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ACOUSTIC MAPPING OF CONTAMINATED-SEDIMENT THICKNESS IN LAC SAINT-LOUIS, RESULTS OF EQUIPMENT TRIALS, 1990

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MANAGEMENT PERSPECTIVE

Trials of three echo sounders were carried out in Lac Saint-Louis to assess their ability to measure the thickness of modern contaminated sediments and to discriminate sediment type. This is part of an ongoing program in acoustics of sediments at the National Water Research Institute in which the Centre Saint-Laurent is cooperating because of the need for improved procedures for sediment surveys in the St. Lawrence River.

Test areas were first surveyed by sounding, sampling and coring to establish ground-truth data. None of the sounders was able to meet the objective of resolving modern-sediment layers 10 cm thick. Success rates for detection of 25-cm layers were 38% (BioSonics), 17% (Datasonics) and 33% (Edo). Bottom discrimination was poor except for the Edo which was moderately successful in distinguishing fine-grained sediments from sand and exposed glacial clays.

Improvements in the performance of existing equipment should be possible with better colour recording (BioSonics, Datasonics), more scale expansion (Edo, Datasonics), and post-processing to enhance record quality (BioSonics, Datasonics). At this point there is no indication that conventional acoustics will ever detect all the zones of geological interest. Some interfaces may remain acoustically invisible because the acoustic impedances above and below the interface match. The alternative is to develop a new sounder dedicated to real-time, high resolution of fine-grained modern sediments.

PERSPECTIVES DE LA DIRECTION

On a essayé trois écho-sondeurs dans le lac Saint-Louis pour déterminer dans quelle mesure ces appareils permettent de mesurer l'épaisseur des sédiments récents contaminés et d'identifier le type de sédiment dont il s'agit. Ces essais font partie d'un programme permanent de l'Institut national de recherche sur les eaux dans le domaine de l'acoustique des sédiments. Le Centre Saint-Laurent collabore à ce projet parce qu'on a besoin de meilleures méthodes de relevés sédimentologiques dans le Saint-Laurent.

Dans un premier temps, on a étudié les zones expérimentales par écho-sondage, par échantillonnage et par carottage, pour déterminer la vraie nature du fond. Aucun des écho-sondeurs n'a permis de réaliser l'objectif consistant à déterminer les caractéristiques des couches sédimentaires récentes de 10 cm d'épaisseur. Pour ce qui est de la détection des couches de 25 cm, voici les résultats obtenus selon l'appareil : 38 % pour Biosonics, 27% pour Datasonics et 33 % pour Edo. Pour ce qui est du fond, les résultats obtenus ont été mauvais, sauf dans le cas de l'écho-sondeur Edo, qui a permis de faire relativement bien la distinction entre les sédiments à grains fins et les sables ou les argiles glaciaires exposés.

On devrait pouvoir améliorer la performance de l'équipement utilisé et obtenir un meilleur enregistrement des couleurs (Biosonics, Datasonics), une échelle de lecture plus large (Edo, Datasonics) et un post-traitement pour améliorer la qualité de l'enregistrement (Biosonics et Datasonics). Pour le moment, cependant, rien n'indique que l'acoustique classique permettra un jour de détecter toutes les zones présentant un intérêt sur le plan géologique. Certaines interfaces peuvent demeurer inaudibles, parce que l'impédance supérieure et l'impédance inférieure sont identiques. La solution consiste à élaborer un nouvel écho-sondeur spécialisé dans l'analyse en temps réel et à haute résolution des sédiments récents à grains fin.

ABSTRACT

Trials of three echo sounders were carried out in Lac Saint-Louis to assess their ability to measure the thickness of modern contaminated sediments and to discriminate sediment type. Test areas were first surveyed by sounding, sampling and coring to establish ground-truth data. None of the sounders was able to meet the objective of resolving modern-sediment layers 10 cm thick. Success rates for detection of 25-cm layers were 38% (BioSonics), 17% (Datasonics) and 33% (Edo). Bottom discrimination was poor except for the Edo which was moderately successful in distinguishing fine-grained sediments from sand and exposed glacial clays. Improvements in the performance of existing equipment should be possible with better colour recording (BioSonics, Datasonics), more scale expansion (Edo, Datasonics), and post-processing to enhance record quality (BioSonics, Datasonics). The alternative is to develop a new sounder dedicated to real-time, high resolution of fine-grained modern sediments.

RÉSUMÉ

On a essayé trois écho-sondeurs dans le lac Saint-Louis pour déterminer dans quelle mesure ces appareils permettent de mesurer l'épaisseur des sédiments récents contaminés et d'identifier le type de sédiment dont il s'agit. Dans un premier temps, on a étudié les zones expérimentales par sondage, par échantillonnage et par carottage, pour déterminer la vraie nature du fond. Aucun des écho-sondeurs n'a permis de réaliser l'objectif consistant à déterminer les caractéristiques des couches sédimentaires récentes de 10 cm d'épaisseur. Pour ce qui est de la détection des couches de 25 cm, voici les résultats obtenus selon l'appareil : 38 % pour Biosonics, 17 % pour Datasonics et 33 % pour Edo. Pour ce qui du fond, les résultats obtenus ont été mauvais, sauf dans le cas de l'écho-sondeur Edo, qui a permis de faire relativement bien la distinction entre les sédiments à grains fins et les sables ou les argiles glaciaires exposés. On devrait pouvoir améliorer la performance de l'équipement utilisé et obtenir un meilleur enregistrement des couleurs (Biosonics, Datasonics), une échelle de lecture plus large (Edo, Datasonics) et un post-traitement pour améliorer la qualité de l'enregistrement (Biosonics, Datasonics). La solution consiste à élaborer un nouvel écho-sondeur spécialisé dans l'analyse en temps réel et à haute résolution des sédiments récents à grains fins.

1 INTRODUCTION

During the summer of 1990, the National Water Research Institute (NWRI) and Centre Saint-Laurent (CSL) cooperated on the assessment of three echo-sounders for mapping the thickness and texture of contaminated sediments. This report outlines the procedures used for the trials, discusses the results obtained, and provides some recommendations on what can be done with existing equipment and procedures and what further trials would be useful.

The criteria used in selecting sounders for the trials are discussed in Ford and Rukavina (1990). Detailed testing was limited to the two top-rated sounders, the BioSonics and the Datasonics. The models used, the BioSonics 101 and 105 and the Datasonics SBP220, were functionally identical to those assessed. Limited trials were also made of the Datasonics DSP 601/2/3 chirp sonar at the request of Datasonics.

The sounder trials were conducted on a test course in Lac Saint-Louis. Prior to the trials, a sounding, sampling and coring survey was used to establish ground-truth. The operations guide for the survey (Rukavina 1990a) and the field report (Fortin 1990) provide the details of the procedures used. The sediment types and thicknesses mapped during this survey are discussed in Rukavina (1990b) and summarized below.

The test sounders were only partially successful in mapping modern-sediment thicknesses of less than 0.5 m and were incapable of discriminating surface-sediment type. The best results in real-time were obtained with the BioSonics sounder. Surprisingly good data, although with lesser resolution, were obtained from an old Edo 9040 hydrographic sounder that was part of the launch instrumentation. It proved to be useful in both thickness measurements and bottom discrimination.

2 OBJECTIVES/APPROACH

The primary purpose of the trials was to assess the use of selected echo sounders for measuring the thickness of the surficial layer of contaminated sediments in inland waters in general and Lac St-Louis in particular. This layer is generally less than 1 m thick and overlies a substrate of glacial sediment or bedrock. To be useful, the sounder must be able to detect the sediment-water interface and the contact with the substrate, and to resolve the thickness of the surficial sediment to within 10 cm. Ideally it should do this in real time and display it on a paper record. Thickness data are needed to assist in selection of sample sites during the same survey and there is generally no time available for post-processing of acoustic data. Details of the sounder requirements and selection have been discussed in an earlier technical note (Ford and Rukavina 1990).

A secondary purpose of the trials was to determine the extent to which sounders could be used to classify bottom-sediment type and texture. The requirements here were the ability to discriminate bedrock, boulders, glacial sediment, and unconsolidated sediments, and to resolve the latter into at least four grain-size fractions (gravel-sand, muddy sand, sandy mud, and mud).

3 SOUNDER SPECIFICATIONS AND USE

The sounders chosen for the tests were the BioSonics Models 101 and 105 and the Datasonics Model SBP-220. These are conventional sounders which use a short burst of sound at a fixed frequency. Their selection was based on the best combination of specifications for detection and resolution of the modern-sediment layer. Burst-length, beam-width, and band-width characteristics were used to estimate the total resolution and this, in combination with the availability of appropriate frequencies, determined the choice (Ford and Rukavina 1990). A second Datasonics sounder, model DSP 601/2/3 (Schock and LeBlanc 1990), was recommended by the manufacturer as superior to the model requested, and this was also subjected to limited testing. In contrast to the other sounders which use a fixed frequency, the chirp sonar makes use of a sound burst that sweeps a range of frequencies. More detailed sounder specifications are listed in Appendix 1.

The BioSonics sounders were used with 38kHz and 420kHz transducers fixed to a gunwale-mounted frame. Records were printed to an EPC 8700 thermal recorder and simultaneously captured on DAT tape.

The Datasonics Model SBP-220 sounder was tested with 28kHz and 200kHz transducers mounted in a towfish towed abeam of the survey launch. Records were printed to the Datasonics printer which is part of the system. A fault in the transmitter's quieting circuit resulted in very poor record quality and prevented a proper assessment of the sounder. Because the problem could not be corrected in the limited time available, trials were limited to the north area. The Datasonics chirp sonar was run with a 2-10kHz towed-transducer array. Records were displayed on a built-in colour monitor and captured on DAT tape. Only limited hard-copy records were available and these lacked the geographic control necessary for comparison with the core data.

The launch sounder, an Edo 9040 sounder, was used for navigation and depth profiling. Because some of its records were superior to those of the trial sounders, it was included as part of the test. The Edo transducer was 24kHz and was mounted in the hull of the survey launch.

In all cases, sounding was carried out at a boat speed of between 3 and 4 knots and in conditions of calm or low sea state. The speed was not varied to adjust for the differences in ping rates and footprints of the sounders because the intent was to compare the sounders at the minimal speed practical for the survey. Better quality displays may have been achieved by reducing the speed of the survey to increase the horizontal sampling rate.

4 TEST COURSE GEOLOGY AND BATHYMETRY

The two test courses used for the trials are in the northwest and southwest basins of the lake (Figure 1). They were selected on the basis of the results of lakewide mapping in 1985 (Rukavina 1985, 1986; Rukavina et al 1990) to provide a variety of bottom-sediment textures and types and a variable thickness of modern-sediment cover. More detailed mapping of the test lines themselves which took place as part of this survey is reported separately in Rukavina (1990b) and summarized below.

Part of the pre-trial work consisted of echo-sounding along the test lines with an Edo 9040 hydrographic echo sounder. Depth profiles for the test courses are shown in Figures 2 and 3.

Both test areas are floored by thin muddy to sandy sediments of recent origin draped over an irregular surface of glacial clays and bedrock (Figures 4,5). The modern sediments range in texture from 1 to 70 percent sand and in thickness from 0 to more than 76 cm. Texture of surface sediments is coarser in the north area than the south. Stratigraphic analysis of the sediments was limited to shipboard examination of cores for changes in grain size and for evidence of the contact of modern and glacial sediments. Vertical variations in modern-sediment texture were generally small in the south except near the areas of shallow glacial sediments. Variability was somewhat greater in the north area with a tendency towards increasing grain size down the core. Underlying glacial sediments recovered in several cores were generally uniform, stiff, grey clays. In some cores, a thin layer of sandy or gravelly lag sediment separated the modern and glacial deposits.

5 ANALYSIS OF ECHO-SOUNDING RECORDS

Record quality varied from sounder to sounder. BioSonics records on thermal paper were crisp and well-defined with a depth resolution of 1:40 (1 cm of record represents a 40-cm interval) but were limited in grey scale to only 3 levels. Datasonics records on carbon-backed paper had a superior depth resolution (1:22) and grey scale (15 levels) but were of extremely poor quality apparently because of a fault in the transmitter's quieting circuit. Only limited samples of Datasonics chirp-sonar records were available as hard copy in the form of colour and black-and-white ink-jet printer plots. Record definition was considerably superior to that of the conventional Datasonics sounder and colour was superior to grey tones in displaying bottom response but depth resolution was poor (1:133). Edo records on carbon-backed paper showed the best combination of clear traces and range in grey scale but lacked resolution (1:222) because the scale was set for the maximum depth of the survey area. Figures 6-8 are samples of records from the same area for the BioSonics 101, the Datasonics SBP220 and the Edo 9040.

The minimal layer thickness that could be resolved by the BioSonics and Datasonics sounders was about 25 cm, well above the 10-cm resolution required for useful thickness mapping. Resolution in the chirp-sonar printed records was between 10 and 20 cm. Minimal resolution in the Edo sounder was 50 cm at the scale used for navigation and depth profiling.

Paper records for the conventional test sounders and the Edo were examined for evidence of sub-bottom reflectors at fix marks corresponding to the core sites. In each case the depth below the interface of the shallowest reflector was read off the sounder paper with a Gerber variable scale and recorded. No adjustment was made for the difference in acoustic impedance and velocity between water and sediment. Care was taken to ensure that the reflector recorded was not a multiple of the reflection from the sediment-water interface. Table 1 lists reflector depths and

Table 1. Depths of Mud-Glacial Contact, cm

SITE	CORES	BIOSONICS	EDO	DATASONICS
70	2	85	50	noisy record
1	2	280	75	200/240
71	>51	40/65	500	noisy record
2	16	40	50?	45/110
72	>24	NC	60/850	60
3C	>11	225?	80/150	75/195
73	11	85/90	NC	85?/125?
4	>18	70	100	100
61	11	60	NC	NC
5	>18	NC	940	noisy record
49	11	NC	700	NC
6	7	30	350	NC
38	2	130	250	230/235
7	40	65	70/80	50
28	>49	225/230	50/250	170/185
8	10	NC	50?	NC
27	3	NC	2[illegible]?	NC
9	3	NC	50	noisy record
36	32	25?	NC	25?/30?
10	49	NC	50	25
47	42	25?/55	60	25?/55?
11	>45	210	150	175
59	>48	400	750	360
12	>50	30/55	170	NC
1	42	NA	NC	NA
13C	3	60	50/200	NA
3	1	55	120/430	NA
14	>55	50	50/450	NA
5	>30	30	50?	NA
15	>76	NC	100?	NA
8	>40	40	40?	NA
16	36	30?	NC	NA
13S	>25	40?	NC	NA
17	>37	NC	50?	NA
9S	16	NC	50?	NA
18	>38	40?	50?	NA
24	>37	NC	NC	NA
19C	24	NC	NC	NA
32	0	NC	NC	NA
20	1	NC	100	NA
43	2	NA	NC	NA

NA = no data NC = no contact ? = poor data core data on the depth of the interface between modern and glacial sediments. Reflectors which correspond approximately to the substrate depths found in the cores are shown in boldface; values with a "?" were poorly defined and considered to be less reliable.

Sounders were assessed according to their ability to detect the depth of glacial sediment at each of the control points provided by the cores. Of the 41 cores collected, 24 intercepted the interface between modern and glacial sediments and provided a direct measure of the thickness of the modern-sediment layer. Although no glacial sediment was recovered in the remaining cores, it was assumed that their length was a reasonable estimate of depth to the glacial interface because it was likely the resistance of the glacial sediment or of overlying coarse lag deposits that prevented any further penetration. Eleven of the 41 sites had a sediment thickness of less than 10 cm, the required resolution. In these cases, the lack of a reflector was an acceptable response. At the remaining 30 sites, the sounders were rated according to their success in displaying a reflector within ±25 cm of the control depth.

The BioSonics sounder produced acceptable reflectors at 11 of the 29 sites surveyed for a score of 38%. The Datasonics recorded reflectors at 3 of 18 sites for a score of 17%. The Edo was successful at 10 of 30 sites for a score of 33%. No comparable score is available for the Chirp Sonar because only partial records were available for analysis and these lacked the geographic-reference data needed for comparison with the core data.

At the majority of sites where there was no reflector corresponding to the control depth, the sounders recorded deeper horizons ranging from depths of a few decimetres to several metres. These may represent textural discontinuities within the glacial clay or contacts with underlying glacial till or bedrock. In the absence of control data, these deeper reflectors could be misinterpreted as the surface of the glacial sediment and lead to large overestimates of modern-sediment thickness. It is important, therefore, that the acoustic data always be used in conjuction with direct measurements from cores and that there be continuity of a reflector from the control point to the area of interest to ensure that it represents the correct interface.

Another limitation of the acoustic data is evident at those sites where modern sediments were present but sounder records showed no reflectors below the sediment-water interface. In these cases the low density of the record traces suggests a modern-sediment cover but sediment thickness cannot be determined because there is no substrate echo.

Attempts to use the BioSonics and Datasonics sounders for discrimination of the texture of surface sediment were unsuccessful. The grey scale of the BioSonics recorder was too limited (3 levels) to permit this to be done and Datasonics record quality was too poor to justify an attempt. The Datasonics chirp sonar provides a "bottom hardness" as part of its display. This may be useful as an indicator of bottom type but could not be tested because no hard copy was available and because geographic control was lacking. Moderate success was obtained with the Edo records by classifying traces as light, medium or dark and then comparing class type with the data on the grain size of surficial sediments and on the presence or absence of near-surface glacial sediments. The relationship between record trace and bottom type is shown in Table 2. Other factors being equal, dark traces should be associated with high sand content or near-surface glacial sediment, light traces with very low sand content and medium traces with low to moderate sand content.

Of the 20 samples analysed, 8 had grain size or glacial-sediment depth that fit the trace density, 6 were slightly lower or higher than expected and 6 showed large differences from the expected density. In general, the correlation was good enough to be useful for discrimination of thin or coarse sediments from thicker fine-grained sediments.

Table 2. Sounder-record trace vs. grain size/sediment thickness

Site #	Trace density	Sand Pct	Sed. Thickness	Fit
73	dark	70	11	good
70	dark	57	2	good
1	dark	37	42	fair
49	dark	11	11	poor
3	dark	1	1	poor
61	med	67	11	poor
27	med	49	3	poor
38	med	40	2	poor
28	med	8	49+	good
72	med	6	24+	good
59	med	5	48+	good
5	med	2	30?	fair
36	med	1	32	fair
8	med	0	40?	fair
43	light	67	2	poor
71	light	1	51+	good
13	light	1	25?	good
19	light	2	16	good
47	light	3	42	fair
24	light	7	40?	fair
32	light	NA	0	NA

6 CONCLUSIONS

The major purpose of the trials was to assess the ability of the test sounders to resolve modern-sediment layers thicker than 10 cm at a number of test sites with control data from cores. None of the conventional sounders was capable of resolving layers less than 25 cm thick in real-time and they were only moderately successful in detecting an interface at depths greater than 25 cm. The Datasonics chirp sounder should be able to resolve layers 12 cm thick but this could not be confirmed because hard-copy records were incomplete and had no geographic reference. At sites with sediment thickness greater than 10 cm, the success rate in detecting the base of modern sediment as determined from core data was 38% for the BioSonics, 33% for the Edo and 17% for the Datasonics. Poor Datasonics results were partly dependent on a faultly quieting circuit which severely degraded record quality.

Both BioSonics and Datasonics were able to improve record quality by reprocessing the data and resetting the grey-level thresholds or using colour thresholds. The good Edo display was the result of a grey scale with a continuously-variable density. The importance of a good real-time display in surveys where post-processing is not practical because of time limitations cannot be overstressed.

All sounders showed reflectors below the contact between modern and glacial sediment which could be variations in the glacial sediment itself or represent the contact with underlying till or bedrock. Misinterpretation of these reflectors as the base of modern sediment could lead to sizeable errors in the estimates of modern-sediment thickness. This makes it critical that any acoustic data be properly calibrated with core data and that reflector depth be used only when the reflector trace is continuous from a calibration point.

The test sounders were unable to discriminate surface-sediment texture from record density because of limited grey scale (BioSonics) and poor record quality (Datasonics). The bottom-hardness data from the chirp sounder may be useful for this purpose but were not available for evaluation. The Edo was moderately successful in distinguishing sediments of high and low sand content.

At this point there is no indication that conventional acoustics will ever detect all the zones of geological interest. Some interfaces may remain acoustically invisible because the acoustic impedances above and below the interface match.

7 RECOMMENDATIONS

Short term

Some minor changes in existing equipment might be useful in improving record quality. Edo resolution could be improved from 50 cm to 25 cm by changing the operating range from 36 m to 18 m. The other sounders would benefit from a hard-copy record with a larger number of colours and the ability to set thresholds. Layer resolution of the Datasonics chirp could be improved from the current 12 cm to 1-2 cm by raising the digital-sampling rate from 20 to 200 kHz with a proportionate increase in band width. Post-processing could also be used to enhance record quality in situations where this could be done without interfering with the survey schedule.

An alternative approach would be to concentrate on signal processing so that the full dynamic range of the digitizer could be used for the sub-bottom range of 0-2 m. Both BioSonics and Datasonics appear to be capable of making the software changes required to accomplish this and of producing real-time hard copy in colour.

Long term

The sounder specifications for high-resolution, sub-bottom profiling have been laid out in Ford and Rukavina (1990). Improvement in sounder performance beyond that observed in this study will require either the modification of existing equipment to improve specifications and data presentation, or the development of a new sounder dedicated to real-time, high resolution of fine-grained modern sediments.

A continuous process of improvements can be expected in echo sounders as they are applied to mapping of dredge materials and polluted sediments. The development will go in at least two parallel paths, hardware and software/firmware.

Recent hardware developments in transmitters include parametric arrays (Guigné et al 1990) and generalized transmitters (Knudsen 1991; Schock and LeBlanc 1990). Parametrics offer the ability to produce a very narrow-beam, wide-bandwidth sound source with no side lobes to clutter the echoes. The generalized sounder provides for customization because the transmitter can send any coded signal and the receiver is capable of rapid, on-line, digital signal processing optimised for the user. The lower sound penetration required for modern-sediment mapping will ease the problems of operating with low-power, coded or parametric sound sources. The chirp sonar is one form of a coded source that is designed for good penetration. Others may follow using more complex and higher resolution codes. For discrimination of bottom materials, dual beams at vertical and acute angles will improve the discrimination factors compared to a single beam. A dual beamwidth on the vertical axis may be equally effective.

Another useful improvement in hardware would be the reduction of transducer motion to minimize the number of survey days lost due to wave conditions. The usual methods include tow bodies, servo-mechanical stabilizers, phased-array beam pointers and transmission gates that act according to the attitude of the launch. Each has its advantages and costs which must be balanced against the costs of the survey. The phased-array approach has the greatest potential in future developments (no moving parts and high ping rate) providing it is well done.

Software developments should concentrate on signal processing to optimize the capability to see and interpret layers of ten centimetres or less in a few metres of penetration. In the case of the Chirp sonar, this could involve reprogramming to operate on shallow signals and take full advantage of its digitizer. All sounders could benefit from improvements in data presentation. Very small deviations in the back-scattering strength of the bottom must be detected because some layer interfaces produce very little or a gradual change in acoustic impedance. This means extracting faint deviations in echo intensity from the noise and from the much larger bottom-reverberation signal. Even moderate changes in impedance must be picked out from a highly speckled background caused by modulations of the echo by transducer motion over the bottom (Denbigh and Tucker 1983). Some forms of analysis (Ford and Rukavina 1991) may alleviate this problem and it may also be useful to explore attenuation patterns in combination with backscattering (Guigné, pers. communication). Colour presentations are the best means of contrasting adjacent levels of intensity. If a black and white record must be used, then a plot of the echo envelope for each ping is more revealing than a grey scale. Finally, the beginnings of neural-network analysis in some disciplines (Ramani et al. 1990) have shown the power of these analysers in assisting in classification of echoes. This may be applied to identifying bottom types once the best combinations of input to the network are decided.

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LIST OF FIGURES

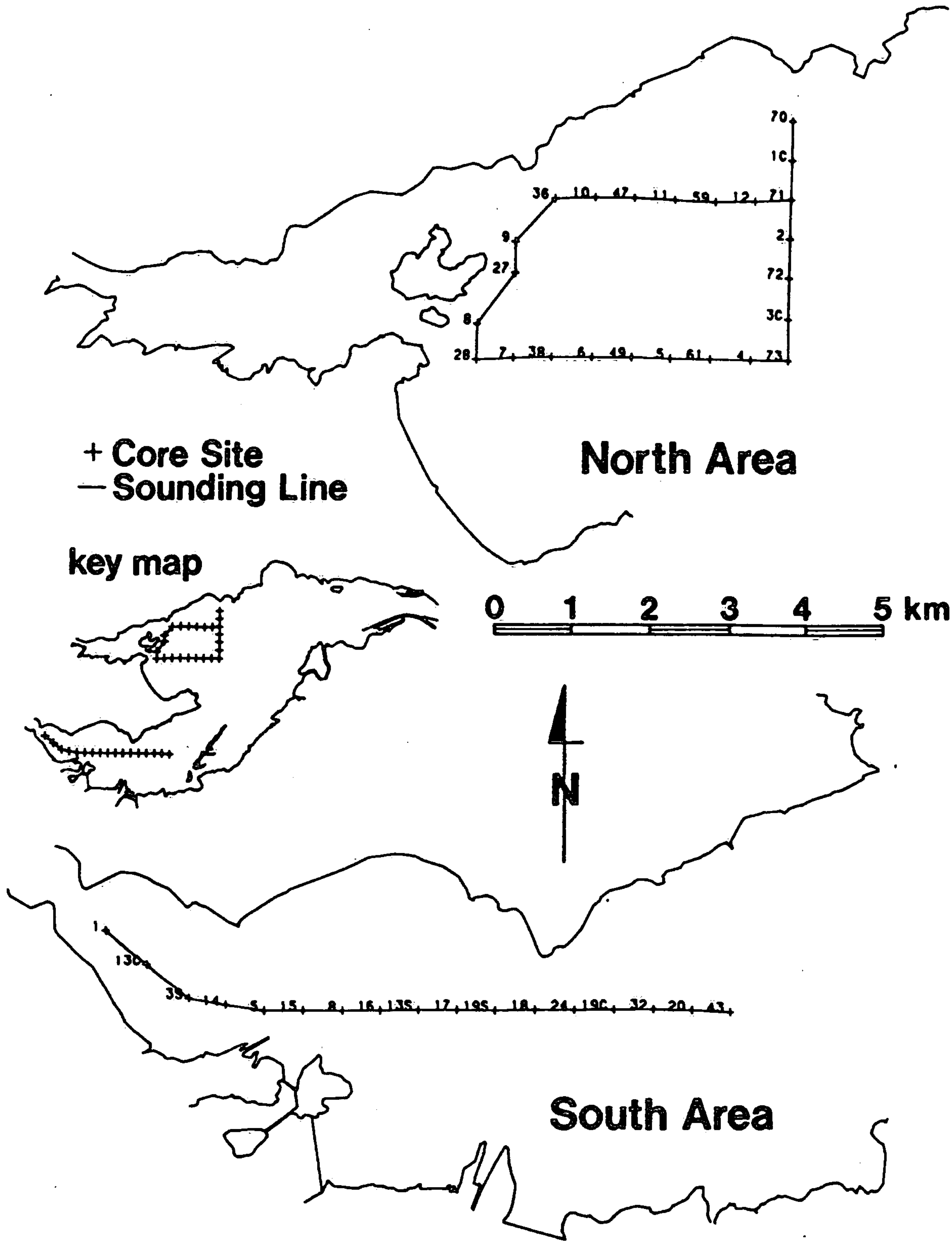

Fig. 1 Survey grid, Lac Saint-Louis

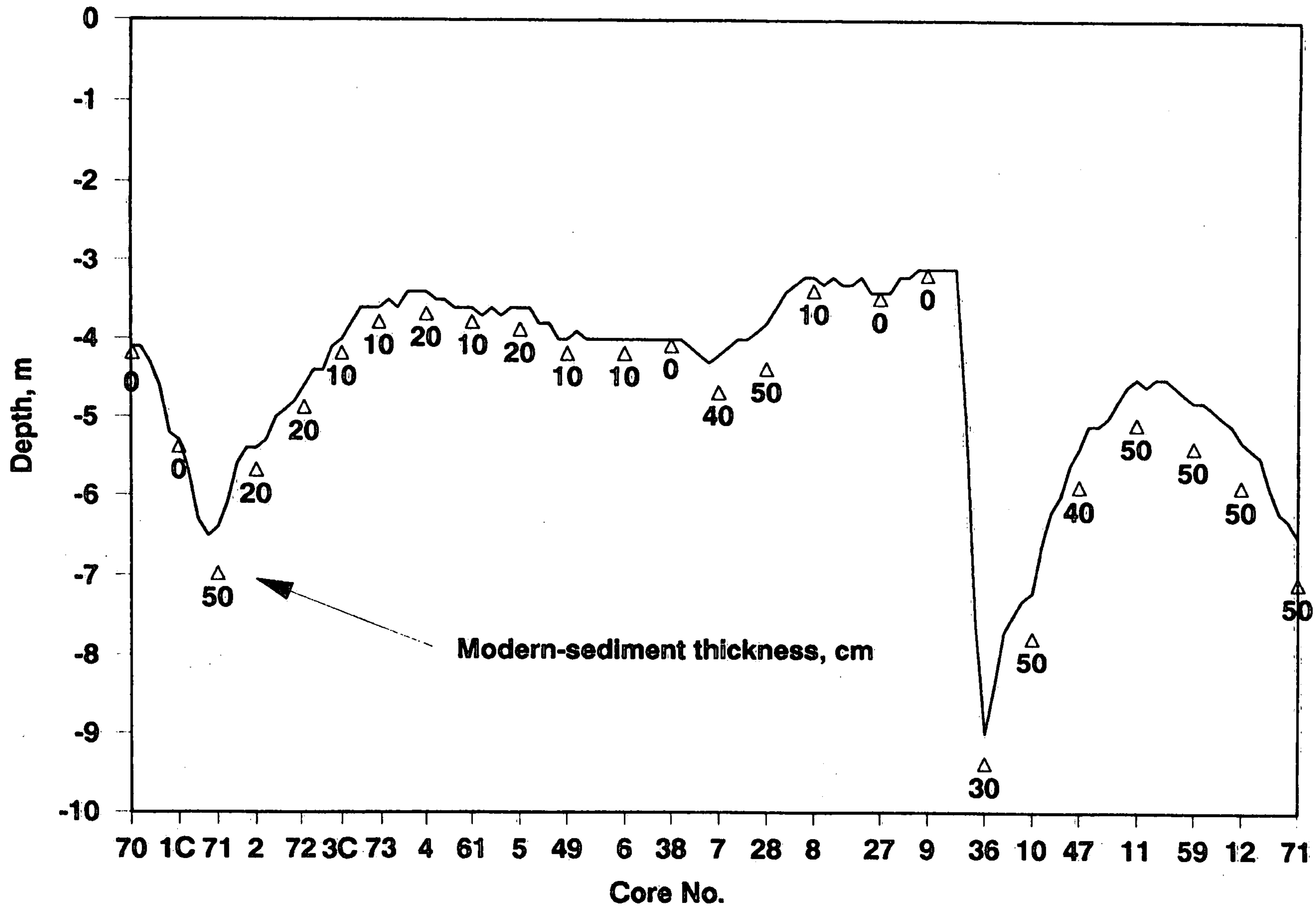

Fig. 2. Depth Profile, North Area

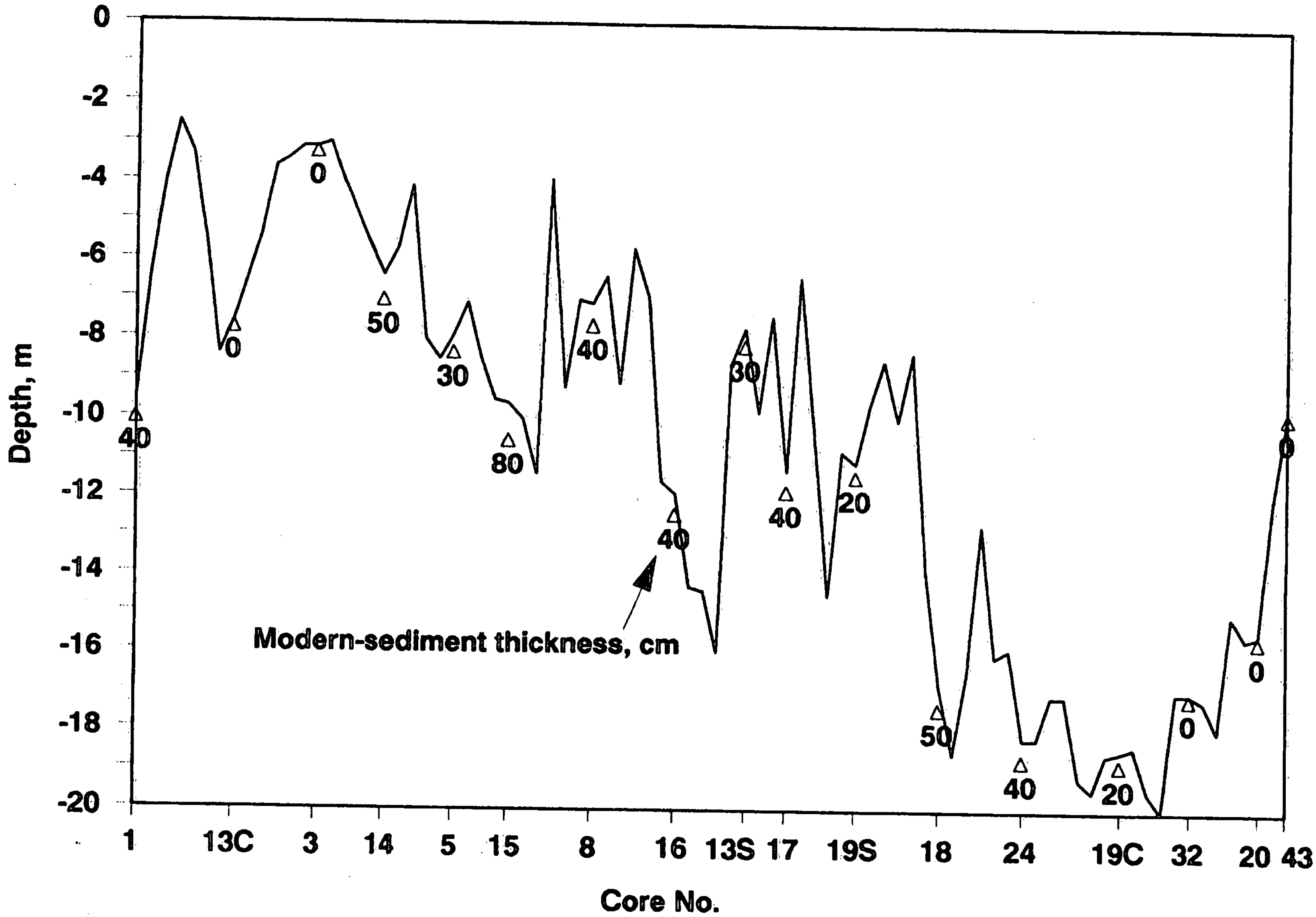

Fig. 3. Depth Profile, South Area

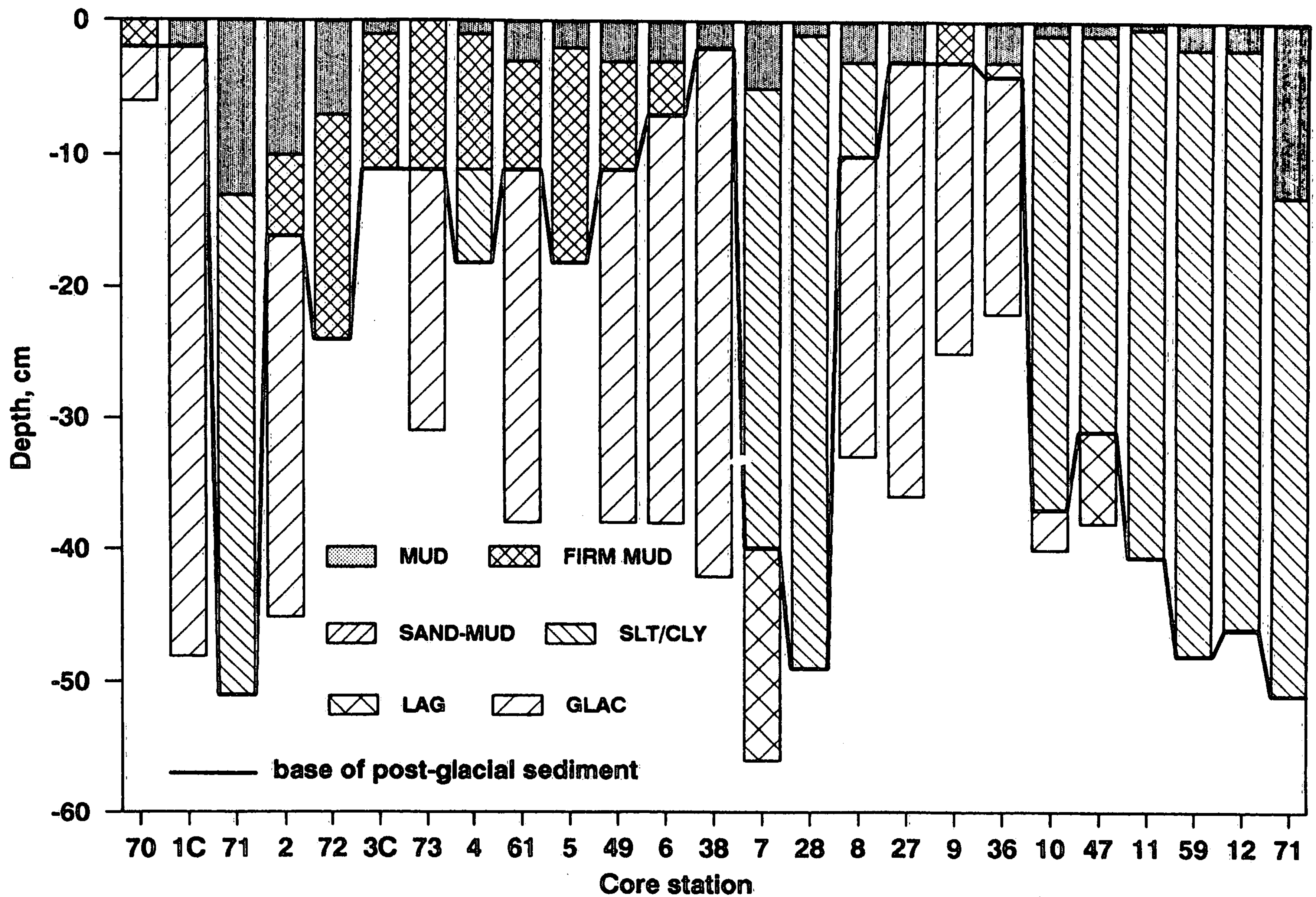

Fig. 4. Modern-sediment Thickness, North Area

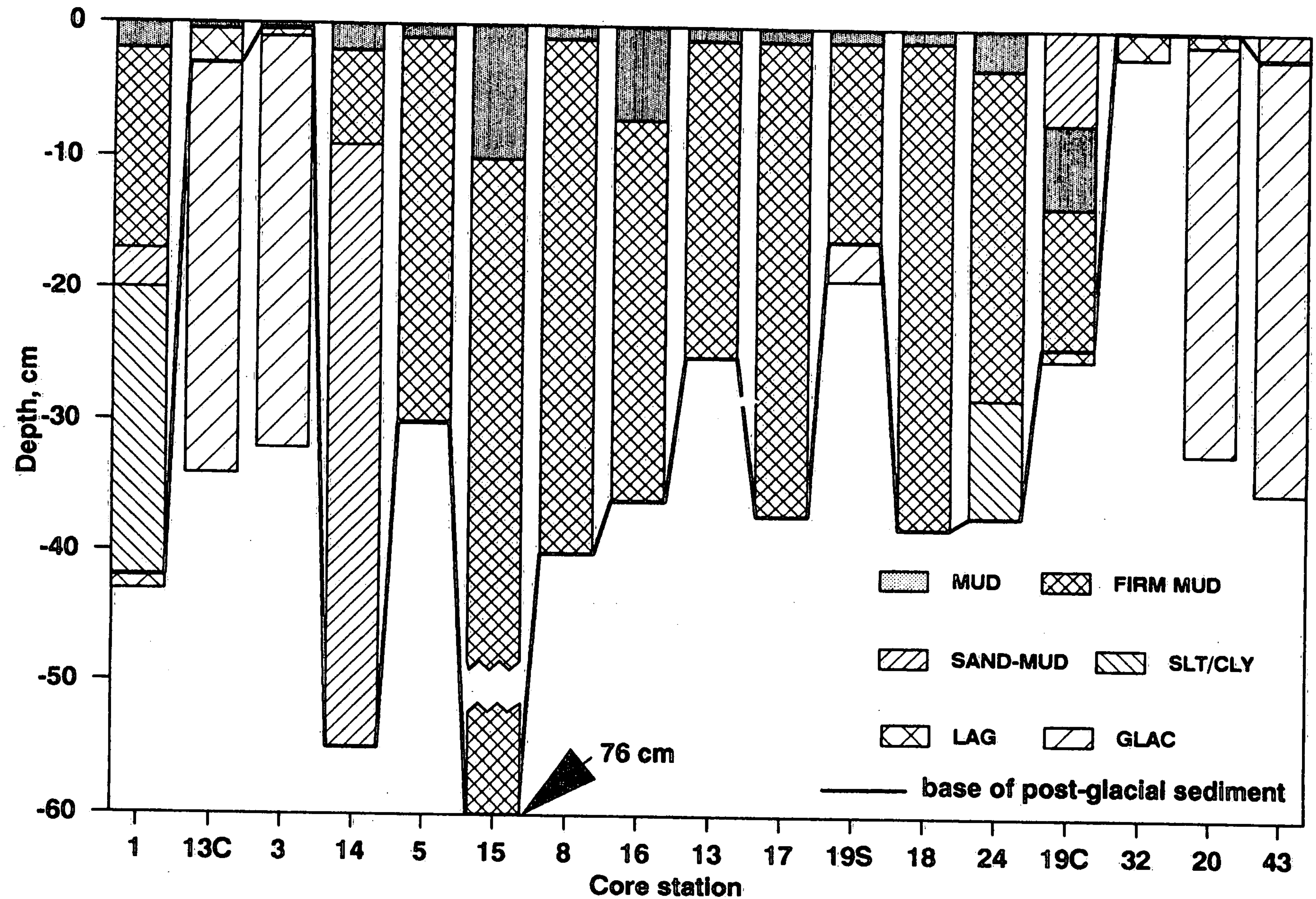

Fig. 5. Modern-sediment Thickness, South Area

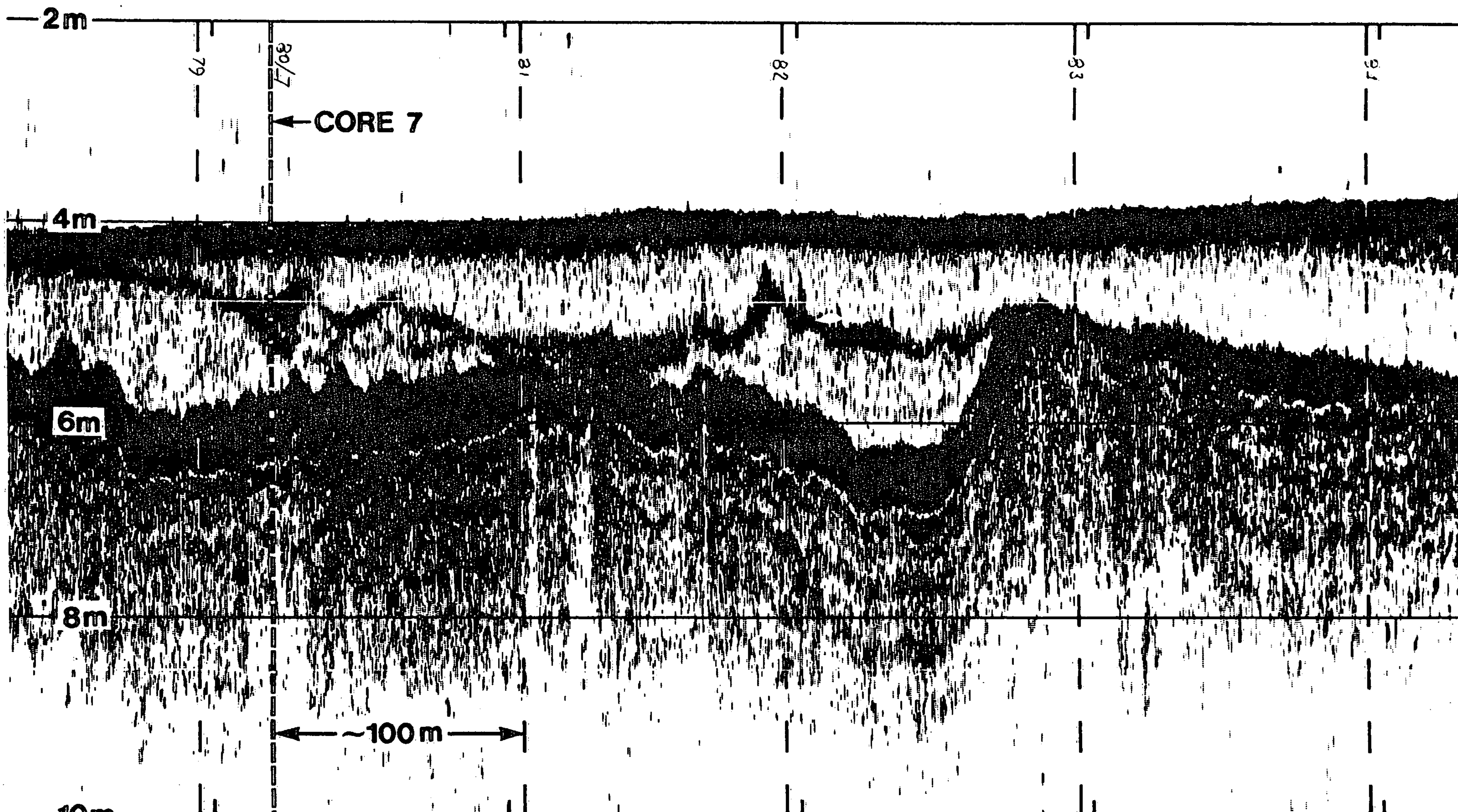

Fig. 6 Biosonics 101 record (reduced 20%)

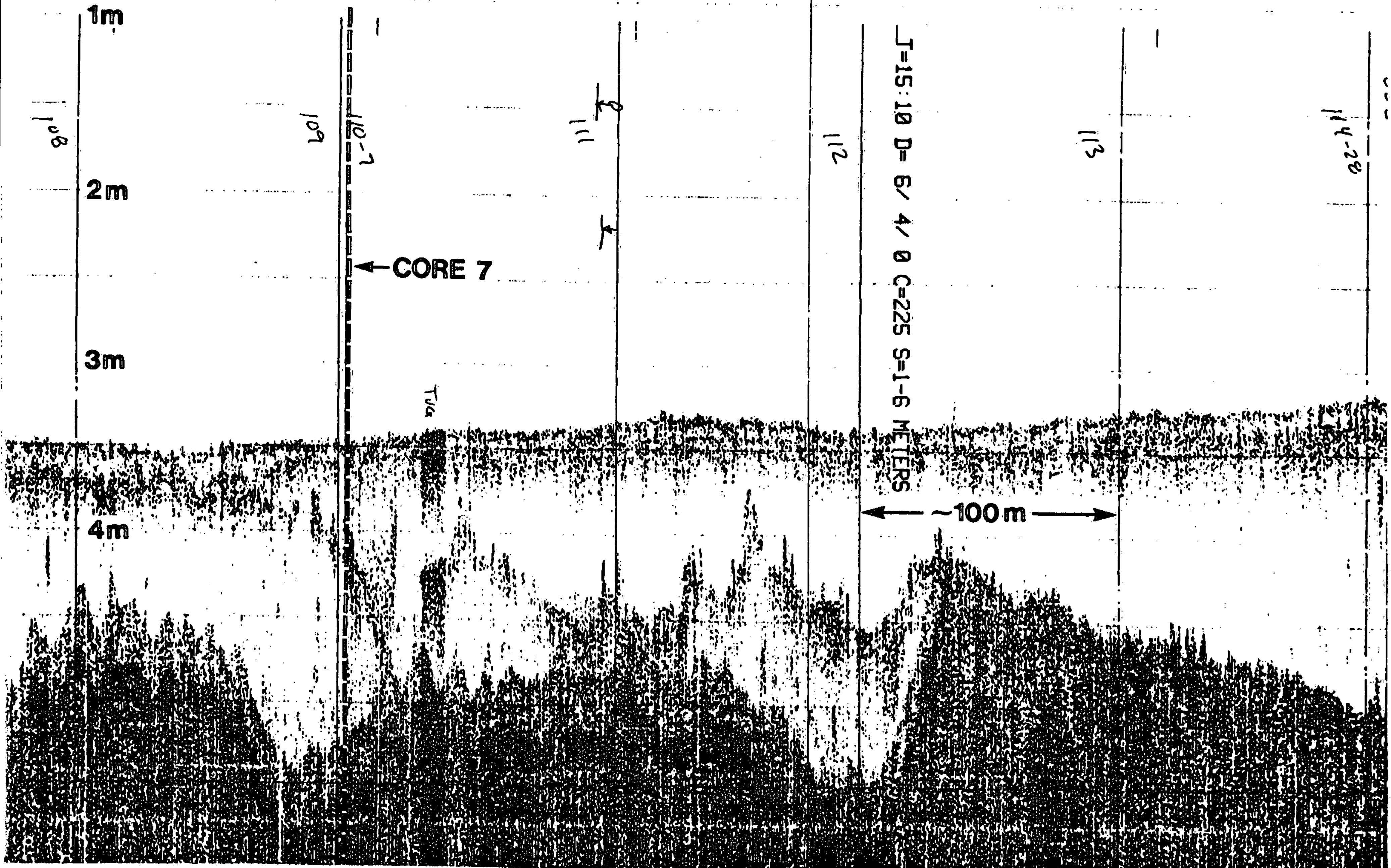

Fig. 7 Datasonics SBP220 record (reduced 20%)

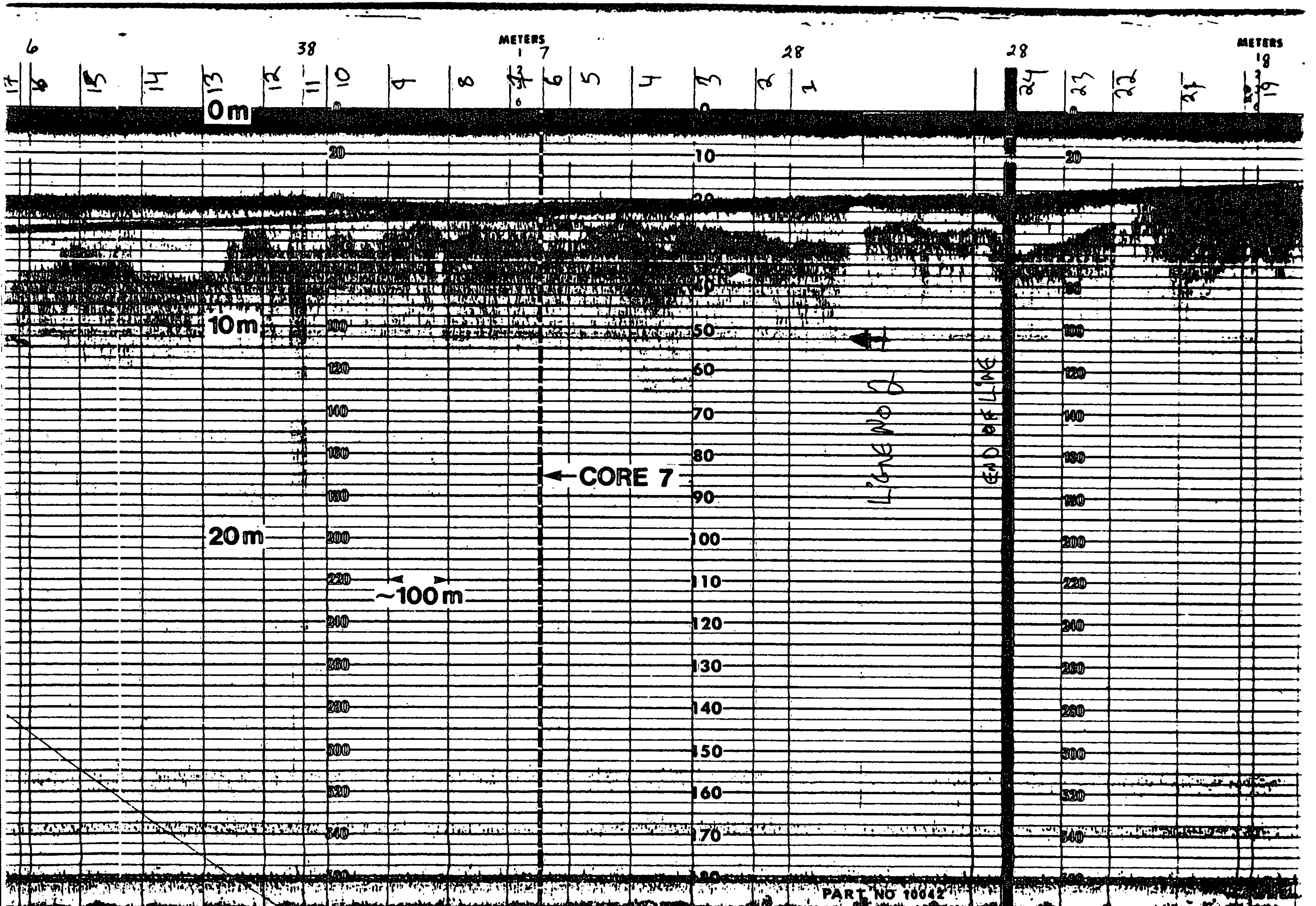

Fig. 8 Edo 9040 record (full scale)

APPENDIX 1

Echo-sounder specifications

ECHO-SOUNDER SPECIFICATIONS*

Brand & Model #	Oper. freq. kHz	Burst time μs	Beam width deg	Pulse power kW	Rep. rate pps	Rec. Sens. dB	Rec. BW kHz	Grey shades
BioSonics:								
Model 101	38	100	20(@-3dB)	214**	10	-12	10	3
Model 105	420	200	6(@-6dB)	216**	10	+6	10	3
Datasonics:								
SBP220	28 200	100	20(@-3db) 5(@-3dB)	0.8	8	+19	10	15
DSP601-603	2-10 (chirp)	20000	variable	1-2 (variable & compensating)	2	adj.	20	15
Edo:								
Model 9040	24	250	20(@-3dB)	0.8	8	adj.	2	2***

* front-panel settings and advertised features

** as source level dB re μPa @ 1m

*** modulated to give variable grey

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