Sample locations and numbers for Navicula 89-009 (Phase A) in Halifax Inlet.

A Motorola Miniranger Falcon 484 navigation system was used during the survey but could only function well in small cells. The survey therefore was designed to complete small sections of the Inlet at a time before moving to the next area. A north to south progression was adopted.

An experimental trawling program was undertaken by Environment Canada to study bottom dwelling fish in Bedford Basin and Halifax Harbour and is also included in this report (see Appendix III).

Data collected during the survey of Halifax Inlet will also be used to study the mineral and aggregate potential particularly of the outer Harbour area where large quantities of these materials have been documented (Miller and Fader, 1989a).

EQUIPMENT DESCRIPTION AND PERFORMANCE

Sidescan Sonar System

The sidescan sonar deployed during the cruise was a Klein 100 kHz, model 421T, with a "K" wing and a remote controlled Markey hydraulic winch. Sidescan signals were logged on seven inch reels of magnetic analog recording tape at a speed of three and three quarters inches per second. The eighteen hundred foot reels of Ampex type 641 tape provided one and a half hours of recording time per reel. The four channels of the Racal Store 4D tape recorder were used in the following manner: Channel one-FM port sidescan signal, Channel two-FM starboard sidescan signal, Channel three-DR sidescan reference signal, and Channel four-DR Seistec signal and voice fixes. Part way through the cruise, seismic reflection data collection was synchronized to the sidescan system providing an opportunity to record the Seistec signal on channel four and recover synchronization during playback. A sidescan recorder is necessary for playback of this signal on a digital EPC because it recovers the synchronizing signal for triggering the TVG and graphic recorder from the tape. Voice fixes were kept to a minimum because they were found to interrupt the recording process on channel four. Record annotator signals were recorded along with the sidescan signals on channel two. For the majority of the cruise, the sidescan was set at a one hundred metre range and sixty lines per inch paper speed. This provided a resolution of $\simeq$ 0.5 m across track. The sidescan fish was towed at a constant height above the seabed to aid in the production of sidescan mosaics. The data are generally of high quality.

Datasonics "Bubble Pulser"

A Datasonics "Bubble Pulser" 500 Hz source and hydrophone streamer was used to define subsurface stratigraphy and delineate the bedrock surface in areas of "gas-charged" sediments. Its output was displayed on an EPC 1600 graphic recorder using a paper rate of 150 lines per inch. A sweep speed of 190 milliseconds was used at first to correspond to data collected in 1988, but it was later changed to 100 milliseconds once the seismic reflection signal was synchronized to the sidescan sonar signal. The seismic profiles from this system has a lower resolution of $\simeq$ 3-5 m when compared to the 1 m resolution, or less, of the other systems.

Huntec Sea Otter and IKB Seistec Line and Cone Array

High resolution seismic reflection data were gathered using an ORE Geopulse power supply firing a Huntec Model 4425 boomer at 105 Joules, an ORE 5210A seismic receiver, an EPC graphic recorder, an NSRF LT06 hydrophone or an IKB Seistec surface towed line and cone array. During the first week of the cruise in Halifax Harbour, the NSRF hydrophone and an EPC 4100 boomer was used to display data at a one second rate. Later, the IKB Seistec system became available and it was tested successfully and employed for the remainder of the cruise. The Seistec data were displayed on an EPC 1600 recorder using a 60 millisecond sweep speed and a paper rate of 150 lines per inch. Water column time delays were included as required and noted on the graphic records. A firing rate of 400 milliseconds was used for the Seistec system. For the part of the survey that included the Seistec system, the Bubble Pulser firing rate was also increased from one second to 400 milliseconds. The resolution of this system was $\simeq$ 0.5 m.

Few equipment problems were experienced. Less than one half day survey time was needed to replace the lost sidescan sonar fish. The entire timing and synchronization scheme for the survey systems was changed from the 1988 version. A trigger pulse was sourced from the sidescan recorder and this was used to fire the Seistec and Datasonics systems. Synchronizing the systems removed the boomer transient pulse from the sidescan records. This transient had been present on the 1988 records and its removal dramatically improved the images. An intermittent instability in the manual mode of the sidescan slew control appeared early in the cruise. This was initially attributed to a thermal problem, but was found to have been caused by the boomer transient pulse. A diode clamp and level buffer circuit was constructed on Navicula to allow the sidescan trigger pulse to be used by the seismic reflection systems. Using 100 metre range on the Klein sidescan, a trigger pulse was produced every 130 milliseconds. It was necessary to divide this time by three to produce a seismic trigger every 400 milliseconds. Since the low cut frequency of the Seistec was 100 Hz and the Bubble Pulser system had a centre frequency of 500 Hz, there was little overlapping between the two systems and they could be triggered at exactly the same time. The alternating trigger pattern used in 1988 was no longer necessary.

During the first ten days of the survey, the TSS annotator was not available. The "Labels Plus" program was used to generate time labels to fix on the records. Tests were also conducted on a new subtowed vehicle called "The Baby Boomer" that was fitted with a Huntec model 4425 boomer.

An EPC 1600 graphic recorder was installed in the lab to monitor the Elac sounder on the bridge. This was particularly useful for the sidescan operator in areas of rough bottom as early warning was provided. This recorder had to be dedicated to the Seistec system during the latter half of the cruise as it required a digital machine. Profiles from the Elac sounder were annotated with time by hand. This system penetrated the muds of Bedford Basin and the Inner Harbour.

NAVIGATION

A Motorola Miniranger Falcon 484 system was used for navigation. It was calibrated at B.I.O. and seven transponders were deployed throughout the harbour (Fig. 3). Codes 2,3,4,6,8,10,12 were used in Halifax Harbour. The Falcon 484 range console, R/T, Track plotter, and C.D.U were installed aboard the Navicula at B.I.O. prior to the survey; the new plotter software was tested with the Minnav logging software aboard the Launch Ibis prior to its installation on Navicula. For the Bedford Basin part of the survey, four transponders were set up on survey control points, as shown in Table I, (Sites 1-4) with the additional sites 5 & 7 used to cover Bedford Bay and the Mill Cove area. On June 4th, the transponders were relocated to cover the next leg of the survey in and around the Mackay Bridge and The Narrows. This area was covered by siting transponders at stations Grav, Dom, Pow and Ment (Table II). These locations were all positioned so as to cover The Narrows area; they were later re-positioned for survey operations in the Halifax Harbour area. As the area of survey proceeded to Halifax Harbour and Approaches, extra transponders were located at the Dartmouth backrange (IBR) and Meagher Beach Lighthouse. Further stations were set up to cover the Halifax Approaches at station Fire, and Chebucto Head Lighthouse. As several days were available between transponder location changes, stations at Pow, Grav, and Dom were moved to cover the Northwest Arm during that part of the survey. This deployment required two transponders at the Dingle Tower, one pointing north, one pointing south; one transponder pointing south from Horseshoe Island, and one pointing north from Point Pleasant Park (Point). This configuration was only used for a single day to cover the Northwest Arm survey area. The transponders were then repositioned to fill in any areas of poor coverage. A site was set up at Hartlen Point (Fix) and an interim station was located at the Bonaventure wharf at Shearwater (Bon) to cover the Eastern Passage area.

Figure 3. Miniranger location sites for Navicula 89-009 (Phase A) in Halifax Inlet.

All stations were monitored for operation and serviceability and batteries were changed every three days at the stationary sites. This operation continued until June 18th, when the Navicula proceeded to survey between the outer approaches of Halifax and B.I.O. This required two teams ashore to position the transponders in a "Leapfrog" pattern as the survey progressed from The Narrows to B.I.O.

Few problems were encountered with the transponders. The AGC-supplied batteries were charged and recharged frequently with only a loss of two cells in different batteries. Two batteries were stolen from Station Ment during a weekend period. This station was then abandoned because of the ease of access for would-be "battery thieves". The Positioning shop at BIO experienced only one transponder fault which was quickly rectified by the Positioning shop at BIO and redeployed.

MINIRANGER FIELD SITES FOR BEDFORD BASIN

SITES	CODE	UTM	LATITUDE/ LONGITUDE
1 GRAV	6	N4947479.OY E451284.5X	44° 40' 51.53" N 63° 36' 52.84" W
2 SEWER	8	N4945671.3Y E449725.3X	44° 39' 52.56" N 63° 38' 03.02" W
3 PRINCE'S LODGE	10	N4948606.OY E447721.7X	44° 41' 27.15" N 63° 39' 35.08" W
4 MINE	12	N4950548.7 E449520.5X	44° 42' 30.57" N 63° 38' 14.05" W
5 DOWN	2	N4950512.8Y E447352.7X	44° 42' 28.8" N 63° 39' 52.50" W
7 SEW	3	N4951380.9Y E446683.7X	44° 42' 56.79" N 63° 40' 23.27" W

Table I

MINIRANGER FIELD SITES FOR HALIFAX NARROWS TO CHEBUCTO HEAD

SITES	CODE	UTM	LATITUDE/ LONGITUDE
1 GRAV	6	N4947479.0Y E451284.5X	44° 40' 51.53" N 63° 36' 52.84" W
2 DOM	8	N4946774.99 E451895.46	44° 40' 28.86" N 63° 36' 24.85" W
3 POW	10	N4946819.28 E452599.520	44° 40' 30.46" N 63° 35' 52.89" W
4 DRY	12	N4945742.29 E453031.59	44° 39' 55.6" N 63° 35' 32.8" W
5 IBR	2	N4945906.8Y E454408.5X	44° 40' 01.31" N 63° 34' 30.44" W
6 CABLE	3	N4943948.36 E454752.88	44° 38' 57.8" N 63° 34' 14.1" W
7 MENT	4	N4944278.79 E456088.92	44° 39' 08.92" N 63° 33' 13.62" W
8 ROYAL	6	N4941369.279 E455589.99	44° 37' 34.53" N 63° 33' 35.37" W
9 FIRE	8	N4936898.3 E456750.19	44° 35' 09.89" N 63° 32' 41.41" W
10 FIX (HARTLEN PT)	10	N4937538.38 E463937.32	44° 35' 31.97" N 63° 27' 15.53" W
11 CAMPERDOWN G.	12	N4929675.61 E456975.76	44° 36' 56.89" N 63° 32' 28.97" W
12 DAL	2	N4940218.29 E454484.69	44° 36' 56.89" N 63° 34' 25.08" W
13 MEAGHERS BEACH LIGHT	3	N4938684.62 E457601.67	44° 36' 07.96" N 63° 32' 04.80" W
14 PLEA	4	N4940731.79 E454385.90	44° 37' 13.59" N 63° 34' 29.80" W
15 POINT	6	N4941147.77 E454006.47	44° 37' 26.90" N 63° 34' 47.08" W
16 CHEBUCTO LIGHT	6	N4928134.0 E458398.6	44° 30' 26.20" N 63° 31' 24.07" W
1 BON	10	N4941596.52 E458420.09	44° 37' 42.50" N 63° 31' 27.01" W
2 DINGLE	12	N4941813.3 E452565.1	44° 37' 48.22" N 63° 35' 52.78" W
3 HORSESHOE	10	N4942859.0 E451317.5	44° 38' 21.80" N 63° 36' 49.76" W
4 DINGLE	3	N4941813.3 E452565.1	44° 37' 48.22" N 63° 35' 52.78" W

Table 2

DISCUSSIONS AND COMMENTS

Sonogram Interpretation

1. Bedford Basin

Sidescan sonograms collected in Bedford Basin indicate a wide variety of seabed features. The most dominant feature of the Basin seafloor is the presence of linear-curvilinear furrows which occur virtually over the entire area below 20 m (Fig. 4). These furrows were formed as a result of anchors and their chains impacting on the seafloor. Most are believed to be anchor drag marks left behind by the convoys which assembled in the Basin during World War II (Miller and Fader, 1989a). These furrows are often criss-crossed by more modern anchor marks presumably made by the large, modern freight and cargo ships which frequent the Basin. The anchor marks have a maximum relief of approximately 3 m in the softer sediments of the central deepest part of the Basin. Their average depth is between 0.5 and 2 m. They are continuous, lineal furrows which in some areas extend up to 1 km in length. Sometimes the furrows occur in plumose-like patterns (Fig. 4) believed to result from anchored ships moving in a weathervane fashion with changing winds and tides. Anchor marks in the Fairview Cove area are subdued, probably as a result of their burial by material from a storm water outfall at Fairview Cove and by fine-grained sediment from the building of the container terminal which has partially infilled the furrows. Large linguoid-shaped scours occur on the seafloor adjacent to the Fairview Container Terminal and are believed to be excavations caused by ships propellers.

Borrow pits (dredge pits) occur adjacent to Fairview Cove (Fig. 5) perhaps reflecting previous seabed mining activities. Sidescan sonograms also revealed two boulder berms (paleoshorelines) which extend continuously along the entire shoreline of Bedford Basin in water depths of approximately 10 m (Fig. 6). This pattern is discontinuous along the eastern shore of Bedford Basin. These features were probably formed as push ridges when Bedford Basin was a lake before the marine invasion. The eastern side of Bedford Basin is characterized by an even distribution of

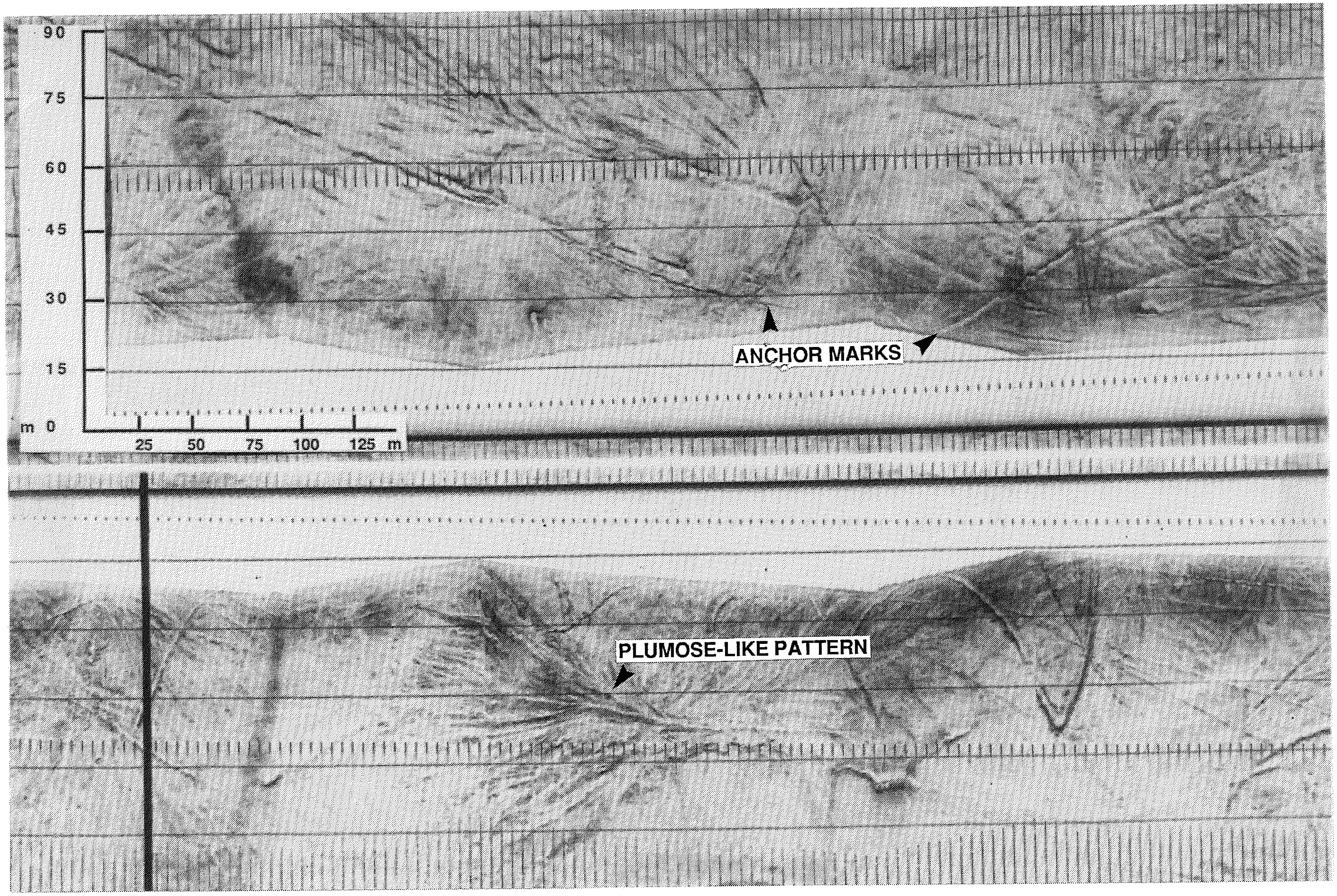

Figure 4. Anchor drag marks on the seafloor of Bedford Basin. Note plumose-like pattern. This pattern is probably caused by ship's anchor chains moving about the seafloor as the ship is moved about by winds and tides.

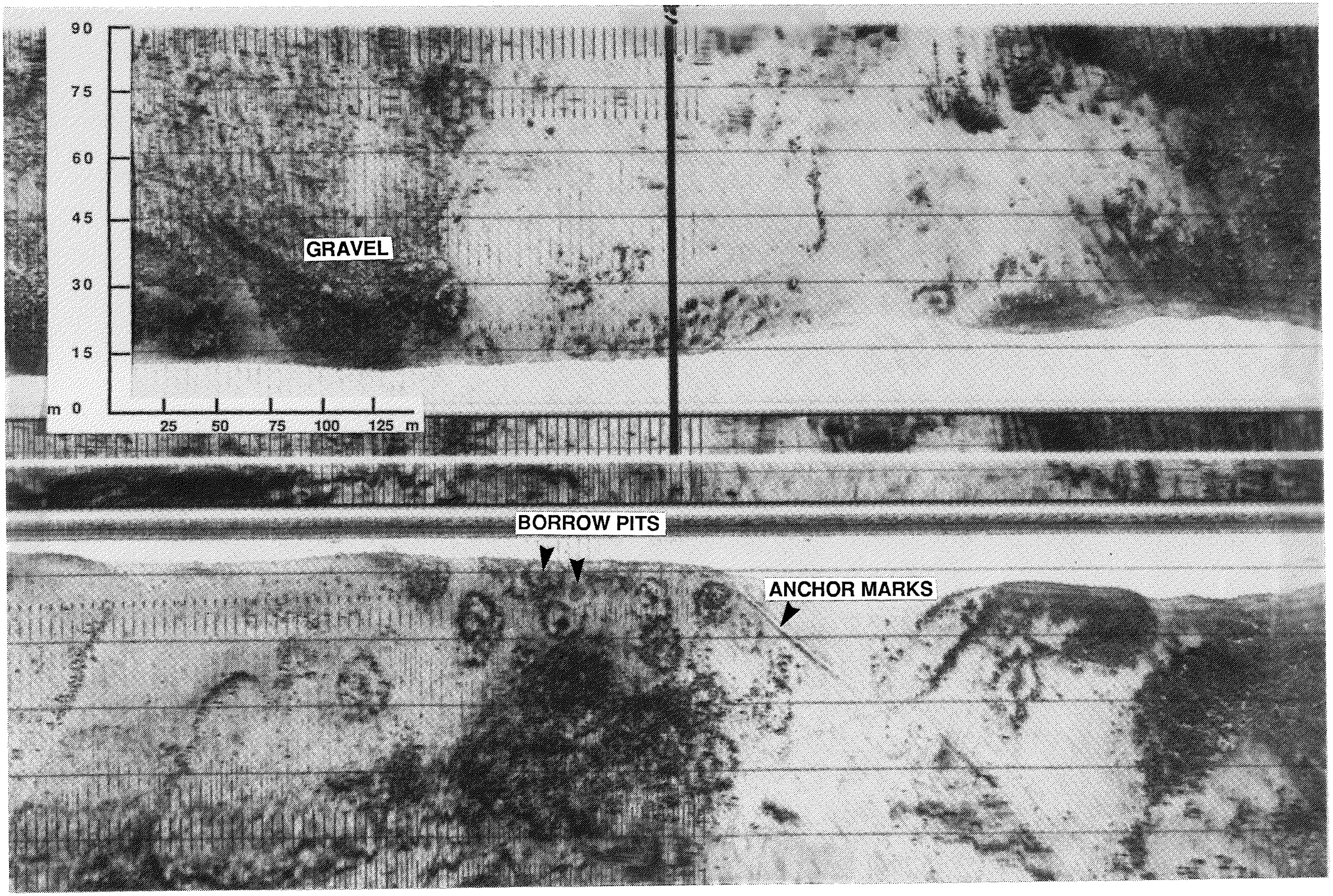

Figure 5. Borrow pits off Seaview Point. They occur only in softer sediments which have been dredged leaving a hole behind that range up to 15 m in diameter

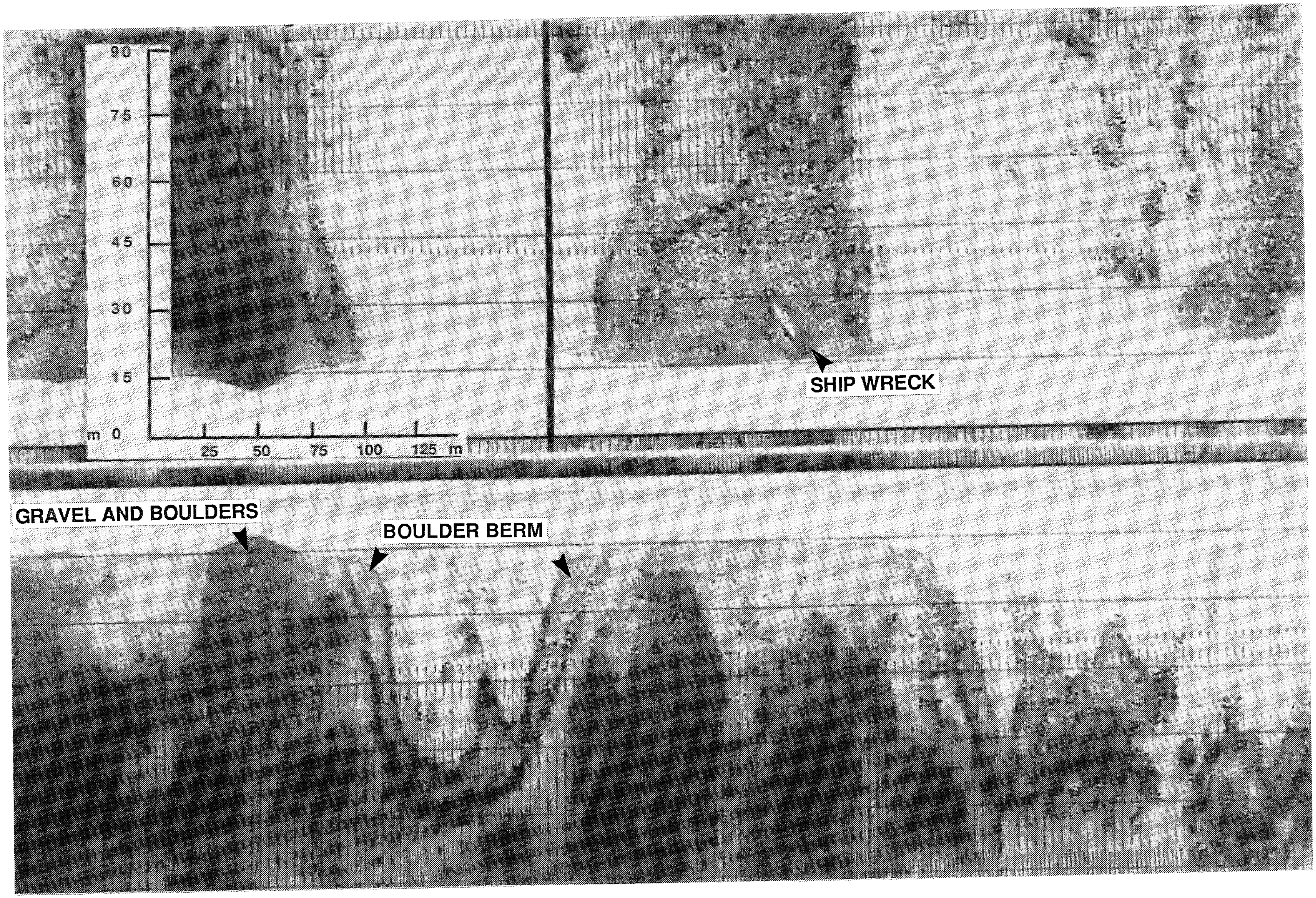

Figure 6. Paleoshoreline in the form of boulder berms ring most of the Bedford Basin shelf. This particular boulder berm occurs north of Fairview Cove along the western edge of Bedford Basin. Note shipwreck.

large boulders with a muddy sediment matrix. These boulders average 1 m in diameter but range up to 5 m.

A sill at the mouth of Bedford Bay and in the northernmost part of Bedford Basin appears on sidescan sonograms as a ridge of bedrock with intervening mud fill. To the southwest of this sill a field of mottled circular structures occurs. These mottles may result from the venting of biogenic gas from beneath the Basin floor, or may represent benthic invertebrate communities attracted by the venting of methane or the presence of methane metabolizing bacteria.

Wrecks, and other large features on the sidescan sonograms to be possible wrecks, occur at several locations throughout the Basin. Some of the more notable occurrences are: 1) a wooden barge and scuttled ship (now known to be the drifter "Achorn") which were originally surveyed in 1988 (Miller and Fader, 1989a) near the Navy compass buoy in the centre of the Basin; 2) a ship wreck and possible plane wreckage near the North Magazine Jetty; and (3) a ship wreck located in the southwestern section of the Basin (Fig. 6). Several other possible wrecks and debris targets require further investigation to determine their exact nature. Dredge spoils are common across the Basin and display circular patches of debris 15 m in diameter. Varying sonar reflectivity signatures suggests that they represent a wide variety of materials.

2. Narrows and Inner Harbour

The seabed in the Narrows consists of gravel with boulders and outcropping bedrock. The footings of the original two bridges constructed in 1884 and 1892 that spanned The Narrows were recorded on the sidescan sonograms (Fig. 7) and their location has been mapped approximately 500 m south of the present A. Murray MacKay bridge. The bridges apparently curved from the northern end of the old Volvo pier on the Halifax side to Norris Cove on the Dartmouth side. The deepest water in this part of the harbour is only 24 m.

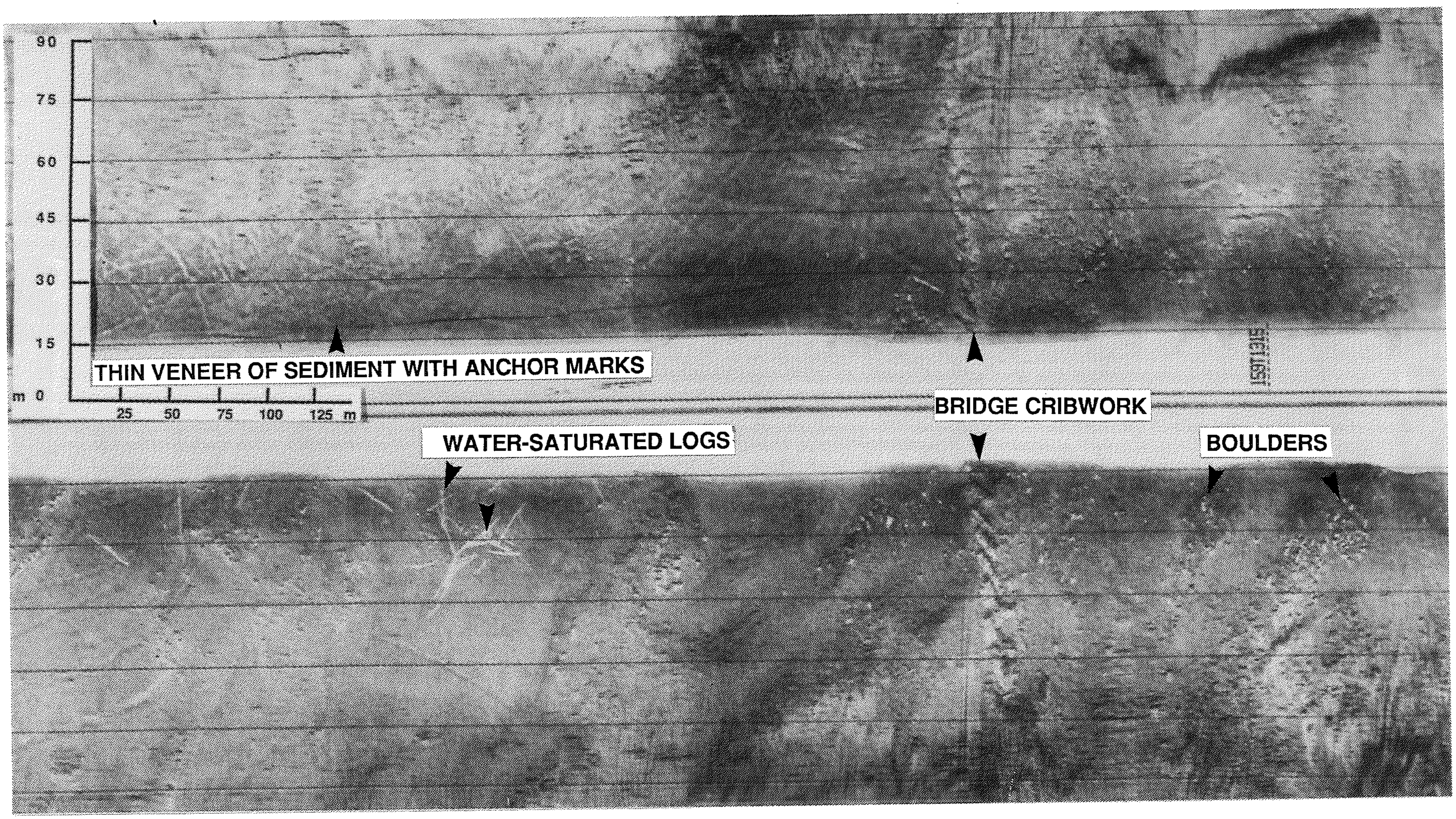

Figure 7. Sidescan sonar recording showing the seafloor in The Narrows. The imagery indicates that the seafloor in this area is hard and compoosed of cobbles, boulders and bedrock. Note the remains of the original Narrows Bridges as well as long, white, linear features that are thought to be water-saturated logs.

The first bridge was a railway bridge built in 1884; it was the first steel swing bridge manufactured in Canada. Built by the Starr Company of Dartmouth, it stood on piers of rock and cribwork with a centre section that pivoted to allow for the passage of ships into Bedford Basin. Each of the pier bases were filled with over 20 tons of rock ballast. With the convex side facing Bedford Basin, the bridge was designed to withstand impacts from winter ice in the Basin. It was swept away on September 7, 1891 during a severe hurricane. In 1892 another bridge was built in the same location using piles driven into the seabed. It lasted only eighteen months and fell on July 23, 1893 on a calm summer morning. Sidescan data indicate that the seabed of the Narrows is composed of bedrock, gravel and boulders which may have prevented the piles of the second bridge from penetrating deep enough thereby resulting in an unstable foundation.

To the south, in the Narrows, a large number of linear acoustic returns interpreted as logs were found on the seabed (Fig. 7). They may have been used in the construction of the old bridge. Several targets in The Narrows appear to be large pieces of debris, some of which may have been parts of the old bridges. The results of recent blasting and dredging of a bedrock/boulder shoal near the Volvo pier appeared on sidescan sonograms as a rough sea floor of boulders and bedrock.

A sewage bank observed on sidescan sonograms is interpreted as originating from sewage outfalls in Tufts Cove. The western side of this bank appears to be rippled. There are several anchor marks adjacent to the Power Corporation dock, some of which appear to be partially infilled. Another sewage bank adjacent to the Duffus Street sewer outfall is evident on the sidescan sonograms. It appears to extend in a northerly direction across the Harbour towards The Narrows. Off of the Halifax Naval Docks, anchor marks are very numerous as well as large pieces of unidentified debris.

Anchor marks are numerous off Purdy's Wharf. Fill used to create a foundation for the construction of buildings is easily recognizable prograding from the shore across the seabed. Adjacent to the Historic Properties sewage outfall, a large water column plume occurs on the sidescan sonograms (Fig. 8) and the sludge deposited near this sewage outfall infills and obliterates local anchor marks. This plume of suspended sediment appears to continue as a coherent mass up the Harbour. Two separate submarine pipelines run from this area of Halifax to Dartmouth. Several pieces of debris as well as a possible wreck occur off the Queen's Wharves. Anchor marks appear to be buried near the Water Street sewage outfall. The burial of old anchor furrows by sewage banks is a common characteristic of the harbour bottom. The distribution of the sewage banks can easily be mapped using this relationship. It can also be used to deduce sediment transport pathways. Along the Ocean Terminals, several generations of anchor marks occur in muddy sediments. It appears that ships use their anchors as control during docking.

Cribwork, measuring approximately 10 m × 40 m rests on the seafloor adjacent to Black Rock Beach. It could potentially be a hazard especially for anchoring as it protrudes above the seabed. Adjacent to Point Pleasant Shoal, there is a large zone of featureless mud. Anchorage is prohibited in this zone.

Sidescan sonograms reveal a paleoshoreline along Georges Island. To the east of Georges Island, the seafloor is riddled with anchor marks which end dramatically in the central harbour off the Queen's Wharves and resume again off Dartmouth Cove. At the entrance to Dartmouth Cove, features on the sidescan sonogram appear to be dredge spoils.

Two large parallel features occur in the central harbour adjacent to the Queen's Wharves. They measure approximately 30 m × 50 m and may represent either large pieces of debris, or wreckage.

Immediately offshore from the Nova Scotian Hospital, sidescan imagery reveals a target which is similar to the large buoy located off of the North Magazine Jetty in Bedford Basin that was mentioned previously.

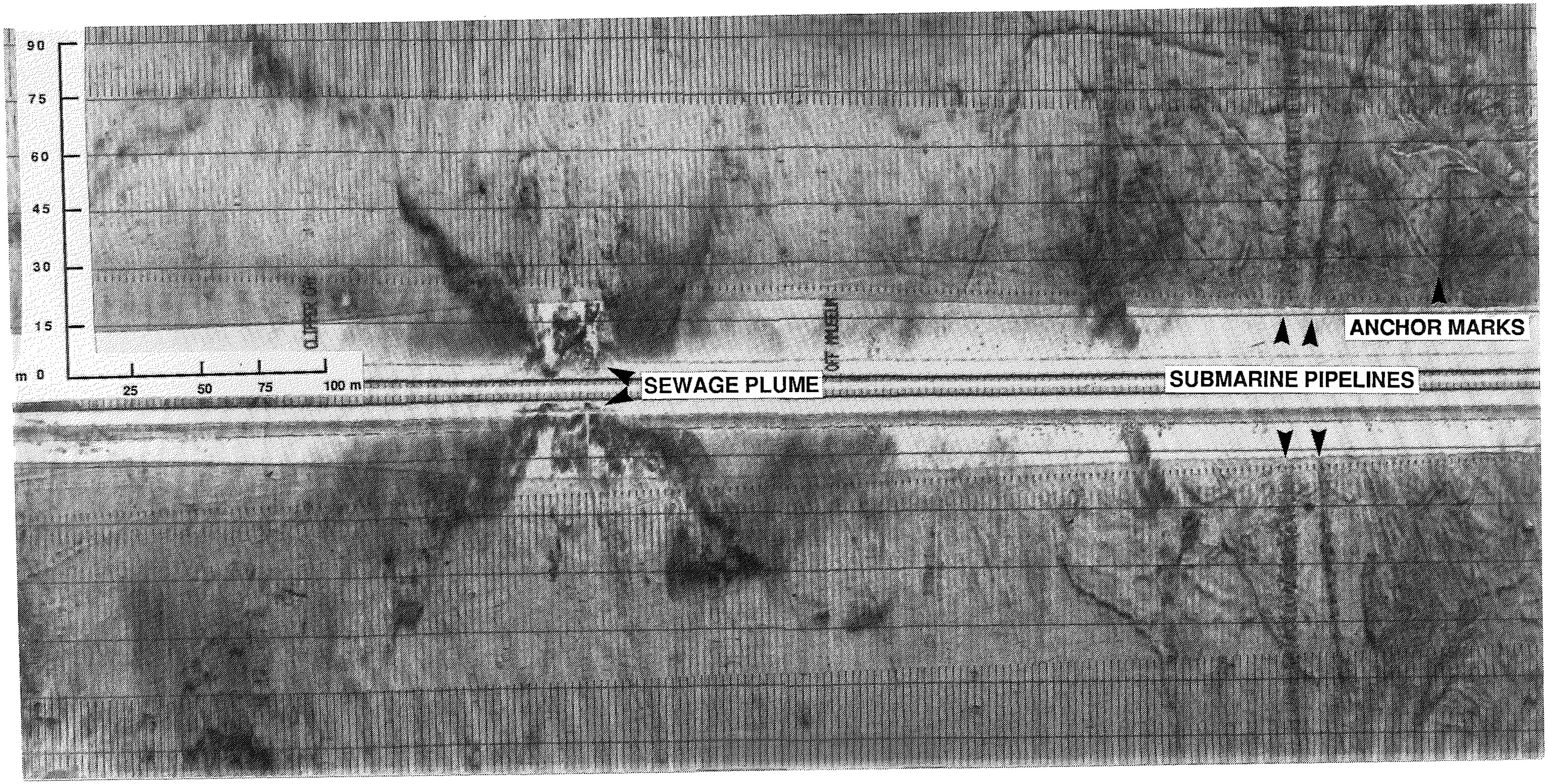

Figure 8. Domestic sewage outfall plume off Historic Properties, Halifax. Note the absence of anchor marks in area of plume and the increased number of anchor marks to the south of the two submarine pipelines.

There are a large number of anchor marks along the Imperial Oil docks. A diving range, consisting of several blocked and joined quadrangles occurs at the Navy A dock as part of the Navy Diving Unit facilities.

Several pits, approximately 10 m in diameter, occur on the sea floor in the area northeast of Ives Point. These pits may be footing imprints left by jack-up oil rigs or may be borrow pits formed during aggregate mining operations. The seafloor of Eastern Passage consists of featureless muddy sediments and several pieces of debris.

The ancient Sackville River channel occurs in the subsurface between McNabs Island and Point Pleasant Shoal. The seabed in this area is comprised of Holocene gas-charged mud. The gas is likely biogenic methane and is widespread in the sediments of the Basin and Harbour as well.

At the entrance to the Northwest Arm, south of the HO2 buoy, peculiar highly reflective, patchy returns occur on the sidescan sonograms. Several features may be "eyed" pockmarks or dense benthic communities. High resolution Seistec boomer records show that shallow gas comes to within 2 metres of the seabed and that the muddy sediments show relief similar to that found in pockmarks.

Two sidescan swaths were conducted up the Northwest Arm. The Arm is largely floored with mud except for old shorelines parallel to the present shoreline and the bedrock/gravel outcrop off the Dingle. A few anchor marks occur in the mud. Moorings were seen on the sidescan sonograms off the Royal Nova Scotia Yacht Squadron and a few possible wrecks occur on the seabed.

3. Outer Harbour

The outer harbour, for purposes of this report is defined as that part of the Halifax Inlet which extends from Point Pleasant Shoal south to Chebucto Head. Water depth in this area ranges up to $\approx$40 m with the deepest areas following the course of the ancestral Sackville River along the western side of the Harbour. Adjacent to the ancestral Sackville River channel, the outer harbour is relatively flat and is characterized by many shoals where bedrock outcrops. The seafloor around these shoals generally comprises gravel with boulders and occasional patches of gravel ripples and sand.

Many unique sidescan returns were recorded off York Redoubt. Long linear features are interpreted as channel edges while several point source reflections in elongate depressions suggest that tidal current scour is intense. The origin of a furrow-like or slump feature here remains unclear but may be associated with submarine gates that were deployed during the second world war.

The mouth of Herring Cove is dominated by a thin sand overlying mud deposits; inside the Cove, bedrock is exposed across the seabed. A patch of gravel ripples occurs just off Eastern Head.

A large zone of megaripples extends from off Bear Cove and Bear Cove Shoal to Chebucto Head (Fig. 9). At Chebucto Head, as well as in a few areas within the zone of megaripples such as around Lichfield Shoal, the seafloor is dominated by outcropping bedrock, interspersed with gravel and boulders. Cables occur through the zone of megaripples. Megaripples also occur isolated in the deep (30 m) channel off Sandwich Point and represent the northernmost occurrence of bedforms in Halifax Inlet.

Alternating patches of sand and gravel with isolated zones of gravel ripples occur in an area to the west of Thrumcap Shoal. Boulders appear to increase in density towards the Shoal. Small lineal outcrops of bedrock occur west of the southernmost part of the Shoal and isolated areas of megaripples are also found here.

Several oval-shaped patches of high acoustic backscatter were noted during the survey. These patches were approximately 10 m in diameter and appeared to have no relief. The best examples

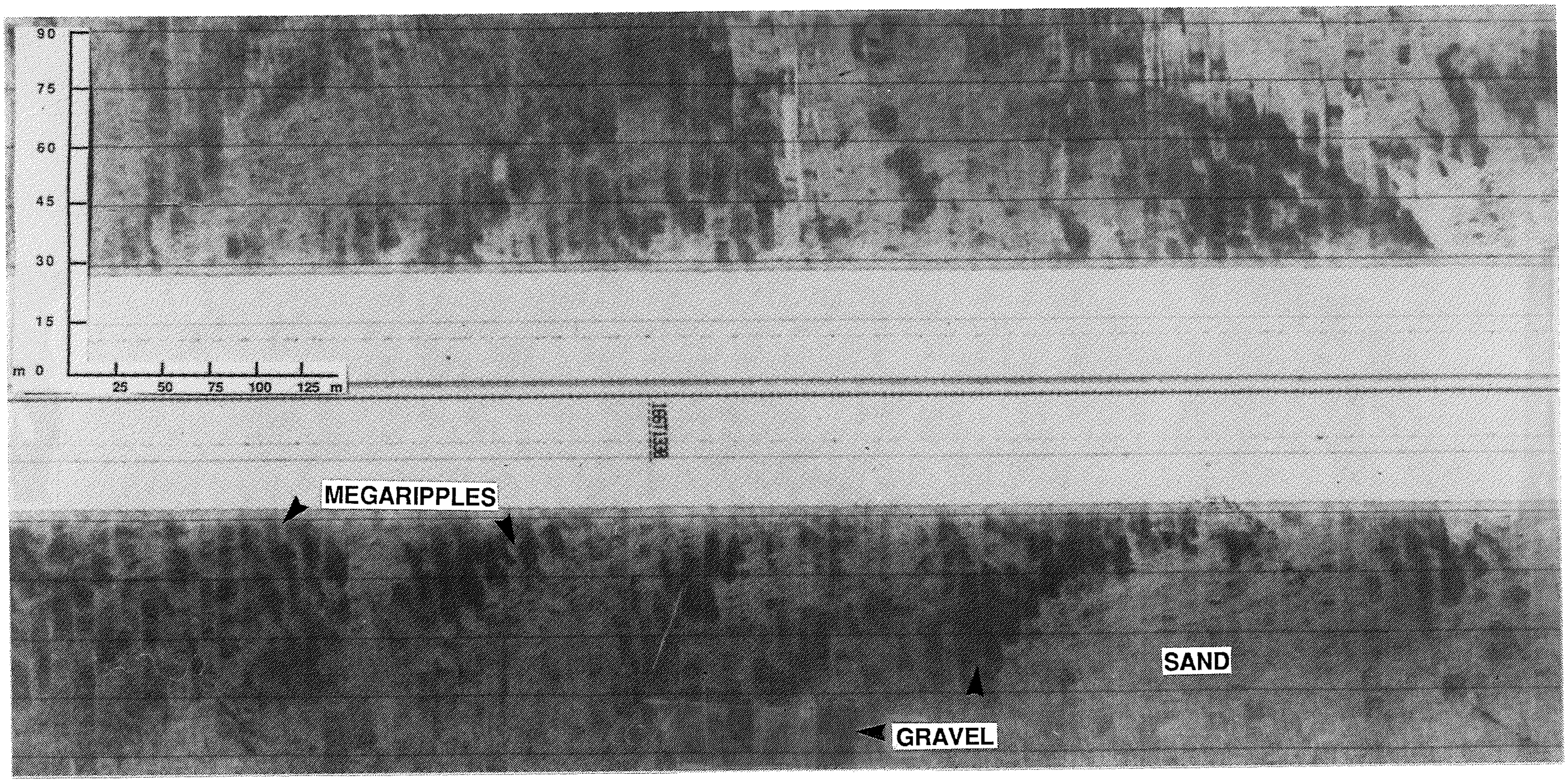

Figure 9. Megaripples off Bear Cove overlying estuarine muddy sediments.

were located off Sandwich Point, south of the HK5 buoy to the west of Horse Shoe, and inside McNabs Cove. They may represent pockmarks (gas-escape craters) or may be similar to depressions noted along the eastern shore of Nova Scotia (Forbes et al., 1988) where estuarine muds are exposed beneath the Holocene, transgressive sand cover.

Many wrecks were discovered during the survey. Some of these are well known while others have not been reported previously. The most notable wrecks were located in McNabs Cove, where there appears to be 2 wrecks and off Herring Cove adjacent to the HM1 buoy, where one may represent the Tribune. A possible wreck exists along the western edge of Lichfield Shoal and another was observed Northeast of Duck Point. Other wrecks occur in an area of boulders and gravel North of Mars Rock. In addition to the known wrecks, many other targets occur in the Harbour. High resolution sidescan imagery and/or diving surveys will be necessary for a positive identification. Scours were recognized on the seafloor of Outer Middle Ground. These are interpreted to have formed by movement of buoy anchors. The survey was extended further offshore to collect sidescan data in an area off Chebucto Head centered at Longitude 63°24'30" and Latitude 44°30'30". A grid survey consisting of five lines,approximately 2 km long, at 100 m intervals was carried out. The seabed in this area comprises bedrock outcrop with areas of sand and gravel infilling and the occasional occurrence of gravel ripples (Fig. 10).

Seismic Reflection Systems

Interpretation of the high frequency, high resolution seismic reflection data (Fig. 11) is hindered by the widespread presence of biogenic methane within the Holocene muds and estuarine sediments that are buried beneath the sands in the outer Harbour. In some areas, the low frequency content of the Bubble Pulser system allows resolution of geological features lying beneath the gassy sediment.

A major unconformity occurs at the top of the estuarine/late glacial sediments throughout the Harbour. In the outer Harbour, the sediments are overlain by thin basal transgressive sands and

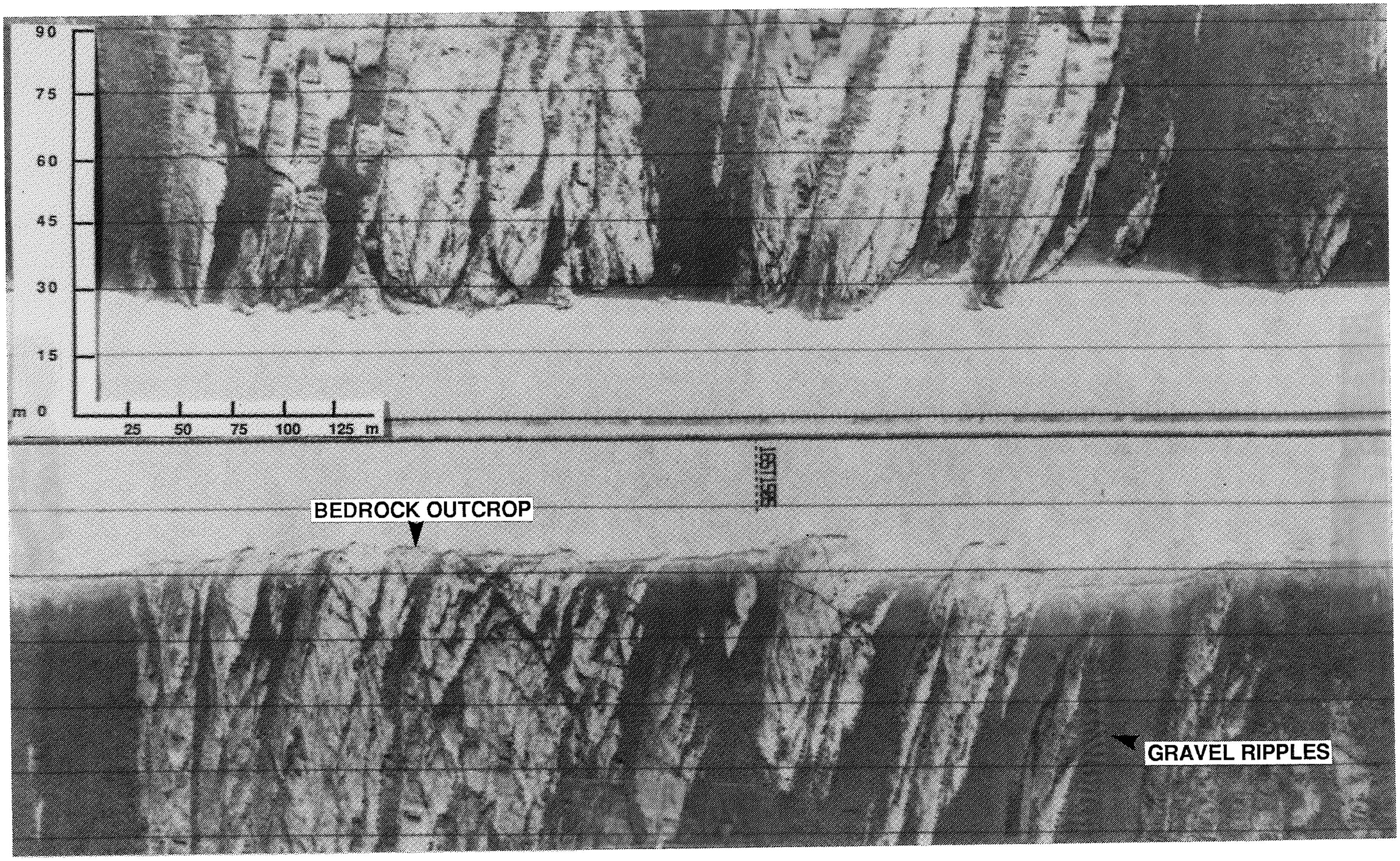

Figure 10. A seafloor area south of the entrance to Halifax Harbour on the inner Scotian Shelf dominated by outcropping bedrock. Note gravel ripples.

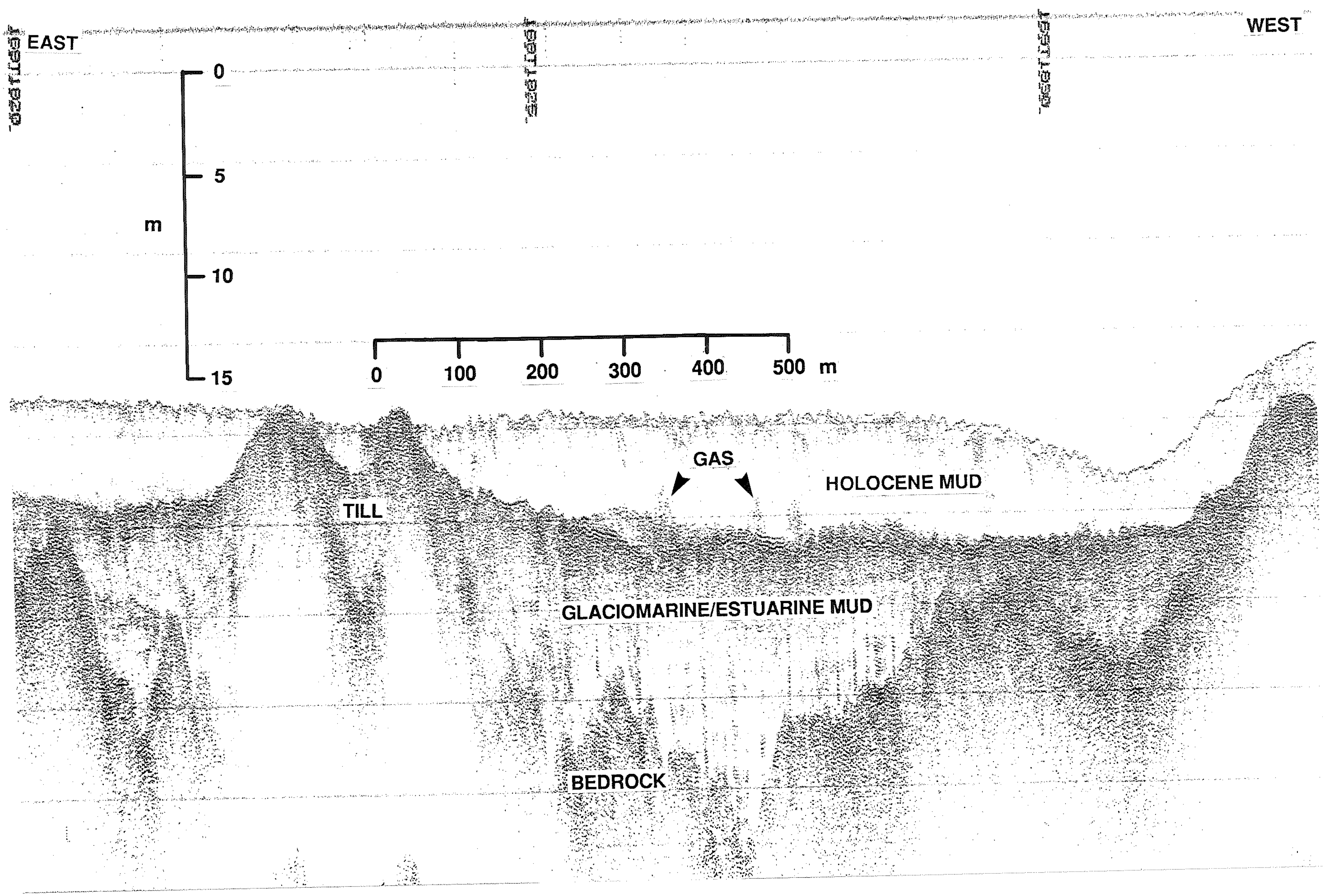

Figure 11. I.K.B. Seistec Boomer high resolution seismic profile from north of Georges Island running East to West showing bedrock, till, glaciomarine/estuarine and Holocene sediments. Note the roughness of the surface of the Holocene mud resulting from the anchor marks.

gravels. The thickest sections in the area occur in the ancestral Sackville River channel which follows the western side of the outer Harbour. In the inner Harbour, Holocene muds overlie the unconformity. These muds are patchy and in several places older sediments are exposed at the seabed.

ACKNOWLEDGMENTS

We wish to thank Captain Joseph Bray and his excellent crew, Enrique de Arcos and Hugh Marryatt for their support during the cruise. Their efforts were unrelenting in assuring that all objectives of the cruise were met. Special mention is reserved for Anthony Atkinson and Darrell Beaver of Program Support Subdivision. Anthony worked long, hard hours to insure that data quality and equipment performance was as good as possible, while Darrell was constantly engaged in plotting our positions at sea and then providing accurate plots of ship tracks after the cruise. Jack Davison of the Positioning Shop receives our thanks for a job well done in setting up the transponder network and constantly repositioning transponders during the survey. We would also like to thank Ami Häkkinen, Geological Survey of Finland for helpful discussion, suggestions and technical skills during the survey. Thanks are extended to Peter Simpkin, IKB Technologies who initially set up the Seistec boomer for use during the survey.

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APPENDIX I

NAVICULA 89-009 CRUISE REPORT

GEOCHEMICAL INVESTIGATIONS

D. E. Buckley, R. E. Cranston

G. V. Winters, R. A. Fitzgerald, W. K. G. LeBlanc

Objectives

In conjunction with the geophysical mapping program, a geochemical and sedimentological sampling program was designed to obtain representative samples of near-surface seafloor deposits that could be used to determine the thickness and geochemical nature of contaminated sediments throughout Halifax Harbour. This sampling program was designed on the basis of data already obtained from previous studies carried out by Buckley et al. (1989) in which the uppermost thin layer of sediments (1 to 2 cm) had been sampled and analyzed for a number of chemical elements. This new program was designed to obtain a series of high resolution cores that would sample the upper 10 to 100 cm of sediment. These cores would be subsampled at 1 to 2 cm intervals to determine the geochemical and sedimentological profiles that could indicate how these sediments were reacting under various conditions of contaminant loading. Another objective of the study is to determine the age of the sediments in order to determine when contaminants were added to the Harbour and the rate of accumulation.

Sampling

Two types of samplers were used. A specially designed and modified Eckman dredge made of stainless steel was deployed to collect sediments from the uppermost 20 cm. This 30 cm cubic box was expected to retain representative sediments from the surface veneer to a depth of about 25 cm. The sampler could be opened from the top immediately after being landed on deck so that any water retained on top of the sediment could be sampled. This water sample was collected in acid-cleaned 125 ml polyethylene bottles. Because of limited penetration of the sampler into the sediment, and the poor seal of the bottom- closing spade, much of the interface water usually drained from the sediment surface. This rapid drainage also probably removed some of the thin veneer of surface sediment that consisted of fine floccules of sediment particles. After the surface water drained from the Eckman dredge, a 30 cm long plastic core tube (11 cm diameter) was inserted into the mud. This tube was then capped at the top and the Eckman dredge was opened at the bottom so that the bottom of the core could be sealed. This core was then labelled, photographed and immediately placed in an insulated cold box.

The second type of sampling device used was a modified Lehigh corer. This corer consisted of a 1 to 1.5 m length of PVC pipe (10 cm diameter) with a 75 kg core head weight and a water tight valve. A standard stainless steel core catcher was used in the bottom of the core barrel. The corer was allowed to free fall into the sediments from a height of about 3 m above the bottom. The retrieved core was kept in a vertical position while the overlying water was siphoned from the upper part of the core barrel. The core was then returned to the BIO laboratories in a vertical position as soon as possible, usually within one to two hours after sampling. All cores were subsampled within 8 hours of being collected.

Laboratory Processing

Eckman Samples

Eckman samples were kept at 4°C in their respective shore core liners until subsampling was undertaken. During the subsampling operation, the sediment was extruded vertically using a plastic piston. The following operations were conducted at 1 cm intervals for these samples. Electrodes were inserted to measure pH and Eh, after which a 50 ml centrifuge tube was filled with wet sediment for pore water recovery. One gram subsamples were taken for water content and carbon analyses and 100 mg subsamples were taken for Coulter Counter particle size determinations.

STATION LOCATIONS AND SAMPLE RECOVERY

SAMPLE TYPE	STATION/ SAMPLE NO.	LOCATION	POSITION	WATER DEPTH (m)	CORE LENGTH (cm)
Lehigh	89-009-001	Bedford Basin (CN)	44° 41.87'; 63° 39.00'	62	75
Lehigh	89-009-003	Bedford Bay	44° 43.19'; 63° 40.04'	11	75
Lehigh	89-009-005	Bedford Basin (CS)	44° 41.11'; 63° 37.82'	58	50
Eckman	89-009-007	Bedford Bay	44° 43.17'; 63° 40.01'	14	14
Eckman	89-009-008	Bedford Basin (CS)	44° 41.11'; 63° 37.75'	59	8
Eckman	89-009-009	Bedford Basin (CN)	44° 41.89'; 63° 38.96'	67	12
Eckman	89-009-010	Tufts Cove	44° 40.63'; 63° 35.98'	10	7
Eckman	89-009-012	Duffus St. Outfall	44° 40.32'; 63° 36.93'	22	13
Eckman	89-009-014	Dartmouth Cove	44° 39.73'; 63° 33.60'	11	0
Lehigh	89-009-016	George's Island, north	44° 38.77'; 63° 33.78'	24	50
Eckman	89-009-018	George's Island, north	44° 38.77'; 63° 33.78'	24	16
Lehigh	89-009-019	Dartmouth Cove	44° 39.64'; 63° 33.63'	14	45
Eckman	89-009-020	Eastern Passage	44° 37.66'; 63° 31.57'	18	12
Eckman	89-009-023	McNabs Cove	44° 36.67'; 63° 32.43'	17	12
Lehigh	89-009-024	Northwest Arm	44° 37.70'; 63° 35.52'	11	85

Lehigh cores

Lehigh cores were examined initially using the AGC x-radiography video system and then stored at 4°C until subsampling could be done. The sediment was extruded vertically using a plastic piston. Sample resolution was 1 cm for the upper 15 to 30 cm for most cores and 5 cm for the remainder of each core. Core 24 was subsampled at 5 cm intervals throughout. Electrochemical measurements and subsampling were done in the same manner as was described above for the Eckman cores.

Pore water collection

Subsamples were centrifuged in 50 ml tubes to recover 5 to 15 ml of pore water. The samples were spun at 3000 rpm (rcf = 1500 g's) for 1 hour with the temperature held at 4°C. Worm activity was observed in two tubes before and after centrifuging, indicating the durability of these life forms. The pore water collected from intervals in which the presence of H_2S, was detected and had a distinct yellow color as compared to colourless water observed above the H_2S boundary.

Pore water and overlying water samples were filtered through 0.45 um Millipore HA membranes and split into 3 subsamples, each with a volume of 3 to 5 ml. One portion, to be analyzed for dissolved trace metals, was stored in acid-cleaned Teflon vials and acidified with 10 uL of 1 M HCl for each millilitre of pore water. A second portion was stored in a 20 ml scintillation vial and used for pH, alkalinity, ammonia, sulfate and major cation determinations. The final portion was stored in a 7 ml nutrient vial and used by the Marine Chemistry Division, BIO for analyses of silicate, phosphate, nitrate and nitrite.

RESULTS

A total of 202 samples were processed from 8 Eckman cores and 5 Lehigh cores. The following concentration-depth profiles contain all of the data that were obtained immediately after subsampling, except for sulfate data, which were obtained a week after the samples were recovered. Because of the stable nature of the sulfate anion, it was concluded that sample storage effects over a one week period are insignificant. All data, along with subsequent results for trace and major elements in the pore water and sediment samples, are stored in the AGC Geochemistry Data Base and will be released as a GSC open-file data report.

The profile shapes and concentrations levels are well within what was expected. Sample contamination and oxidation errors do not appear to be significant. In general, the quality of data is very good. The results from the short (Eckman sampler) cores suggest that organic carbon fluxes are greatest at station 10 in Tufts Cove, making conditions there the most reducing. The least reducing conditions occurred in cores from Bedford Bay (station 7) and Bedford Basin, central-north (station 8), suggesting lower sedimentation rates.

Initial evaluation of the Lehigh core data suggests that the most reducing core was collected in the Northwest Arm, based on the strongest production of phosphate, ammonia and bicarbonate ions from organic matter decomposition, and on its relatively low pE readings and high consumption of sulfate. These profiles indicate sedimentation rates on the order of 10 to 100 cm per century, based on established relationships between sulfate and ammonia gradients and sedimentation rate. The least reducing Lehigh cores were found at Bedford Basin, north-central (core 1) and Dartmouth Cove (core 19), although the redox conditions predict sedimentation rates that will probably also fall in the 10 to 100 cm per century range. Final estimates of sedimentation rates will be made using lead-210 dating curves and anthropogenic markers such as plastic and coal fragments.

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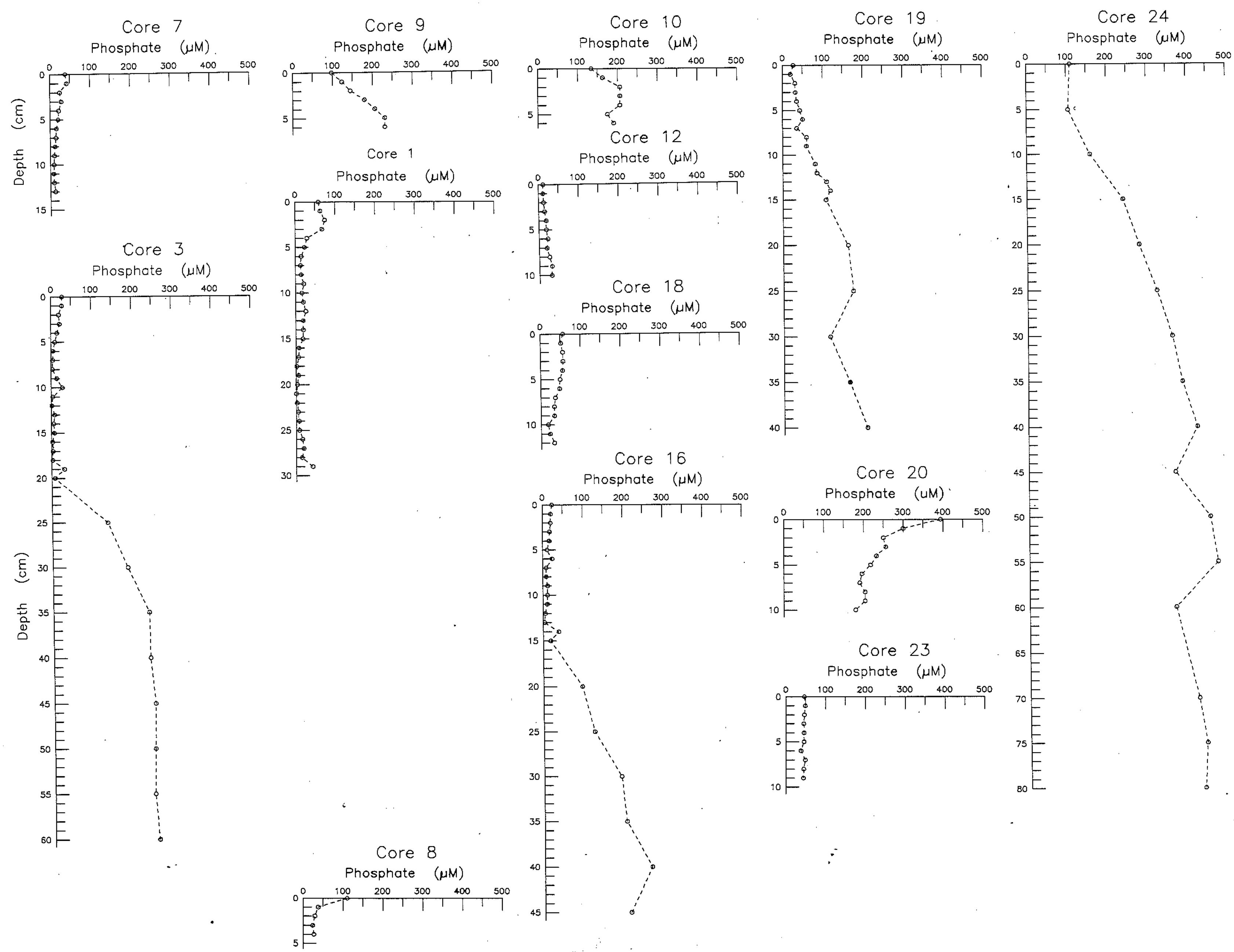
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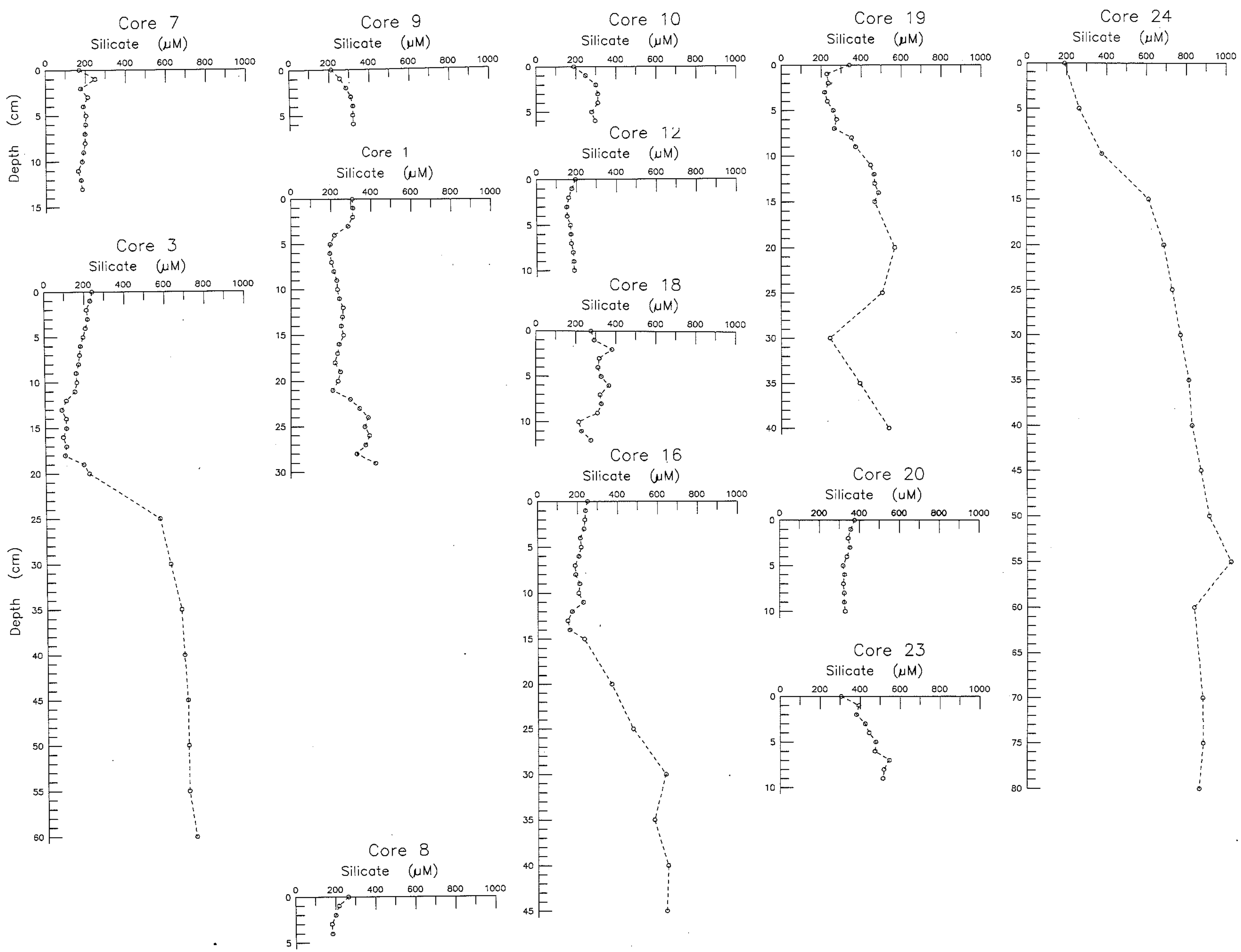
Phosphate (μM)
Depth (cm)
Core 9
Phosphate (μM)
Core 1
Phosphate (μM)
Core 3
Phosphate (μM)
Depth (cm)
Core 8
Phosphate (μM)
Core 10
Phosphate (μM)
Core 12
Phosphate (μM)
Core 18
Phosphate (μM)
Core 16
Phosphate (μM)
Core 19
Phosphate (μM)
Core 20
Phosphate (μM)
Core 23
Phosphate (μM)
Core 24
Phosphate (μM)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Silicate (µM)
Depth (cm)
Core 3
Silicate (µM)
Depth (cm)
Core 9
Silicate (µM)
Core 1
Silicate (µM)
Core 8
Silicate (µM)
Core 10
Silicate (µM)
Core 12
Silicate (µM)
Core 18
Silicate (µM)
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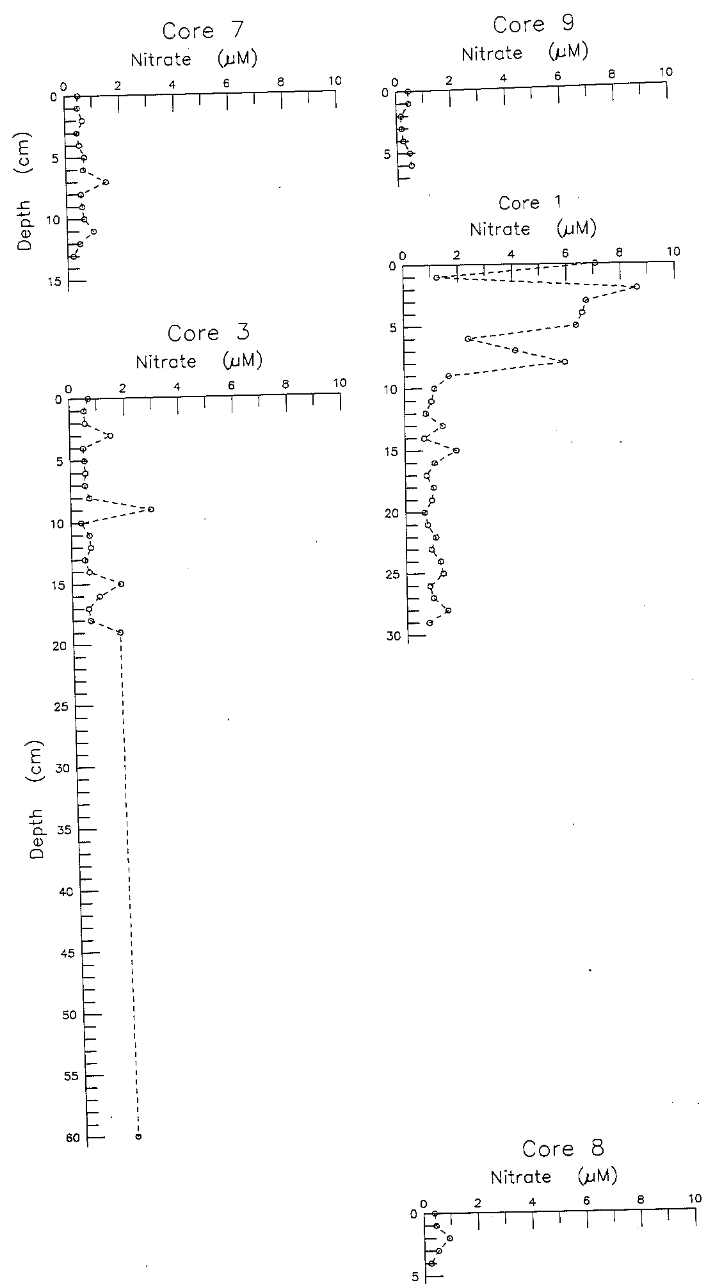
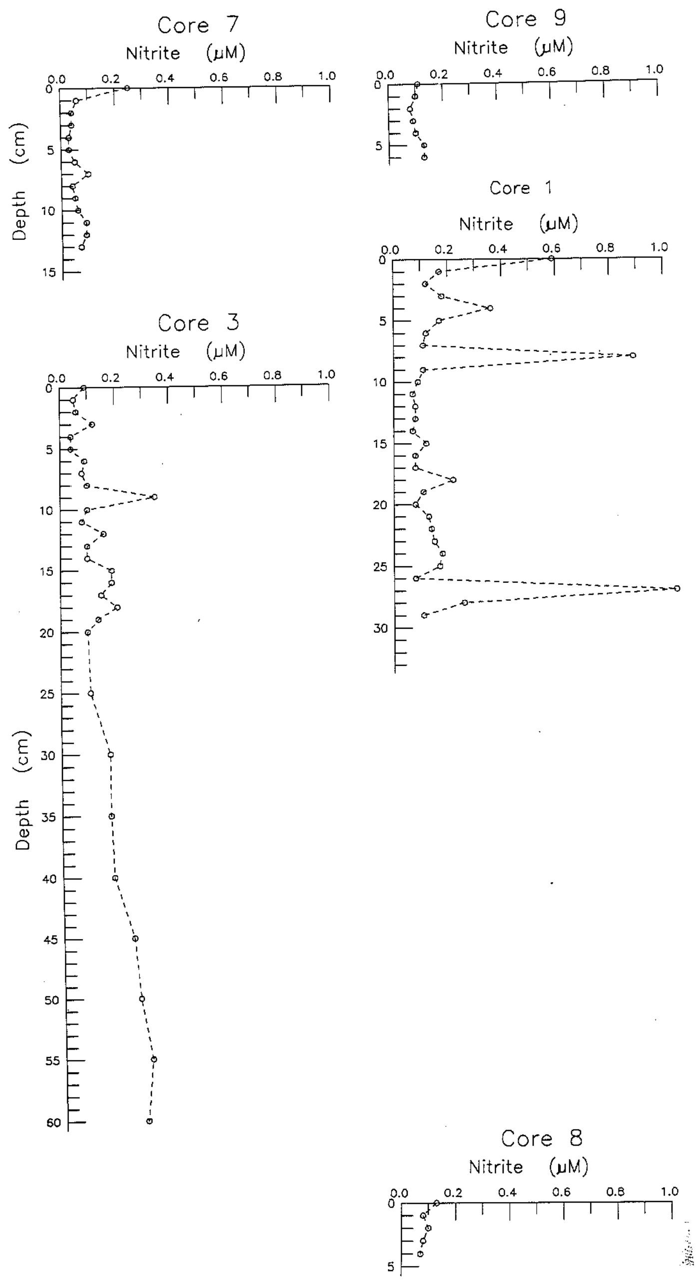
Silicate (µM)
Core 24
Silicate (µM)



Core 7
Nitrate (μM)
Depth (cm)
Core 9
Nitrate (μM)
Core 1
Nitrate (μM)
Core 3
Nitrate (μM)
Depth (cm)
Core 8
Nitrate (μM)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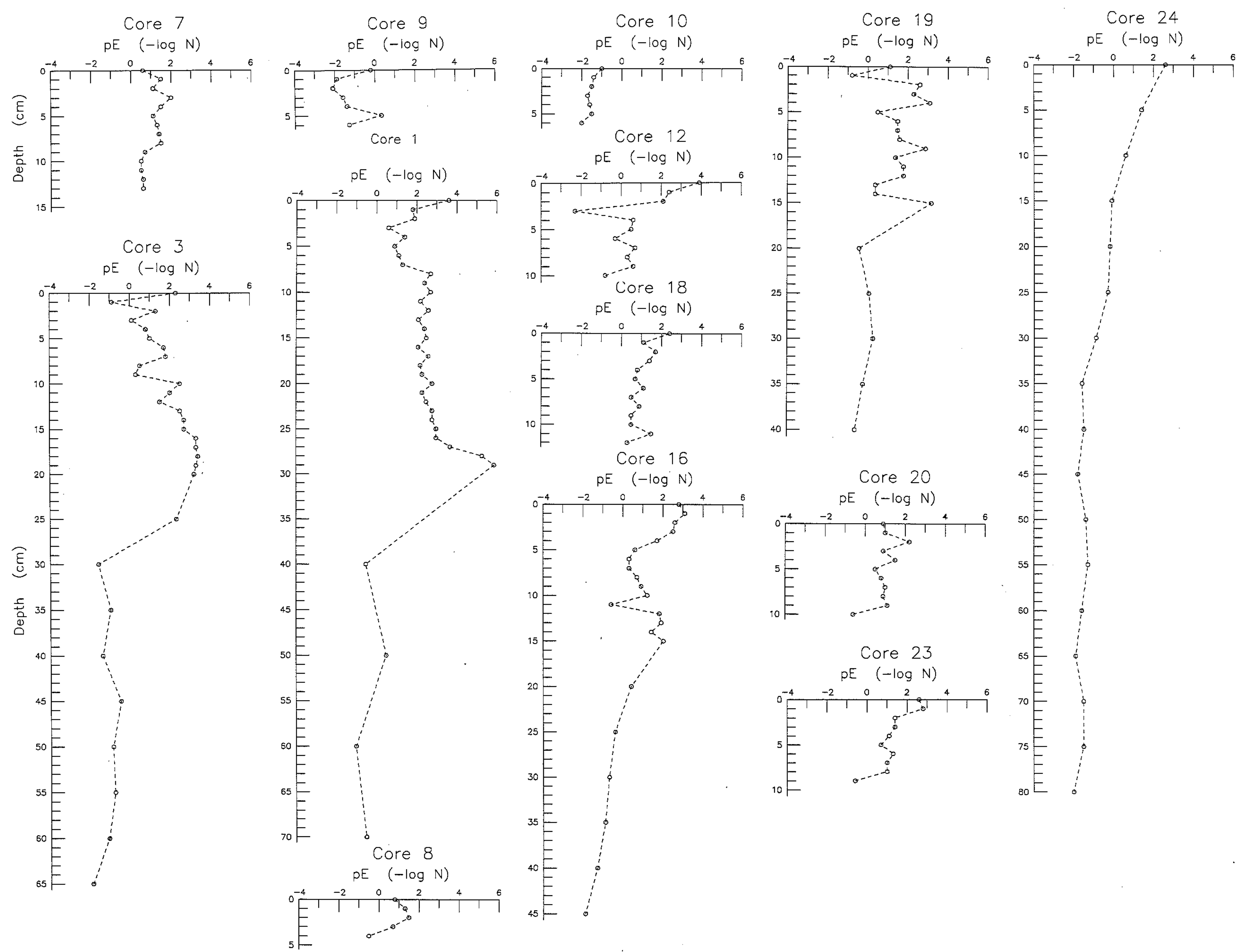
Nitrite (μM)
Depth (cm)
Core 9
Nitrite (μM)
Core 1
Nitrite (μM)
Core 3
Nitrite (μM)
Depth (cm)
Core 8
Nitrite (μM)



Core 7
pE (−log N)
Depth (cm)
Core 3
pE (−log N)
Depth (cm)
Core 9
pE (−log N)
Core 1
pE (−log N)
Core 8
pE (−log N)
Core 10
pE (−log N)
Core 12
pE (−log N)
Core 18
pE (−log N)
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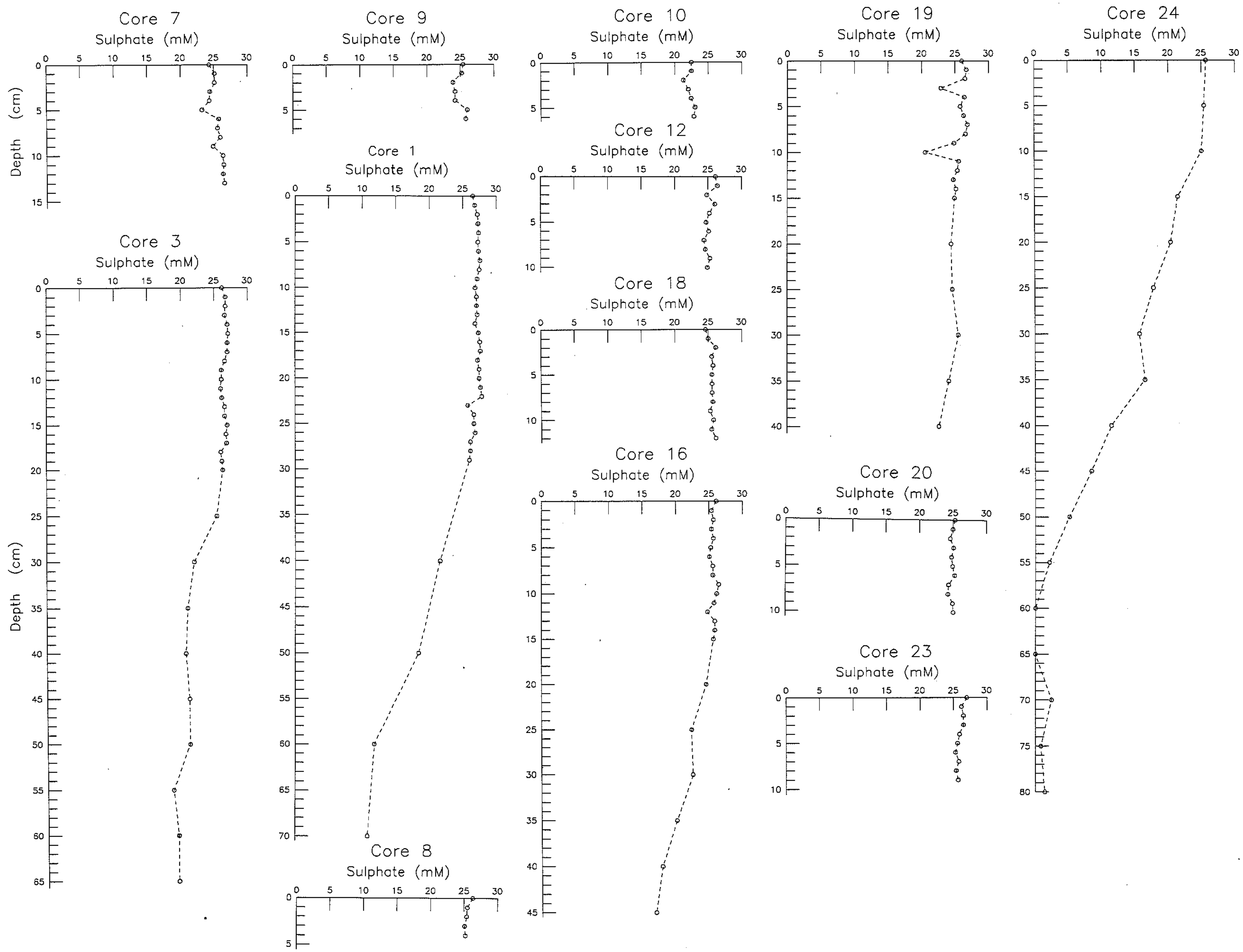
Core 24
pE (−log N)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Sulphate (mM)
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Sulphate (mM)
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Sulphate (mM)
Core 24
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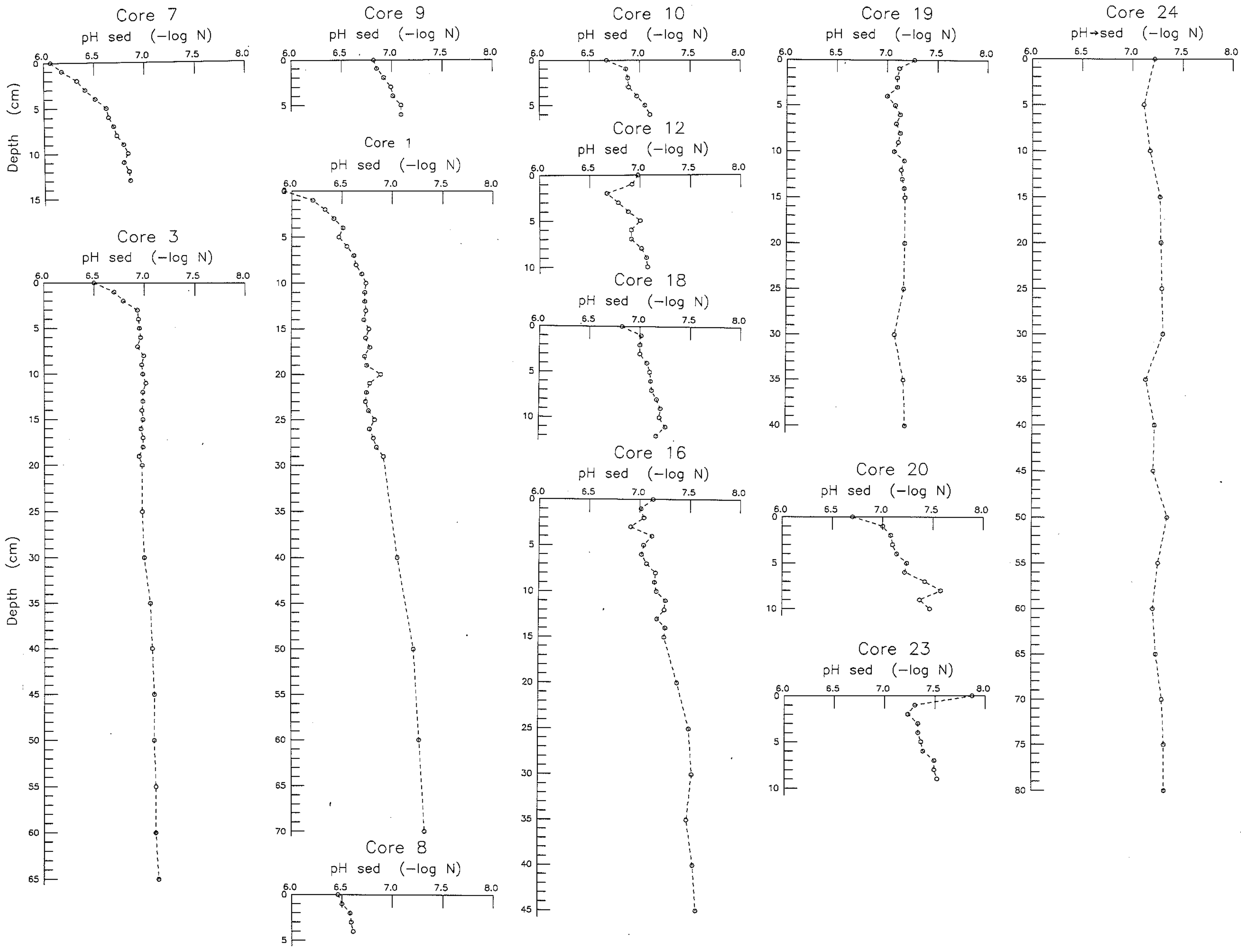
Core 1
Sulphate (mM)
Core 12
Sulphate (mM)
Core 18
Sulphate (mM)
Core 3
Sulphate (mM)
Core 16
Sulphate (mM)
Core 20
Sulphate (mM)
Core 23
Sulphate (mM)
Core 8
Sulphate (mM)
Depth (cm)
Depth (cm)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pH sed (−log N)
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Core 24
pH→sed (−log N)
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pH sed (−log N)
Core 12
pH sed (−log N)
Core 3
pH sed (−log N)
Core 18
pH sed (−log N)
Core 16
pH sed (−log N)
Core 20
pH sed (−log N)
Core 23
pH sed (−log N)
Core 8
pH sed (−log N)
Depth (cm)
Depth (cm)
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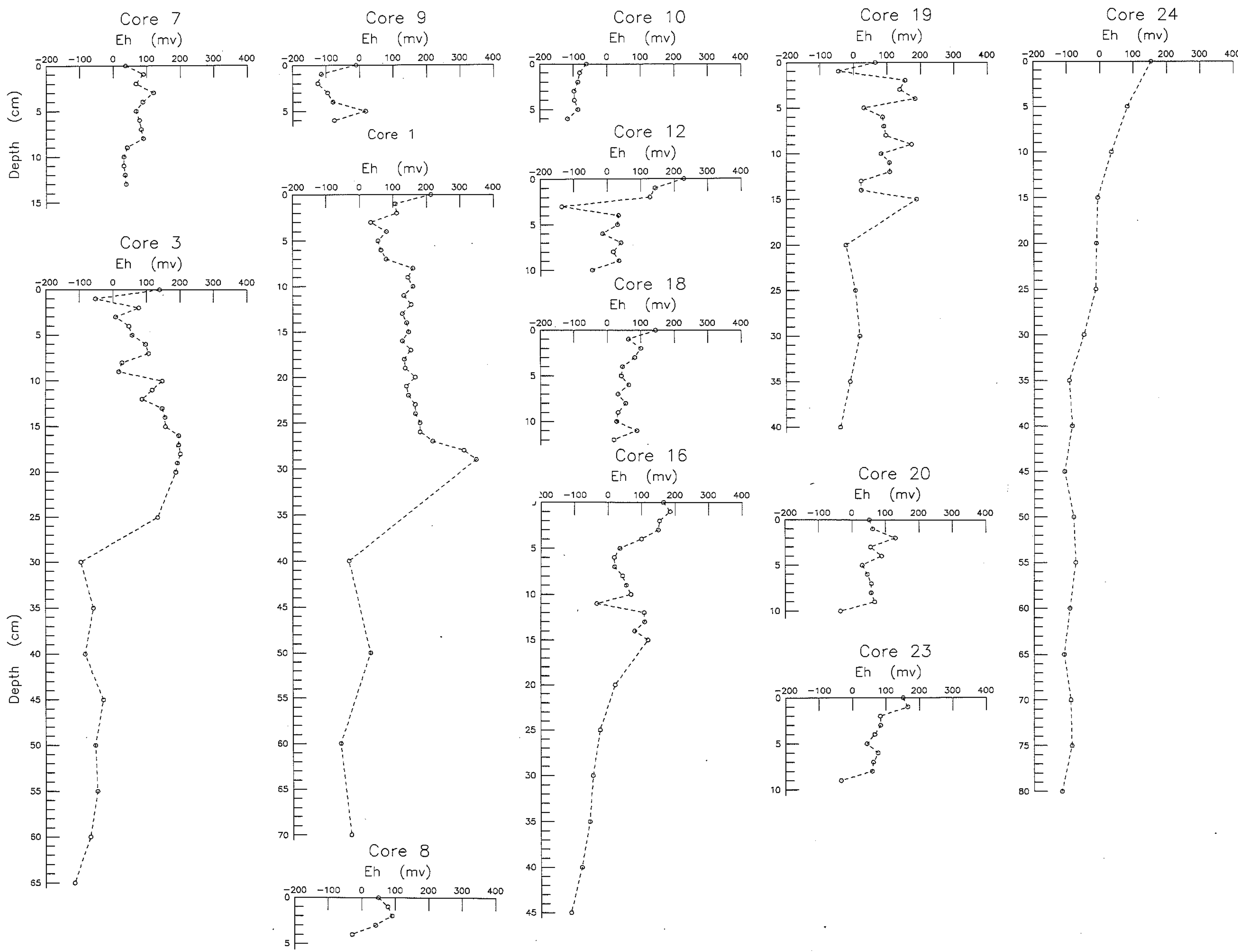
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Eh (mv)
Depth (cm)
Core 9
Eh (mv)
Core 1
Eh (mv)
Core 10
Eh (mv)
Core 12
Eh (mv)
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Core 16
Eh (mv)
Core 19
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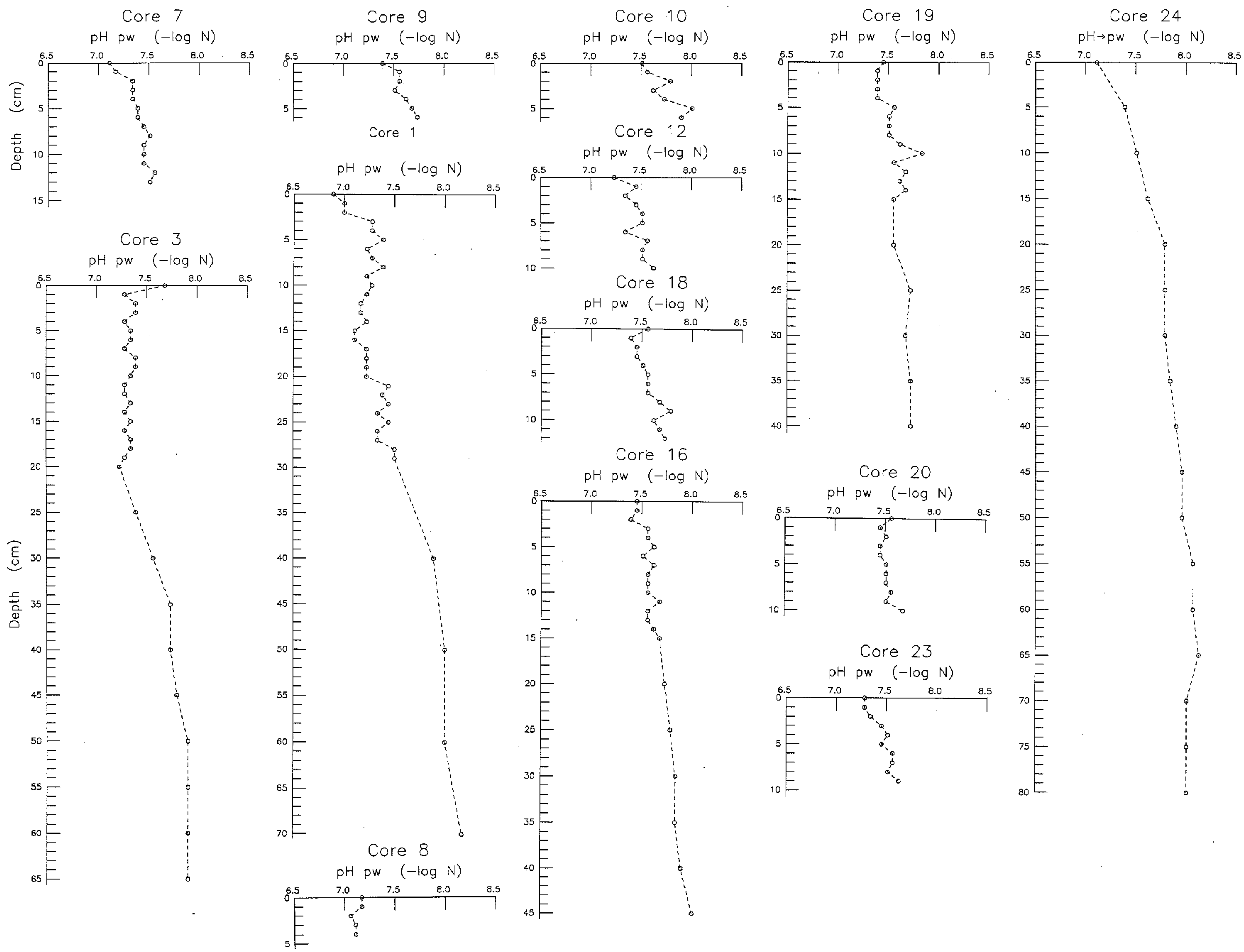
Depth (cm)
Core 8
Eh (mv)



Core 7
pH pw (−log N)
Depth (cm)
Core 3
pH pw (−log N)
Depth (cm)
Core 9
pH pw (−log N)
Core 1
pH pw (−log N)
Core 8
pH pw (−log N)
Core 10
pH pw (−log N)
Core 12
pH pw (−log N)
Core 18
pH pw (−log N)
Core 16
pH pw (−log N)
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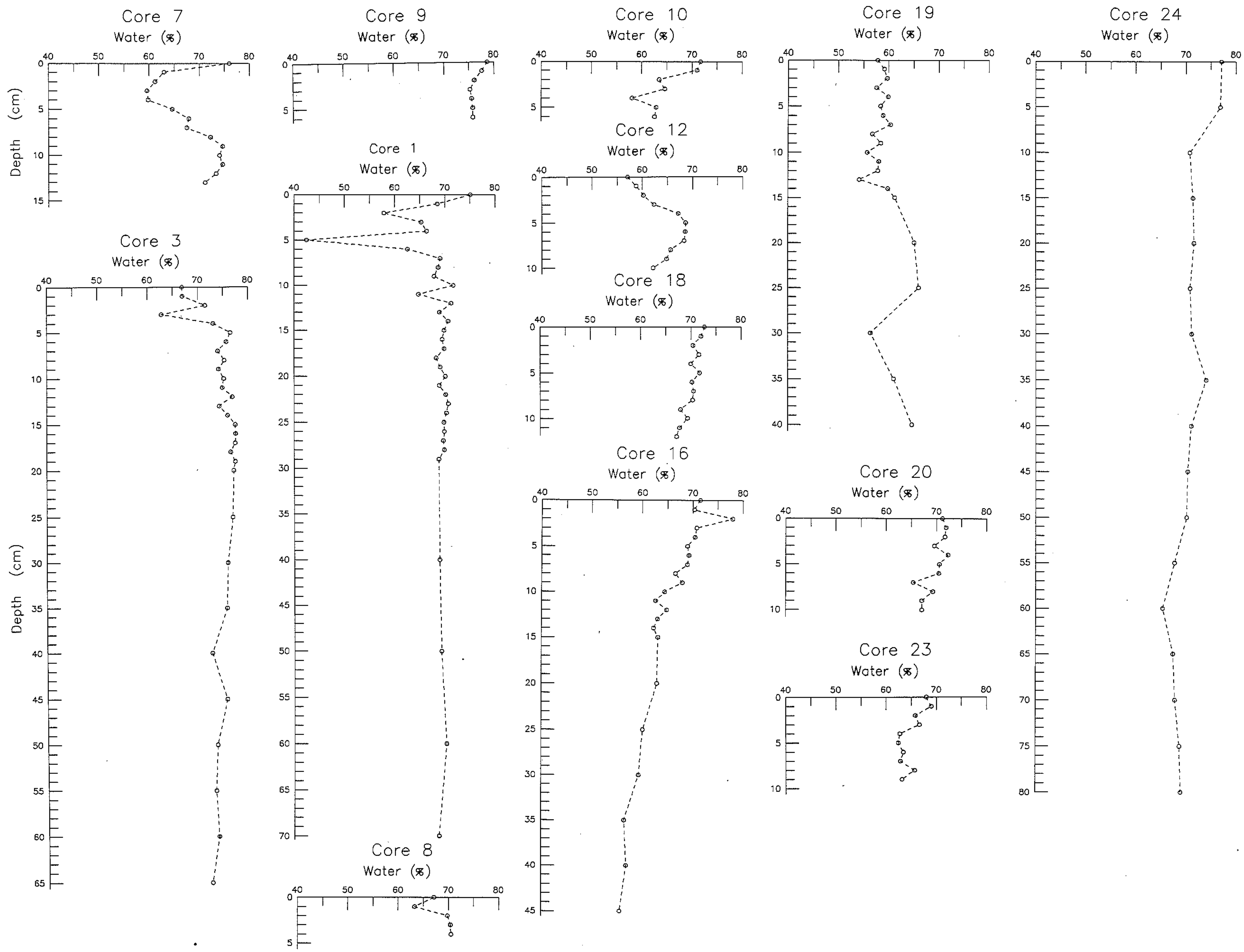
Core 24
pH→pw (−log N)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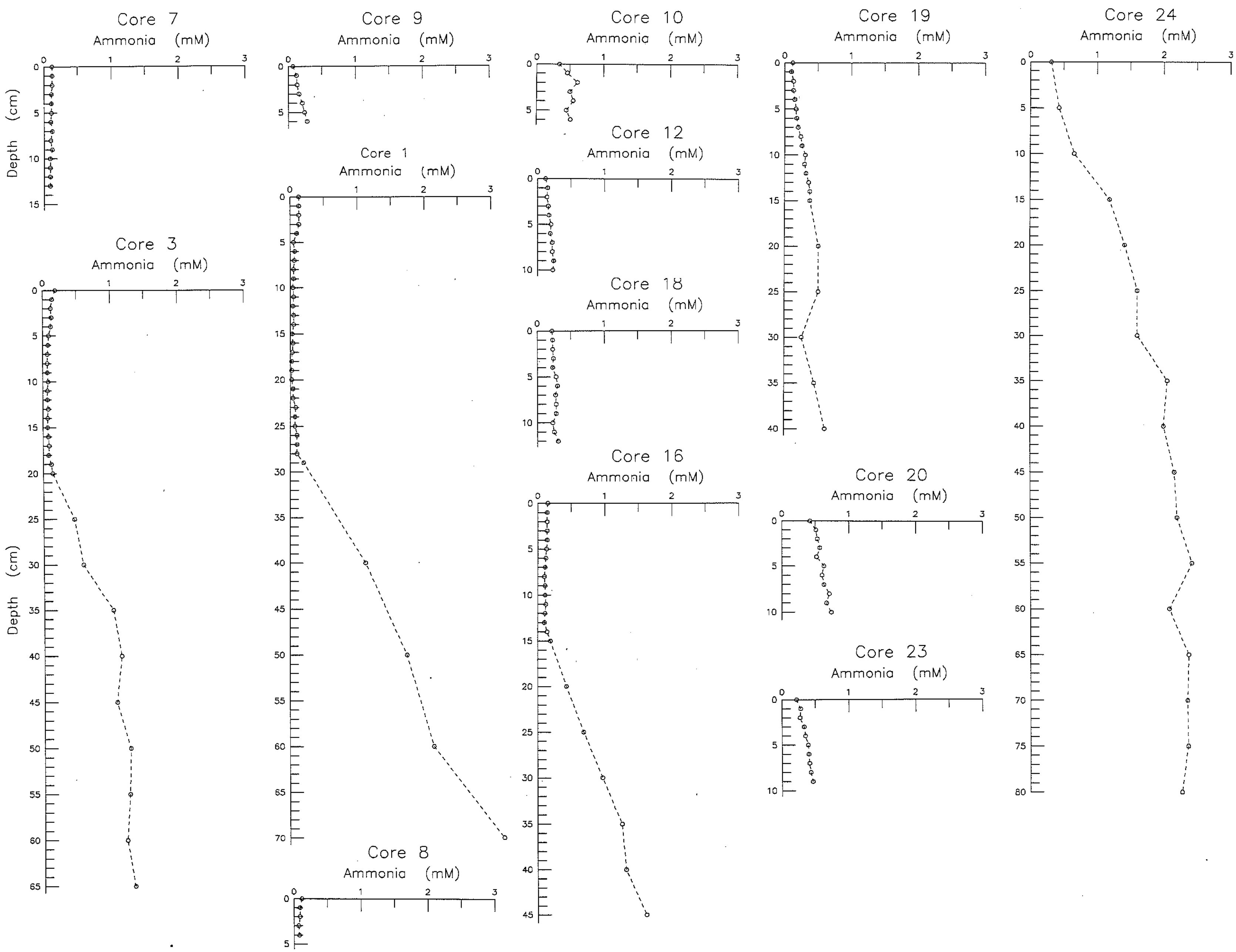
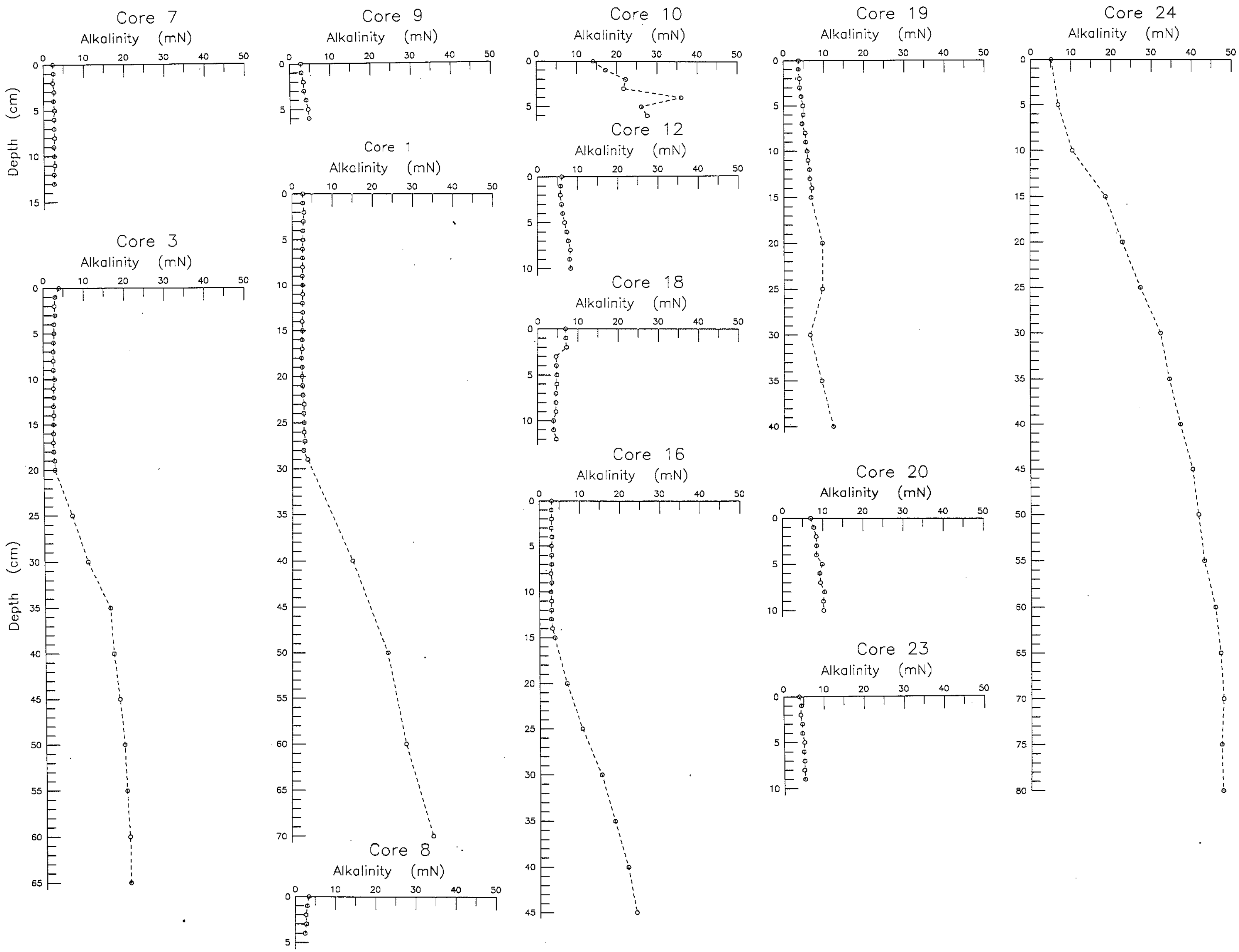
Water (%)
Depth (cm)
Core 9
Core 1
Core 8
Core 3
Core 10
Core 12
Core 18
Core 16
Core 19
Core 20
Core 23
Core 24



Core 7
Ammonia (mM)
Depth (cm)
Core 9
Ammonia (mM)
Core 10
Ammonia (mM)
Core 19
Ammonia (mM)
Core 24
Ammonia (mM)
Core 1
Ammonia (mM)
Core 12
Ammonia (mM)
Core 3
Ammonia (mM)
Depth (cm)
Core 18
Ammonia (mM)
Core 16
Ammonia (mM)
Core 20
Ammonia (mM)
Core 23
Ammonia (mM)
Core 8
Ammonia (mM)



Core 7
Core 9
Core 10
Core 12
Core 18
Core 16
Core 19
Core 20
Core 23
Core 24
Core 3
Core 1
Core 8
Alkalinity (mN)
Depth (cm)

APPENDIX II

HALIFAX HARBOUR AND BEDFORD BASIN SAMPLING

BIOLOGICAL SAMPLING

The infaunal benthos was the only community collected using the two surficial sediment sampling devices (Van veen, Eckman). A coarse and fine screen (10 and 0.5 mm) were used to seive the samples for organisms onboard the Navicula. Therefore, only the organisms that were larger than 0.5 mm were considered.

Note: longest *spiochaetopterus* case found to this date is 34 cm from sample NAV 89009-002.

SAMPLE #	LAT./ LONG.	DATE	SAMPLER	DEPTH (m)	ANIMALS FOUND
NAV 89009-002	44° 41.85' N 63° 38.92' W	June 2, 1989	Van veen -full soft mud	62	-being examined now -lots of empty *spiochaetopterus* cases
NAV 89009-004	44° 43.21' N 63° 39.94' W	June 2, 1989	Van veen -full soft mud	11	
NAV 89009-006	44° 41.14' N 63°37.59' W	June 2, 1989	Van veen -full soft mud	58	-a lot of dumped coal found in this sample -19 *Trochochaetids multisetasa* -1 *Pectinaria* case -74 *Nereimyra punctata* -714 *Cossura longocirrata* -dead shells -lots of organic matter from land -lots of empty *spiochaetopterus* cases -an unidentified orange-coloured worm case
NAV 89009-007	44° 43.17' N 63° 40.01' W	June 3, 1989	Eckman (30cm x 30 cm) -10-15 cm of soft mud	14	-dead shells -*spiochaetopterus* cases only -unidentifiable pieces of polychaete tubes
NAV 89009-008	44° 41.11' N 63° 37.75' W	June 3, 1989	Eckman -8 cm of soft mud	59	-dead shells -1 *pectinaria* case -unidentifiable pieces of polychaetes and orange worm cases -*spiochaetopterus* cases and badly preserved worms
NAV 89009-009	44° 41.89' N 63° 38.96' W	June 3, 1989	Eckman -12 cm of black soft mud	67.5	-dead shells -*spiochaetopterus* cases only -1 *Pectinaria* case
NAV 89009-011	44° 40.63' N 63° 35.98' W	June 6, 1989	Van veen -soft mud, 1/2 full	10	
NAV 89009-013	44° 40.32' N 63° 36.93' W	June 6, 1989	Van veen -full soft mud	23	
NAV 89009-015	44° 39.73' N 63° 33.60' W	June 6, 1989	Van veen -full soft mud	11	
NAV 89009-017	44° 38.77' N 63° 33.78' W	June 6, 1989	Van veen -full soft mud	24	
NAV 89009-020	44° 37.66' N 63° 31.57' W	June 13, 1989	Eckman -10 cm of soft mud	18	
NAV 89009-021	44° 37.72' N 63° 31.56' W	June 13, 1989	Van veen -full soft mud	17	
NAV 89009-022	44° 36.67' N 63° 32.43' W	June 13, 1989	Van veen -full soft mud	27	
NAV 89009-024	44° 37.70' N 63° 35.52' W	June 13, 1989	Van veen -full soft mud	11	

APPENDIX III

TRAWLING STUDY

On June 8, 1989, a trawling program was conducted by Environment Canada personnel on the BIO vessel "NAVICULA" in Halifax Harbour with the following objectives:

1. To study the morphological and histological alterations in bottom-dwelling fish collected from Halifax Harbour;
2. To design an assessment program based on this pilot project for assessing the health of bottom-dwelling fish in Halifax Harbour in relation to the levels of sediment organic matter concentrations.

BACKGROUND

PAH levels in digestive gland tissue that are higher than levels characteristic of clean areas were reported by Uthe *et al.* (unpublished data) for lobsters caught in Halifax Harbour. The existence of high PAH levels indicated that organic contamination of commercial species tissue might be a major problem in the harbour. Since hepatic neoplasms and other lesions detected in bottom-dwelling fish have been consistently related to organic pollutants in marine sediments (Malins *et al.*, 1984, 1985 a, b; Krahn *et al.*, 1986), it seemed likely that similar pathological alterations might also be observed in bottom fish or other benthic biota obtained from Halifax Harbour.

METHOD AND MATERIALS

A 10 ft. beam trawl was used for this study. A total of six trawls (10-17 minutes each) completed in different areas of the harbour.

RESULT AND DISCUSSION

One of the major objectives of this study was to collect bottom-dwelling fish such as winter flounder. However, with the exception of a few juvenile cod fish, no other species of fish was caught in the four separate trawls. It was later found that the opening of the trawl net had been reduced after a recent repair of the net. Because of this change, the net could not be positioned properly to catch any bottom-dwelling fish during the trawling process. However, the fact that the water temperature in the harbour might be too cold for the winter flounder at the time of the sampling could also be one of the reasons that no fish was caught by the trawl.

The polychaete (*Spiochaetopterus*) which was reported by Hargrave *et al.* (unpublished data) as the abundant polychaete species in the Bedford Basin was consistently caught by the trawl net suggesting that they are perhaps the dominant benthic form in the harbour sediments. In addition to this polychaete genus, several other benthic species were quite abundant:

1. Stalked sea squirt (*Boltenia ovifera*): occurred mostly at the middle and outer portions of the harbour;
2. Yoldias (*Yoldia species*);
3. Green sea urchins (*Strongylocentrotus drohbachiensis*);
4. Several species of starfish.

Other biota caught by the net included several species of sea anemones, sponges, shrimps, soft shell clam, and some clam shells.

A field summary of the trawling program is attached to this report.

HALIFAX HARBOUR TRAWLING FIELD NOTES

Date: June 8, 1989

1st Trawl:

- In Bedford Basin near the ocean dump site
- Start at 1324
- Trawl speed 3.5 knots
- 10 minutes trawling time
- Many polychaete tubes;

  Black and silty mud;

  Some sponges;

  Clam shells.

2nd Trawl:

- In Bedford Basin
- Start at 1350
- Trawl speed 3.5 knots
- 16 minutes trawling time
- Two juvenile cod;

  Few soft shell clams;

  Starfish;

  Lots of garbage and debris in mud.

3rd Trawl:

- In Bedford Basin off 24 hour Sobey's and end of Shore Drive to Bedford Yacht Club
- Start at 1435
- Trawl speed 3.5 knots

- 10 minutes trawling time
- Some starfish;

  Yoldias;

  Lots of mud.

4th Trawl:

- In Bedford Basin off Clearwater Foods heading towards Narrow
- Start 1523
- Trawl speed 3.5 knots
- 17 minutes trawling time
- Many polychaete tubes;

  Starfish.

5th Trawl:

- Off Maritime Mall proceeding towards Ocean terminals and stop near Pier B
- Start 1613
- Trawl speed 3.5 knots
- 17 minutes trawling time
- Stalked sea squirt;

  Anenones;

  Starfish;

  Shrimps;

  Sea urchin;

  Sponges;

  Yoldias.

6th Trawl:

- Off Container Pier and stop at northern end of McNabs Island and Point Pleasant

- Start 1643
- Trawl speed 3.5 knots
- 11 minutes trawling time
- Stalked sea squirt;

  Starfish;

  Sea urchin;

  Sponges;

  Yoldias.

Table 1: Grab Samples 89-009 Phase A

Samp. #	Sample Type	Jul. Day/ Time	Latitude	Longitude	Depth (m)	# of Attempts	# of Sub-samples	Seismic Time	Geographic Location	Notes
002	Van Veen	1531402	44°41.85 N	63°38.92 W	62.0	1		1491627	Bedford Basin	Biological sample, sieved with three coarse and fine screens to recover biota.
004	Van Veen	1531610	44°43.21 N	63°39.99 W	11.0	1	1	1491830	Bedford Bay	Sieved for biota.
006	Van Veen	1531744	44°41.14 N	63°37.59 W	58.0	2	1	1512015	Bedford Basin	Sample screened on board for biological material. Note numerous rocks (cobble size and greater) suspicious of dumped material.
007	Eckman	1541227	44°43.17 N	63°40.01 W	14.0	3	2	1491830	Bedford Bay	About 10-15 cm of soft mud (light brown mud patches on surface).
008	Eckman	1541326	44°41.11 N	63°37.75 W	59.0	5	2	1512015	Bedford Basin	About 8 cm of soft mud in bottom of sampler.
009	Eckman	1541347	44°41.89 N	63°38.96 W	67.5	1	2	1491627	Bedford Basin	About 12 cm of black, soft mud.
010	Eckman	1571230	44°40.63 N	63°35.98 W	10.0	4	1		Tufts Cove	Not much penetration approximately 10 cm still not enough weight. Too much drag on the side?
011	Van Veen	1571237	44°40.63 N	63°35.98 W	10.0	1	1		Tufts Cove	Biological sample.
012	Eckman	1571305	44°40.32 N	63°36.93 W	22.0	4	1		Duffus Street Outfall	Slight brown smears at top - oxidized sediments, or finless brown? 0.13 cm recovered.
013	Van Veen	1571315	44°40.32 N	63°36.93 W	23.0	1	1		Duffus Street Outfall	Biological sample.
014	Eckman	1571350	44°39.73 N	63°33.60 W	11.0	5	0		Dartmouth Cove	No sample.
015	Van Veen	1571357	44°39.73 N	63°33.60 W	11.0	1	1		Dartmouth Cove	Biological sample. Gravelly mud.
017	Van Veen	1571418	44°38.77 N	63°33.78 W	24.0	1	1		North of Georges Island	Biological sample.
018	Eckman	1571423	44°38.77 N	63°33.78 W	24.0	1	1		North of Georges Island	Good sample - about 16 cm recovered.
020	Eckman	1641233	44°37.66 N	63°31.57 W	18.0	3			Eastern Passage	
021	Van Veen	1641246	44°37.72 N	63°31.56 W	17.0	2			Eastern Passage	1st attempt 1244, jaws open.
022	Van Veen	1641312	44°36.67 N	63°32.43 W	27.0	2			McNabs Cove	
023	Eckman	1641316	44°36.67 N	63°32.43 W	17.0				McNabs Cove	
025	Van Veen	1641356	44°37.70 N	63°35.52 W	11.0	1			Northwest Arm	

Table 2: Core Samples 89-009 Phase A

Samp. #	Sample Type	Jul. Day/ Time	Latitude	Longitude	Depth (m)	Corer Length (cm)	App. Penn (cm)	Core Length (cm)	# of Sect	Seismic Time	Geographic Location	Notes
001	Lehigh	1531343	44°41.87 N	63°39.00 W	62.0	140	140		1	1491627	Bedford Basin	Penetrated full length to weight. Water drained from bottom while being lifted inboard. Approximately 60% full, with no water left on top after core head removed. Core off loaded at BIO 1425.
003	Lehigh	1531600	44°43.19 N	63°40.04 W	11.0	150	150	75	1	1491830	Bedford Bay	75 cm recovered. No water. Core off loaded at BIO at 1630.
005	Lehigh	1531720	44°41.11 N	63°37.82 W	58.0	150	70	50	1	1512015	Bedford Basin	
016	Lehigh	1571412	44°38.77 N	63°33.78 W	24.0	100	90	50	1		North of Georges Island	50 cm. recovered. Panetrated 80-90 cm. No water on top.
019	Lehigh	1571444	44°39.64 N	63°33.63 W	14.0	80	60	45	1		Dartmouth Cove	45 cm. recovery - slight brown colour at top, looks like good interface.
024	Lehigh	1631347	44°37.70 N	63°35.52 W	11.0				1		Northwest Arm	

Table 3: Sidescan Records 89-009 Phase A

Roll #	Start Day/ Time	Stop Day/ Time	Geographic Location	Recorder	Sidescan System
001	1491615	1492110	Bedford Basin	Klein 401	100 kHz Klein
002	1501236	1501820	Bedford Basin	Klein 401	100 kHz Klein
003	1501826	1501945	Bedford Basin	Klein 401	100 kHz Klein
004	1511425	1512240	Bedford Basin	Klein 401	100 kHz Klein
005	1521245	1521400	Bedford Basin	Klein 401	100 kHz Klein
006	1521800	1522045	Bedford Basin	Klein 401	100 kHz Klein
007	1541710	1542000	Hfx. Harb. Narrows	Klein 401	100 kHz Klein
008	1551147	1551510	Hfx. Harb. Narrows	Klein 401	100 kHz Klein
009	1551515	1551935	Hfx. Harb. Narrows	Klein 401	100 kHz Klein
010	1561225	1561900	Halifax Harbour	Klein 401	100 kHz Klein
011	1571655	1571835	Northwest Arm	Klein 401	100 kHz Klein
012	1581305	1581810	Outer Halifax Harb.	Klein 401	100 kHz Klein
013	1591220	1591325	Bedford Basin	Klein 401	100 kHz Klein
014	1601705	1602045	Outer Halifax Harb.	Klein 401	100 kHz Klein
015	1631355	1632005	Outer Halifax Harb.	Klein 401	100 kHz Klein
016	1651305	1651955	Outer Halifax Harb.	Klein 401	100 kHz Klein
017	1661240	1661800	Outer Halifax Harb.	Klein 401	100 kHz Klein
018	1661805	1662045	Outer Halifax Harb.	Klein 401	100 kHz Klein
019	1681220	1681640	Outer Halifax Harb.	Klein 401	100 kHz Klein
020	1681640	1682025	Outer Halifax Harb.	Klein 401	100 kHz Klein
021	1691230	1691925	Outer Halifax Harb.	Klein 401	100 kHz Klein

Table 4: Sidescan Tapes 89-009 Phase A

Tape #	Start Day/ Time	Stop Day/ Time	Geographic Location	Channel Information	Sidescan System
001			Bedford Basin	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
002	1501646	1501840	Bedford Basin	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
003	1501848	1501944	Bedford Basin	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
004	1511731	1511906	Bedford Basin	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
005	1511911	1512046	Bedford Basin	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
006	1512049	1512210	Bedford Basin	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
007	1512227	1521338	Bedford Basin	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
008	1521802	1521938	Bedford Basin	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
009	1521938	1541747	Bedford Basin - Halifax Harbour Narrows	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
010	1541747	1541926	Halifax Harbour Narrows	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
011	1541927	1551313	Halifax Harbour Narrows	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein

Table 4: Sidescan Tapes 89-009 Phase A (continued)

Tape #	Start Day/ Time	Stop Day/ Time	Geographic Location	Channel Information	Sidescan System
012	1551315	1551451	Inner Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
013	1551452	1551632	Inner Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
014	1551633	1551814	Inner Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
015	1551816	1561247	Inner Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
016	1561259	1561433	Inner Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
017	1561434	1561609	Inner Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
018	1561609	1561745	Inner Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
019	1561747	1561900	Inner Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
020	1571700	1571830	Northwest Arm	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
021	1571840	1581410	Northwest Arm, Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
022	1581411	1581547	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein

Table 4: Sidescan Tapes 89-009 Phase A (continued)

Tape #	Start Day/ Time	Stop Day/ Time	Geographic Location	Channel Information	Sidescan System
023	1581548	1581725	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
024	1581725	1591253	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
025	1591254	1601836	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
026	1601837	1602007	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
027	1602020	1631507	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
028	1631507	1631644	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
029	1631647	1631826	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
030	1631828	1631957	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
031	1651306	1651442	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
032	1651442	1651633	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
033	1651634	1651810	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein

Table 4: Sidescan Tapes 89-009 Phase A (continued)

Tape #	Start Day/ Time	Stop Day/ Time	Geographic Location	Channel Information	Sidescan System
034	1651811	1651949	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
035	1661250	1661428	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
036	1661428	1661606	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
037	1661607	1661747	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
038	1661747	1661930	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
039	1661930	1662043	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
040	1681224	1681359	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
041	1681359	1681549	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
042	1681549	1681726	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
043	1681726	1681903	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
044	1681903	1682026	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein

Table 4: Sidescan Tapes 89-009 Phase A (continued)

Tape #	Start Day/ Time	Stop Day/ Time	Geographic Location	Channel Information	Sidescan System
045	1691232	1691407	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
046	1691407	1691544	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
047	1691544	1691730	Outer Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
048	1691730	1691905	Inner Halifax Harbour	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein
049	1691905	1691920	Halifax Harbour Narrows	Port-FM Stbd.-FM Ref.-DR Voice-DR	100 kHz Klein

Table 5: Seismic Records 89-009 Phase A

Roll #	Start Day/ Time	Stop Day/ Time	Hydrophone	Geographic Location	Recorder	System/Sound Source
001	1491655	1511720	External Eel	Bedford Basin	EPC 1600	Bubble Pulser
002	1511730	1512240	External Eel	Bedford Basin	EPC 1600	Bubble Pulser
003	1521250	1522040	External Eel	Bedford Basin	EPC 1600	Bubble Pulser
004	1541710	1551930	External Eel	Halifax Harbour Narrows	EPC 1600	Bubble Pulser
005	1561215	1561900	External Eel	Inner Halifax Harbour	EPC 1600	Bubble Pulser
006	1571645	1581800	External Eel	Northwest Arm	EPC 1600	Bubble Pulser
007	1601540	1602000	External Eel	Outer Halifax Harbour	EPC 1600	Bubble Pulser
008	1631525	1632000	External Eel	Outer Halifax Harbour	EPC 1600	Bubble Pulser
009	1651133	1651955	External Eel	Outer Halifax Harbour	EPC 1600	Bubble Pulser
010	1661150	1661925	External Eel	Outer Halifax Harbour	EPC 1600	Bubble Pulser
011	1661930	1682025	External Eel	Outer Halifax Harbour	EPC 1600	Bubble Pulser
012	1691220	1691925	External Eel	Outer Halifax Harbour	EPC 1600	Bubble Pulser
001	1491620	1492051	External Eel	Bedford Basin	EPC 4100	Huntec Sea Otter
002	1501245	1511320	External Eel	Bedford Basin	EPC 4100	Huntec Sea Otter
003	1511720	1512240	External Eel	Bedford Basin	EPC 4100	Huntec Sea Otter
004	1521250	1522040	External Eel	Bedford Basin	EPC 4100	Huntec Sea Otter
005	1541710	1551930	External Eel	Halifax Harbour Narrows	EPC 4100	Huntec Sea Otter
006	1561215	1561900	External Eel	Inner Halifax Harbour	EPC 4100	Huntec Sea Otter
007	1571655	1581805	External Eel	Northwest Arm, Outer Halifax Harbour	EPC 4100	Huntec Sea Otter
008	1601500	1601735	External Eel	Outer Halifax Harbour	EPC 4100	Huntec Sea Otter
001	1602010	1611650	Internal	Outer Halifax Harbour	EPC 1600	Seistec Boomer
002	1631346	1632000	Internal	Outer Halifax Harbour	EPC 1600	Seistec Boomer
003	1651305	1651950	Internal	Outer Halifax Harbour	EPC 1600	Seistec Boomer
004	1661150	1661935	Internal	Outer Halifax Harbour	EPC 1600	Seistec Boomer
005	1661939	1682025	Internal	Outer Halifax Harbour	EPC 1600	Seistec Boomer
006	1691230	1691920	Internal	Outer Halifax Harbour	EPC 1600	Seistec Boomer

Table 6: **Bathymetric Records 89-009 Phase A**

Roll #	Start Day/ Time	Stop Day/ Time	Geographic Location	Frequency	Recorder
001	1541647	1541905	Halifax Harbour, Narrows	30 kHz	EPC 1600
002	1541915	1551520	Halifax Harbour, Narrows	30 kHz	EPC 1600
003	1551530	1551935	Inner Halifax Harbour	30 kHz	EPC 1600
004	1561225	1561710	Inner Halifax Harbour	30 kHz	EPC 1600
005	1561720	1561925	Inner Halifax Harbour	30 kHz	EPC 1600
006	1571505	1571730	Northwest Arm	30 kHz	EPC 1600
007	1571830	1581400	Northwest Arm, Outer Halifax Harbour	30 kHz	EPC 1600
008	1581410	1581805	Outer Halifax Harbour	30 kHz	EPC 1600
009	1591250	1601855	Outer Halifax Harbour	30 kHz	EPC 1600
010	1601905	1602045	Outer Halifax Harbour	30 kHz	EPC 1600
001	1491610	1491935	Bedford Basin	30 kHz	ELAC
02A	1492000	1511330	Bedford Basin	30 kHz	ELAC
02B	1511715	1561800	Bedford Basin, Halifax Harbour, Narrows	30 kHz	ELAC
003	1571655	1641356	Northwest Arm, Outer Halifax Harbour	30 kHz	ELAC
004	1651300	1711951	Outer Halifax Harbour, Pubnico	30 kHz	ELAC