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MINISTÈRE DE L'ÉNERGIE, DES MINES ET DES RESSOURCES
DEPARTMENT OF ENERGY, MINES AND RESOURCES

Open File 1376

GEOTECHNICAL INVESTIGATIONS OF THE NEAR-SHORE ZONE, NORTH HEAD, RICHARDS ISLAND, N.W.T.

Compiled and Edited by

P.J. Kurfurst[1]

Contributing Authors

S.R. Dallimore[1], J.A. Hunter[1], M.F. Nixon[1], S. Pullan[1]
W.D. Harrison[2] and J.L. Morack[2]

August 1986

[1] Geological Survey of Canada, Terrain Sciences Division, Ottawa, Ontario
[2] University of Alaska, Physics Department and Geophysical Institute, Fairbanks, Alaska, U.S.A.

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1. INTRODUCTION

P.J. Kurfurst

A multi-discipline program of detailed geotechnical investigations of the near-shore zone sediments was carried out off North Head, Richards Island, near Tuktoyaktuk, N.W.T. This program, undertaken in an area near proposed pipeline routes, was a continuation of investigations carried out by the Geological Survey of Canada in this general area in previous years (Kurfurst, 1984). The field work, supported by a mobile "cat train" camp, started April 4 and was completed April 26, 1986; installation of thermistor cables was carried out during August 1985. The field program was entirely financed by the Office of Energy Research and Development (OERD).

The objective of the program was to provide detailed information required for evaluation of physical and engineering properties of the seabottom sediments and to correlate and compare them with their geophysical properties. This data will be used as a base for the development of the comparable model between geophysical and geotechnical parameters of various soils, their depositional environments and ice distribution.

The major part of the field program consisted of drilling, sampling, instrumenting and testing of seven boreholes drilled through the ice and water column ranging in depth from 0.30 m to 1.80 m. All boreholes were drilled to the depth of approximately 30 m below seabottom. The general location of the investigated area and the detailed location of the boreholes are shown in Figures 1-1 and 1-2 respectively.

The multi-disciplinary approach used throughout the program required participation of scientists and technical personnel from various scientific fields. GSC participants, all members of the Terrain Sciences Division, included J. Bisson,

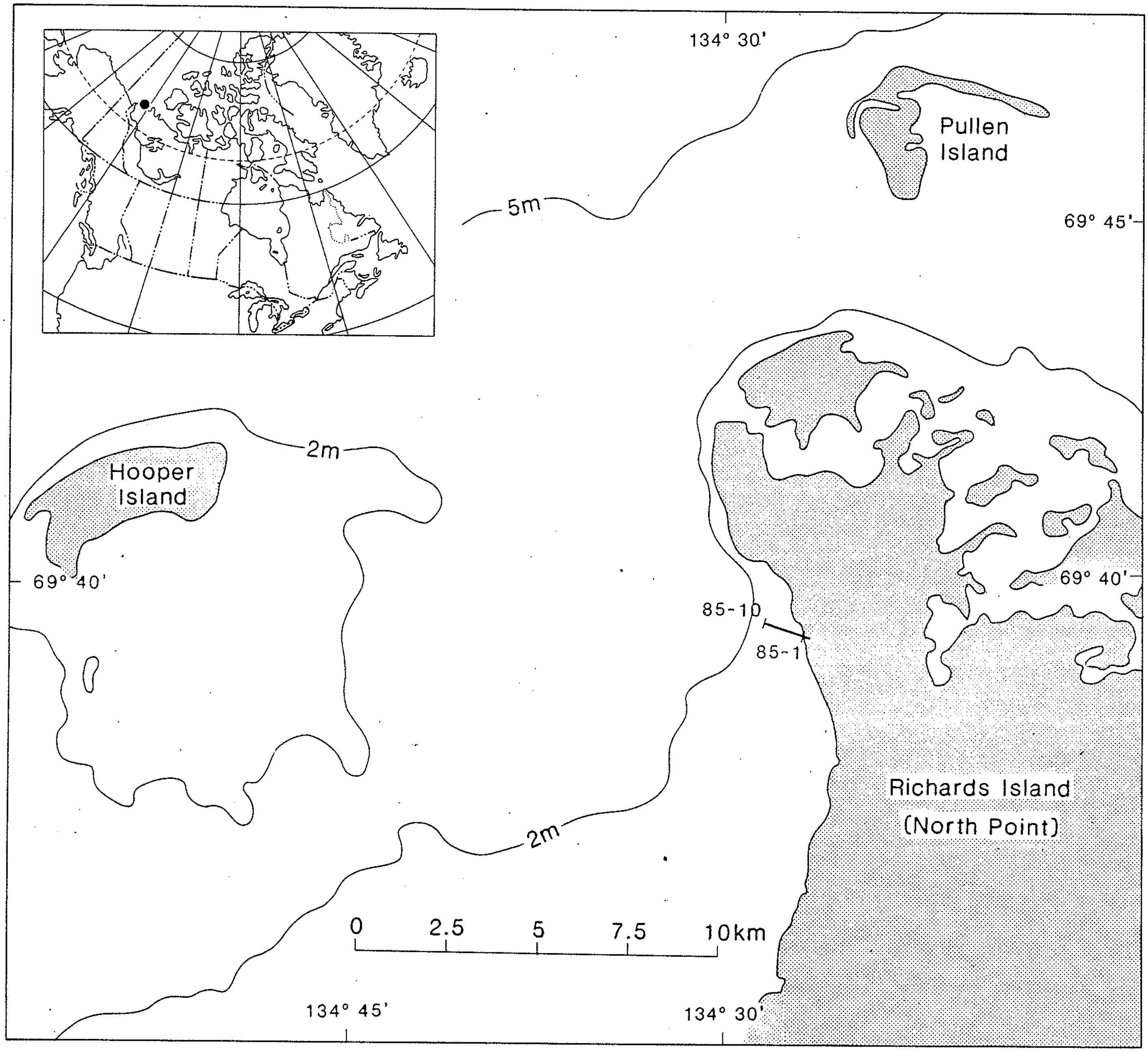


Fig. 1-1: General location map

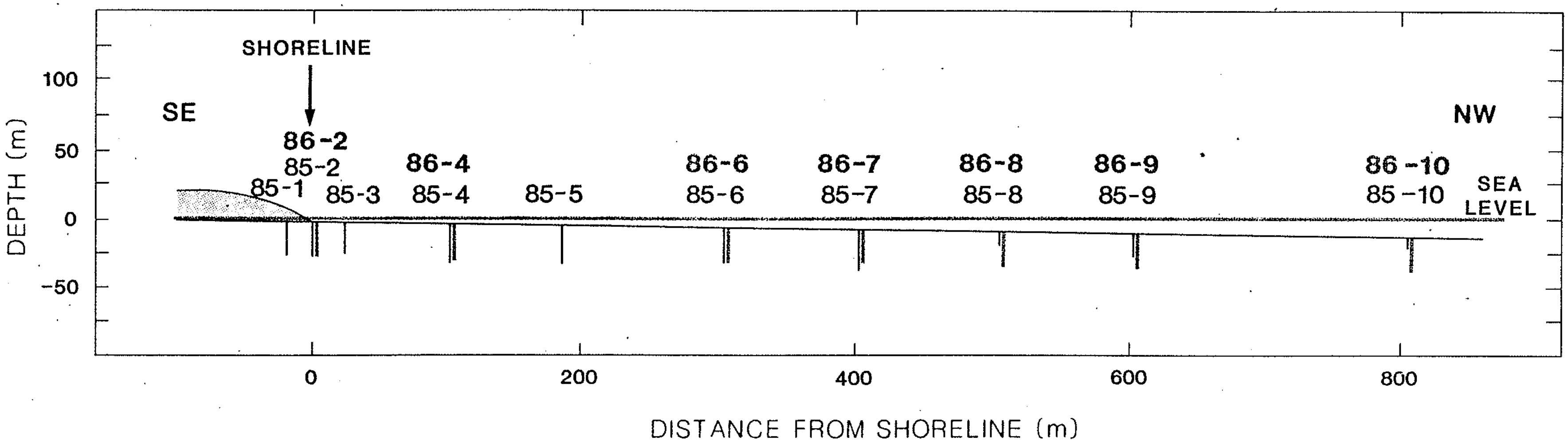


Fig. 1-2: Detailed locations of boreholes

S.R. Dallimore, J.A. Hunter, P.J. Kurfurst, E.J. Norminton and S. Pullan from the Terrain Dynamics Subdivision and M.F. Nixon from the Quaternary Geology Subdivision. W.D. Harrison and J.L. Morack from the University of Alaska in Fairbanks, U.S.A. evaluated data gathered during the borehole heating experiment and describe the results in Chapter 12.

The program components included:

Geology and geological engineering: drilling, sampling, core logging, core temperature measurements, cone penetrometer tests, surficial mapping, and determination of standard physical properties (moisture content, grain size, Atterberg limits).

Geophysics: sub-seabottom temperature measurements, seabottom seismic refraction measurements, uphole seismic measurements, EM-34 measurements, borehole heating tests and radar profiling.

The details of the program field data are described and preliminary results discussed in the following chapters.

2. SURFICIAL GEOLOGY

S.R. Dallimore

North Head is situated at the northern end of Richards Island approximately 25 kilometres northeast of the Mackenzie Delta (Fig. 1-1). The terrain in the North Head area is flat to gently rolling with numerous small lakes, some of which have been inundated by the sea. Local relief is usually less than 15 metres in the north and increases from 15 to 30 metres towards the south. Elevations are generally higher towards the western shore where actively eroding bluffs are exposed to wave action. The offshore profiles in the vicinity of North Head show a gently dipping shoreface with gradients from 0.3 to 1.0 m/km.

The major part of this Open File refers to data collected at drill sites on the western side of the North Head. The drilling and geophysics transects are situated in the nearshore environment, from the shoreline to approximately 1 kilometre offshore. This area and parts of the coast further to the south are characterized by extensive sand flats. At the drill sites multiple longitudinal bars have developed on the sand flats. Much of the sand making up the flats is thought to have derived from erosion of terrestrial sediments exposed along the coast. Similar to other coastal areas of the Beaufort Sea, the North Head area has been undergoing a marine transgression since at least late Wisconsin times (Hill et al., 1985). Measured coastal retreat rates between 1954 and 1985 vary from no change near the drill sites and to the south along the western coast of North Point, to an average rate of more than 3 m/yr near an active retrogressive thaw slide at the northwest tip of North Head.

Since sediments occurring at depth beneath seabottom on the west side of North Head were presumably once subaerially exposed, the field program was expanded in the summer of 1986 to include mapping and sampling of the onshore materials in the vicinity of North Head. Figure 2-1 summarizes the surficial geology of the area showing terrain units and geomorphic features. Recent sediments shown on the figure include lacustrine sands and silts (L) and marine sediments (m) exposed along the coast. Other recent sediments not shown include colluvium, which mantles most slopes in the region, and sporadic areas of eolian sand cover.

A major part of the North Head area has been mapped as a discontinuous veneer of glacial till overlying older pre-glacial sands (Mv/S). The till is thought to have been deposited during an early Wisconsinan glaciation (Rampton, in press) which covered much of the Tuktoyaktuk Peninsula and Richards Island. The till is generally quite thin and discontinuous, occurring as little more that a 0 to 30 cm thick bouldery horizon throughout most of the area shown on Figure 2-1. Some thicker deposits of till-like material were observed on the west side of North Head. In most cases, these materials have been reworked by thaw slide activity or solifluction.

The most common material exposed in North Head cliff sections beneath the till is the Kittigazuit sand (Rampton, in press). The sand is brown in colour and characteristically has a uniform grain size with no pebbles or cobbles. The sand is stratified with very large planar cross-beds often over 10 metres thick. In exposures on Summer Island and some of the outer islands to the west of North Head, the Kittigazuit sand is underlain by the brown grey Kidluit sand, the Hooper clay and the Kendall clay and sand. These sediments are not exposed in cliff sections in the North Head area, except sporadically on the west coast and on the northwest coast near Pullen Island. It is not known if these sediments occur at depth beneath the Kittigazuit at other locations.

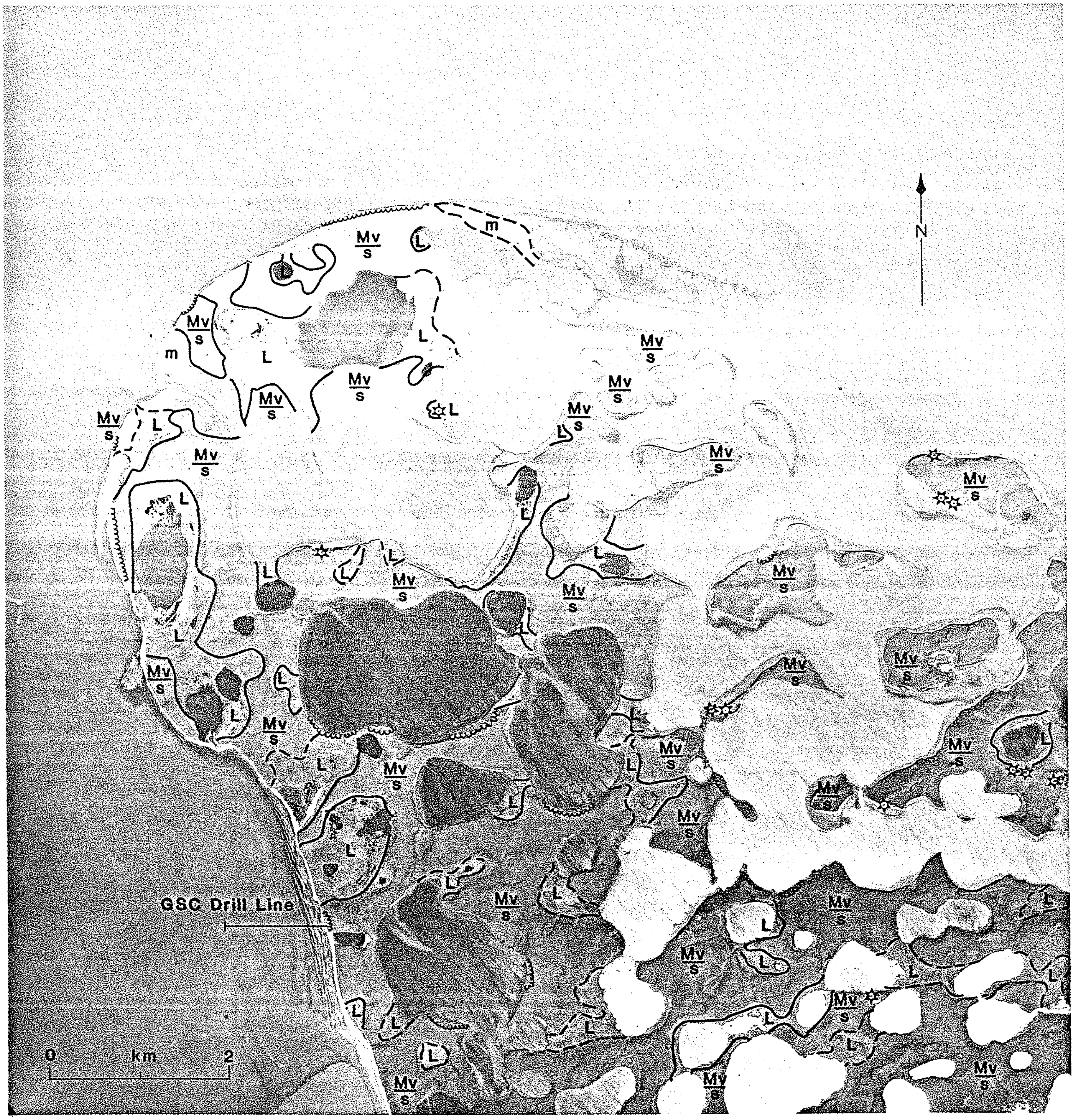


Fig. 2-1: Summary of surficial geology
m - recent marine sediments, L - lacustrine sediments, primarily sand and silt, Mv/s - discontinuous veneer of glacial till over pre-Wisconsin sands

The stratigraphy of the coastal bluffs in the vicinity of the drill sites was investigated in detail by cleaning off several sections with shovels and an hydraulic pump. A detailed section showing the stratigraphy exposed about 75 metres south of the drill sites is shown in Table 2-1. Immediately upslope of the drill transect, 1.5 metres of clayey silt diamicton which overlies 2.5 metres of brown sand is exposed near beach level in the base of a small retrogressive thaw flow slide. The flow slide probably resulted from thaw of a surface layer of ice rich glacial till.

Ground ice content of the soils exposed in sections in the immediate area of the drill sites was found to be quite low. Generally, the sands were ice poor even when scraped back to undisturbed soil. Where observed in section, the overlying till was also ice poor; however, it is expected that this finer-grained material may be locally ice rich. Significant amounts of excess ice and massive ice were found associated with sands and silts near the northwest tip of North Head, approximately 7 kilometres north of the drill sites. Further work is underway to determine the origin of these icy beds.

Table 2-1

Stratigraphic sequence in beach cliffs approximately 75 metres south of drill sites

Unit	Thickness (m)	Description
A	0 - 0.4	Peat and recent organics with silt.
B	0.4 - 0.8	Silt with clay, sand and pebbles to 10 cm diameter (ave. size 1 cm diam.), brown to grey brown; no stratification visible.
C	0.8 - 1.5	Sand, fine-to medium-grained, brown; some beds contain shell fragments, interbedded with irregular grey silty clay layers, occasional pod of clay up to 10 cm thick.
D	1.5 - 2.0	Sand, fine-grained, with silt and clay, grey brown; occasional mottled and irregular layers of grey clay and brown sand, very occasional pebbles.
E	2.0 - 9.0	Sand, medium-grained, brown; occasional orange brown sand and grey silty sand layers, irregular and disrupted layers of near vertical silty clay and silt.
	9.0 - Sea Level	Sandy slough.

3. DRILLING, SAMPLING AND CORE LOGGING

S.R. Dallimore, M.F. Nixon, P.J. Kurfurst

Midnight Sun Drilling Company Ltd. was contracted to provide the drilling operation, camp and the logistics support for the program. Seven boreholes were drilled northwest of Richards Island along a transect established in the fall of 1985 for installation of the thermistor cables. Location of the 1985 thermistor cable holes and 1986 boreholes along the transect are shown in Figure 1-2. The borehole numbers, their depths, ice and water depths and other relevant information are summarized in Table 3-1.

All boreholes were drilled using a mobile CME 750 drill on rubber tires with top drive head. Three furthermost boreholes were drilled using fluid while the remaining boreholes were dry-cored using a CRREL barrel.

An HW-casing drill string was used in wet boreholes with mud return at sea bottom. Drilling mud used was bentonite (Quikgel) and KCl. Sampling interval was 1.5 m with 7.6 cm diameter Shelby tubes deployed through the casing.

Inshore boreholes that were entirely frozen were cored with a CRREL barrel backed with 12 cm diameter flight augers which produced a continuous 10 cm diameter core.

All cores retrieved by the drillers were passed to the GSC staff working the shift. The temperature probe was immediately inserted in the bottom of each core to record its temperature. The core was then extruded into a split PVC casing, its length was measured and the core was photographed. A brief soil type description, and the presence of ground ice and its type, when observed, were then recorded. Samples for future standard physical tests were then selected and transfered into containers and the remaining were sealed and stored for future detailed logging and testing.

Table 3-1

Borehole Information

Borehole	Depth (m)	Ice and Water Depth (m)	Samples	
85-1	24.20	<1.00	No	Jet drilled
85-2	25.00	<1.00	No	
85-3	26.20	<1.00	No	
85-4	30.00	<1.00	No	
85-5	30.20	<1.00	No	
85-6	29.70	<1.00	No	
85-7	30.00	<1.00	No	
85-8	10.50	>1.00	No	
85-9	16.80	>1.00	No	
85-10	8.10	>1.00	No	
86-2	30.57	0.30	Intermittent	Rotary drilled
86-4	29.55	0.60	Intermittent	
86-6	30.69	0.90	Intermittent	
86-7	31.06	1.00	Continuous	
86-8	28.92	1.70	Intermittent	
86-9	29.21	1.80	Intermittent	
86-10	30.87	1.80	Intermittent	
Total	442.17			

After completion of drilling, all samples were transported either to the Inuvik or Ottawa laboratories where they were stored in temperature-controlled freezer or cold room for future testing.

The sediments encountered ranged from clays and silts to sands; ice encountered varied from visible ice to massive ice lenses. The drill logs showing soil types and presence/absence of ice are given in Figure 3-1.

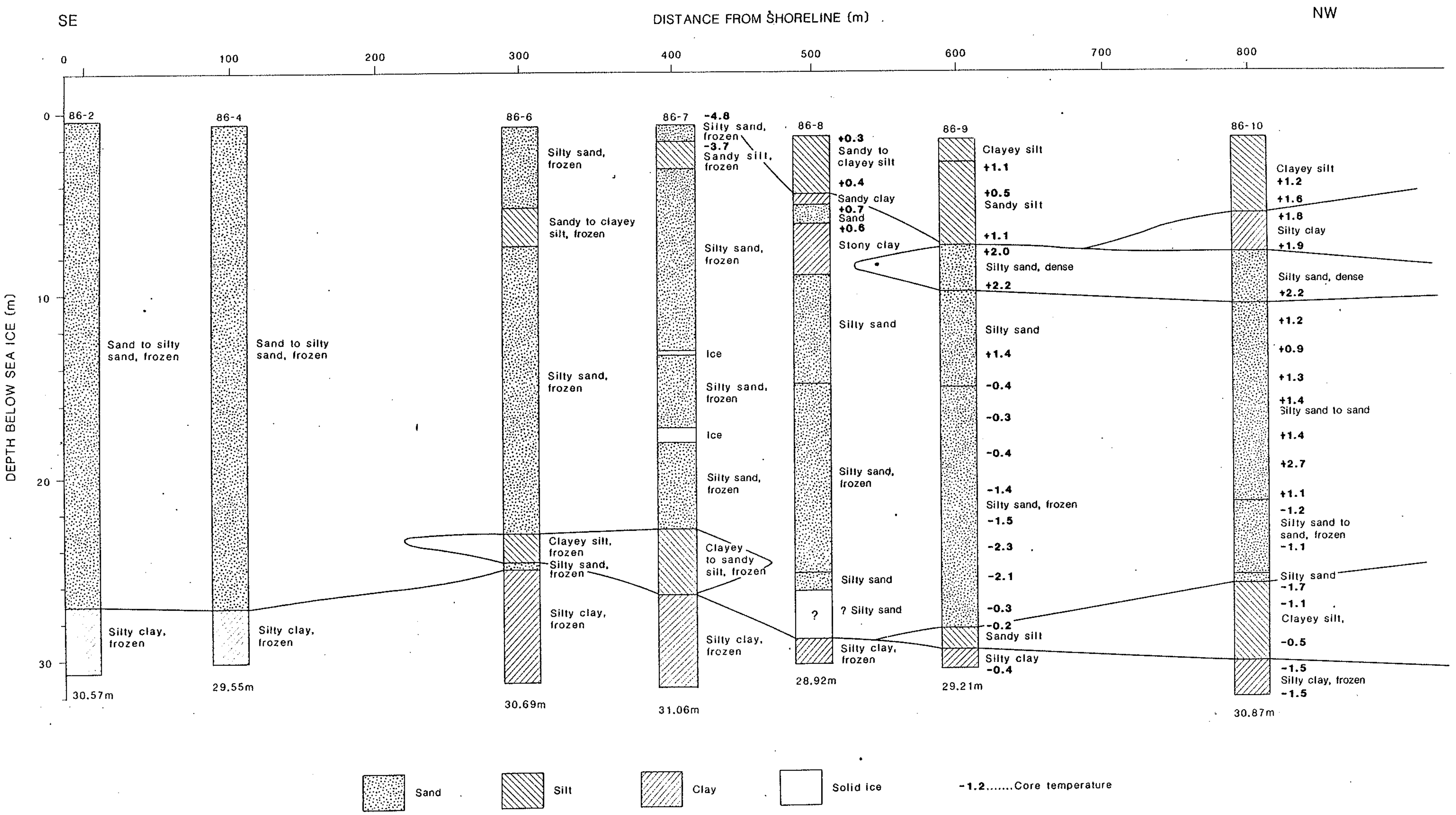


Fig. 3-1: Drilling logs

4. CONE PENETRATION TESTS

(P.J. Kurfurst)

The cone penetration testing was carried out by ConeTec Investigations Ltd. between April 4 and 8, 1986 as part of the drilling program (ConeTec Investigations Ltd., 1986). A "Hogentogler" electronic cone system and a 10 tonne compression type cone were used for all of the soundings. The following parameters were recorded at 5 cm intervals during each sounding: tip resistance, sleeve friction, dynamic pore pressure, temperature and cone inclination. Pore pressure dissipation was recorded at 5 second intervals during pauses in the penetration. A complete set of baseline readings was taken before and after each sounding to determine temperature shifts needed for data corrections when required.

Cone penetration tests were usually undertaken 3 to 5 m from the borehole location to avoid any disturbance which may have been caused by drilling. Prior to each sounding, a hole was augered through the ice and steel casing was installed to the seabottom to prevent buckling of the cone rods during penetration. The cone was pushed using the CME 750 drill rig used for conventional drilling, which had a down-pressure capacity of 10 tonnes.

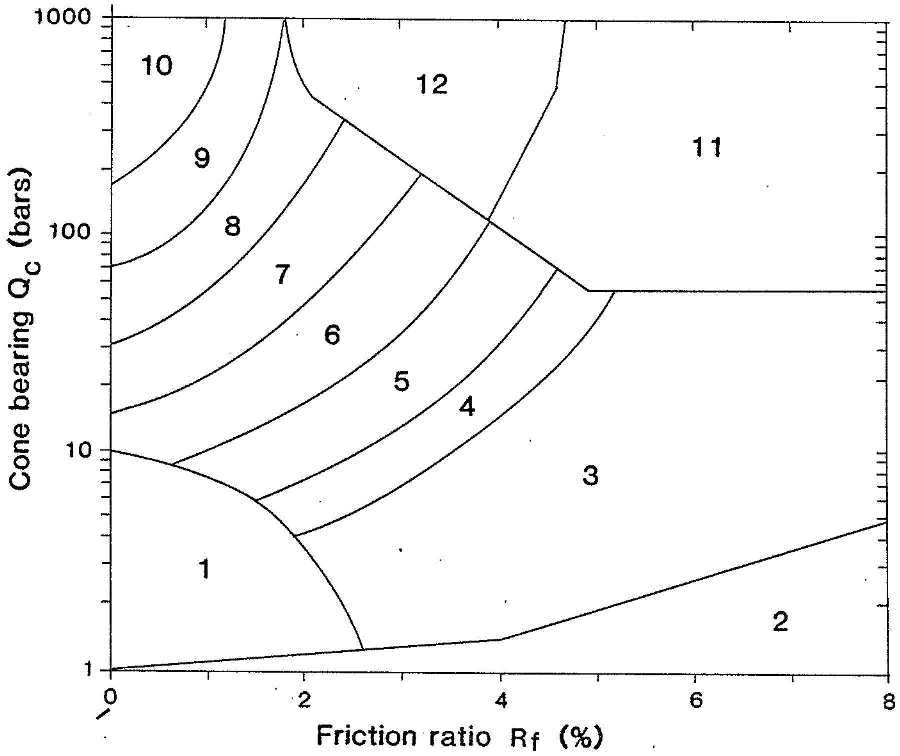
A total of five cone penetration tests were carried out to depths varying from 4 m to 18 m below seabottom at locations near boreholes 86-8, 86-9 and 86-10. Table 4-1 presents a summary of the core penetration tests performed.

The stratigraphic interpretation of the cone penetration test data is based on relationship between cone bearing, Qc and sleeve friction, F_s. The friction ratio, R_f (sleeve friction divided by cone bearing) is a calculated parameter which is used to infer soil behaviour type using the chart shown in Figure 4-1. Generally, cohesive soils have high friction ratios and low cone

Table 4-1

Cone Penetration Testing Summary

Date	Hole No.	Penetration Below Seabottom (m)	Remarks
4/4/86	86-10a	6.2	Stopped on dense sand
5/4/86	86-9	4.1	Stopped on dense sand
6/4/86	86-8a	10.3	Stoped on dense sand
7/4/86	86-10b	18.6	Stopped on frozen ground
8/4/86	86-8b	13.2	Stopped on frozen ground
Total	5	52.4	



GSC

Zone	Q_c/N	Soil behaviour type
1	2	sensitive fine grained
2	1	organic material
3	1	clay
4	1.5	silty clay to clay
5	2	clayey silt to silty clay
6	2.5	sandy silt to clayey silt
7	3	silty sand to sandy silt
8	4	sand to silty sand
9	5	sand
10	6	gravelly sand to sand
11	1	very stiff fine grained (*)
12	2	sand to clayey sand (*)

(*) overconsolidated or cemented

Fig. 4-1: CPT classification chart

bearings and cohesionless soils have low friction ratios and high cone bearings. The cone penetration test data are presented in graphical form in Figures 4-2, 4-4, 4-6, 4-8, 4-10 and 4-11. Computer tabulations of the data recorded and of the interpreted soil behaviour types, based on cone penetration test soil behaviour chart (Fig. 4-1), are shown in Figures 4-3, 4-5, 4-7, 4-9 and 4-12.

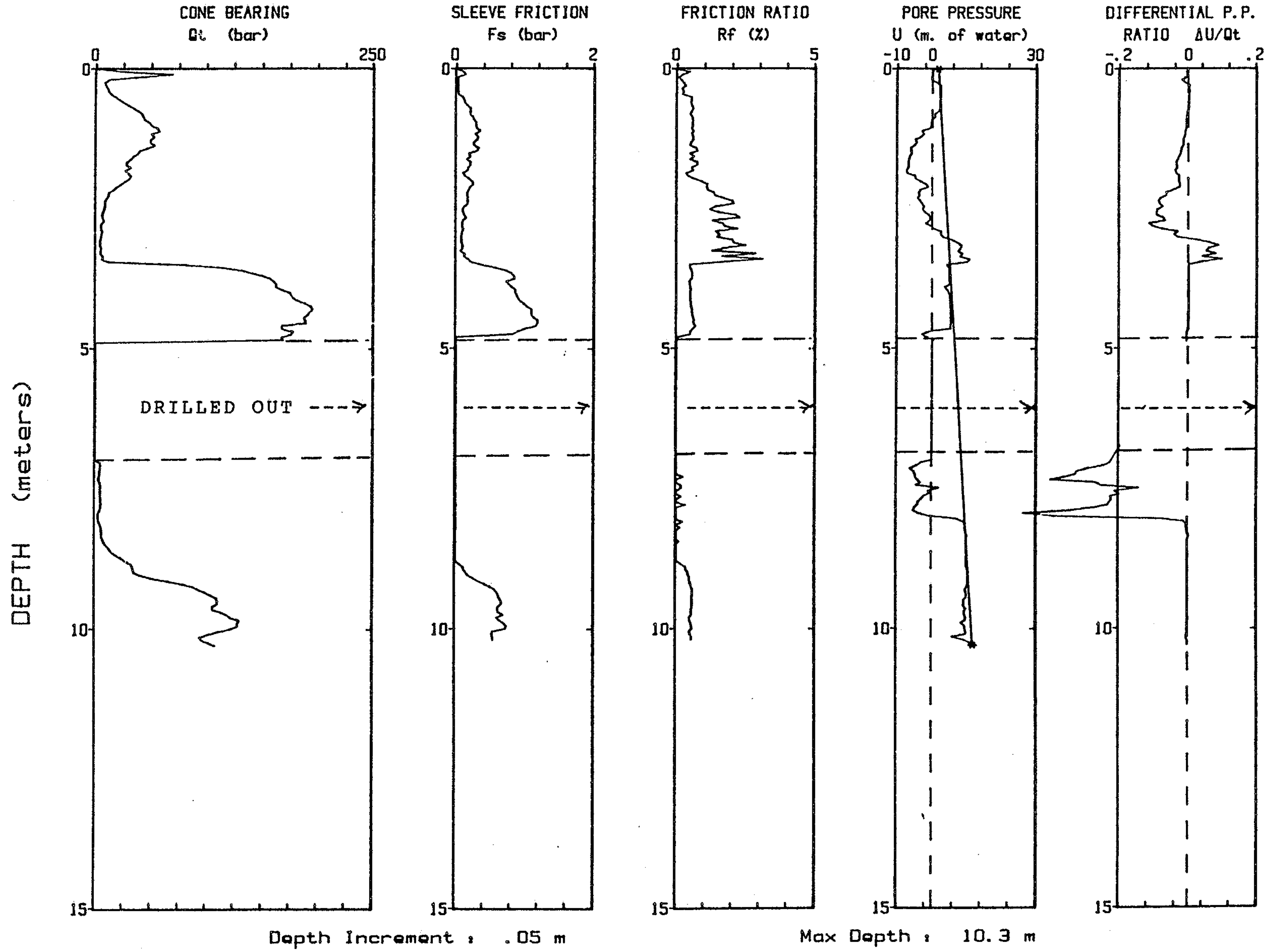
The interpreted results of the cone penetration test data suggest that the soils around holes 86-10a and 86-10b consist of sandy silt to a depth of about 2 m and grade gradually into silty clay to a depth of about 5.5 m. The underlying deposits are interpreted as compact to dense sands to a depth of 18.6 m. The soil profiles around holes 86-9, 86-8a and 86-8b are similar except for a thin layer of silty clay about 0.5 m thick encountered at a depth of about 6 m. These results agree well with drilling data which show similar soil types and indicate presence of hard, dense sand in boreholes 86-9 and 86-10.

The silty clay displays relatively high shear strength which is in part due to slight overconsolidation. This evidence of overconsolidation is supported by the dynamic pore presure response recorded during the sounding. The sand is also relatively dense which is also thought to be caused by overconsolidation.

The cone penetration tests were stopped either on contact with the dense sand layer or with frozen ground which the cone was unable to penetrate. The presence of frozen soils was confirmed by high positive pore pressures recorded.

GEOL SURVEY CANADA

CONTRACTOR: ConeTec DATE: 04/06/86 19:01 Page No: 1 / 1
SITE: NORTH HEAD N.W.T CONE: 10 TON PPE @ 5mm JOB # 86-02 CPT-8a



Depth Increment : .05 m Max Depth : 10.3 m

Fig. 4-2: CPT data-hole 86-8a

ConeTec Investigations Ltd.

Site :ConeTec
On Site Loc:NORTH HEAD N.W.T
Comments :86-02 CPT-8a
Tot. Unit Wt. (avg) : 19 kN/m^3

CPT Date :04/06/86 19:01
Cone Used :10 TON PPE @ 5mm
Water table (meters) : 0

DEPTH (meters)	(feet)	Qc (avg) (bar)	Fs (avg) (bar)	Rf (avg) (%)	SIGV' (kPa)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	Su kPa
0.50	1.64	21.78	0.05	0.24	2.30	silty sand to sandy silt	70-80	>48	7	UNDEFINED
1.00	3.28	38.05	0.21	0.56	6.89	silty sand to sandy silt	70-80	>48	13	UNDEFINED
1.50	4.92	49.20	0.29	0.58	11.48	sand to silty sand	70-80	46-48	12	UNDEFINED
2.00	6.56	29.88	0.18	0.59	16.08	silty sand to sandy silt	50-60	42-44	10	UNDEFINED
2.50	8.20	12.42	0.17	1.34	20.67	sandy silt to clayey silt	UNDFND	UNDFD	5	79.9
3.00	9.84	5.81	0.10	1.70	25.26	silty clay to clay	UNDFND	UNDFD	4	35.2
3.50	11.48	13.00	0.14	1.10	29.86	sandy silt to clayey silt	UNDFND	UNDFD	5	82.5
4.00	13.12	152.53	0.79	0.52	34.45	sand	>90	46-48	31	UNDEFINED
4.50	14.76	187.75	1.04	0.56	39.04	sand	>90	46-48	38	UNDEFINED
5.00	16.40	121.53	0.51	0.42	43.64	sand	80-90	44-46	24	UNDEFINED
5.50	18.04	0.00	0.00	0.00	48.23	undefined	UNDFND	UNDFD	UDF	UNDEFINED
6.00	19.69	0.00	0.00	0.00	52.82	undefined	UNDFND	UNDFD	UDF	UNDEFINED
6.50	21.33	0.00	0.00	0.00	57.41	undefined	UNDFND	UNDFD	UDF	UNDEFINED
7.00	22.97	0.00	0.00	0.00	62.01	undefined	UNDFND	UNDFD	UDF	UNDEFINED
7.50	24.61	4.64	0.00	0.06	66.60	sensitive fine grained	UNDFND	UNDFD	2	21.7
8.00	26.25	4.73	0.00	0.06	71.19	sensitive fine grained	UNDFND	UNDFD	2	21.7
8.50	27.89	6.12	0.00	0.05	75.79	sensitive fine grained	UNDFND	UNDFD	3	30.3
9.00	29.53	25.42	0.05	0.19	80.38	silty sand to sandy silt	<40	34-36	8	UNDEFINED
9.50	31.17	84.63	0.48	0.57	84.97	sand to silty sand	60-70	40-42	21	UNDEFINED
10.05	32.97	119.11	0.67	0.56	89.80	sand	70-80	42-44	24	UNDEFINED

Dr - All sands (Jamiolkowski et al. 1985) PHI - Robertson and Campanella 1983 Su: Nk= 15

**** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****

Fig. 4-3: CPT data computer tabulation - hole 86-8a .

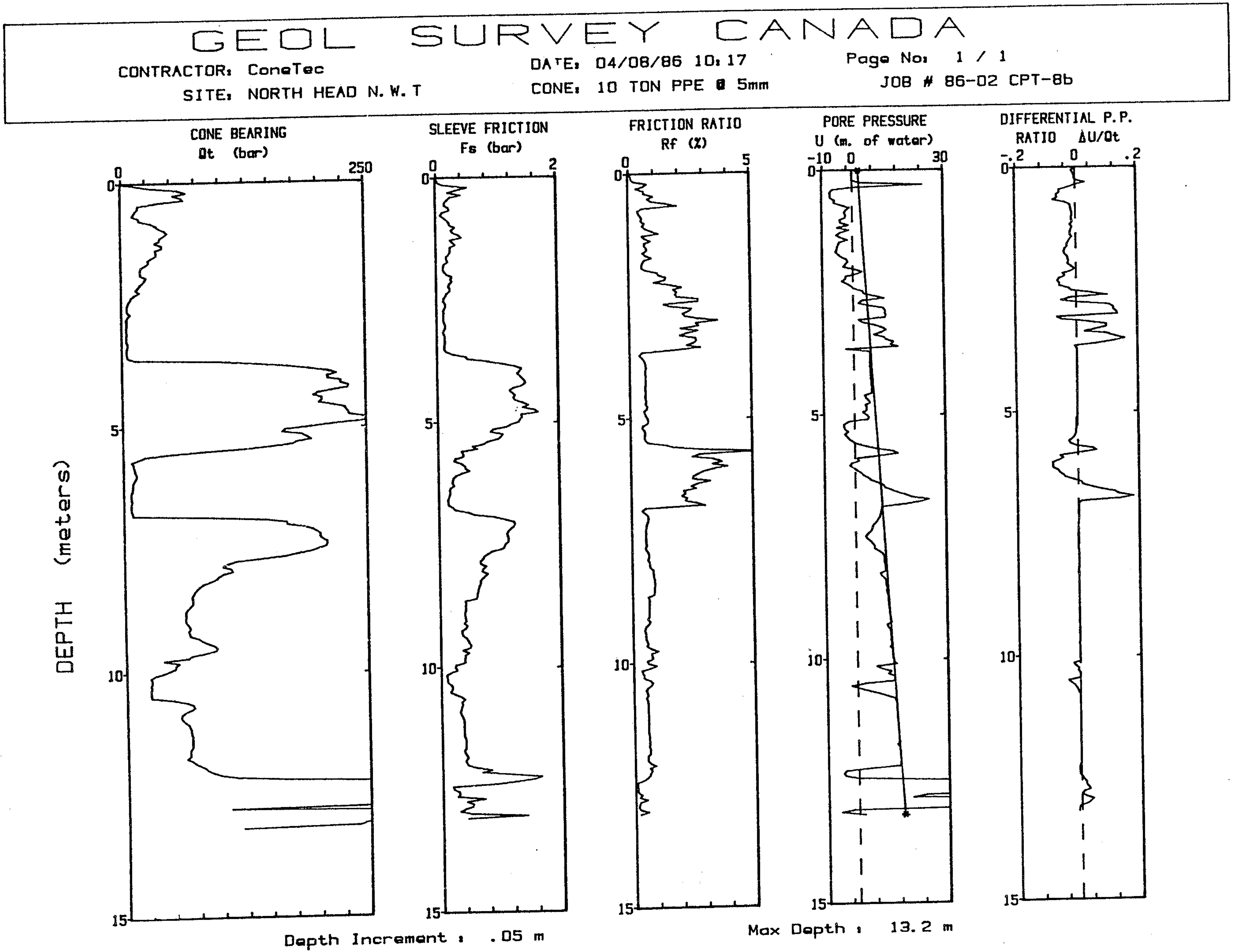


Fig.4-4: CPT data-hole 86-8b

ConeTec Investigations Ltd.

Site :ConeTec
On Site Loc:NORTH HEAD N.W.T
Comments :86-02 CPT-8b
Tot. Unit Wt. (avg) : 19 kN/m^3

CPT Date :04/08/86 10:17
Cone Used :10 TON FPE @ 5mm
Water table (meters) : 0

DEPTH (meters)	(feet)	Qc (avg) (bar)	Fs (avg) (bar)	Rf (avg) (%)	SIGV' (kPa)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	Su kPa
0.50	1.64	43.31	0.22	0.51	2.30	sand to silty sand	>90	>48	11	UNDEFINED
1.00	3.28	27.92	0.18	0.66	6.89	silty sand to sandy silt	60-70	46-48	9	UNDEFINED
1.50	4.92	38.49	0.29	0.74	11.48	silty sand to sandy silt	70-80	46-48	13	UNDEFINED
2.00	6.56	23.27	0.16	0.69	16.08	silty sand to sandy silt	50-60	42-44	8	UNDEFINED
2.50	8.20	11.88	0.18	1.55	20.67	clayey silt to silty clay	UNDFND	UNDFD	6	76.3
3.00	9.84	4.94	0.12	2.41	25.26	clay	UNDFND	UNDFD	5	29.4
3.50	11.48	4.57	0.12	2.58	29.86	clay	UNDFND	UNDFD	5	26.3
4.00	13.12	147.04	0.87	0.59	34.45	sand	>90	46-48	29	UNDEFINED
4.50	14.76	213.29	1.33	0.62	39.04	sand	>90	>48	43	UNDEFINED
5.05	16.57	229.39	1.44	0.63	43.87	sand	>90	46-48	46	UNDEFINED
5.55	18.21	160.56	0.94	0.58	48.69	sand	>90	46-48	32	UNDEFINED
6.05	19.85	15.68	0.42	2.67	53.28	clayey silt to silty clay	UNDFND	UNDFD	8	97.1
6.55	21.49	8.39	0.23	2.79	57.87	silty clay to clay	UNDFND	UNDFD	6	47.9
7.05	23.13	61.51	0.42	0.68	62.47	sand to silty sand	60-70	40-42	15	UNDEFINED
7.55	24.77	200.69	1.17	0.58	67.06	sand	>90	44-46	40	UNDEFINED
8.10	26.57	131.72	0.81	0.62	71.88	sand	70-80	42-44	26	UNDEFINED
8.60	28.22	79.08	0.68	0.86	76.71	sand to silty sand	60-70	40-42	20	UNDEFINED
9.15	30.02	64.44	0.46	0.71	81.53	sand to silty sand	50-60	40-42	16	UNDEFINED
9.65	31.66	75.59	0.41	0.55	86.35	sand to silty sand	60-70	40-42	19	UNDEFINED
10.15	33.30	58.36	0.39	0.67	90.95	sand to silty sand	50-60	38-40	15	UNDEFINED
10.65	34.94	25.24	0.15	0.58	95.54	silty sand to sandy silt	<40	32-34	8	UNDEFINED
11.15	36.58	60.34	0.32	0.54	100.13	sand to silty sand	50-60	38-40	15	UNDEFINED
11.65	38.22	66.19	0.37	0.57	104.72	sand to silty sand	50-60	38-40	17	UNDEFINED
12.15	39.86	69.23	0.40	0.57	109.32	sand to silty sand	50-60	38-40	17	UNDEFINED
12.65	41.50	217.00	0.88	0.41	113.91	sand	80-90	42-44	43	UNDEFINED
13.15	43.14	272.62	0.40	0.15	118.50	gravelly sand to sand	>90	44-46	45	UNDEFINED

Dr - All sands (Jamiolkowski et al. 1985) PHI - Robertson and Campanella 1983 Su: Nk= 15

**** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****

Fig. 4-5: CPT data computer tabulation - hole 86-8b

GEOL SURVEY CANADA

CONTRACTOR: ConeTec
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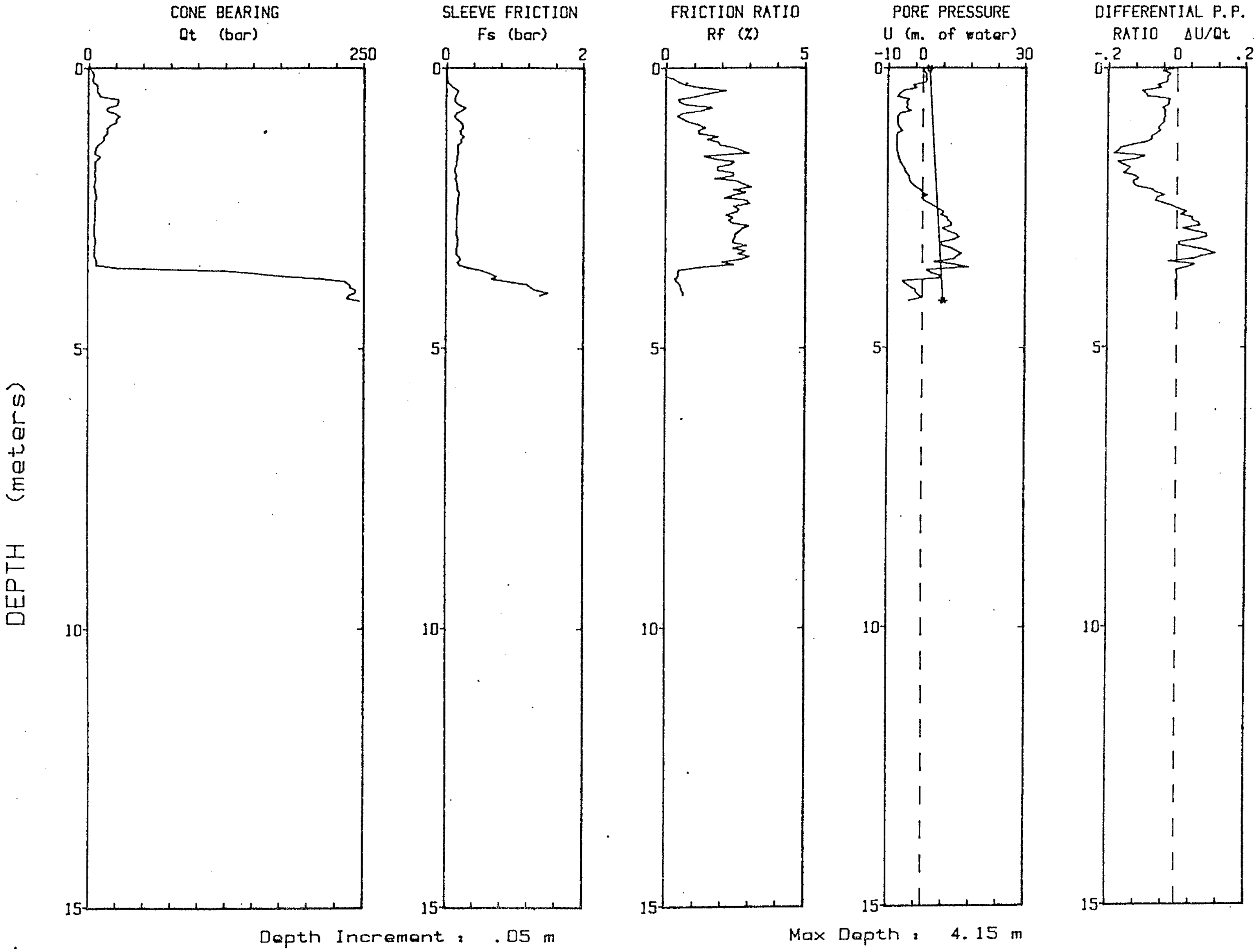
DATE: 04/05/86 19:12
CONE: 10 TON PPE @ 5mm
Page No: 1 / 1
JOB # 86-02 CPT-9a



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                         ConeTec  Investigations  Ltd.

     Site        :ConeTec                              CPT Date    :04/05/86 19:12
     On Site Loc:NORTH HEAD N.W.T                      Cone Used   :10 TON PPE @ 5mm
     Comments    :86-02 CPT-9a                         Water table (meters) : 0
     Tot. Unit Wt. (avg) : 19 kN/m^3
------------------------------------------------------------------------------------------------------------------
     DEPTH          Qc (avg)   Fs (avg)   Rf (avg)    SIGV'      SOIL BEHAVIOUR TYPE       Eq - Dr   PHI    SPT      Su
(meters)  (feet)     (bar)      (bar)       (%)       (kPa)                                  (%)     deg.    N       kPa
------------------------------------------------------------------------------------------------------------------
   0.50    1.64       6.79       0.06       0.94       2.30     sensitive fine grained     UNDFND   UNDFD    3       44.9
   1.00    3.28      24.09       0.18       0.74       6.89     silty sand to sandy silt   60-70    46-48    8   UNDEFINED
   1.50    4.92      11.88       0.20       1.68      11.48     clayey silt to silty clay  UNDFND   UNDFD    6       77.6
   2.00    6.56       6.89       0.14       1.97      16.08       silty clay to clay       UNDFND   UNDFD    5       43.7
   2.50    8.20       6.23       0.16       2.65      20.67       silty clay to clay       UNDFND   UNDFD    4       38.6
   3.00    9.84       5.74       0.15       2.54      25.26       silty clay to clay       UNDFND   UNDFD    4       34.7
   3.50   11.48       6.42       0.17       2.60      29.86       silty clay to clay       UNDFND   UNDFD    4       38.6
   4.00   13.12     188.24       0.90       0.48      34.45             sand                >90      >48    38  UNDEFINED
------------------------------------------------------------------------------------------------------------------

   Dr -  All sands (Jamiolkowski et al. 1985)     PHI -    Robertson and Campanella 1983       Su: Nk= 15

**** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****
```

Fig. 4-7: CPT data computer tabulation-hole 86-9

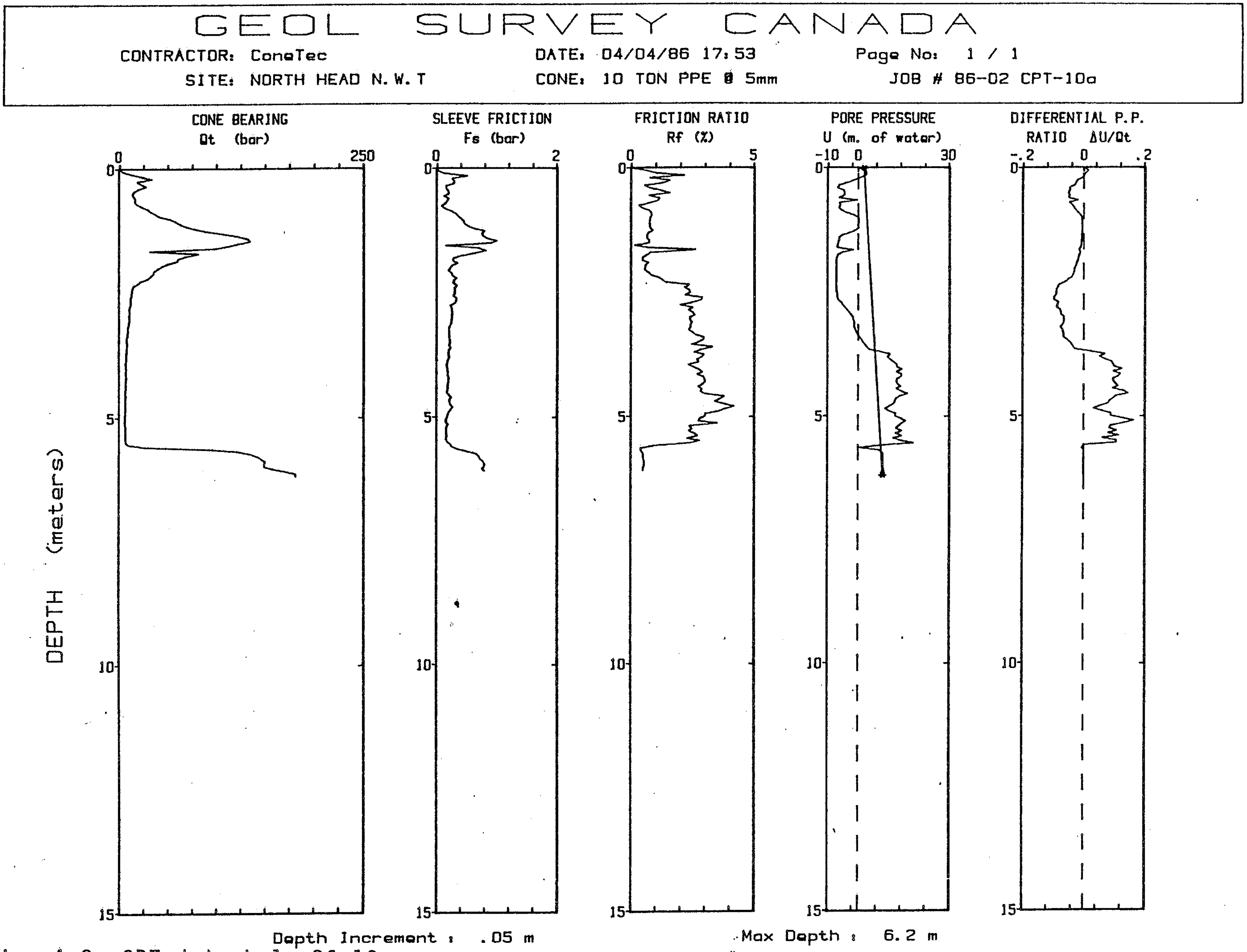

Fig. 4-8: CPT data-hole 86-10a

ConeTec Investigations Ltd.

Site :ConeTec
On Site Loc:NORTH HEAD N.W.T
Comments :86-02 CPT-10a
Tot. Unit Wt. (avg) : 19 kN/m^3

CPT Date :04/04/86 17:53
Cone Used :10 TON FPE @ 5mm
Water table (meters) : 0

DEPTH (meters)	(feet)	Qc (avg) (bar)	Fs (avg) (bar)	Rf (avg) (%)	SIGV' (kPa)	SOIL BEHAVIOUR TYPE	Eq - Dr (%)	PHI deg.	SPT N	Su kPa
0.50	1.64	19.06	0.22	1.15	2.30	sandy silt to clayey silt	UNDFND	UNDFD	8	126.
1.00	3.28	28.50	0.21	0.74	6.89	silty sand to sandy silt	60-70	46-48	10	UNDEFINE
1.50	4.92	97.92	0.71	0.72	11.48	sand to silty sand	>90	>48	24	UNDEFINE
2.00	6.56	64.34	0.41	0.63	16.08	sand to silty sand	80-90	46-48	16	UNDEFINE
2.50	8.20	22.63	0.28	1.24	20.67	sandy silt to clayey silt	UNDFND	UNDFD	9	148.
3.00	9.84	11.00	0.27	2.45	25.26	clayey silt to silty clay	UNDFND	UNDFD	6	69.
3.50	11.48	8.50	0.22	2.55	29.86	silty clay to clay	UNDFND	UNDFD	6	52.
4.00	13.12	6.92	0.19	2.77	34.45	silty clay to clay	UNDFND	UNDFD	5	41.
4.50	14.76	6.24	0.18	2.95	39.04	clay	UNDFND	UNDFD	6	36.
5.00	16.40	5.94	0.22	3.62	43.64	clay	UNDFND	UNDFD	6	33.
5.50	18.04	5.80	0.16	2.72	48.23	clay	UNDFND	UNDFD	6	32.
6.00	19.69	112.72	0.58	0.51	52.82	sand	70-80	44-46	23	UNDEFINE

Dr - All sands (Jamiolkowski et al. 1985) PHI - Robertson and Campanella 1983 Su: Nk= 15

**** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****

Fig. 4-9: CPT data computer tabulation-hole 86-10a

GEOL SURVEY CANADA

CONTRACTOR: ConeTec
SITE: NORTH HEAD N.W.T
DATE: 04/07/86 14:55
CONE: 10 TON PPE @ 5mm
Page No: 1 / 2
JOB # 86-02 CPT-10b

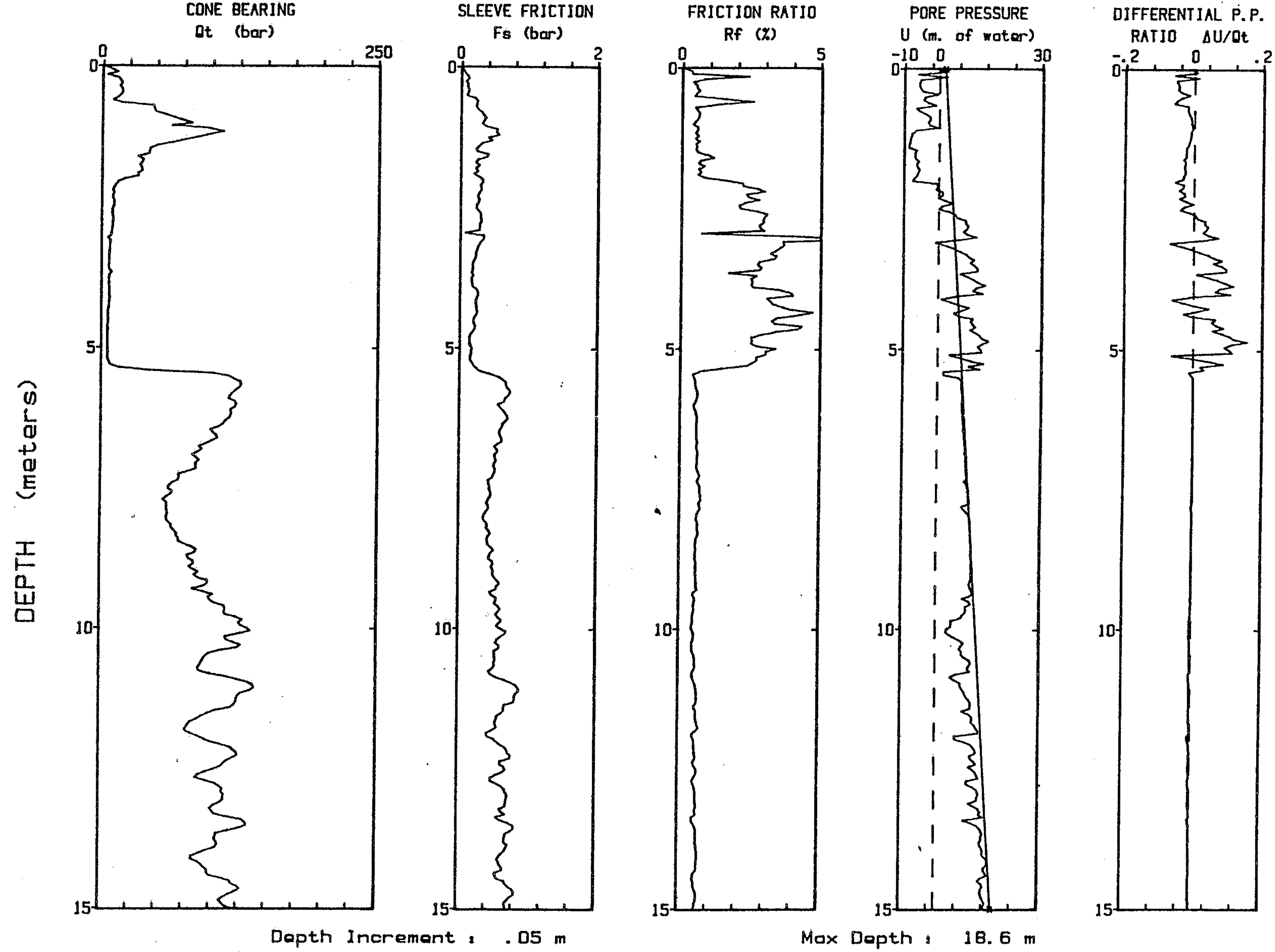

Fig. 4-10: CPT data-hole 86-10b

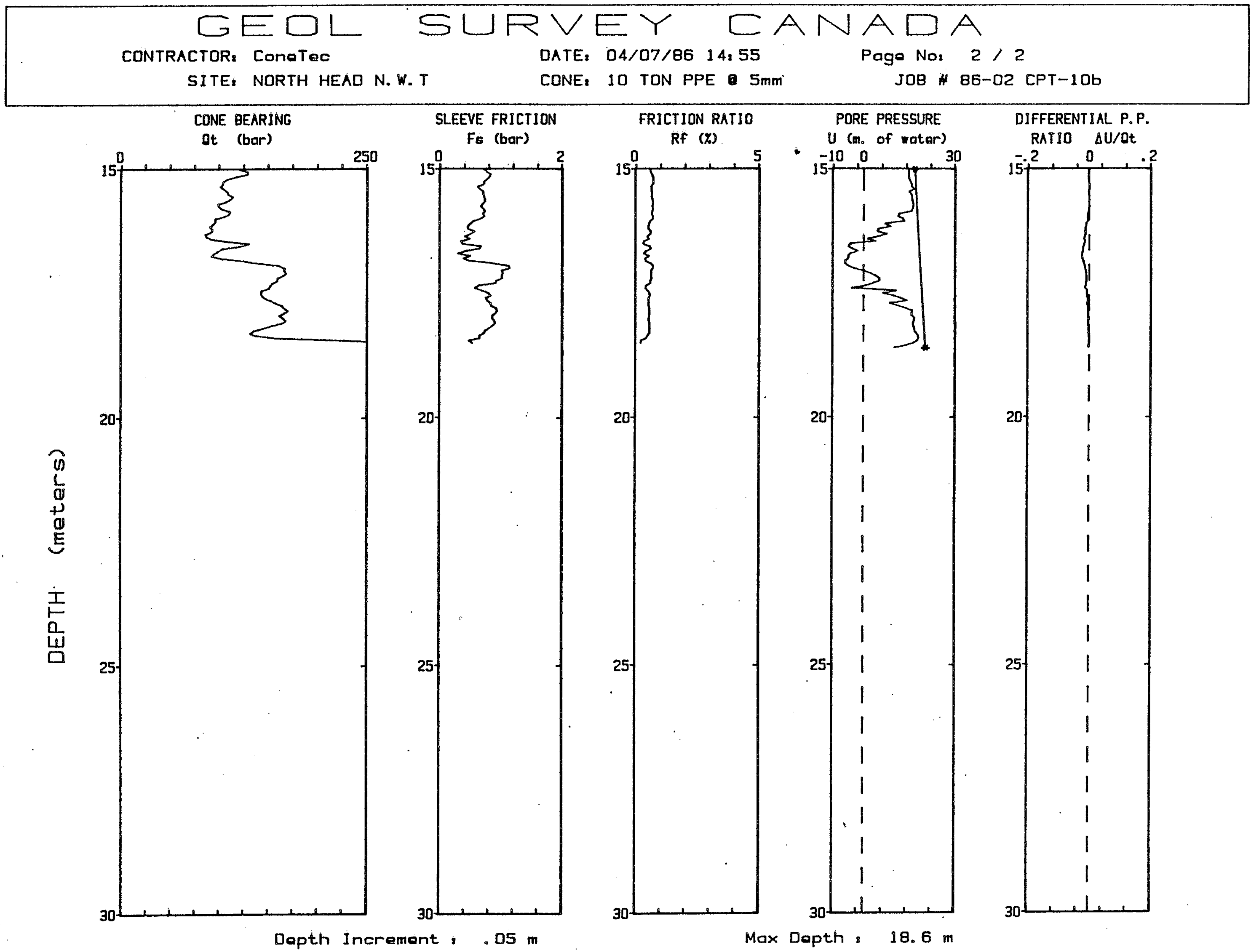

Fig. 4-11: CPT data-hole 86-10b - continuation

```
                              ConeTec  Investigations  Ltd.

      Site          :ConeTec                          CPT Date      :04/07/86 14:55
      On Site Loc:NORTH HEAD N.W.T                    Cone Used     :10 TON FPE @ 5mm
      Comments      :86-02 CPT-10b                    Water table  (meters)  :  0
      Tot. Unit Wt.  (avg)  :  19 kN/m^3
-------------------------------------------------------------------------------------------------------------------
     DEPTH          Qc (avg)    Fs (avg)    Rf (avg)     SIGV'          SOIL BEHAVIOUR TYPE        Eq - Dr    PHI     SPT        Su
(meters)  (feet)     (bar)       (bar)        (%)        (kPa)                                       (%)      deg.     N        kPa
-------------------------------------------------------------------------------------------------------------------
   0.50     1.64     14.34        0.08        0.54        2.30     sandy silt to clayey silt      UNDFND    UNDFD     6          95.2
   1.00     3.28     45.87        0.27        0.60        6.89        sand to silty sand          80-90      >48     11     UNDEFINED
   1.50     4.92     72.94        0.38        0.52       11.48        sand to silty sand          80-90      >48     18     UNDEFINED
   2.00     6.56     34.09        0.27        0.79       16.08     silty sand to sandy silt       60-70     44-46    11     UNDEFINED
   2.55     8.37     11.24        0.27        2.38       20.90     clayey silt to silty clay      UNDFND    UNDFD     6          72.0
   3.05    10.01      9.41        0.26        2.82       25.72        silty clay to clay          UNDFND    UNDFD     6          59.1
   3.55    11.65      6.69        0.24        3.60       30.32               clay                 UNDFND    UNDFD     7          40.4
   4.05    13.29      6.75        0.19        2.79       34.91        silty clay to clay          UNDFND    UNDFD     4          40.1
   4.55    14.93      6.22        0.23        3.68       39.50               clay                 UNDFND    UNDFD     6          36.0
   5.05    16.57      5.10        0.17        3.27       44.09               clay                 UNDFND    UNDFD     5          27.9
   5.55    18.21     31.26        0.25        0.80       48.69     silty sand to sandy silt       40-50     38-40    10     UNDEFINED
   6.05    19.85    121.66        0.67        0.55       53.28               sand                 80-90     44-46    24     UNDEFINED
   6.55    21.49    111.95        0.64        0.57       57.87               sand                 70-80     42-44    22     UNDEFINED
   7.05    23.13     93.27        0.56        0.60       62.47        sand to silty sand          70-80     42-44    23     UNDEFINED
   7.55    24.77     73.61        0.48        0.65       67.06        sand to silty sand          60-70     40-42    18     UNDEFINED
   8.05    26.41     60.60        0.42        0.69       71.65        sand to silty sand          50-60     40-42    15     UNDEFINED
   8.60    28.22     67.36        0.42        0.62       76.48        sand to silty sand          50-60     40-42    17     UNDEFINED
   9.10    29.86     83.78        0.49        0.58       81.30        sand to silty sand          60-70     40-42    21     UNDEFINED
   9.60    31.50     94.07        0.54        0.58       85.89               sand                 60-70     40-42    19     UNDEFINED
  10.10    33.14    119.81        0.59        0.49       90.49               sand                 70-80     42-44    24     UNDEFINED
  10.60    34.78    116.70        0.59        0.51       95.08               sand                 70-80     40-42    23     UNDEFINED
  11.10    36.42    106.68        0.59        0.55       99.67               sand                 60-70     40-42    21     UNDEFINED
  11.60    38.06    122.05        0.78        0.64      104.27               sand                 70-80     40-42    24     UNDEFINED
  12.10    39.70     86.42        0.53        0.61      108.86        sand to silty sand          60-70     40-42    22     UNDEFINED
  12.60    41.34    116.30        0.70        0.60      113.45               sand                 60-70     40-42    23     UNDEFINED
  13.10    42.98    103.22        0.63        0.61      118.05               sand                 60-70     40-42    21     UNDEFINED
  13.60    44.62    114.71        0.69        0.60      122.64               sand                 60-70     40-42    23     UNDEFINED
  14.10    46.26    106.99        0.73        0.68      127.23               sand                 60-70     40-42    21     UNDEFINED
  14.60    47.90     97.32        0.62        0.64      131.82        sand to silty sand          60-70     38-40    24     UNDEFINED
  15.10    49.54    118.61        0.76        0.64      136.42               sand                 60-70     40-42    24     UNDEFINED
  15.60    51.18    111.59        0.73        0.65      141.01               sand                 60-70     40-42    22     UNDEFINED
  16.10    52.82    105.77        0.71        0.67      145.60               sand                 60-70     38-40    21     UNDEFINED
  16.60    54.46     97.45        0.46        0.47      150.20               sand                 60-70     38-40    19     UNDEFINED
  17.10    56.10    121.17        0.65        0.54      154.79               sand                 60-70     38-40    24     UNDEFINED
  17.60    57.74    156.11        0.86        0.55      159.38               sand                 70-80     40-42    31     UNDEFINED
  18.10    59.38    159.53        0.85        0.53      163.98               sand                 70-80     40-42    32     UNDEFINED
  18.60    61.02    169.51        0.72        0.43      168.57               sand                 70-80     40-42    34     UNDEFINED
-------------------------------------------------------------------------------------------------------------------

   Dr -  All sands (Jamiolkowski et al. 1985)     PHI -    Robertson and Campanella 1983        Su: Nk= 15


**** Note: For interpretation purposes the PLOTTED CPT PROFILE should be used with the TABULATED OUTPUT from CPTINTR1 (v 3.02) ****
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Fig. 4-12: CPT data computer tabulation- hole 86-10b

5. CORE TEMPERATURE MEASUREMENTS

P.J. Kurfurst

Temperatures of the Shelby tube samples were measured and recorded, using an Atkins 4400-C temperature probe and readout equipment. The probe was inserted in the bottom of the sample immediately after its retrieval from the borehole. When negative temperatures or signs of ground ice were detected, temperature was also measured in several locations along the sample length after its extrusion. As the readout equipment malfunctioned during the drilling operation, only temperatures on samples from boreholes 86-9 and 86-10 were measured and recorded. The temperature distributions with depth were plotted and are presented in Figure 5-1.

Positive temperatures ranging from 0.4°C to 2.2°C, were recorded in the upper 12 m and between 27.5 m and 30.5 m in borehole 86-9 and throughout most of borehole 86-10. Negative temperature generally decreased with depth and ranged from -0.5°C to -2.2°C.

Previous experience shows that probe temperature measurements are generally higher, than temperatures recorded either by the cone penetrometer or thermistor cables, but show similar trend. This temperature difference is considered to be due to thermal disturbance of the samples caused by drilling and sample recovery, and by the time delay between the sampling and the temperature measurements.

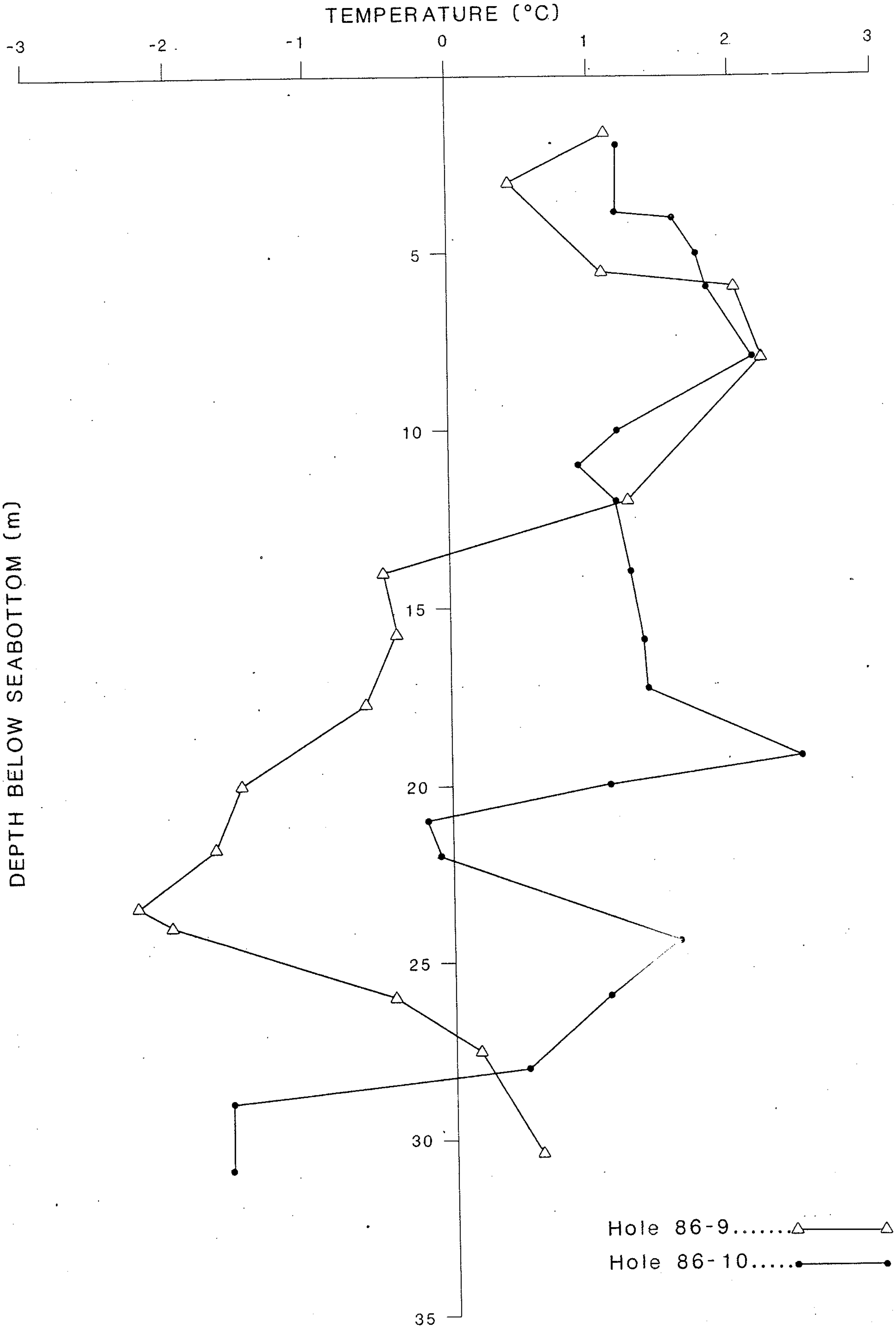


Fig. 5-1: Core temperature profiles

6. CORE PENETRATION TEST TEMPERATURE MEASUREMENTS

P.J. Kurfurst

Temperature measurements taken during cone penetration soundings vary significantly depending on the time allowed for heat dissipation. Penetration through cohesionless soils with high sleeve friction values generates significant amount of heat that requires adequate time for its dissipation before true ambient temperatures are reached.

Temperature dissipation tests were carried out at varying depth intervals in holes 86-8b and 86-10b in an attempt to determine soil ambient temperatures. The results of these tests are presented graphically in Figure 6-1. The results indicate that the ambient soil temperature in both holes are within a range of 2°, varying between -4.8°C and -6.8°C, depending on depth and type of material encountered.

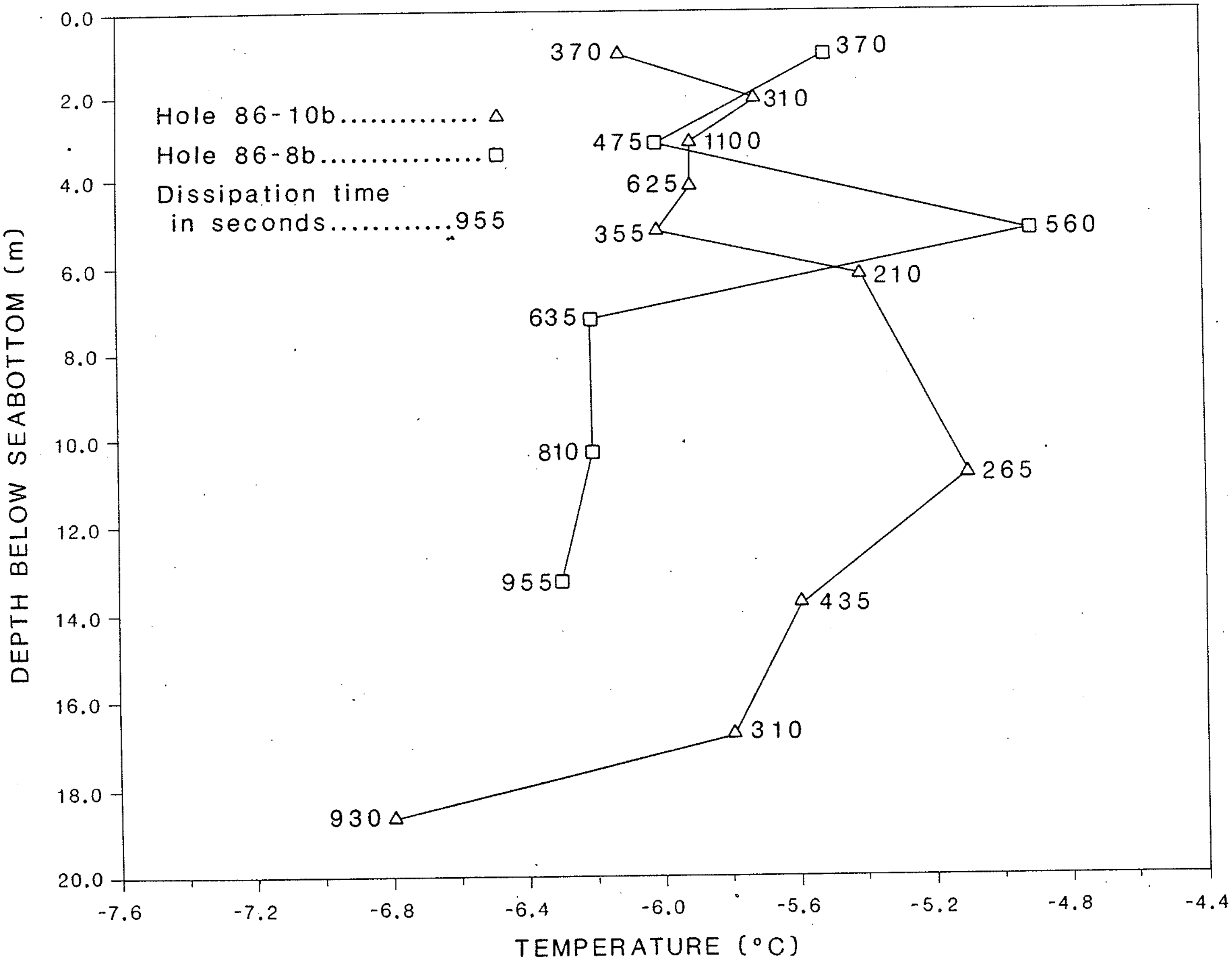


Fig. 6-1: CPT-ground ambient temperature profiles

7. STANDARD PHYSICAL PROPERTIES

P.J. Kurfurst

Thirty-five core samples were sub-sampled, retained and shipped to the Ottawa laboratory for determination of their standard physical properties such as natural moisture contents, Atterberg limits and sand-silt-clay ratios.

Figure 7-1 shows the natural water content data, plotted against depth below seabottom for each borehole. Water contents are generally very low, as all their values range between 20% and 40%. All plots show similar trends with values for samples from depths up to 15 m below seabottom ranging between 20% and 30%, while values for samples from depths between 15 m and 30 m range between 30% and 40%.

Sand-silt-clay ratio analyses of the core samples show very good correlation with the field borehole logs. The majority of recovered samples (about 70%) were fine and medium sands and silty sands with little gravel present. Silts and clayey silts represented approximately 23% and silty clays approximately 6% of all sediments.

Because of the sandy character of most of the sediments, only 9 Atterberg limits tests were performed on clayey silt and clay samples. The results are summarized in Table 7-1.

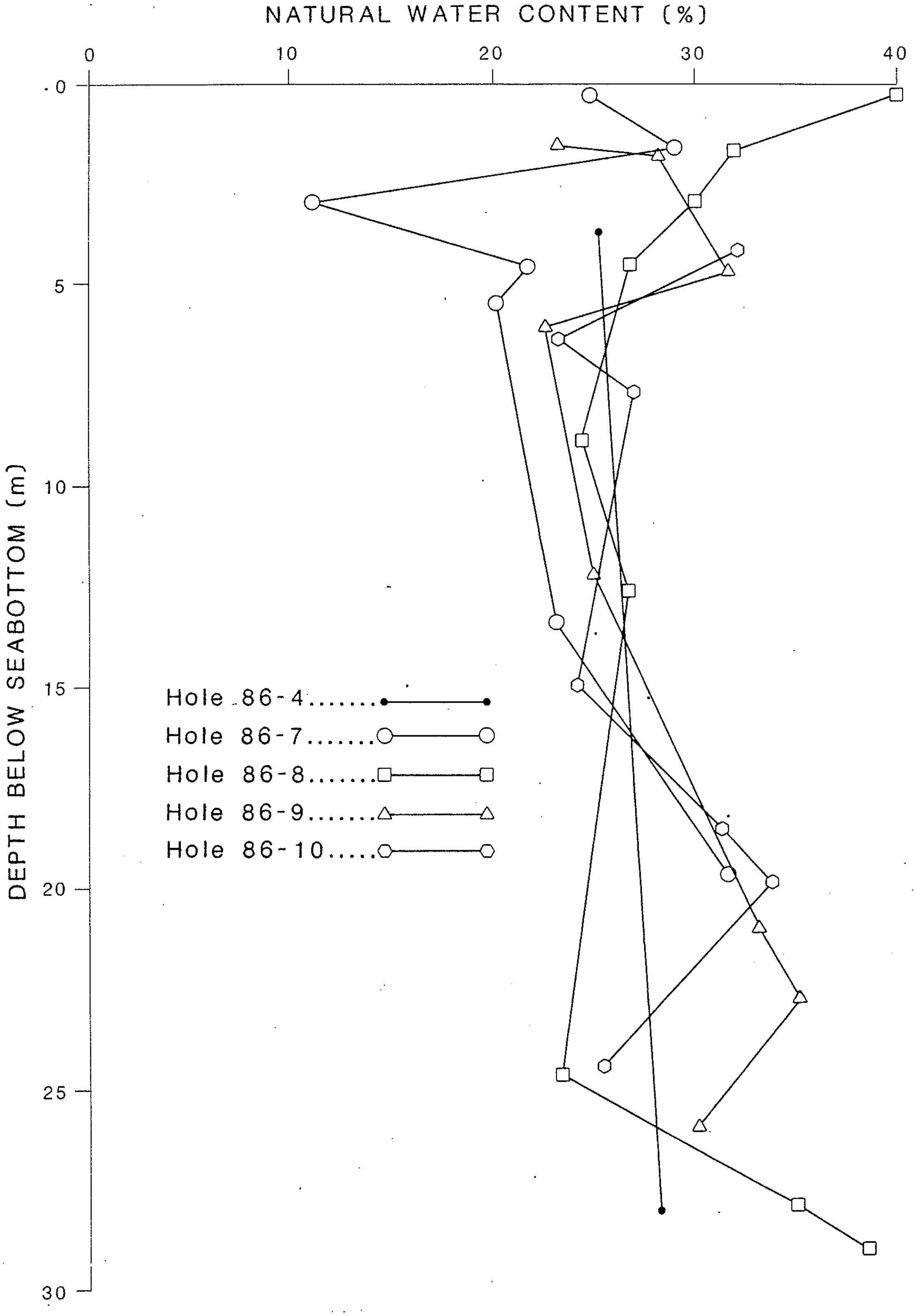


Fig. 7-1: Natural water content distribution

Table 7-1

Atterberg Limits Summary

Borehole	Sample Depth (m)	Liquid Limit	Plastic Limit	Plasticity Index
86-7	2.95-3.05	11.9	11.8	0.1
86-7	5.28-5.34	25.0	13.6	11.4
86-8	2.95-3.05	31.2	19.2	12.0
86-8	24.72-24.82	25.9	14.1	11.8
86-8	27.93-28.01	45.7	25.8	19.9
86-8	28.82-28.92	44.0	24.7	19.3
86-9	1.43-1.53	30.9	18.5	12.4
86-9	4.65-4.75	33.8	19.7	14.1
86-10	6.28-6.34	35.0	20.8	14.2

8. SUB-SEABOTTOM TEMPERATURE MEASUREMENTS

J.A. Hunter, S. Pullan

During August 1985 ten holes were drilled by the contractor, Northern Seismic Analysis Ltd., using hydraulic jetting, for installation of thermistor cables (Northern Seismic Analysis, 1985). The locations of the holes are shown in Fig. 1-2. Hole 85-1 was drilled on the shoreline slope at an elevation of 5 m asl, hole 85-2 was drilled at the base of the slope at the edge of the beach, and hole 85-3 was drilled at the approximate shoreline. The remaining holes (85-4 to 85-10) were located at approximately 100 m intervals along the line out to 800 m offshore from hole 85-2. Most holes were drilled to approx. 30 m depth with the exception of holes 85-8, 85-9 and 85-10 which were approx. 10 m, 17 m and 8 m deep respectively. Twelve thermistors were mounted on each cable with spacings of 3 m between thermistors on cables no. 4 to 12 and 1.5 m spacing between thermistors on cables no. 1, 2 and 3.

All thermistor cables had reached thermal equilibrium by September 1985 and were read on September 8. It was planned to monitor these cables on a monthly basis; however, the installations suffered severe storm damage in late September and most of the cables were either damaged or lost. Only thermistor cables no. 1, 2 and 3 could be read in November.

Thermistor cables no. 4 and 5 were repaired and thermistor cables no. 6, 7, 8, 9 and 10 were re-installed with conventional drilling in April 1986. In addition, borehole 86-2a was drilled and instrumented mid-way between holes 85-2 and 85-3, and borehole 86-4a was drilled and instrumented alongside hole 85-4. All thermistor cables were in thermal equilibrium by April 25 when final readings were taken.

Temperature readings for September 8, 1985, and April 25, 1986, are shown for all cables in Figures 8-1 to 8-12. End of summer and end of winter temperature fluctuations appear to reach as deep as 12 m below seabottom with the largest fluctuations in the near-shore regions.

Isothermal sections for September 8, 1985, and April 25, 1986, are shown in Figures 8-13 and 8-14 respectively. The September 8, 1985 isothermal section indicates an extremely cold permafrost zone out to 400 m offshore with the coldest temperatures of -7°C measured at depths between 6 m and 10 m below seabottom. In this area, a negative temperature gradient of approximately -2°C per metre is indicated. Beyond 400 m offshore, measured temperatures of up to 10 m of sub-seabottom sediments are above 0°C and only very small negative gradients are indicated.

The April 25, 1986 isothermal section shows a radical change from the September 8, 1985 section. Most of the seabottom temperatures measured are below 0°C with an exception of a small zone at hole 85-10, where temperatures are close to, but above 0°C. The inshore region indicates a reversal of temperature gradient of +1°C per metre with seabottom temperatures of -16°C increasing to -7°C with depth.

It appears that the near-shore area, where water freezes to bottom early in winter, experiences colder temperatures than either the beach and shoreline area or the far offshore (deep water) area. The shoreline area is covered in a thick insulating blanket of snow during winter (approx. 1 m), yet the near-shore ice is relatively free of snow. The beach and shoreline area appears to experience a relatively complicated variation in thermal gradients, both laterally and with depth.

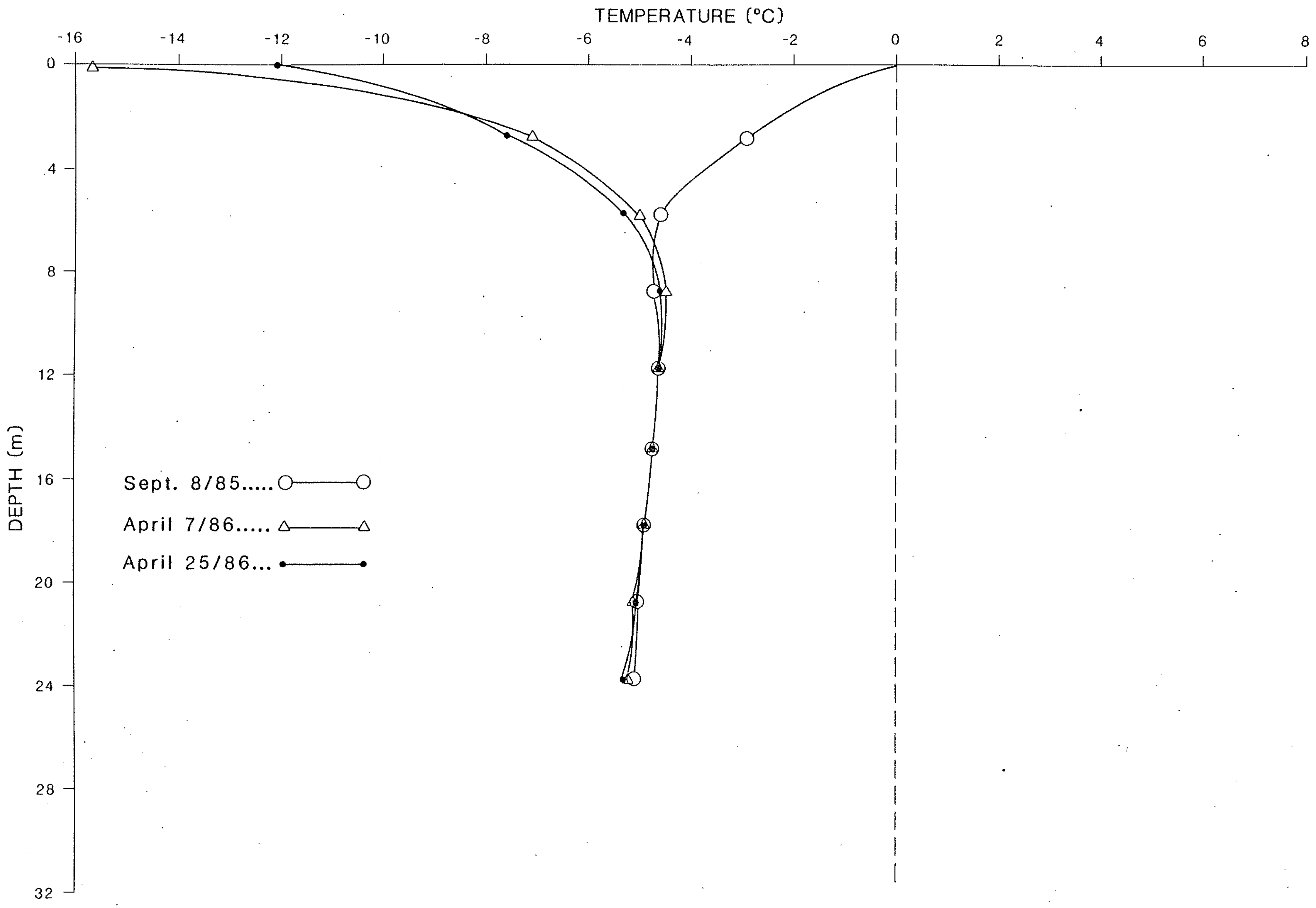


Fig. 8-1: Te,perature profile-hole 85-1

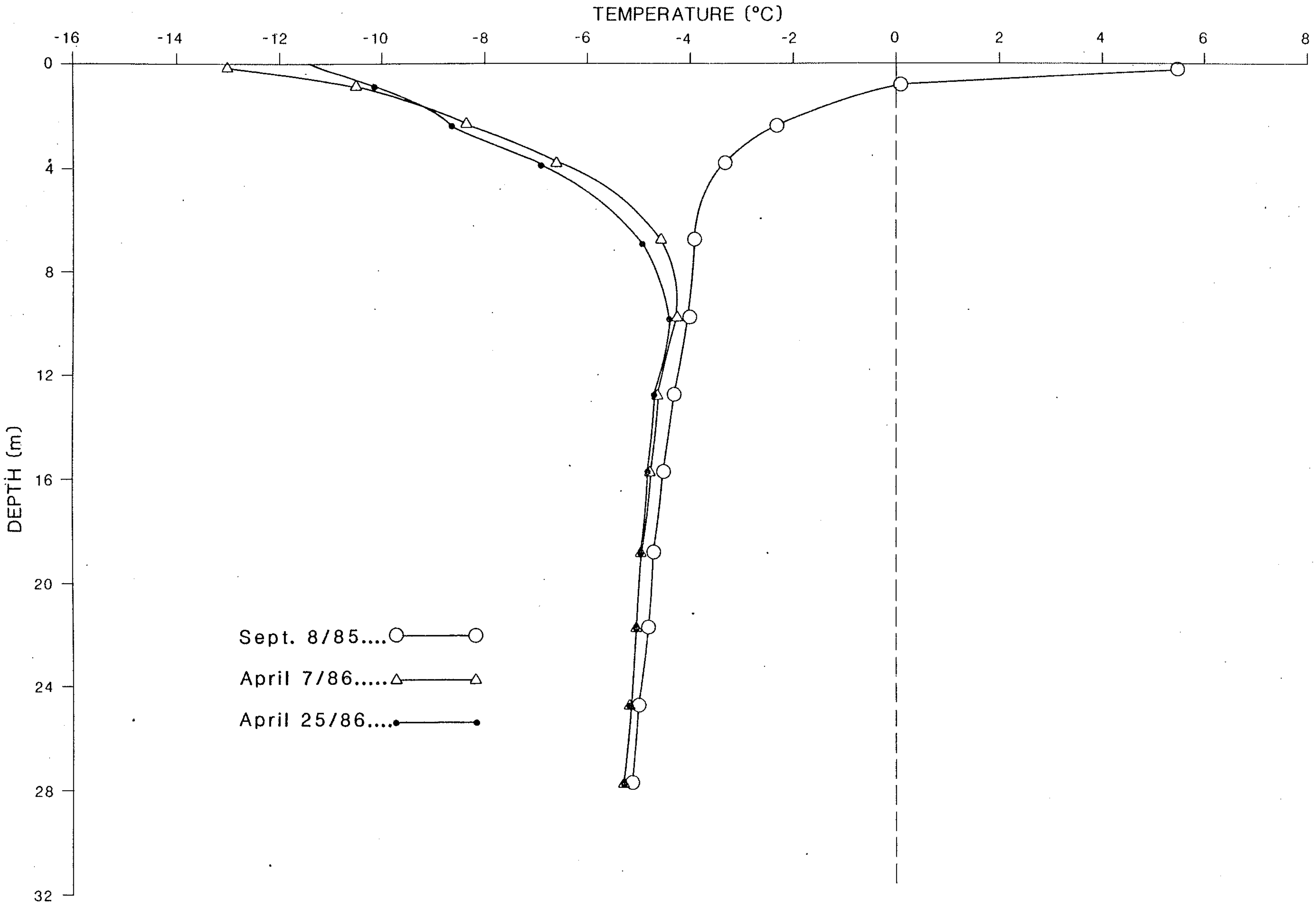


Fig. 8-2: Temperature profile- hole 85-2

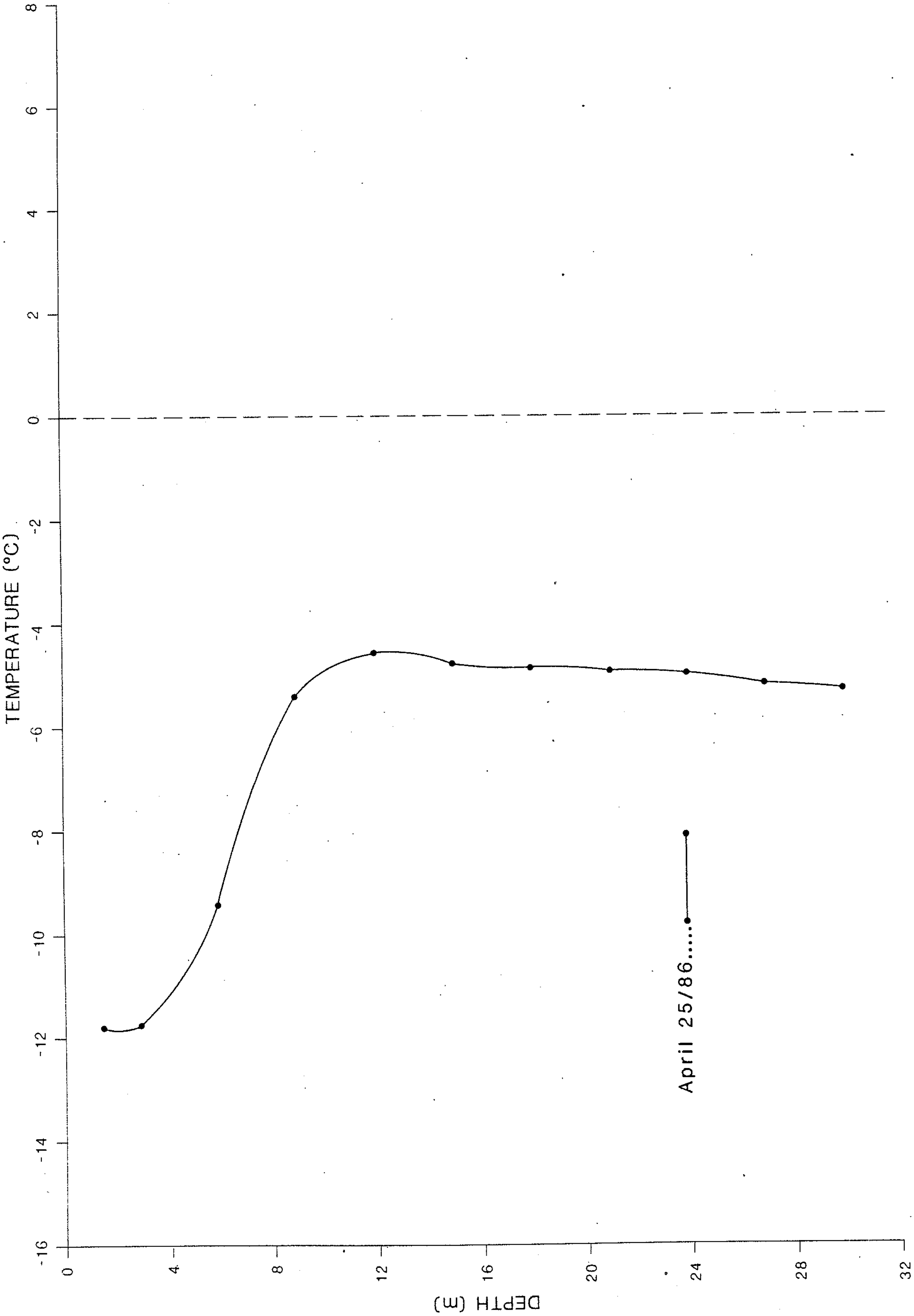


Fig. 8-3: Temperature profile-hole 86-2a

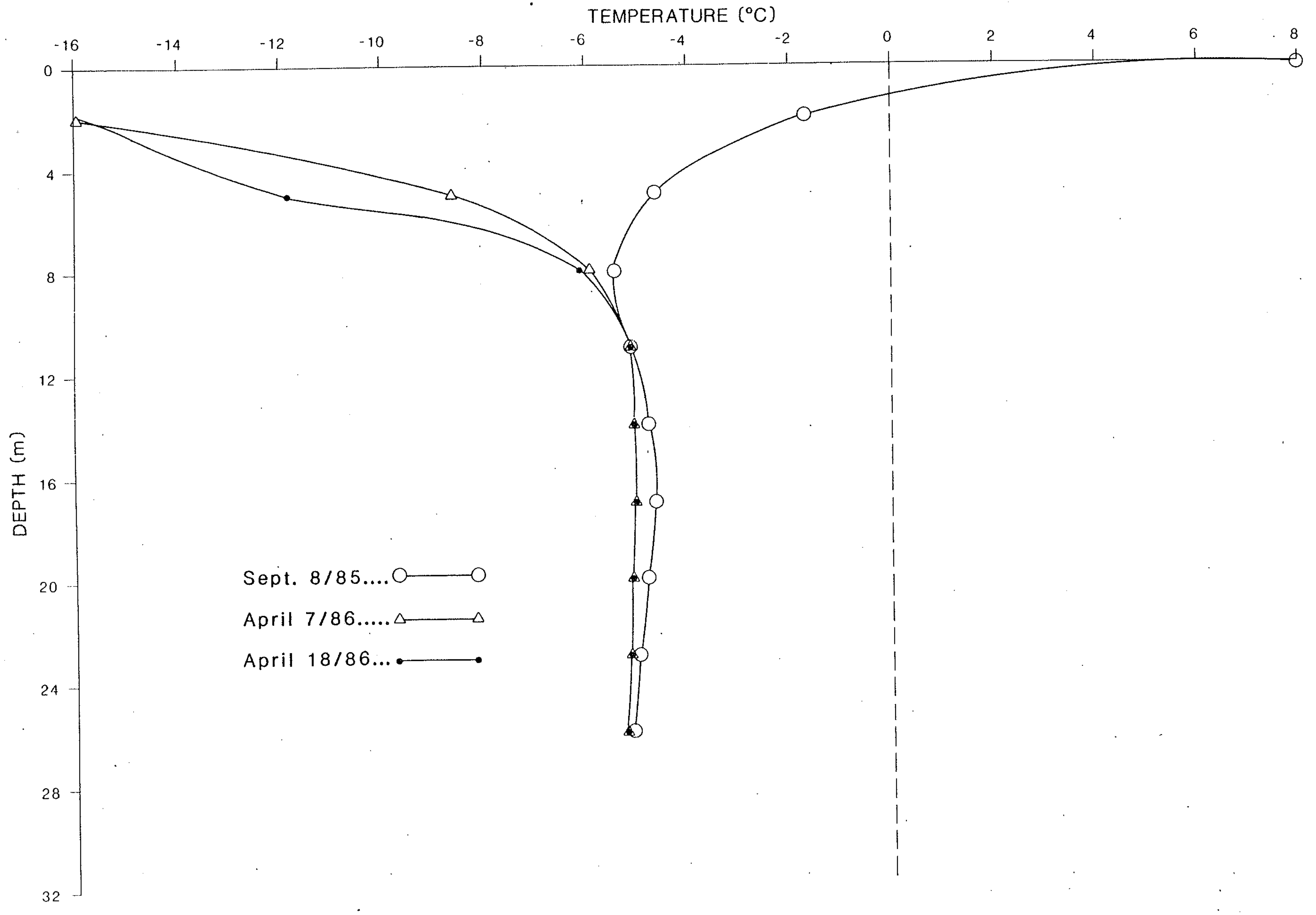


Fig. 8-4: Temperature profile-hole 85-3

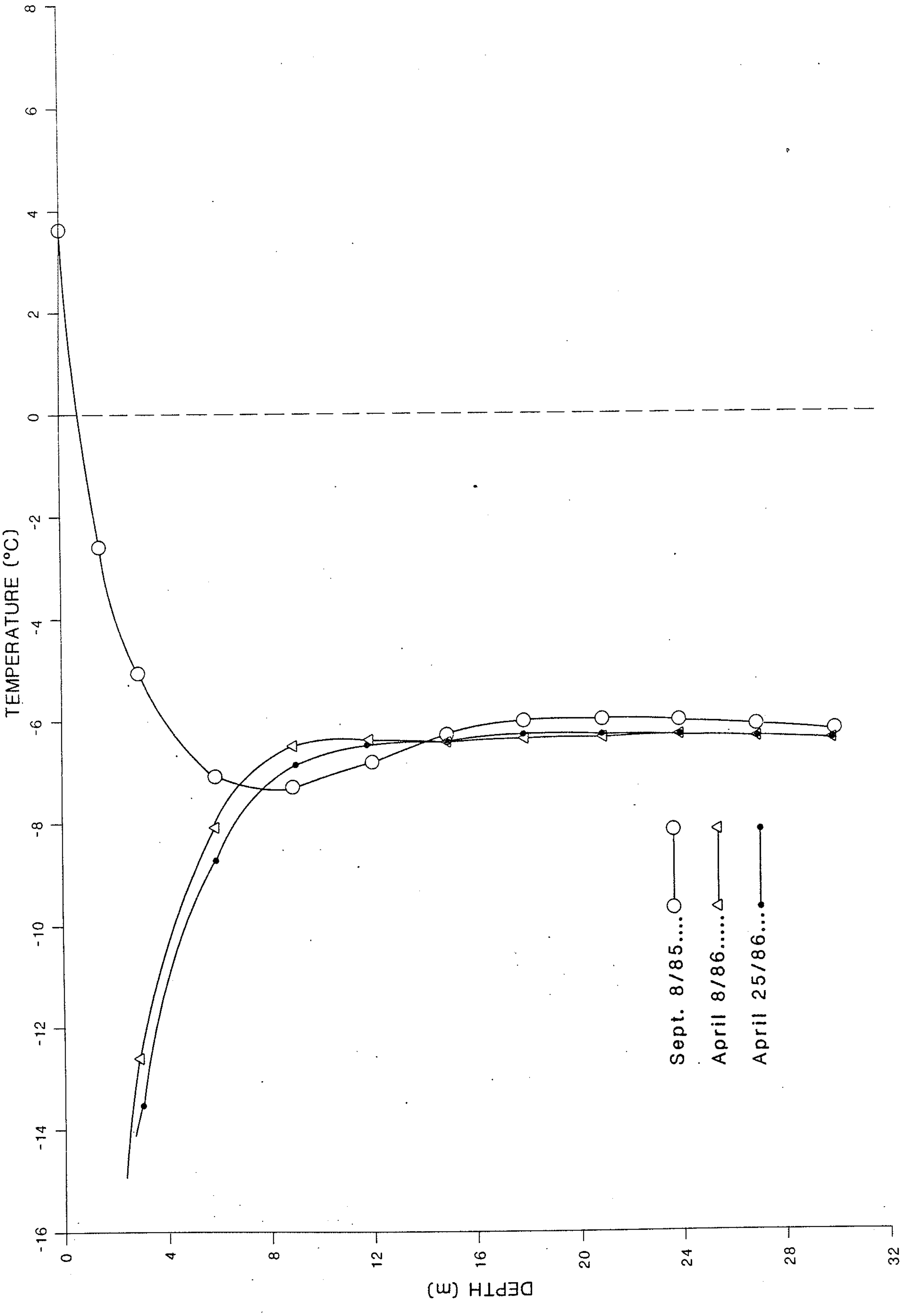


Fig. 8-5: Temperature profile-hole 85-4

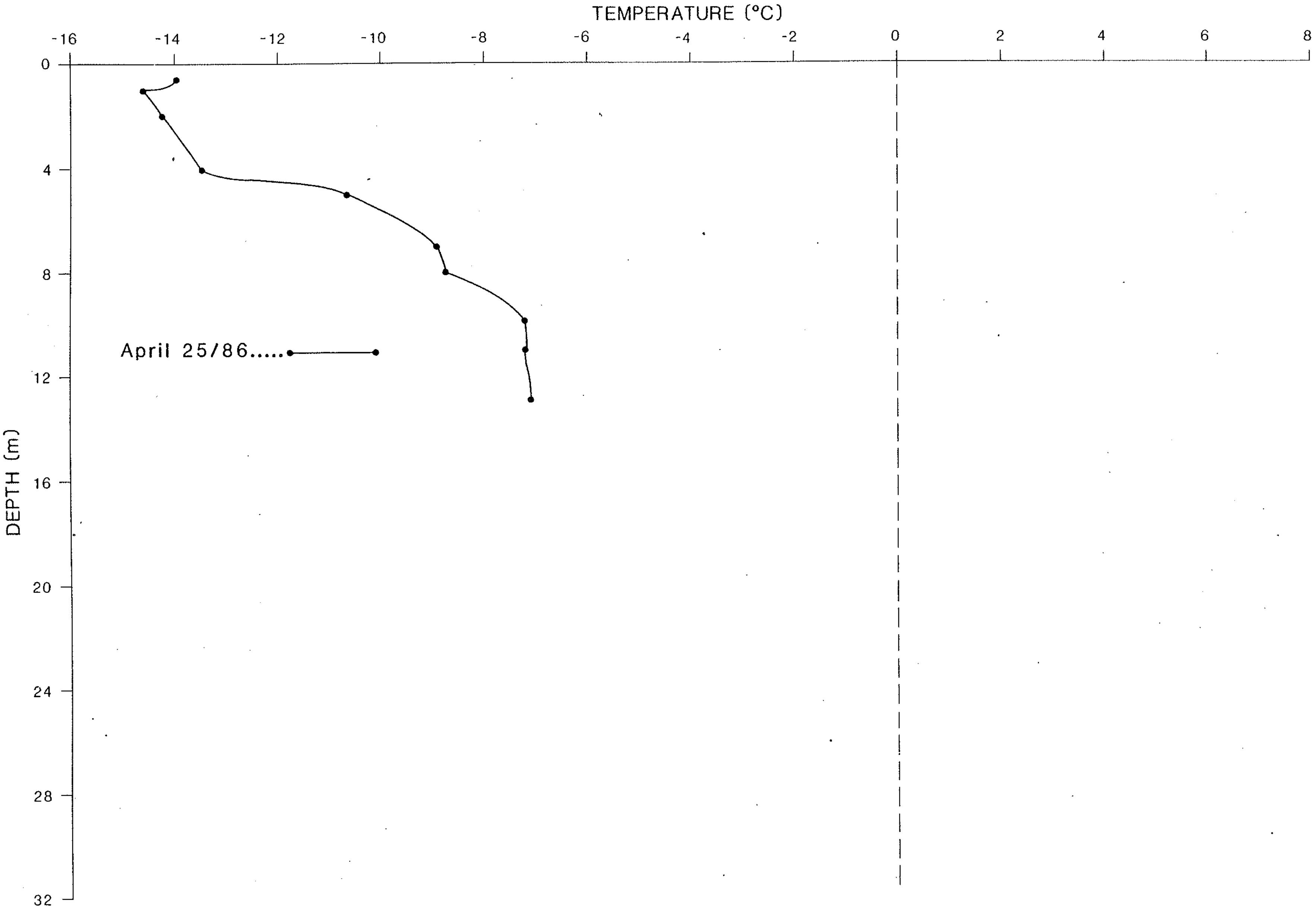


Fig. 85-6: Temperature profile-hole 86-4a

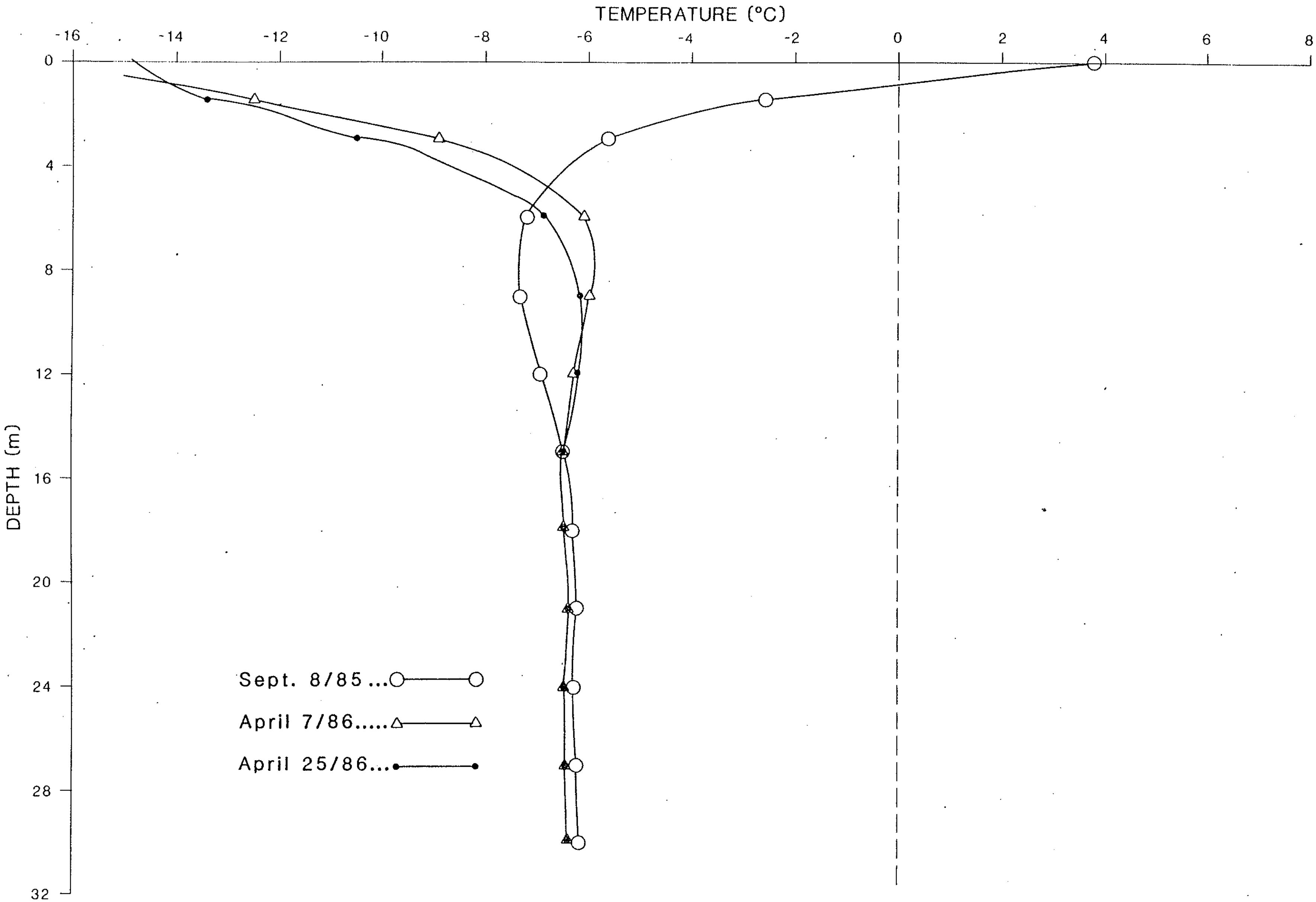


Fig. 8-7: Temperature profile-hole 85-5

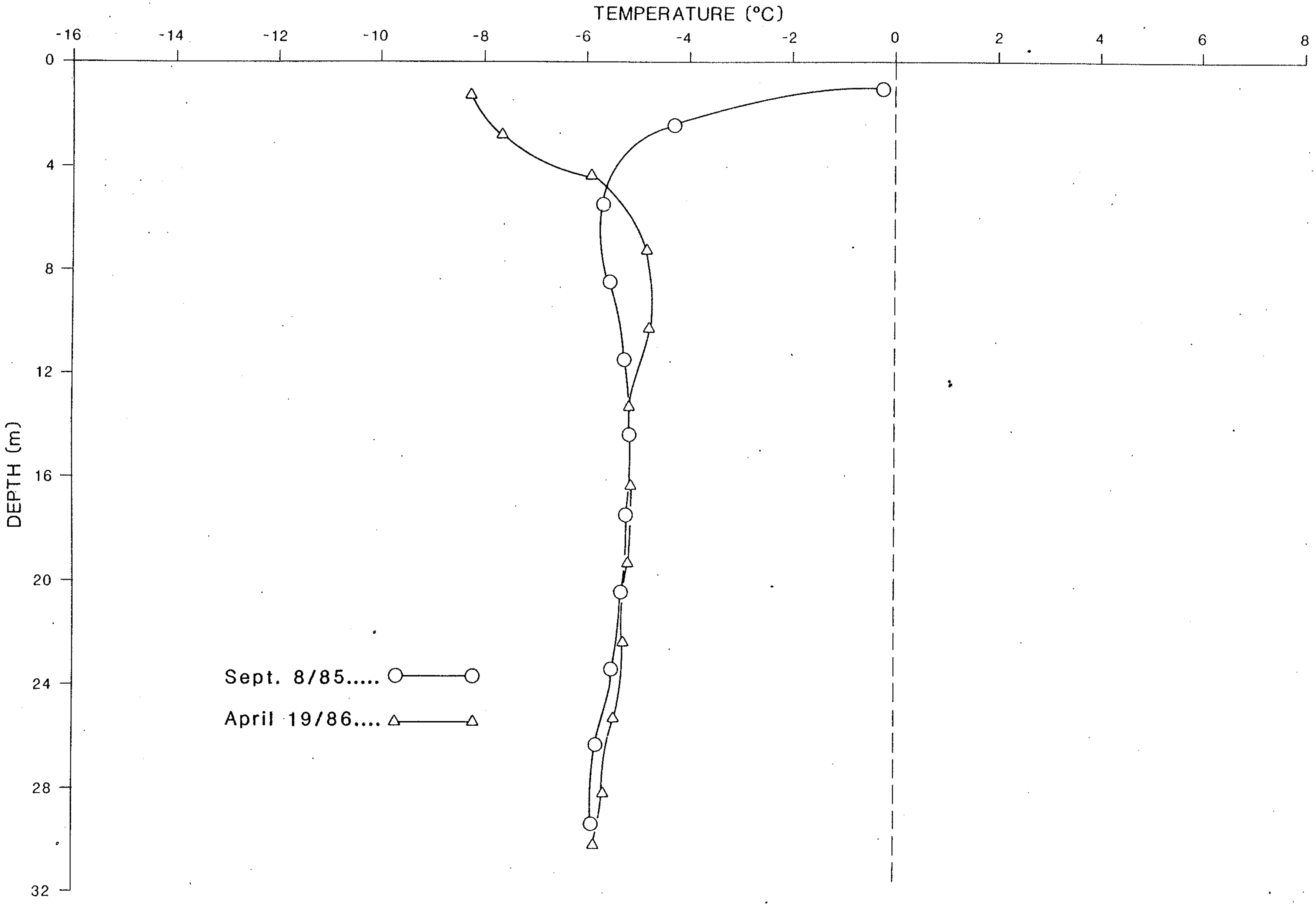


Fig. 8-8: Temperature profile-hole 85-6/86-6

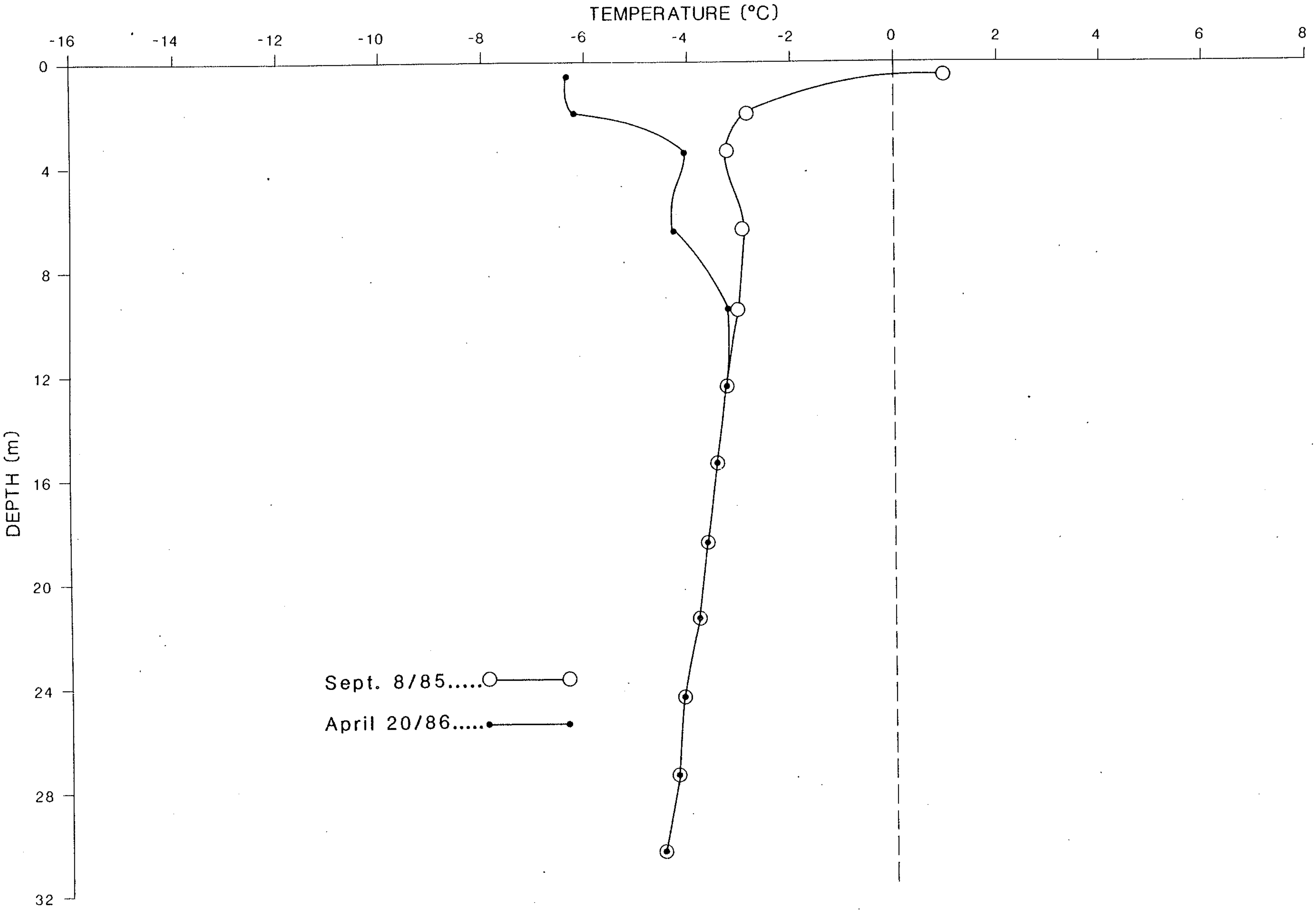


Fig. 8-9: Temperature profile-hole 85-7/86-7

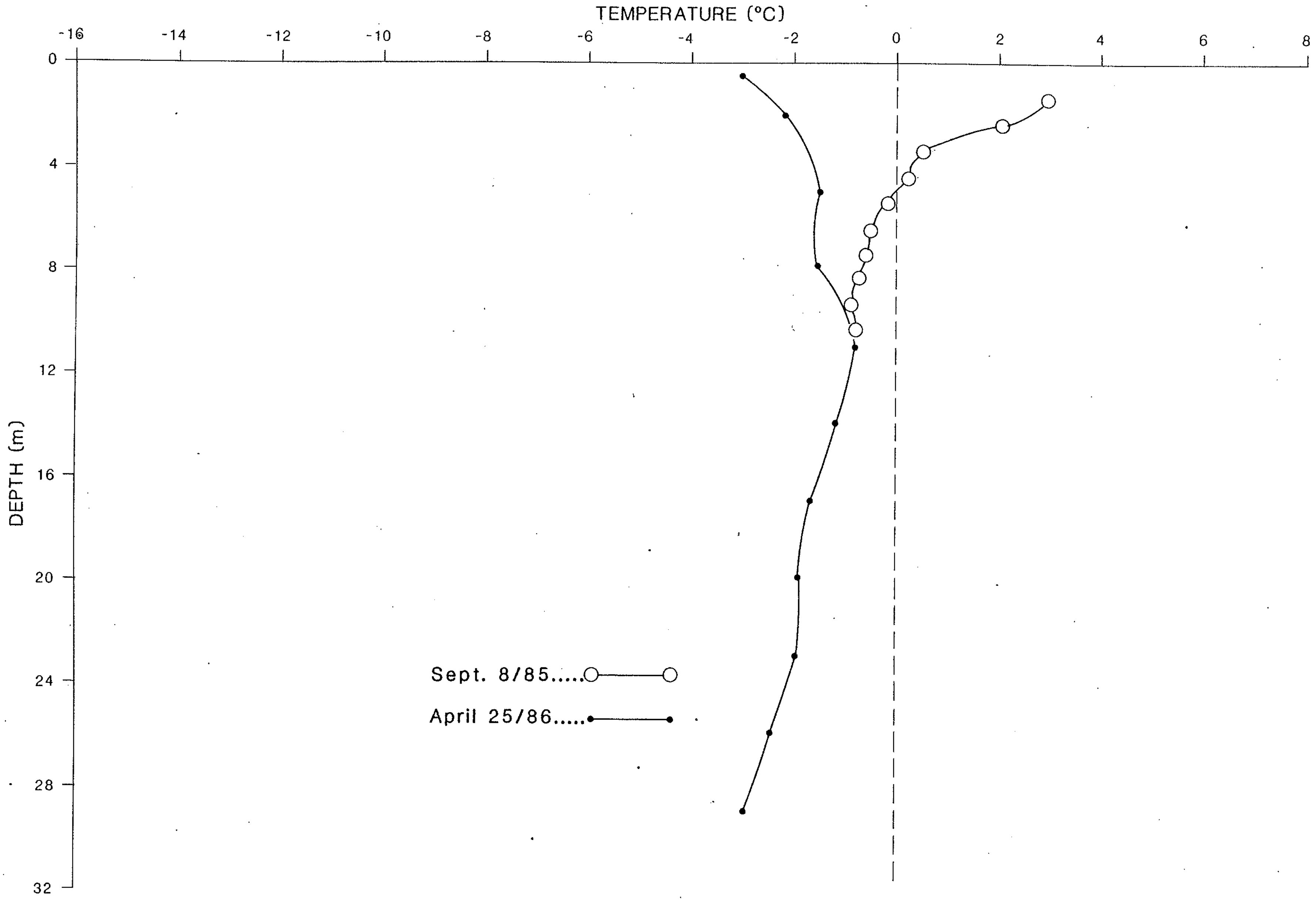


Fig. 8-10: Temperature profile-hole 85-8/86-8

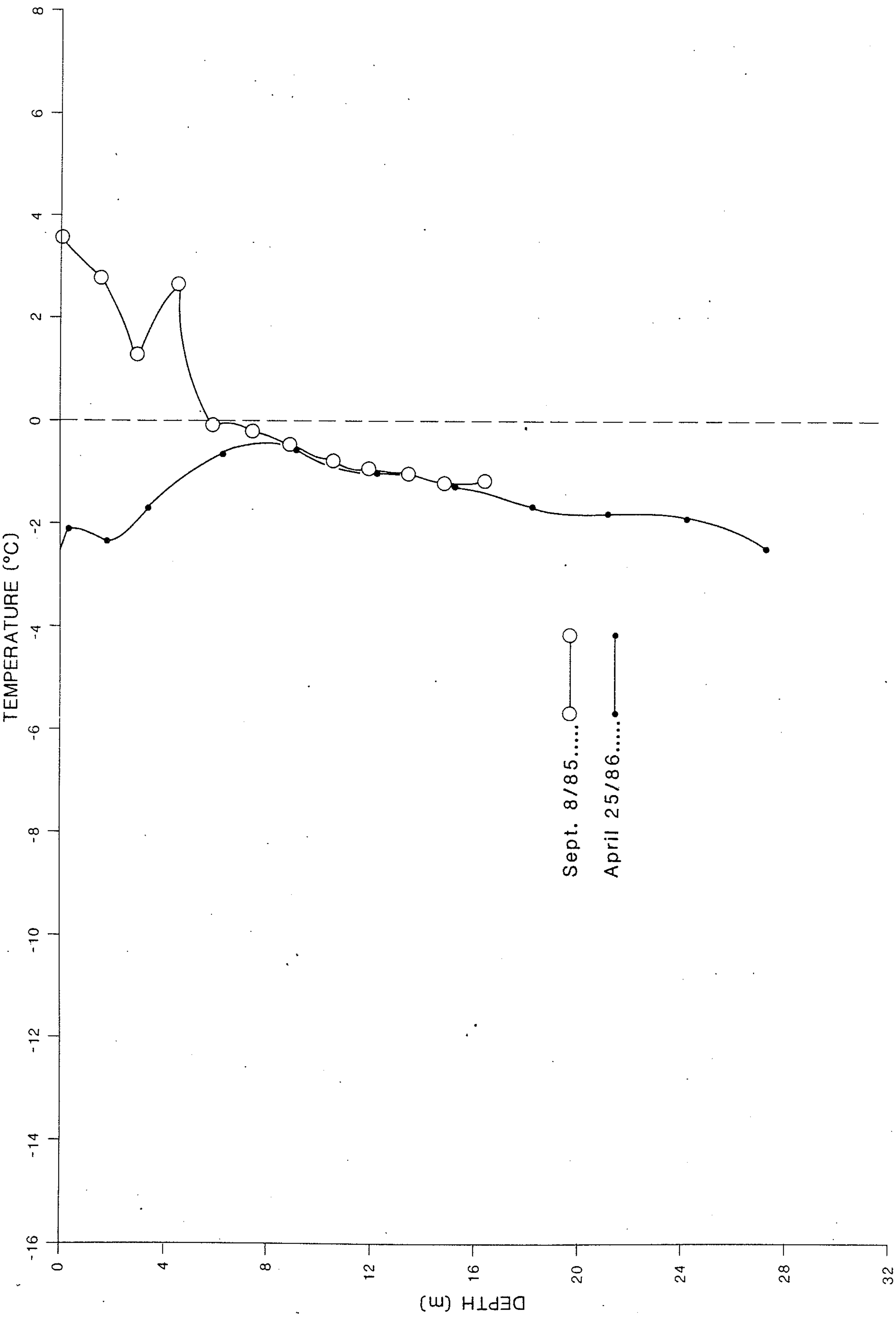


Fig. 8-11: Temperature profile-hole 85-9/86-9

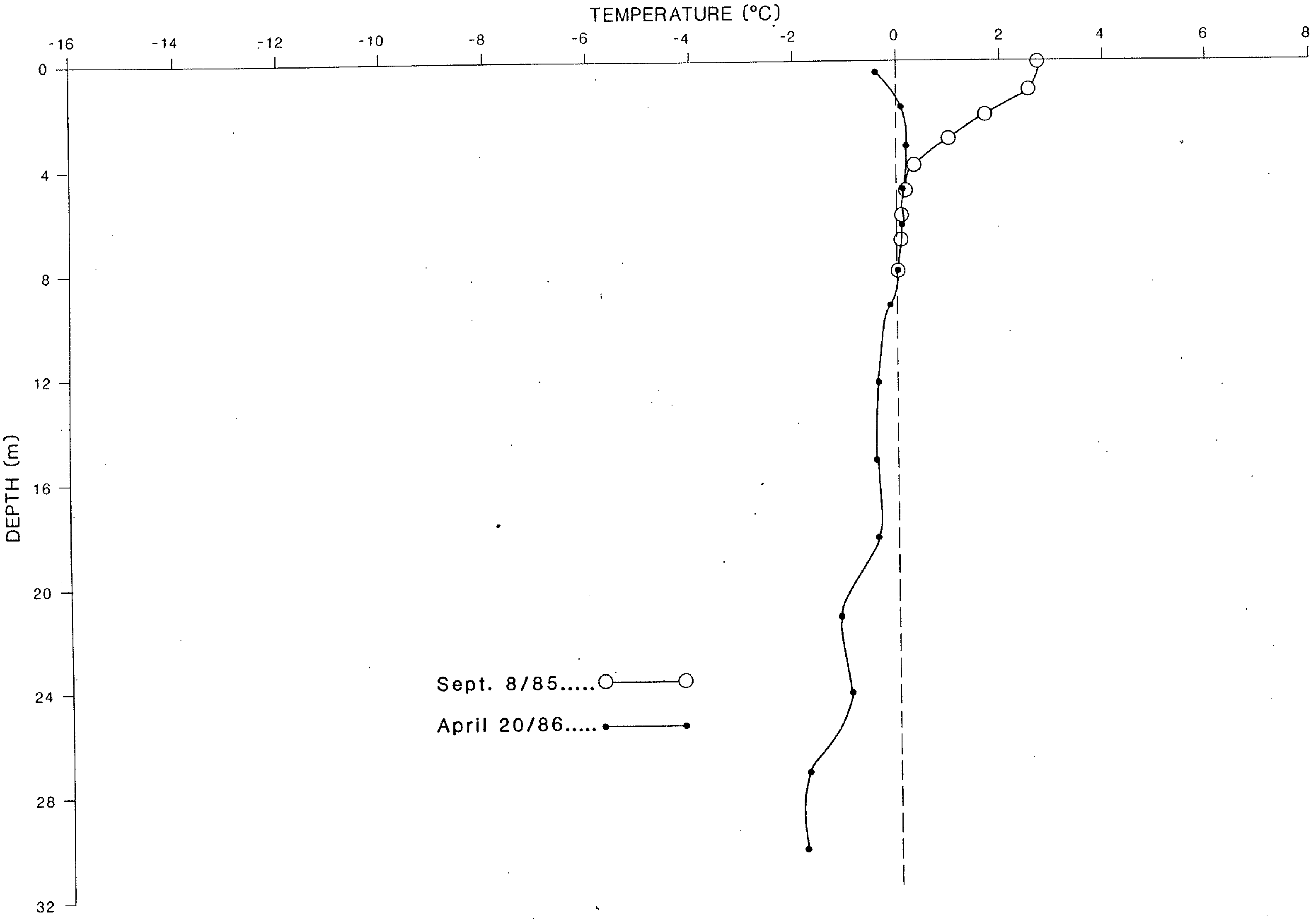


Fig. 8-12: Temperature profile-hole 85-10/86-10

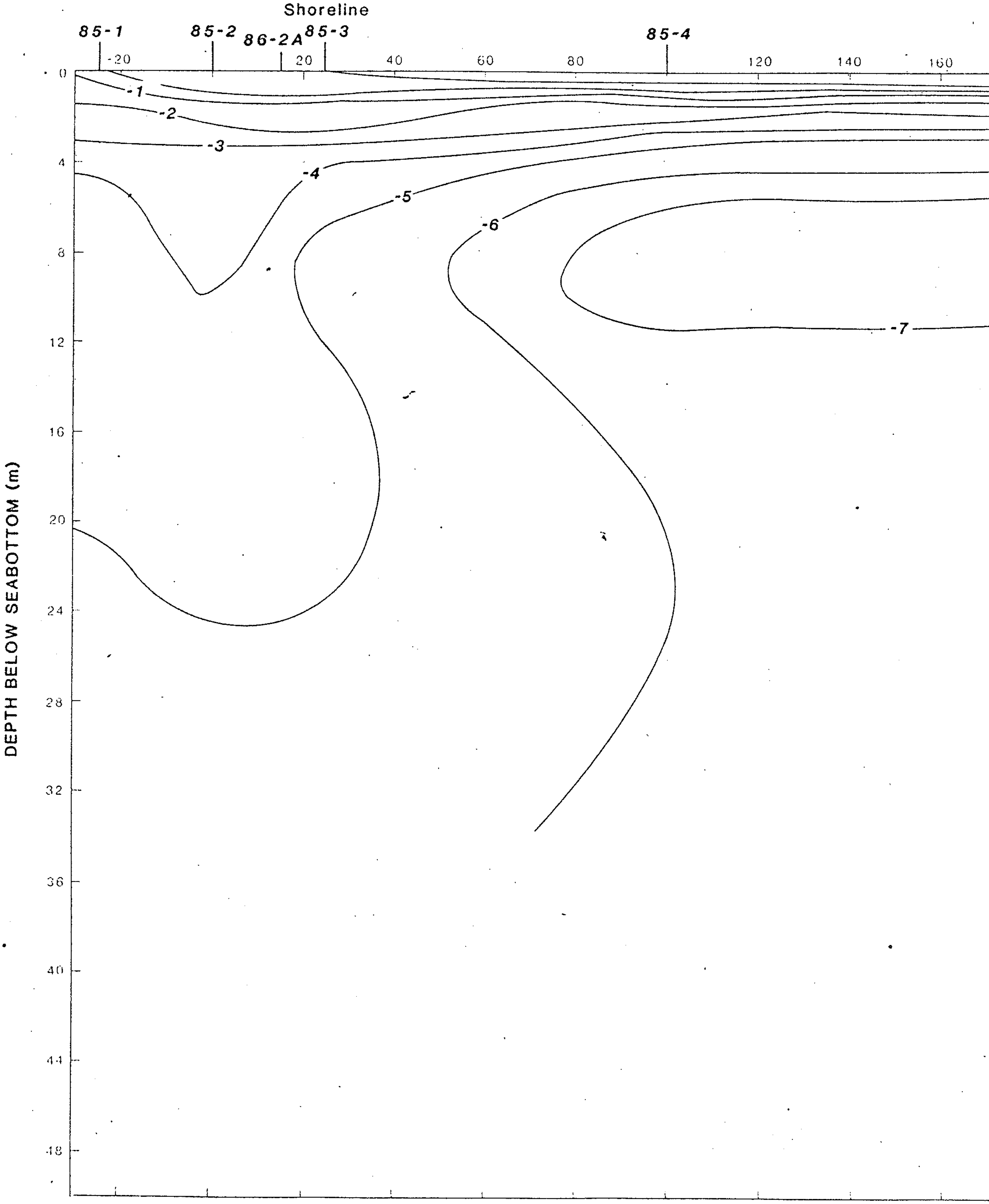
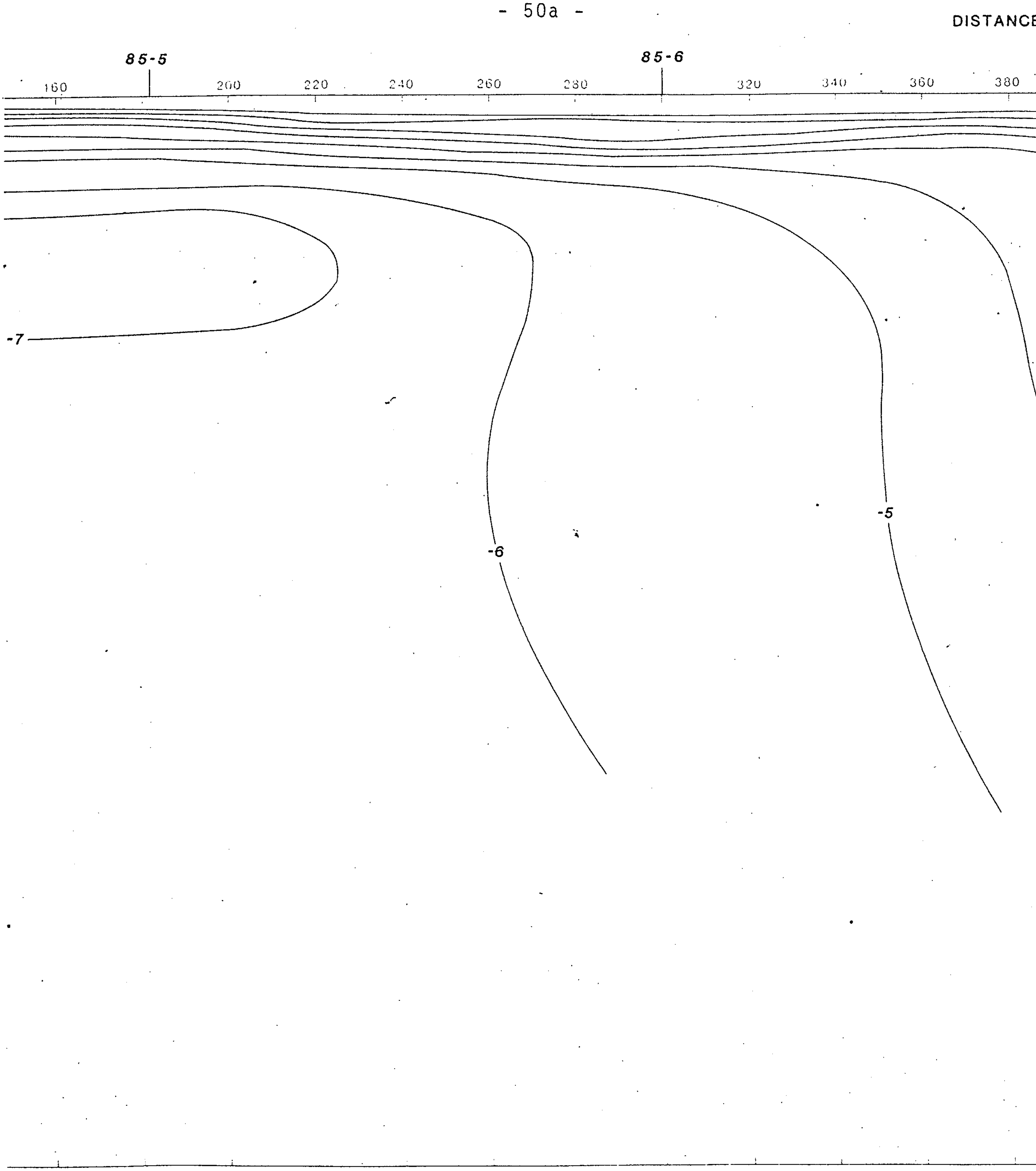
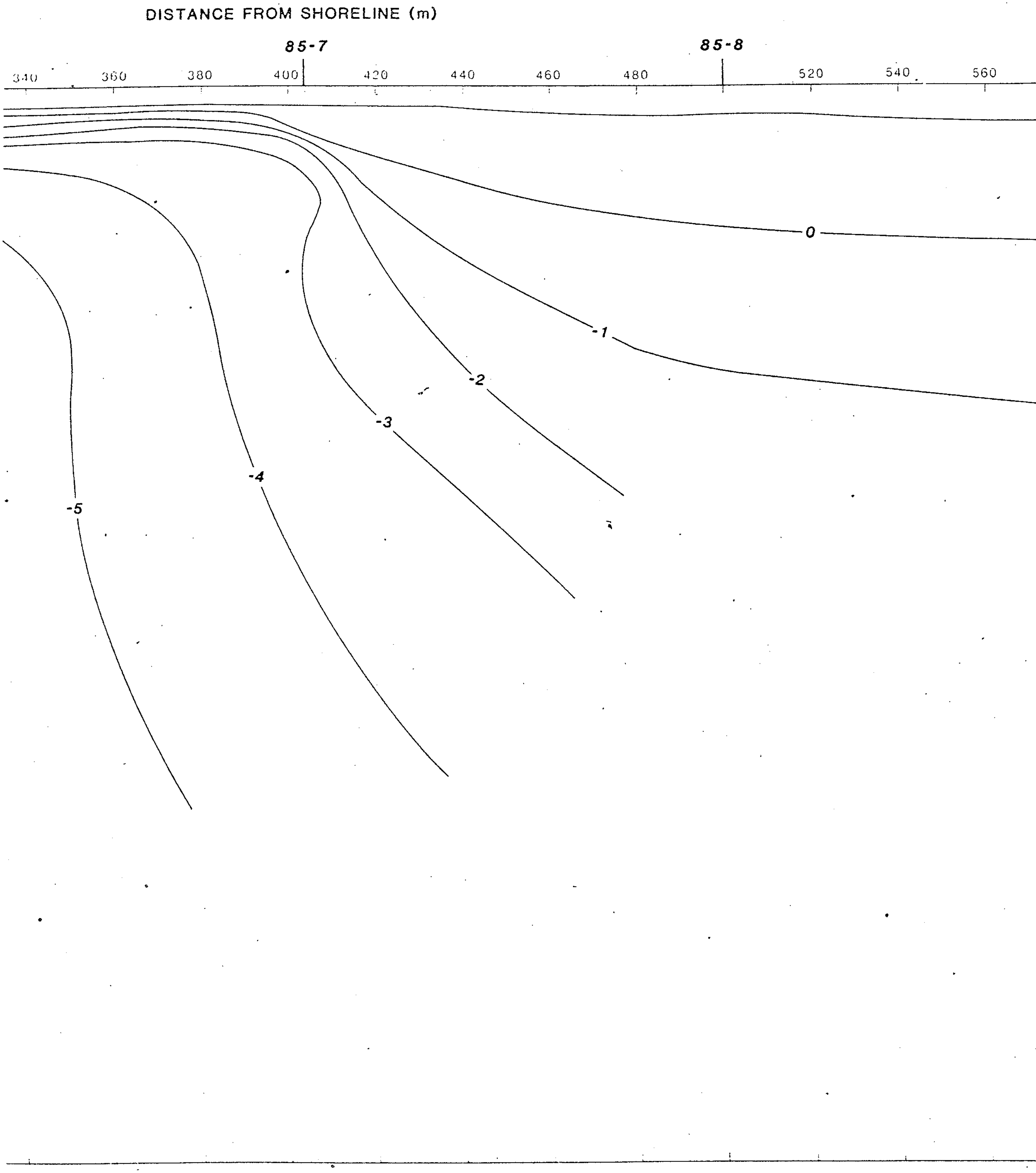
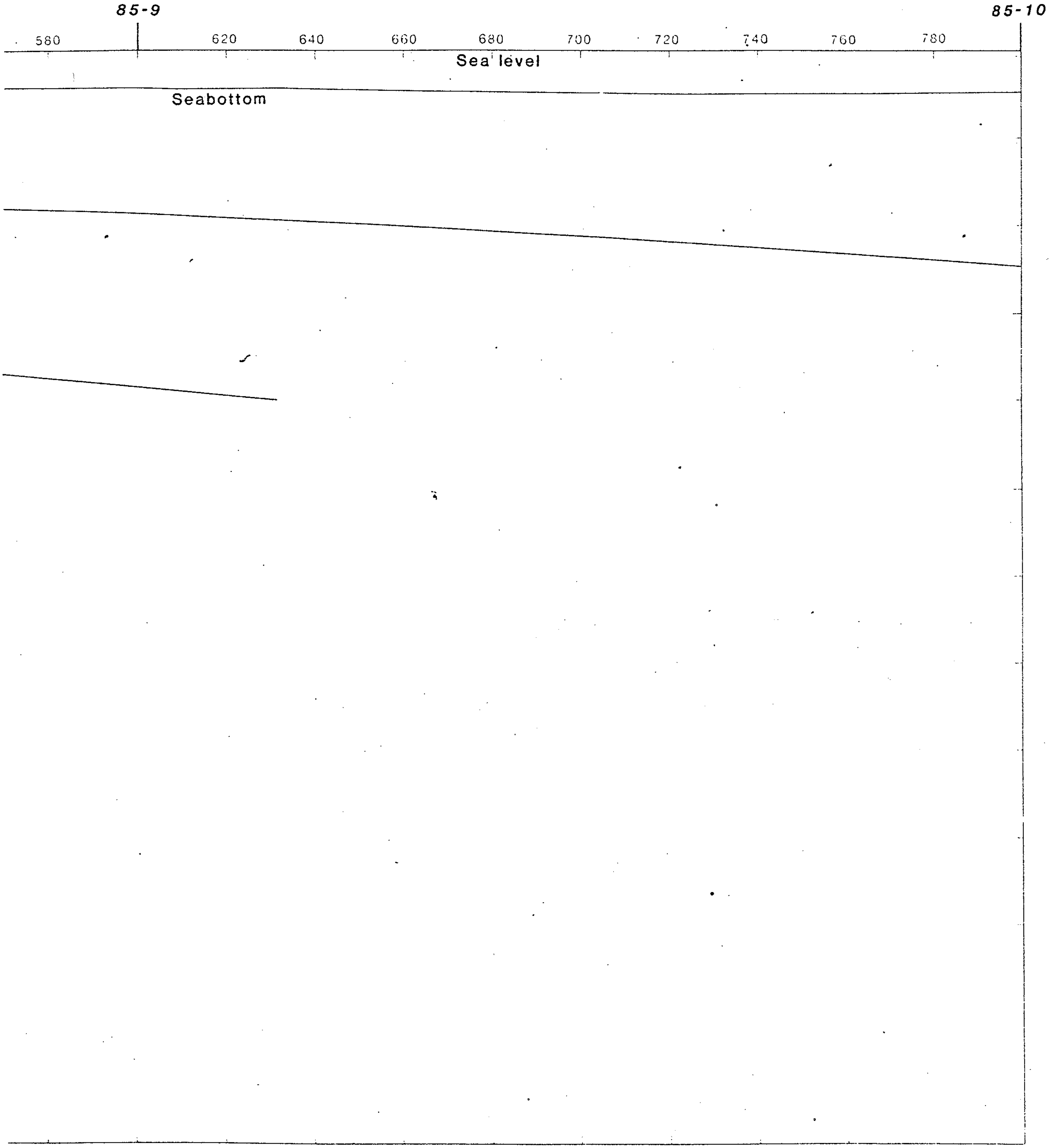


Fig. 8-13: Isothermal section -September 8,1985


DISTANC
85-5
85-6
160
200
220
240
260
280
320
340
360
380
-7
-6
-5


DISTANCE FROM SHORELINE (m)
85-7
85-8
340
360
380
400
420
440
460
480
520
540
560
0
-1
-2
-3
-4
-5


85-9
85-10
580
620
640
660
680
700
720
740
760
780
Sea level
Seabottom

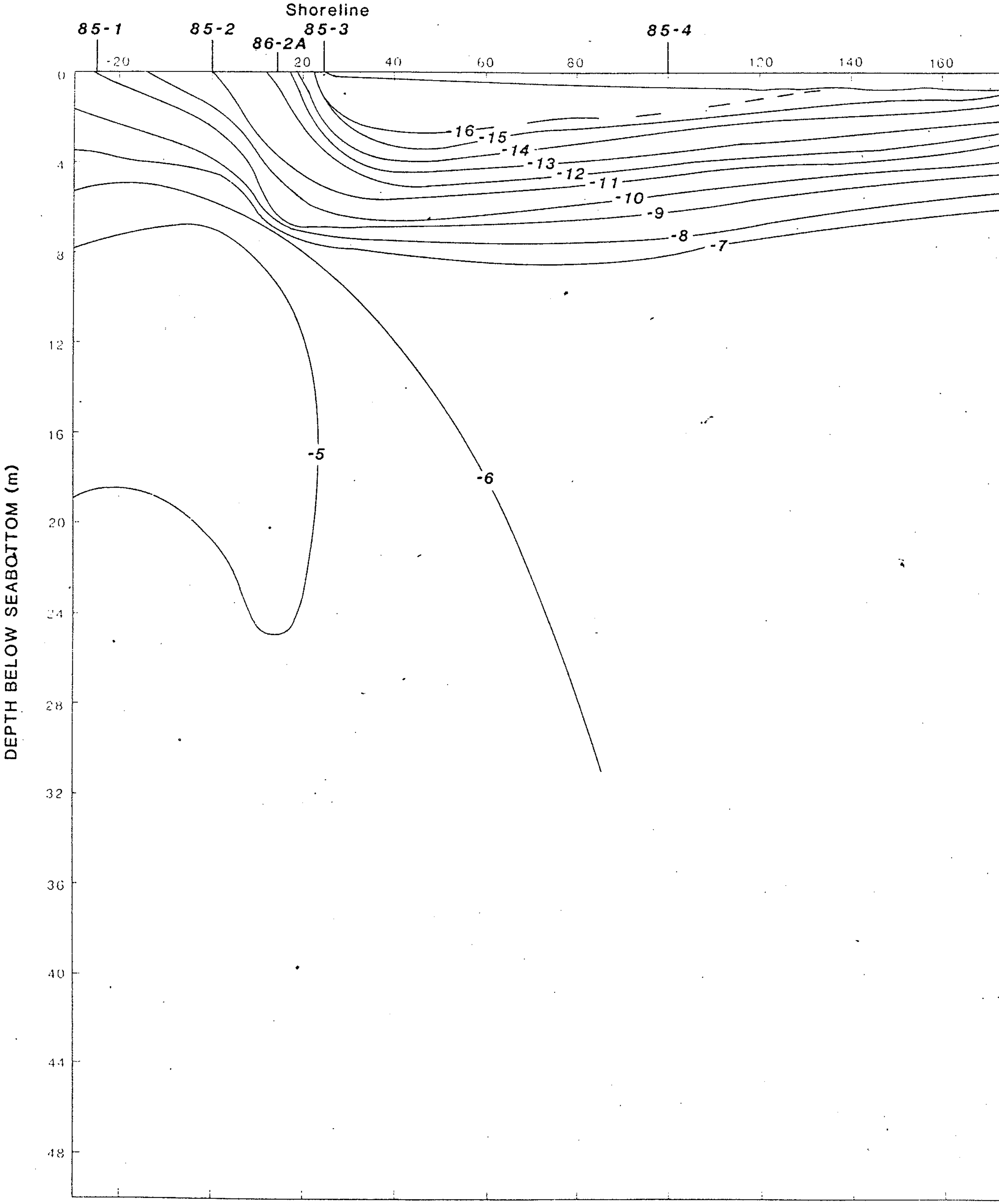
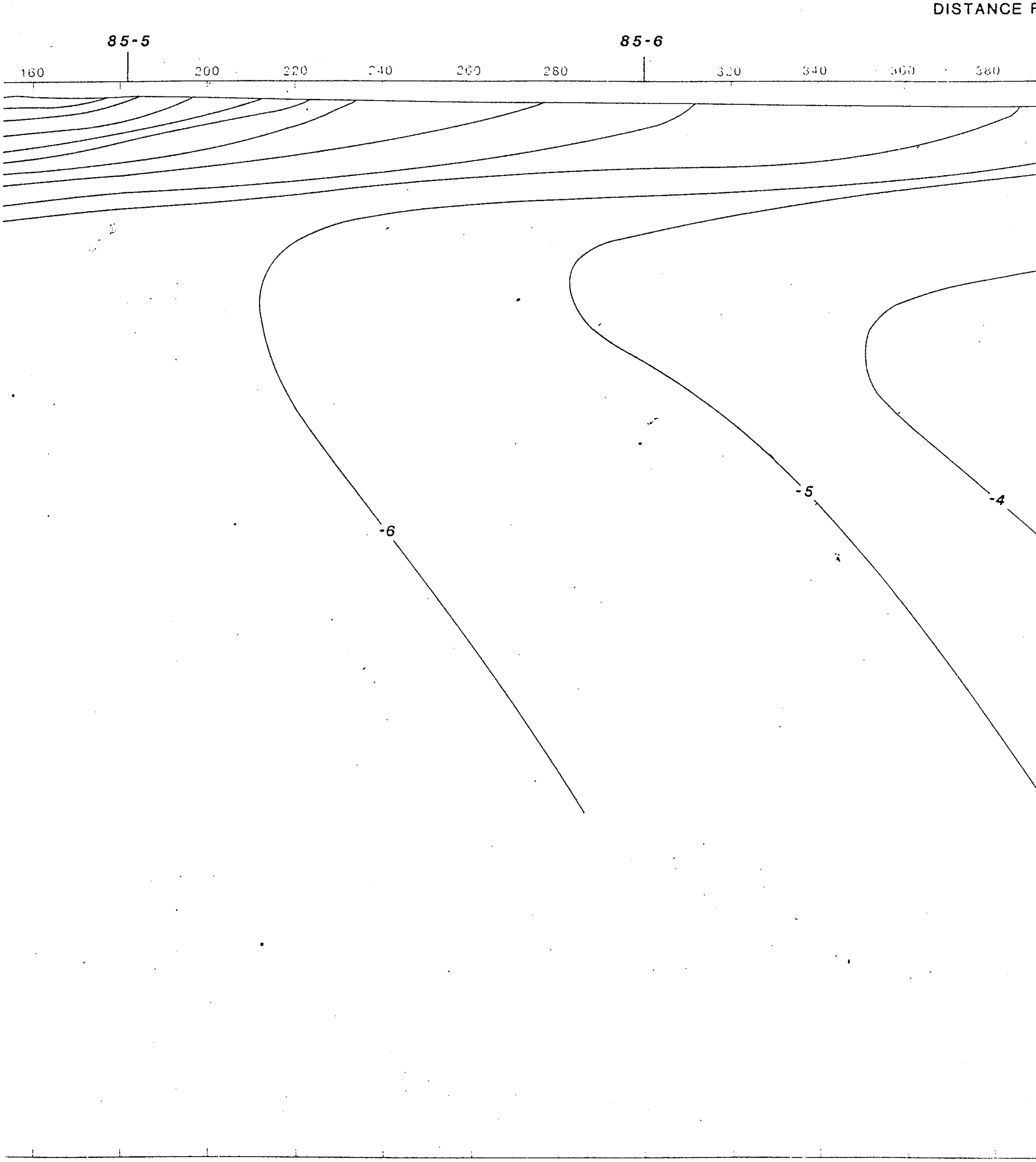
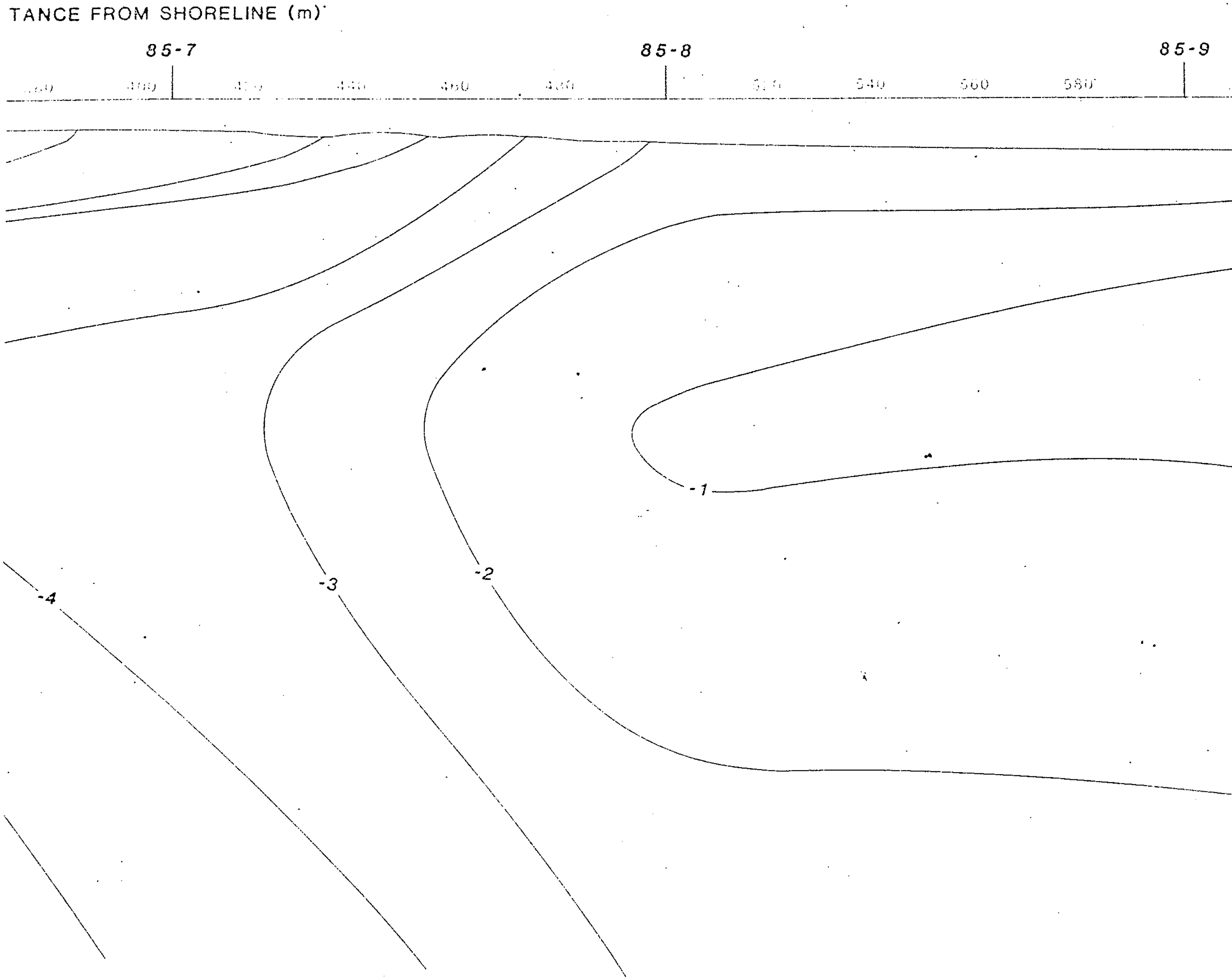
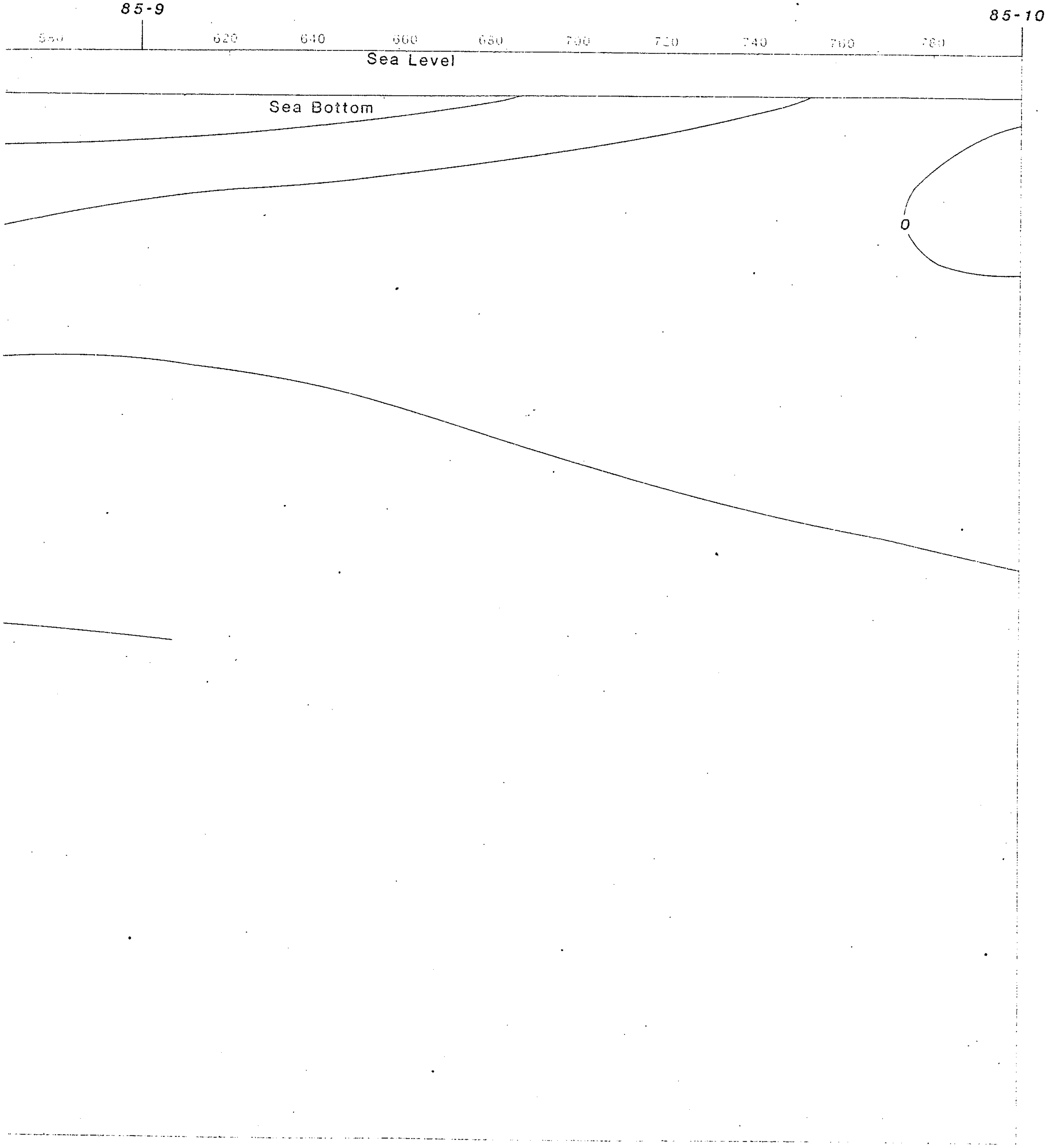


Fig. 8-14: Isothermal section - April 24,1986


DISTANCE F
85-5
85-6
160
200
220
240
260
280
320
340
360
380
-6
-5
-4


TANCE FROM SHORELINE (m)
85-7
85-8
85-9
400
420
440
460
480
520
540
560
580
-1
-2
-3
-4


85-9
85-10
580
620
640
660
680
700
720
740
760
780
Sea Level
Sea Bottom
0

9. SEABOTTOM SEISMIC REFRACTION MEASUREMENTS

J.A. Hunter, S. Pullan

Seismic refraction measurements were carried out under contract during the August 1985 program of installation of temperature cables (Northern Seismic Analysis, 1985). A 12-channel array of hydrophones (Mark Products P-44) with a total length of 97.5 m was laid progressively end-to-end on the seabottom along 800 m of traverse line. Forward and reverse shooting was done using the first hydrophone position for zero time reference. The source consisted of an 8-gauge electrically-detonated industrial shot-gun shell fired into the seabottom. Data were recorded with an S.I.E. RS-4 12-channel analog seismograph.

Although uphole seismic measurements carried out in April 1986 (see Chapter 10) show that high velocity sediments are present in the offshore region at depths beyond 15 m below seabottom, high velocity refraction events were observed only on the inshore portion (holes 85-3 to 85-6) of the traverse line (Fig. 9-1). Beyond a distance of 400 m offshore (approximately at the hole 85-7 location), no high velocities were observed. It is suggested that the signal-to-noise ratio for the refraction work was insufficient to allow detection of the high velocity events and that a stronger source signal is required. Alternatively, a near-seabottom layer (at 5 m depth) with velocities in the range of 2200-2800 m/s may have acted as a masking layer which inhibited refractions from the deeper high-velocity ice-rich sediments.

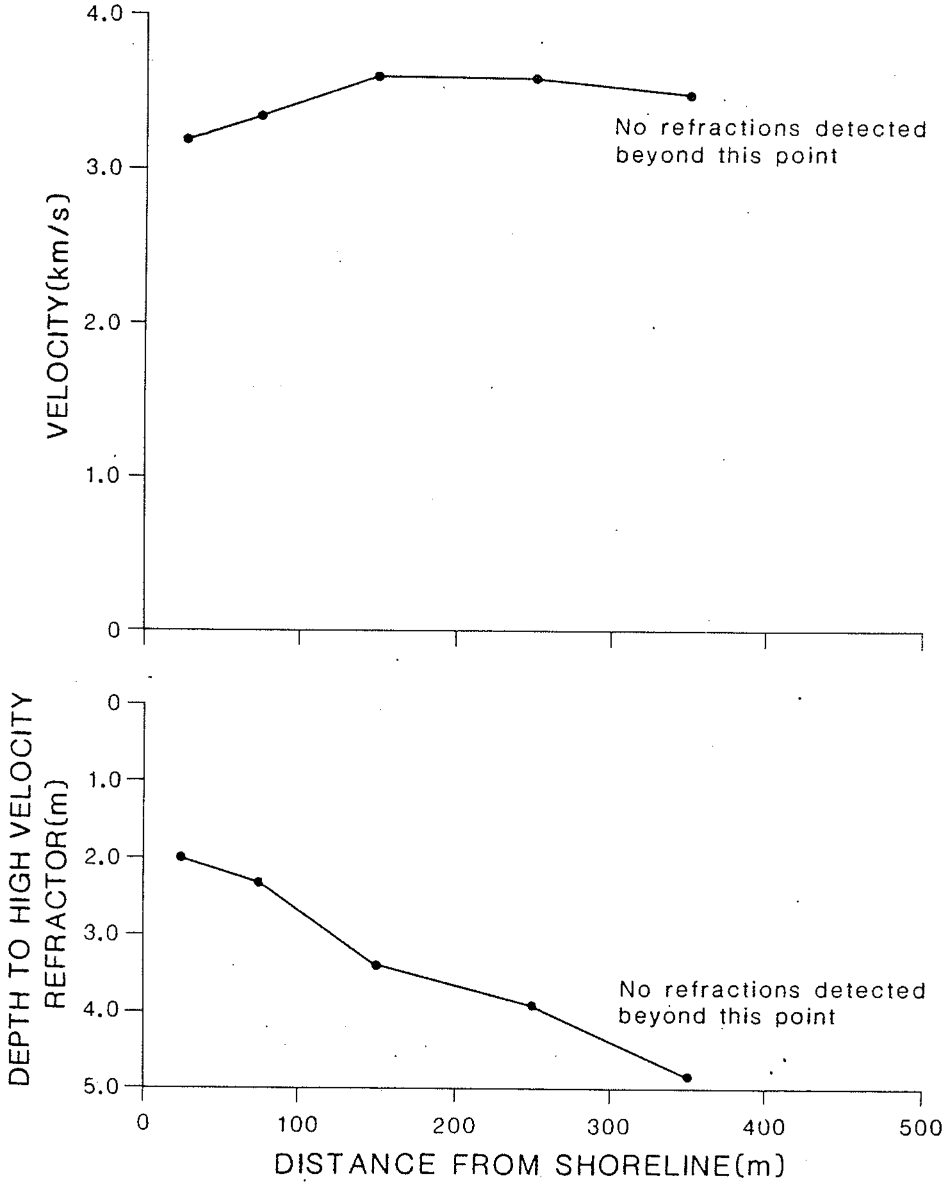


Fig. 9-1: Seabottom refraction profile

10. UPHOLE SEISMIC MEASUREMENTS

J.A. Hunter, S. Pullan

Uphole seismic velocity measurements were made during April 1986 in boreholes 86-2, 86-4, 86-6, 86-7, 86-8, 86-9 and 86-10. The source consisted of a seismocap detonated beneath the bottom of the ice alongside the borehole. The receiver consisted of a Mark Products P-44 hydrophone hanging freely in the fluid-filled borehole. The receiver was moved in 1 meter increments and the shots were recorded using a Nimbus 1210 F engineering seismograph and digital tape recorder. The data were transferred to floppy-disk storage and first arrival times were obtained using computer-based routines. After correction for shot offset and depth, the distance-travel time data were plotted and interpreted. For each borehole, two plots are shown (Figs. 10-1 to 10-14). The first plot shows the shot-hydrophone distance (after correction for shot position) with the interpreted interval velocities shown as straight line segments. The second plot shows the interval velocities and average velocities (total distance/total time) plotted against depth of hydrophone in the borehole. Timing errors are in the order of ± 0.05 ms and hydrophone position errors are in the order of ± 5 cm. Data quality in boreholes 86-2, 86-3 and 86-6 is poor because of high signal-to-noise ratio caused by poor shot coupling in shallow boreholes. Data quality in boreholes 86-7, 86-8, 86-9 and 86-10 is good, although occasionally first-break quality was reduced by electronically generated noise. A conservative approach has been used to interpret interval velocities, and only large scale variations were interpreted.

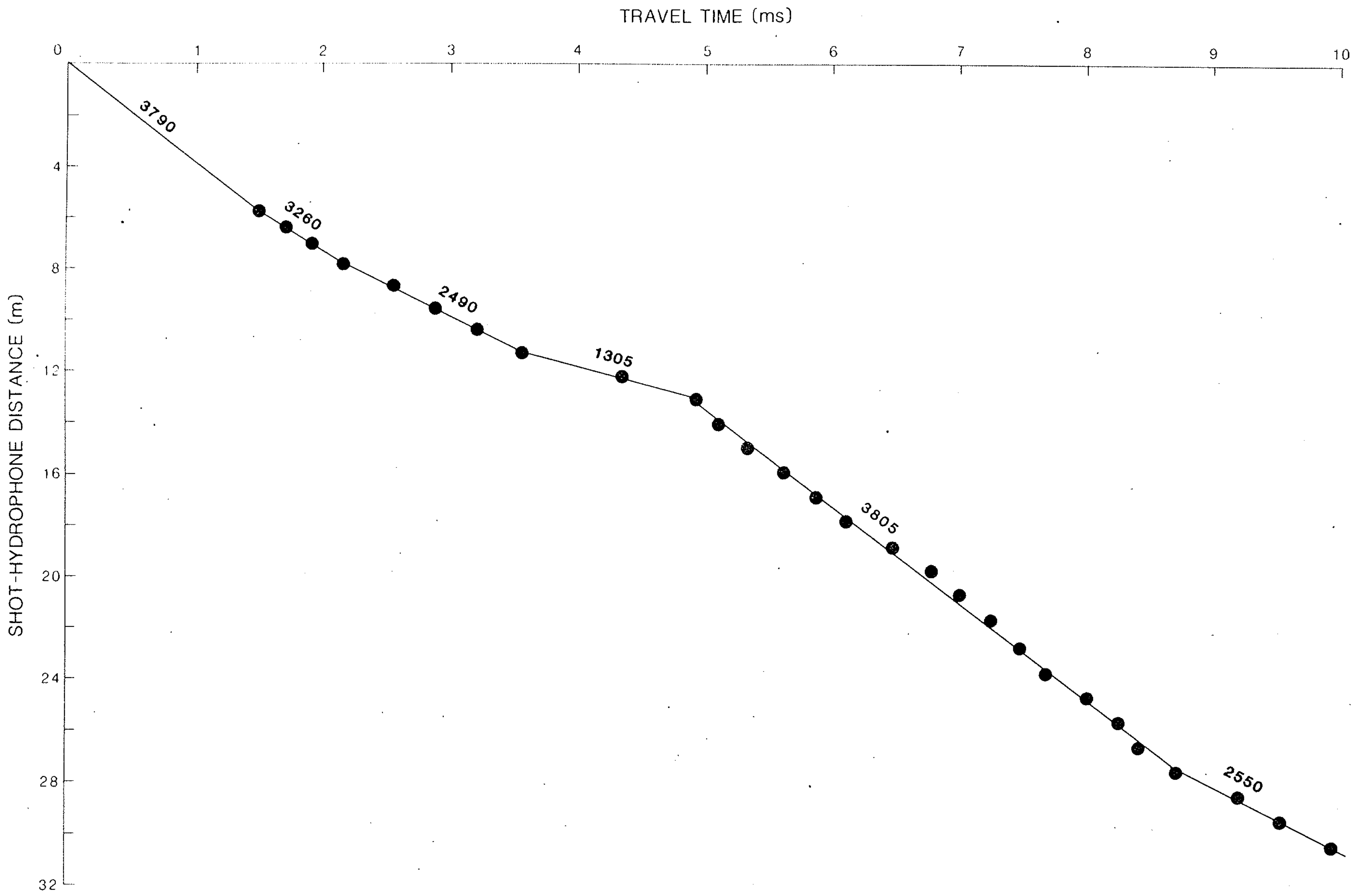


Fig. 10-1: Seismic velocity vs. shot-hydrophone distance - borehole 86-2

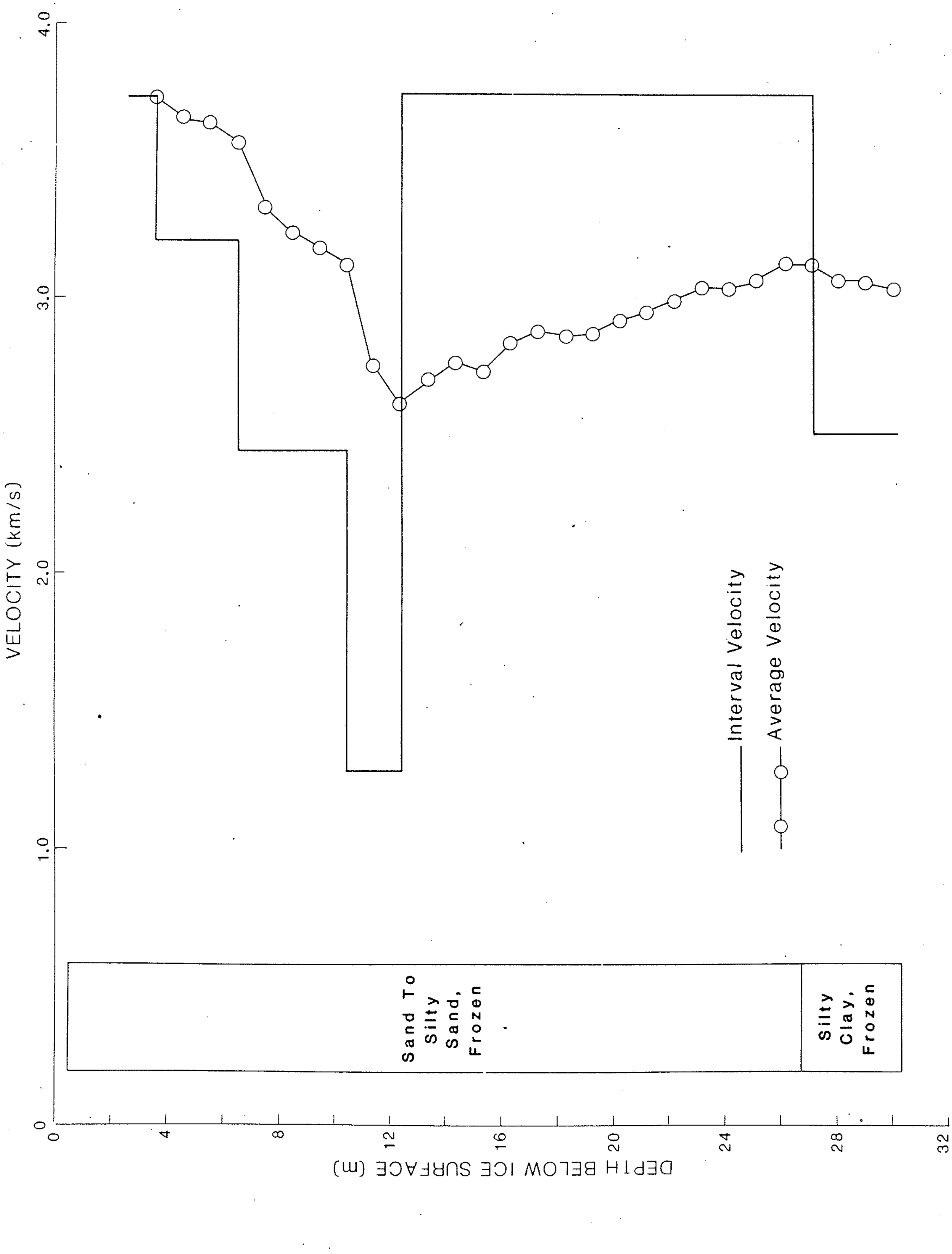


Fig. 10-2: Seismic velocity vs. hydrophone depth -borehole 86-2

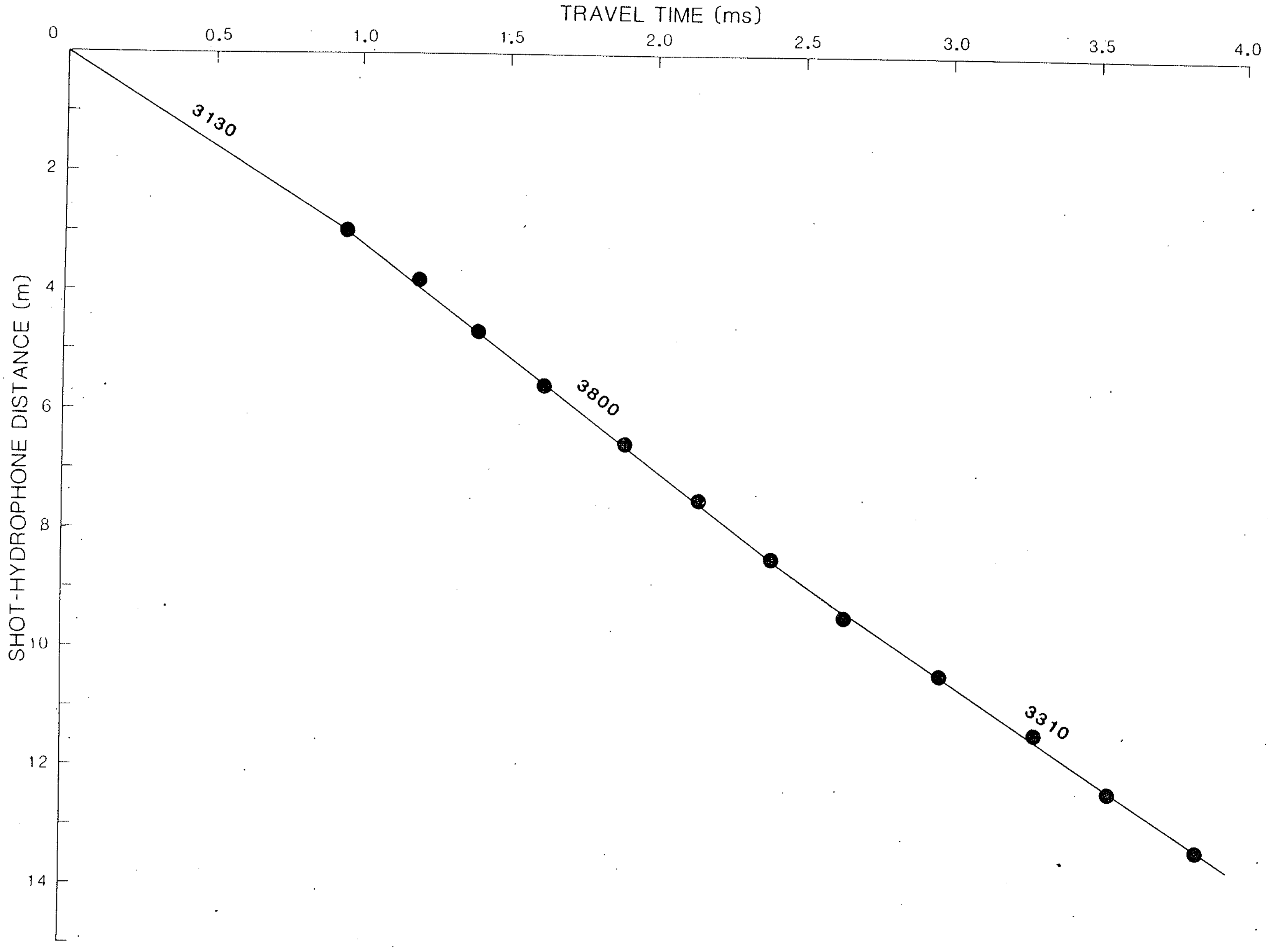


Fig. 10-3: Seismic velocity vs. shot-hydrophone distance - borehole 86-4

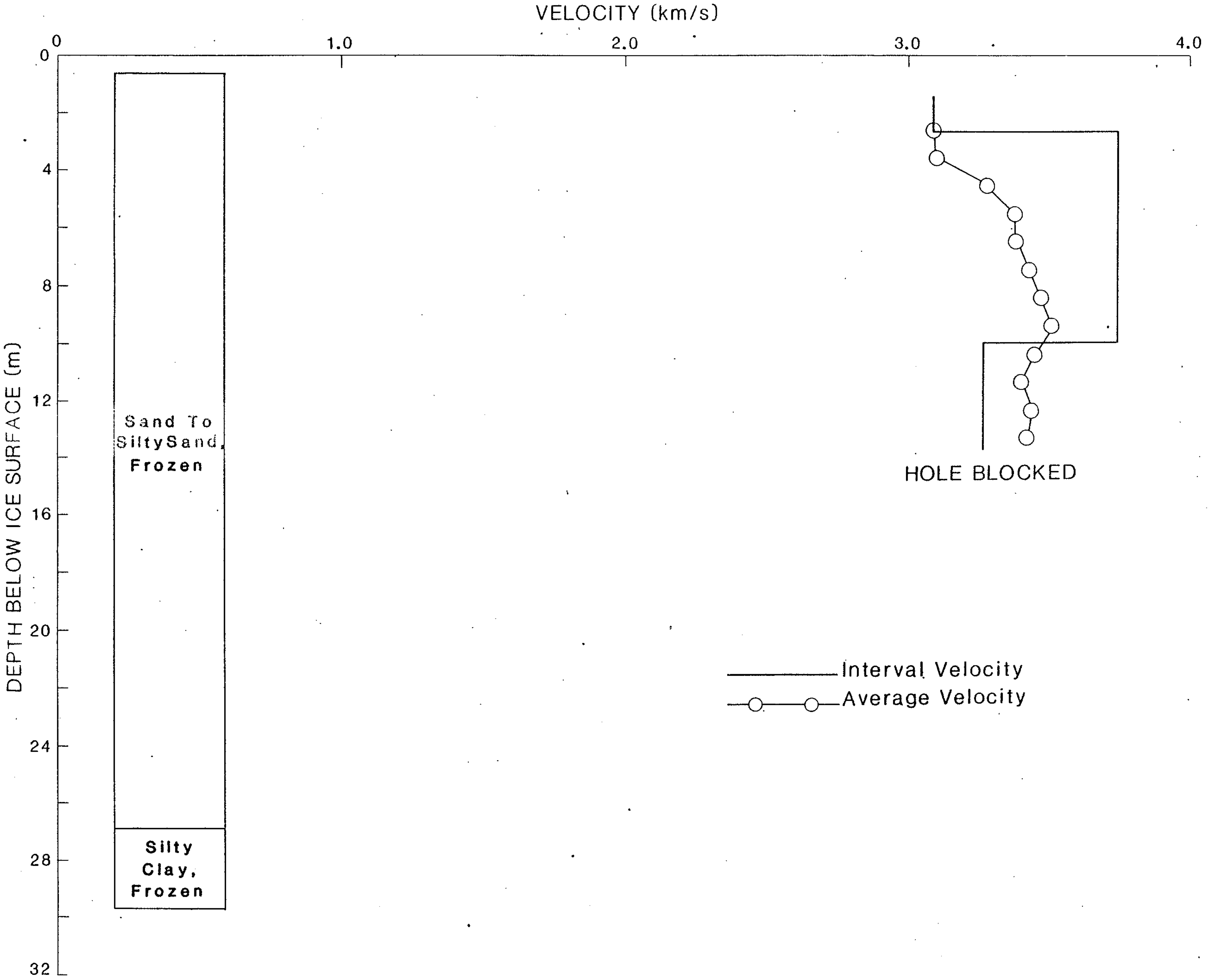


Fig. 10-4: Seismic velocity vs. hydrophone depth - borehole 86-4

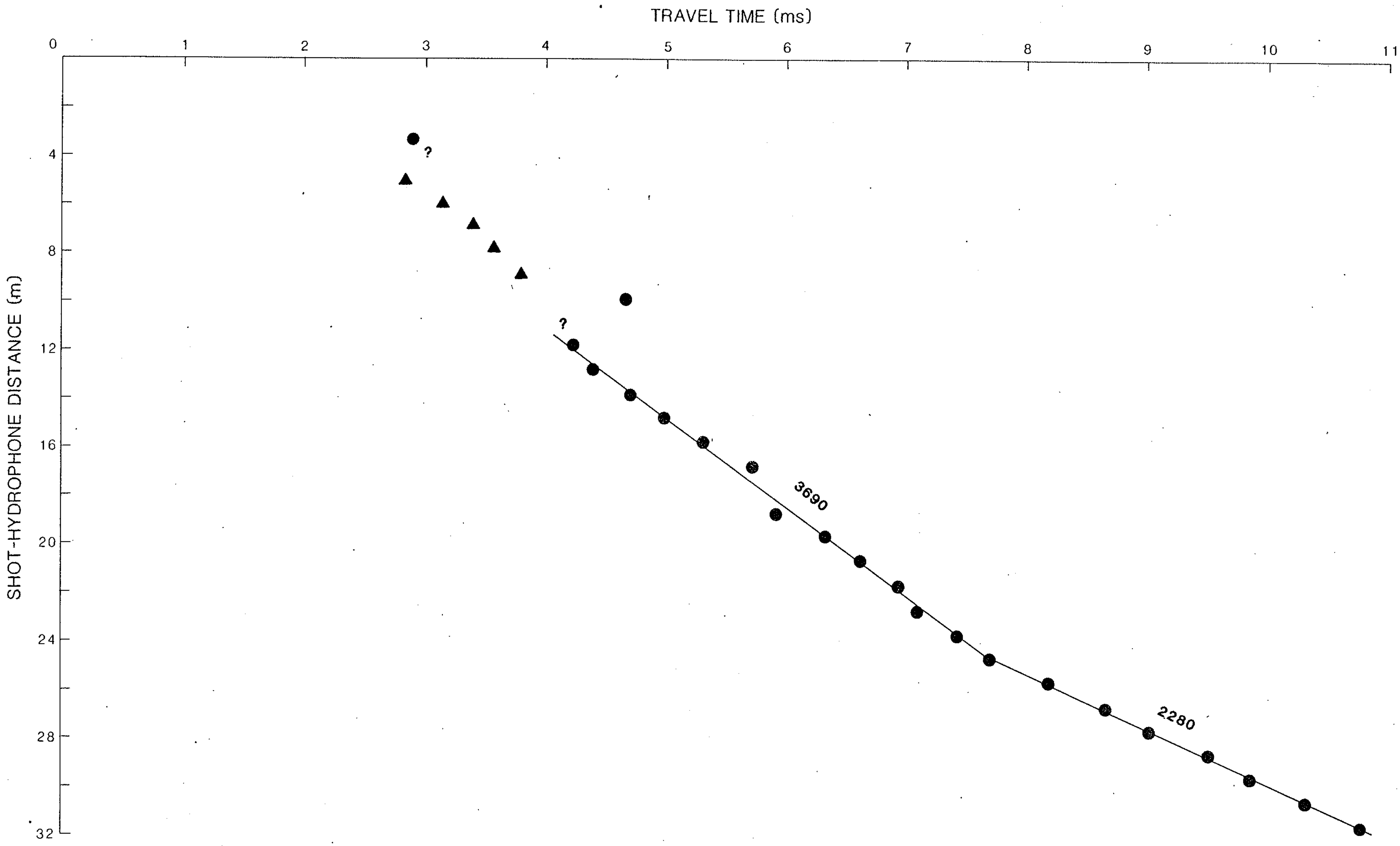


Fig. 10-5: Seismic velocity vs. shot-hydrophone distance - borehole 86-6

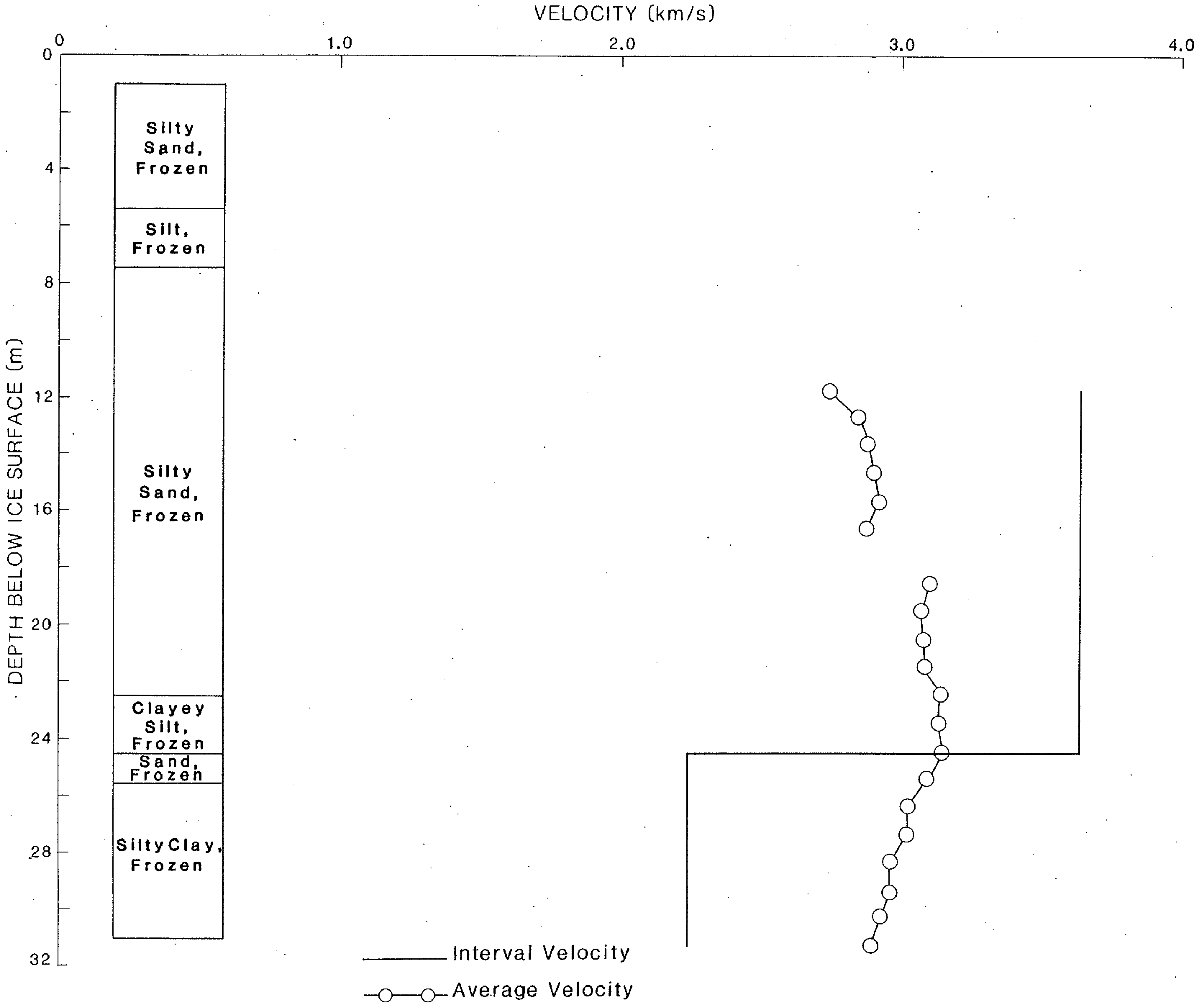


Fig. 10-6: Seismic velocity vs. hydrophone depth - borehole 86-6

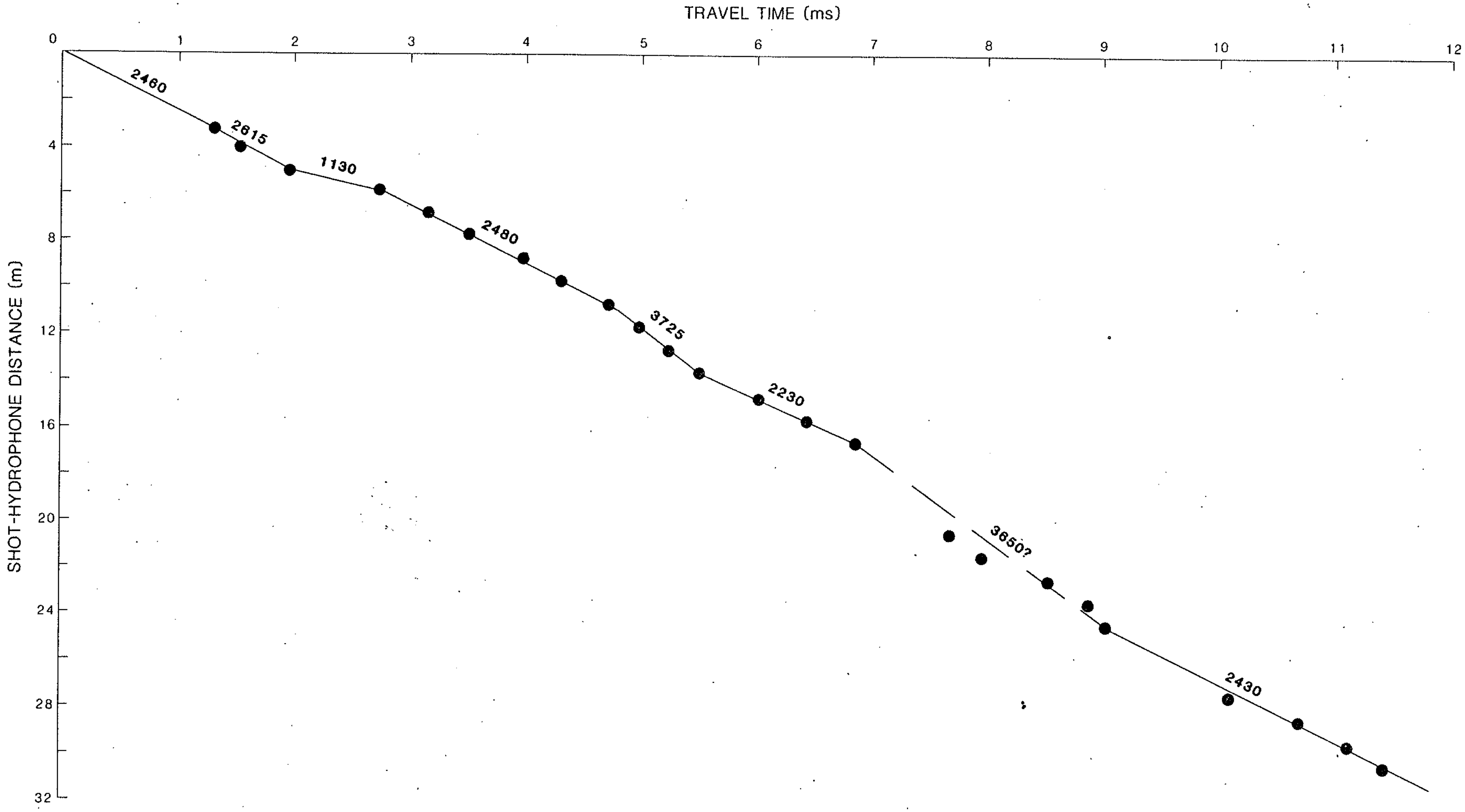


Fig. 10-7: Seismic velocity vs. shot-hydrophone distance - borehole 86-7

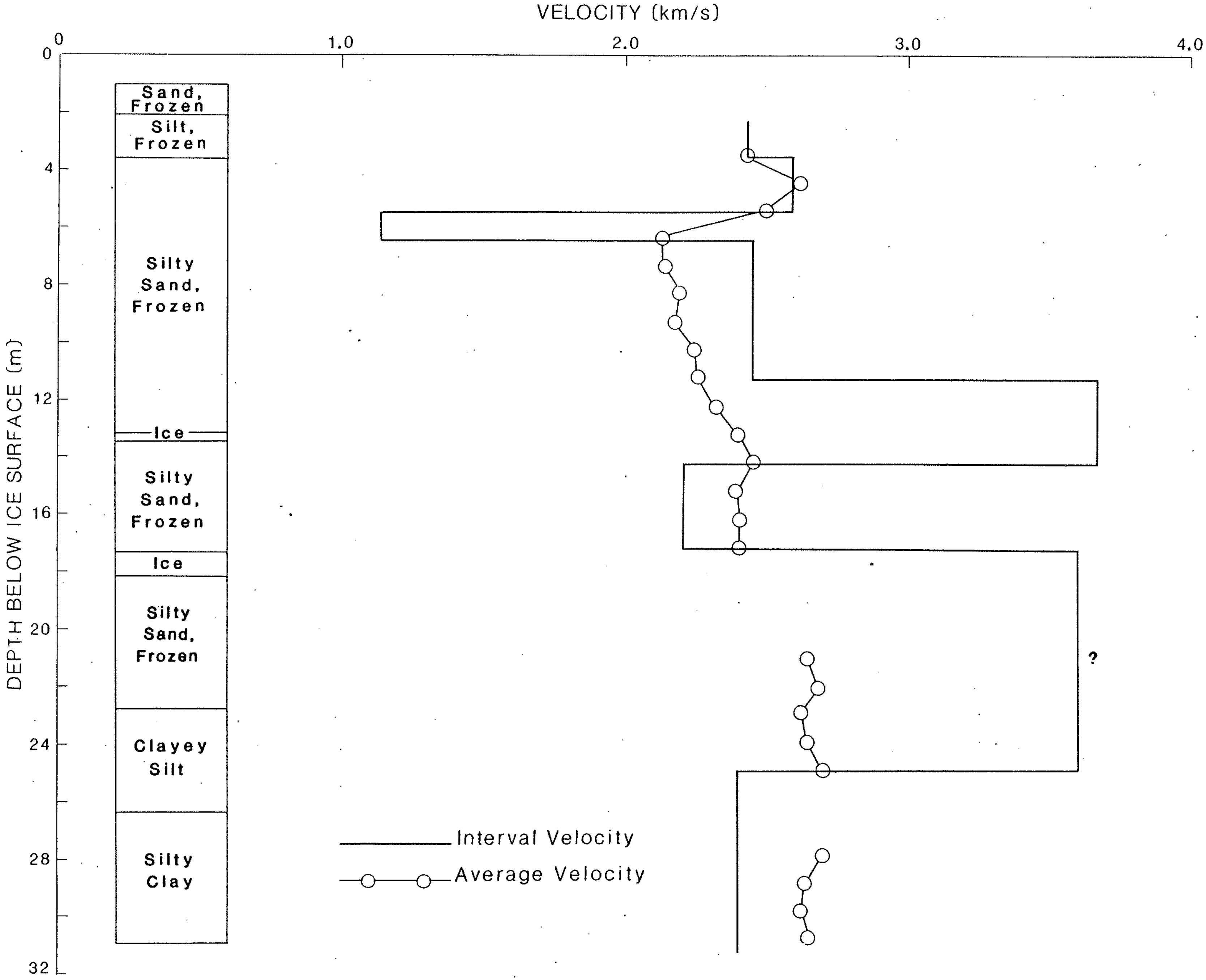


Fig. 10-8: Seismic velocity vs. hydrophone depth - borehole 86-7

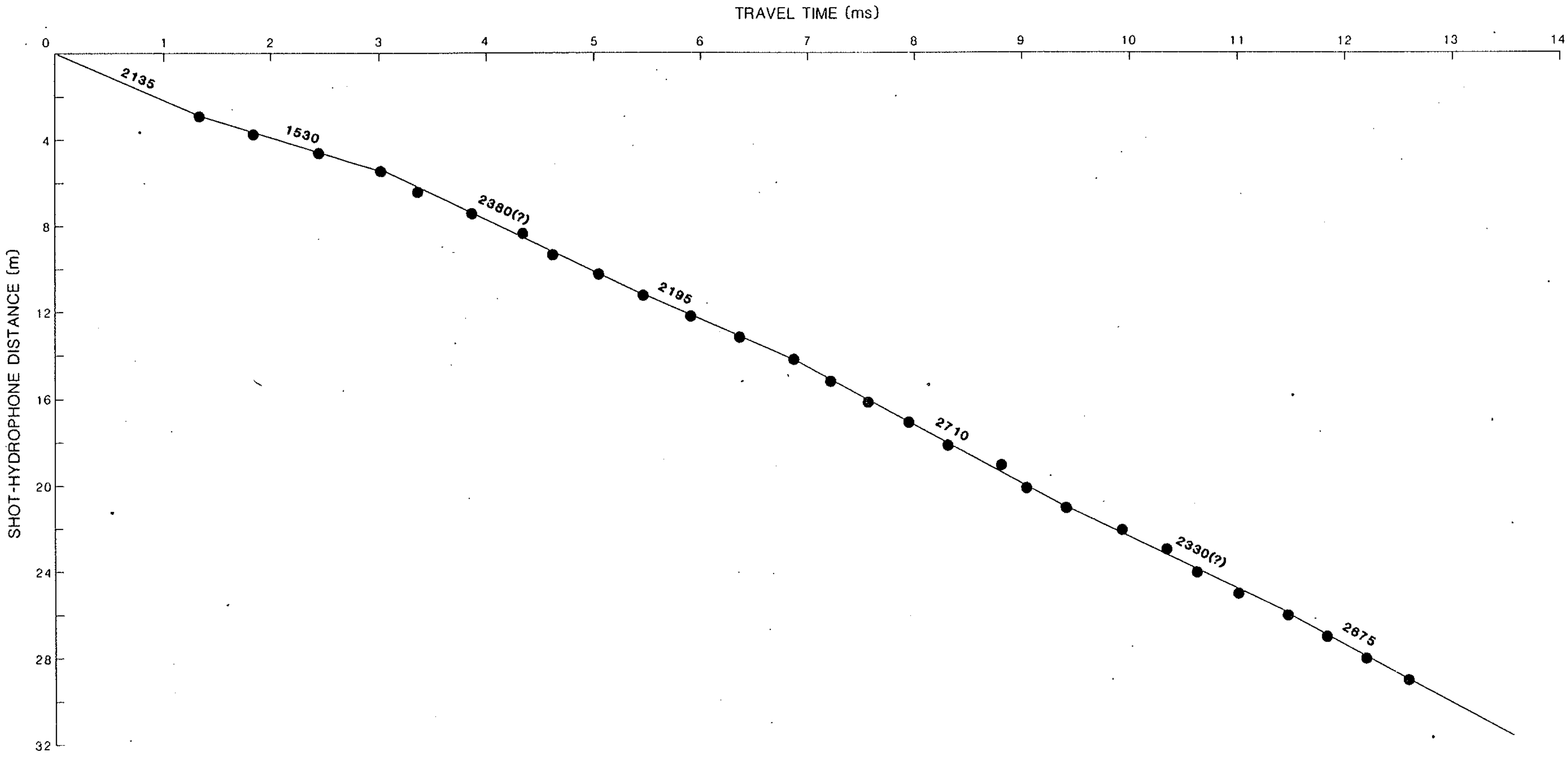


Fig. 10-9: Seismic velocity vs. shot-hydrophone distance - borehole 86-8

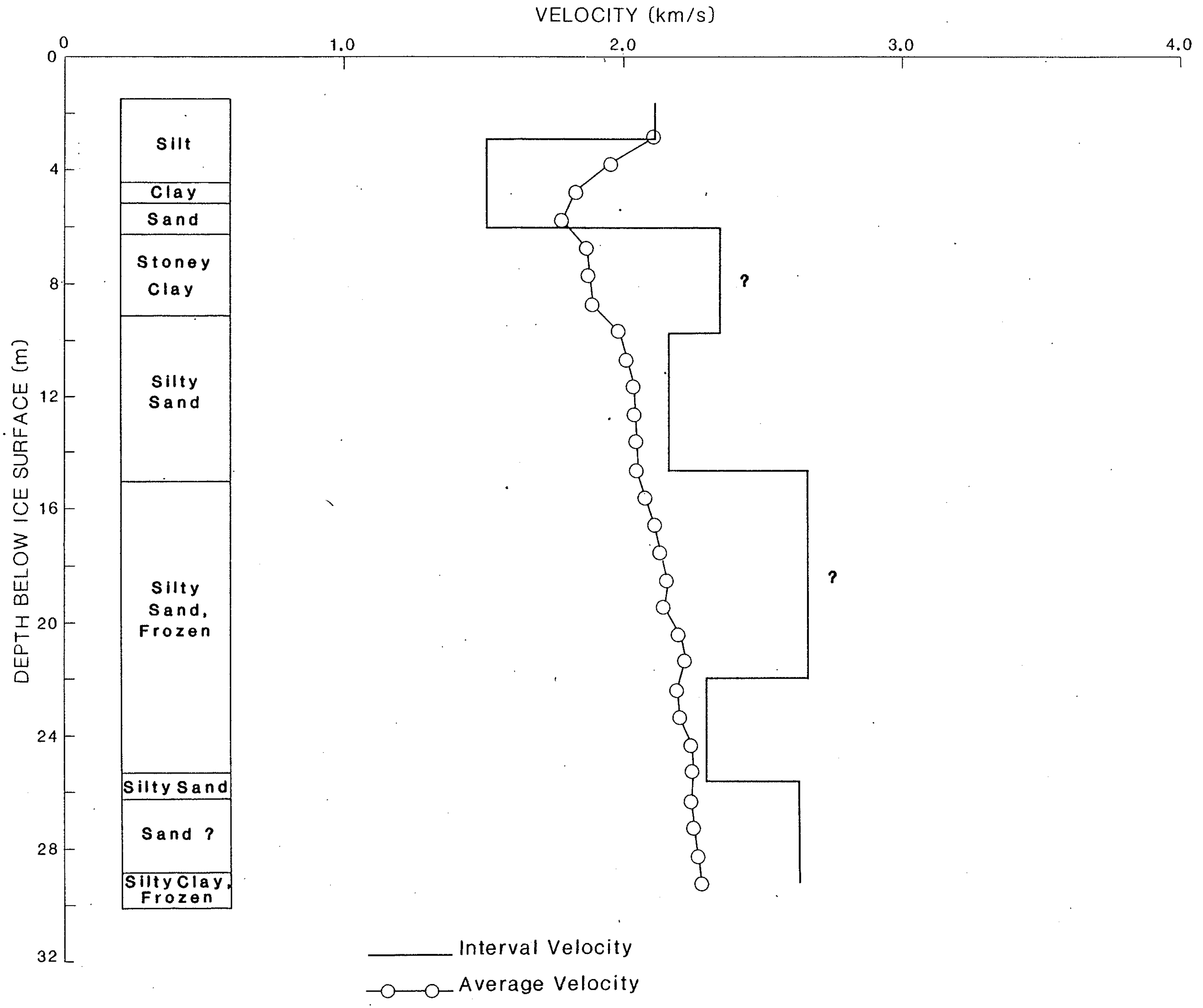


Fig. 10_10: Seismic velocity vs. hydrophone depth - borehole 86-8

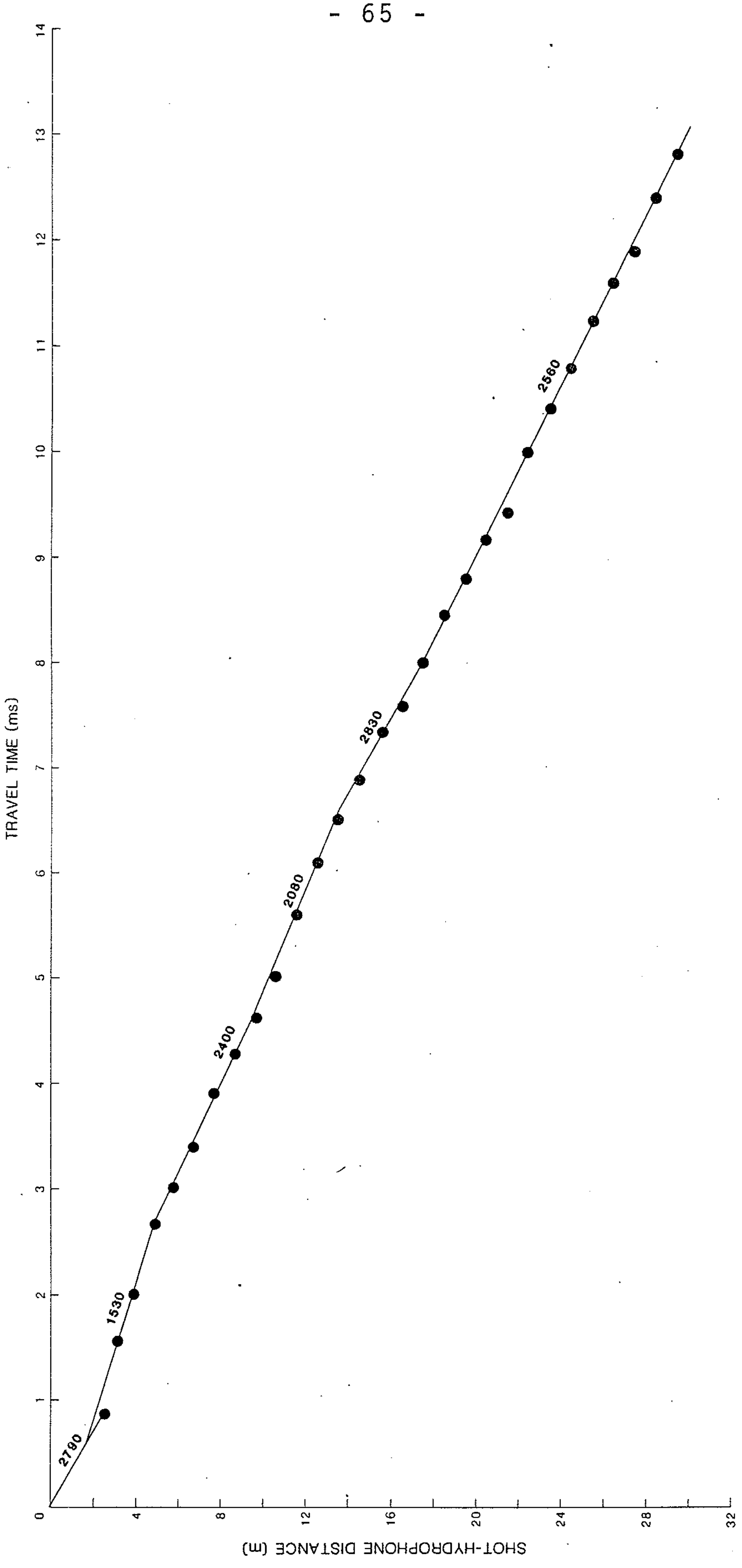


Fig. 10-11: Seismic velocity vs. shot-hydrophone distance - borehole 86-9

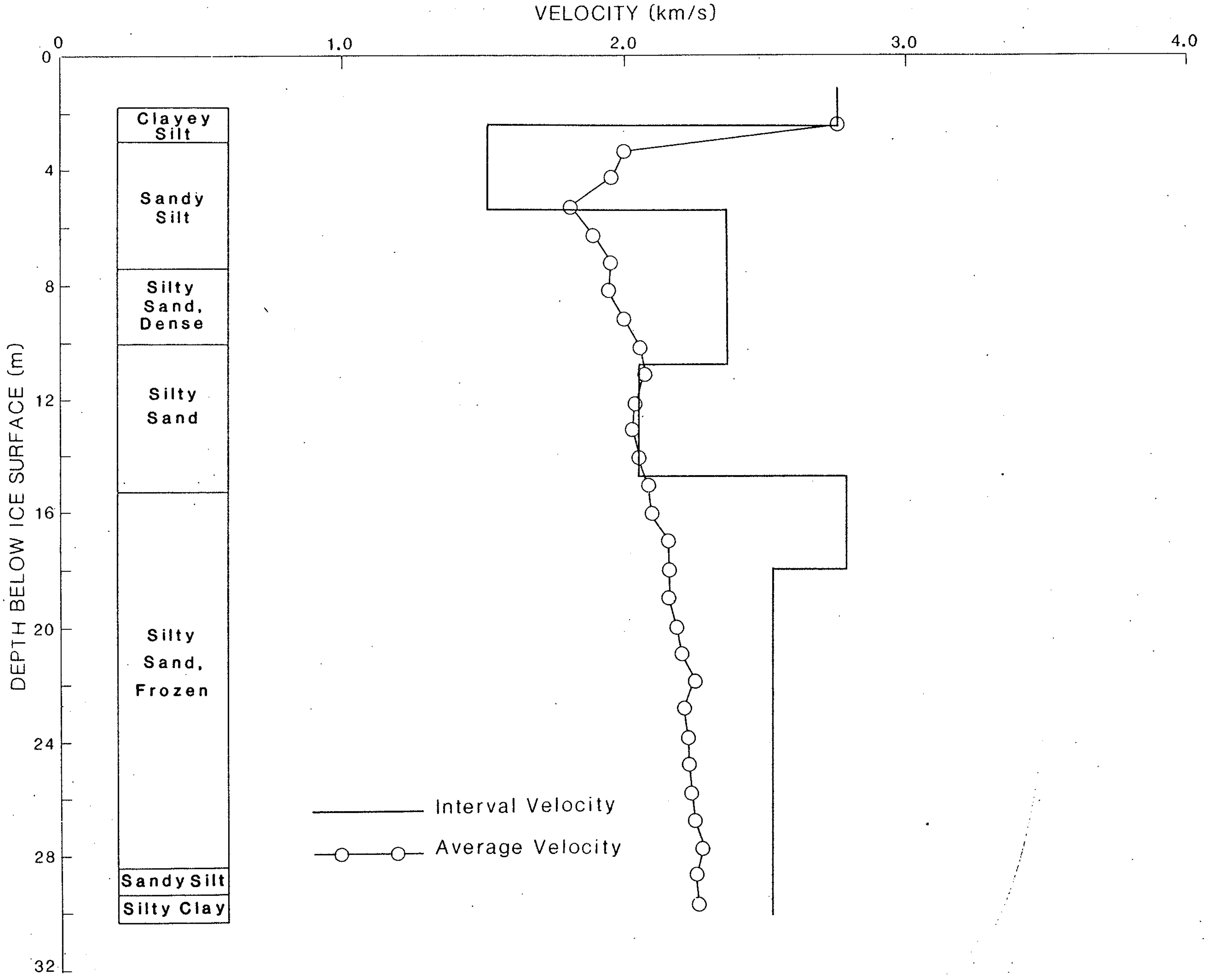


Fig. 10-12: Seismic velocity vs. hydrophone depth - borehole 86-9

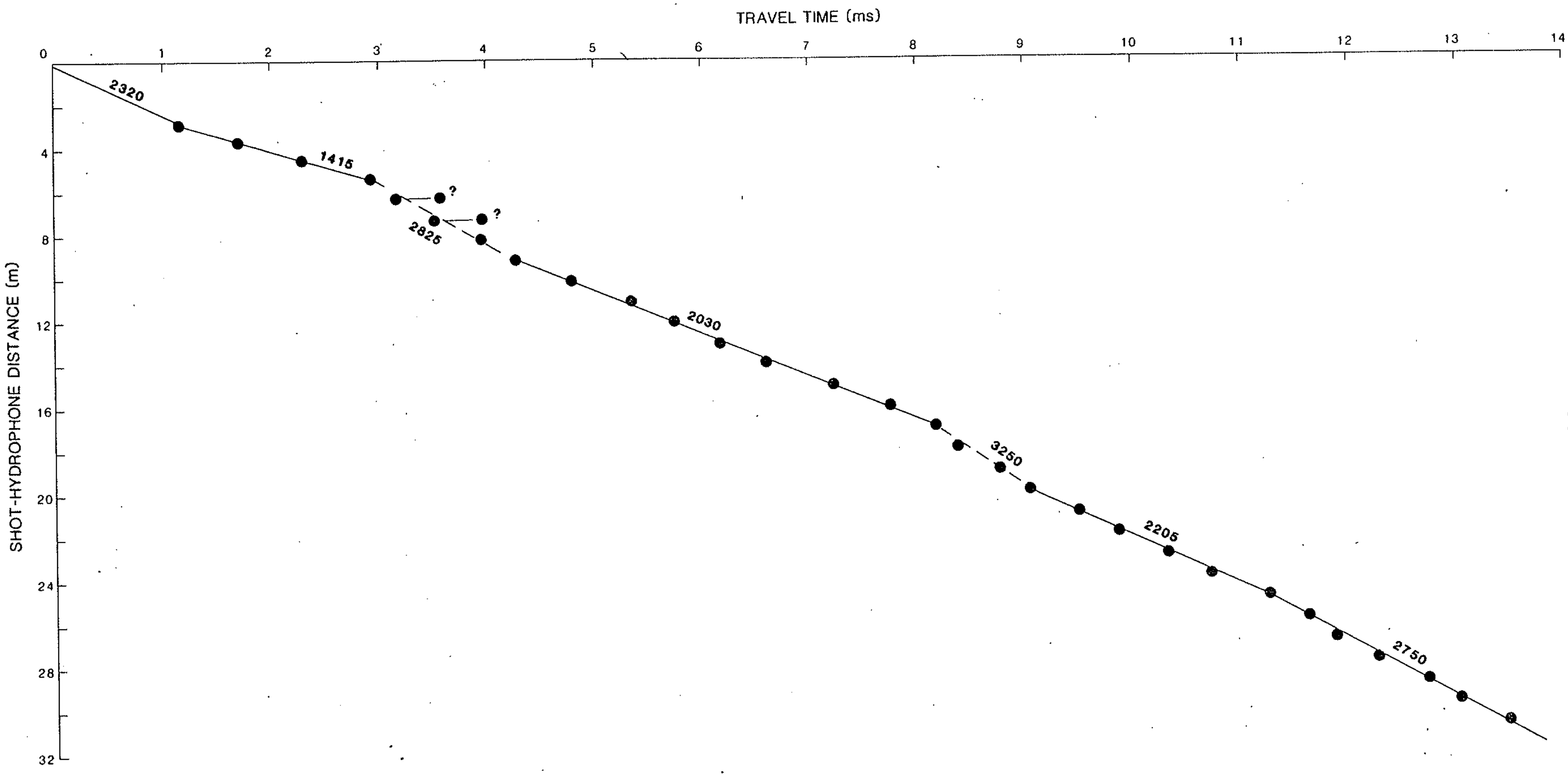


Fig. 10-13: Seismic velocity vs. shot-hydrophone distance - borehole 86-10

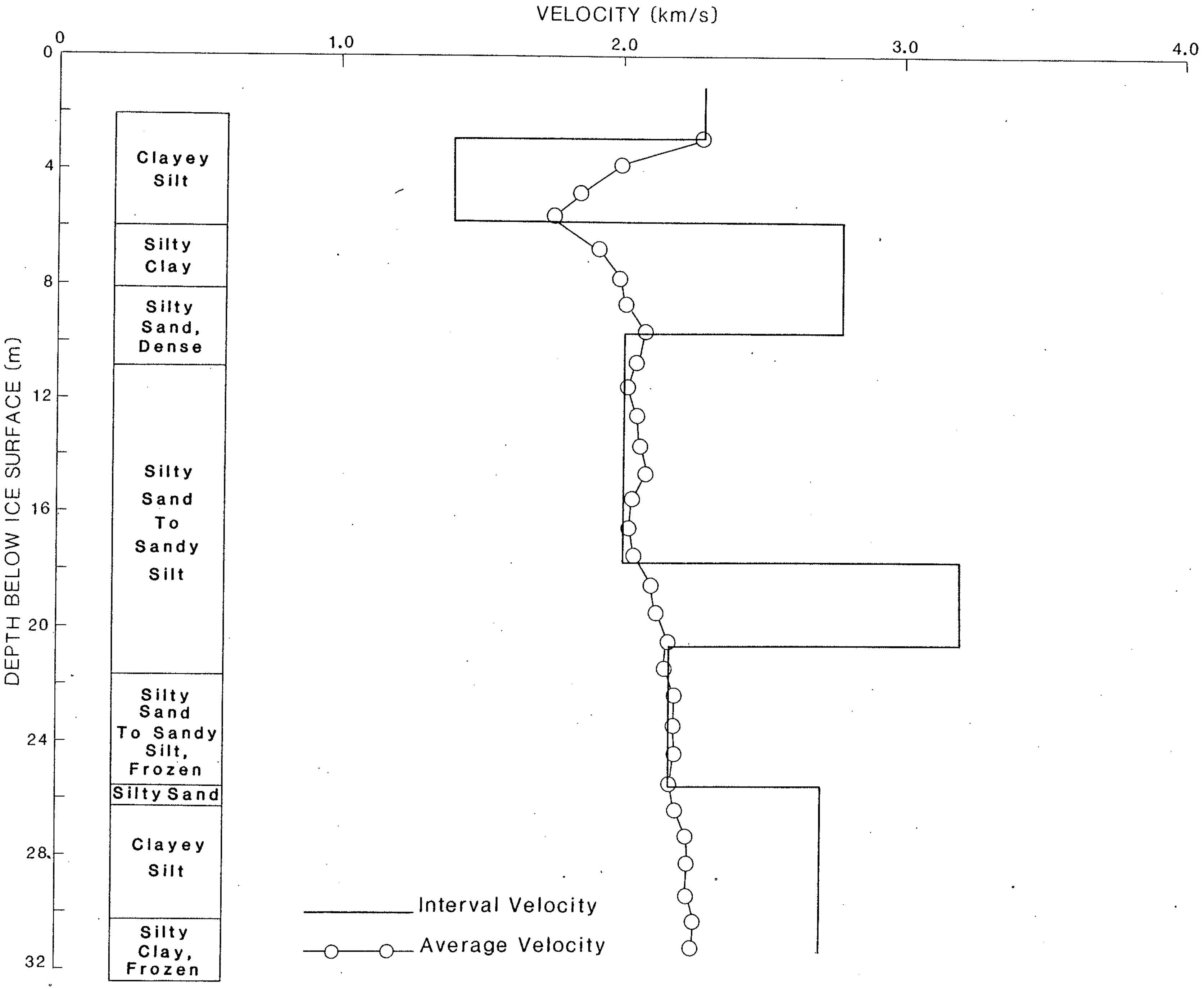


Fig. 10-14: Seismic velocity vs. hydrophone depth - borehole 86-10

11. EM-34 MEASUREMENTS

J.A. Hunter, S. Pullan

EM measurements were carried out in April 1986 along three profiles, using the Geonics EM-34 in vertical-loop mode for coil spacings of 10 and 20 m. The three parallel lines were staked along the drilling transect, and 100 m south and north of this transect. Apparent conductivity measurements were made at 25 m intervals along the lines. The three profiles are shown in Figures. 11-1, 11-2 and 11-3. It is believed that the coil spacing used was sufficiently large to allow signal penetration to the depth of several metres below ice-bottom. A large change towards higher conductivity in the offshore sediments can be correlated with the apparent lack of ice-bonded sediments in the upper several metres in boreholes 86-8, 86-9 and 86-10. The largest change in conductivity occurs in the vicinity of borehole 86-7. It is suggested that this technique can be used to identify ice-bearing sea-bottom sediments in areas where the sea ice is frozen to bottom or where very little saline water is present beneath the ice.

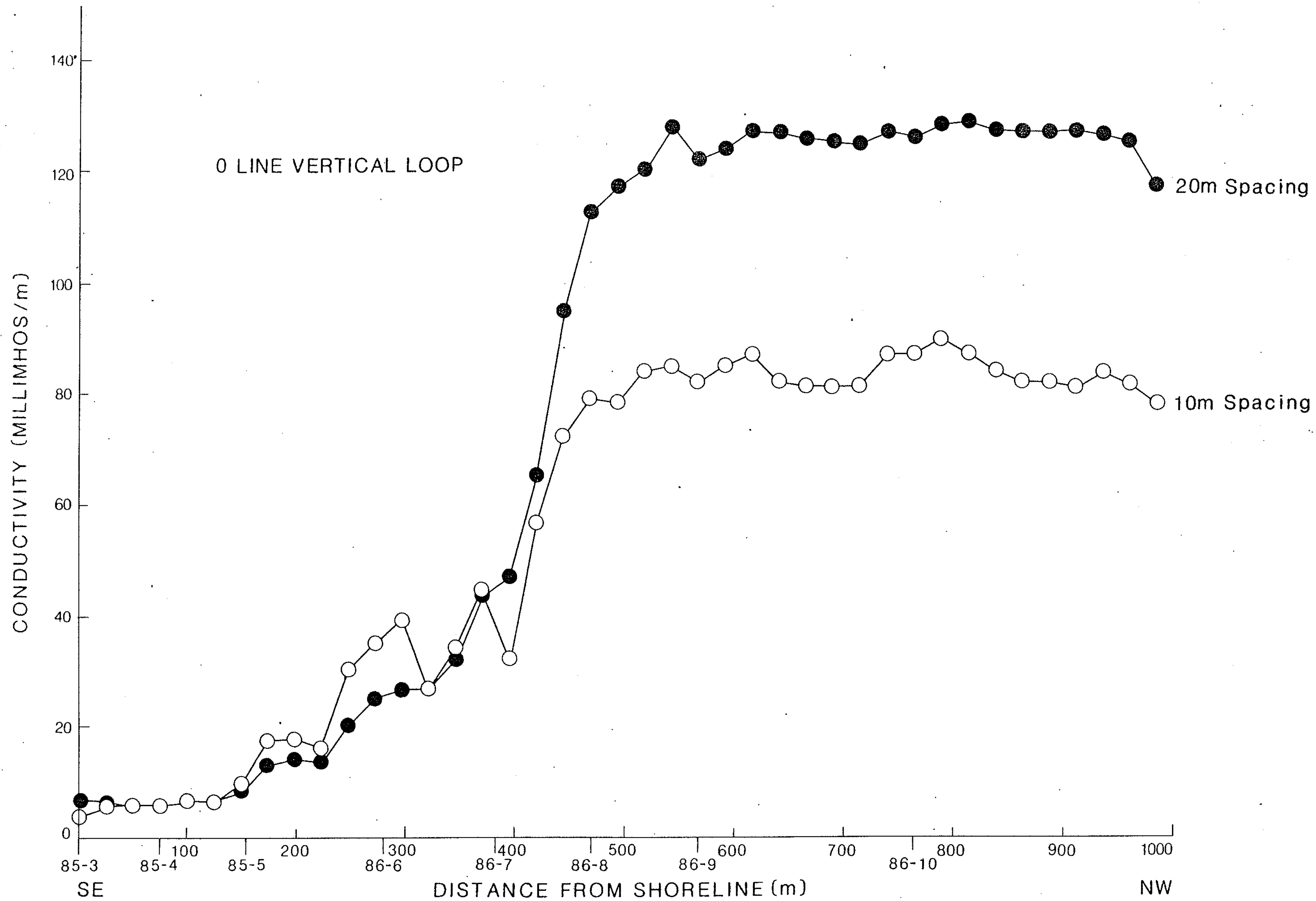


Fig. 11-1: Conductivity profile - 0 line

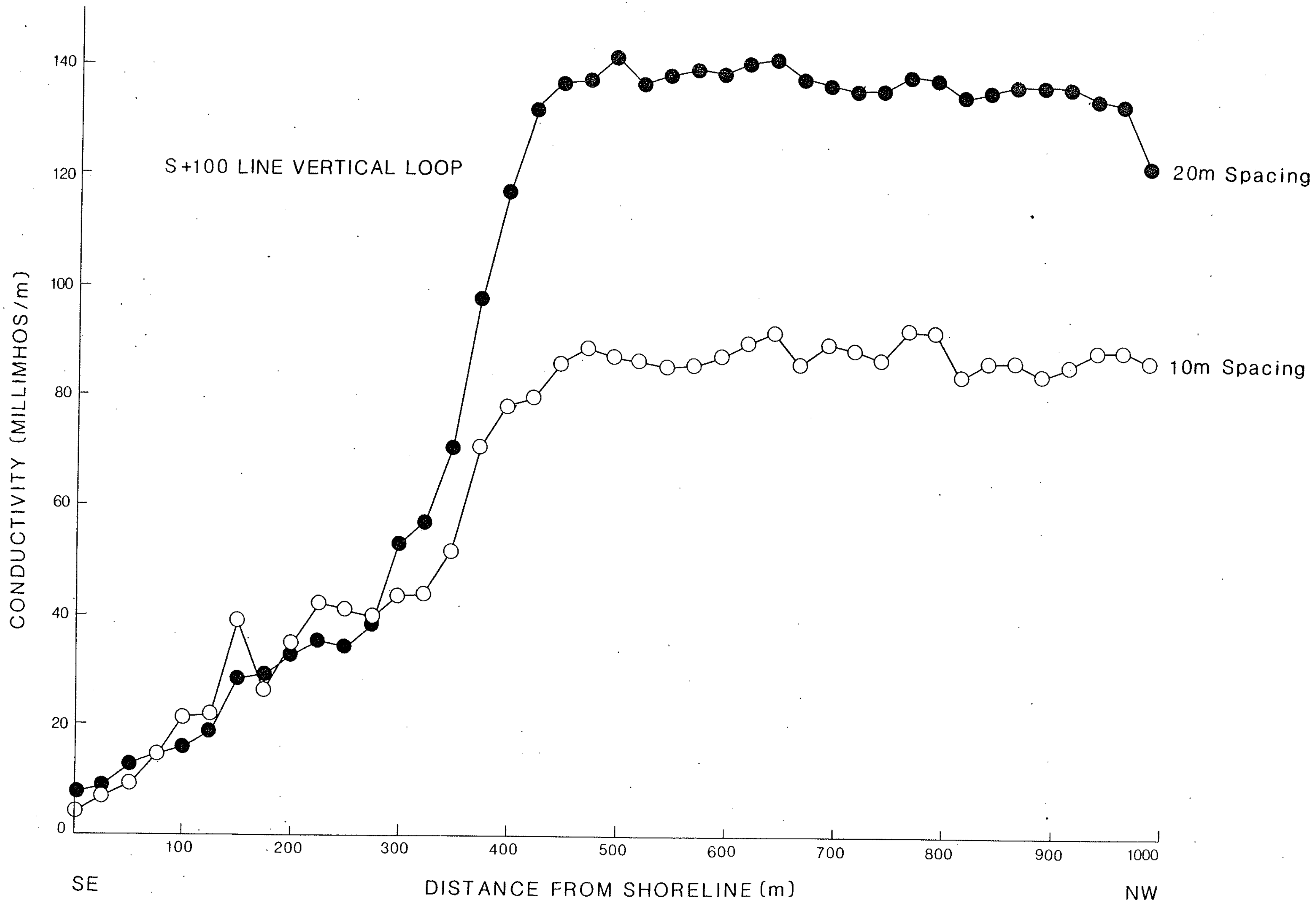


Fig. 11-2: Conductivity profile - S + 100 line

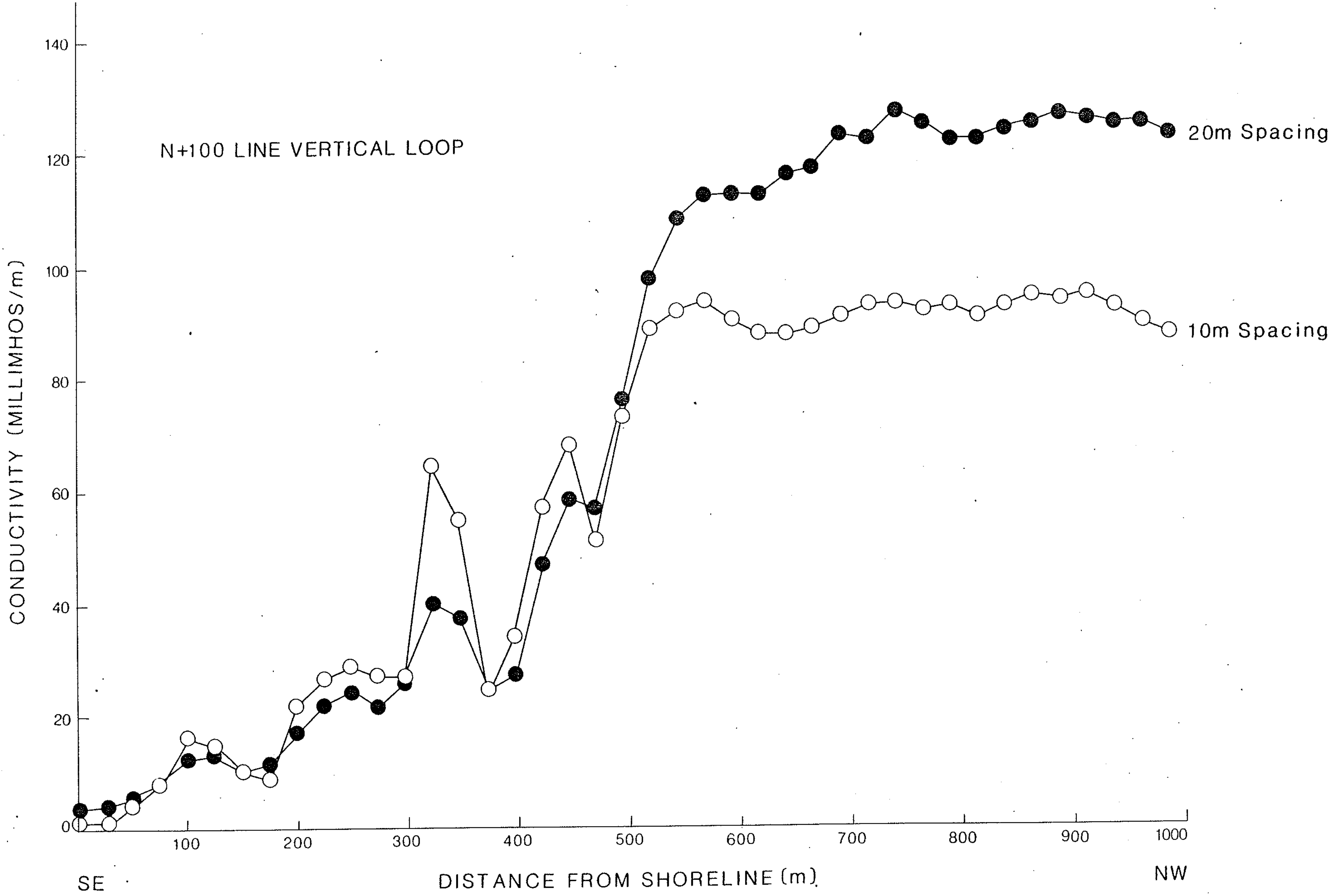


Fig. 11-3: Conductivity profile - N + 100 line

12. BOREHOLES HEATING TESTS

J.L. Morack and W.D. Harrison

Scientists from the University of Alaska were invited to participate in the 1986 Geological Survey of Canada (GSC) spring drilling program in the Beaufort Sea. Two of the boreholes drilled in the nearshore region (86-6 and 86-10) were electrically heated and their temperature responses were measured.

This area was chosen for the drilling program partly due to the presence of ice bearing material in the sub-bottom sediments. The method used in the experiment was to supply a known amount of heat per unit length in the boreholes, using an electrically heated wire. Both boreholes were heated for four hours with about 35 watts/m of power. In most cases, this amount of energy was sufficient to raise the temperature in the boreholes several degrees. The temperature at several depths in the boreholes was then monitored for several days as the sub-bottom materials returned to equilibrium. When no ice is present, the approach to equilibrium after heating can usually be interpreted to give the thermal conductivity as a function of depth (Harrison and Morack, 1985). The presence of ice is indicated by a different temperature response due to the phase changes that occur during the heating and cooling and is more difficult to analyze.

The heating data show that both boreholes have ice bearing materials in them. Figure 12-1 shows the temperature response in borehole 86-6 as a function of time after the beginning of the four-hour heating period. The time at .27 days corresponds to 2.5 hours after the heating was terminated and the time at 5.1 days corresponds to the time when equilibrium was essentially re-established. A large increse in temperature above equilibrium indicates that little or no ice is present and a small increase indicates that most of the energy went into melting the ice. The heating data indicate that there is little or no ice down to 11-13 m, large

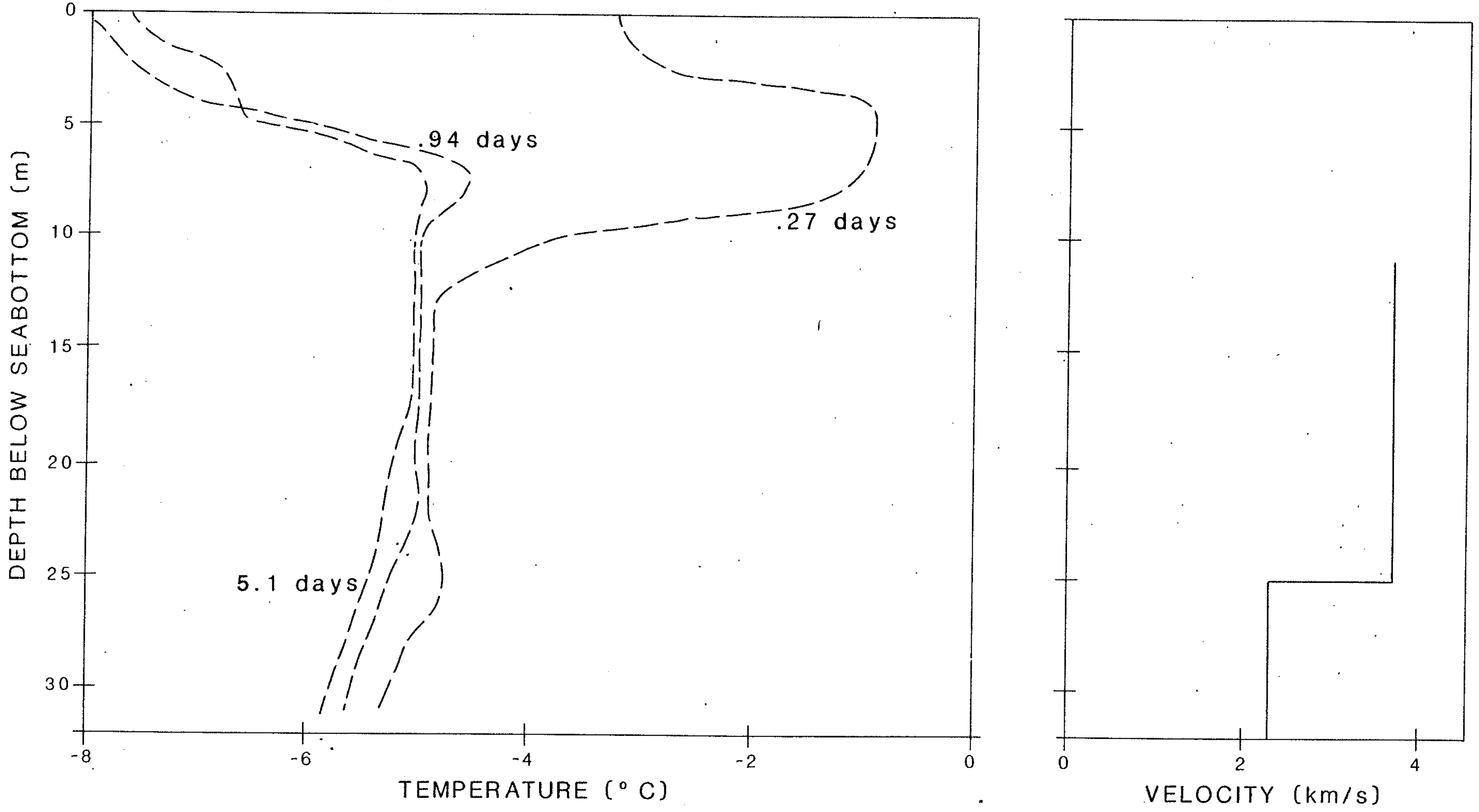


Fig. 12-1: Borehole heating and downhole seismic data - borehole 86-6

amounts of ice from 11-13 m down to 22-25 m, and somewhat less ice below 22-25 m. Downhole seismic data, also shown on the figure, indicate very high-velocity material from 11 m down to 25 m, which is probably ice bonded, and lower-velocity material below 25 m, which is probably ice bearing. The correlation between the seismic and the heating data is very good and the two methods compliment each other.

Figure 12-2 shows the similar data for borehole 86-10. The heating data indicate that the material contains little or no ice down to 15-18 m, large amounts of ice from 15-18 m to 18-21 m, then significantly less ice from 18-21 m to 24-27 m, and then an increase in the ice content below 24-27 m. There is again a good correlation between the seismic heating data below 9 m. However the seismic data above 9 m do not correlate well and further interpretation will be required.

At present, the analysis of the heating data is not sufficiently far advanced to permit interpretations of ice and water contents, thermal conductivities, or other material properties. It is hoped that thermal modelling of the heating and cooling cycle will allow determination of these properties.

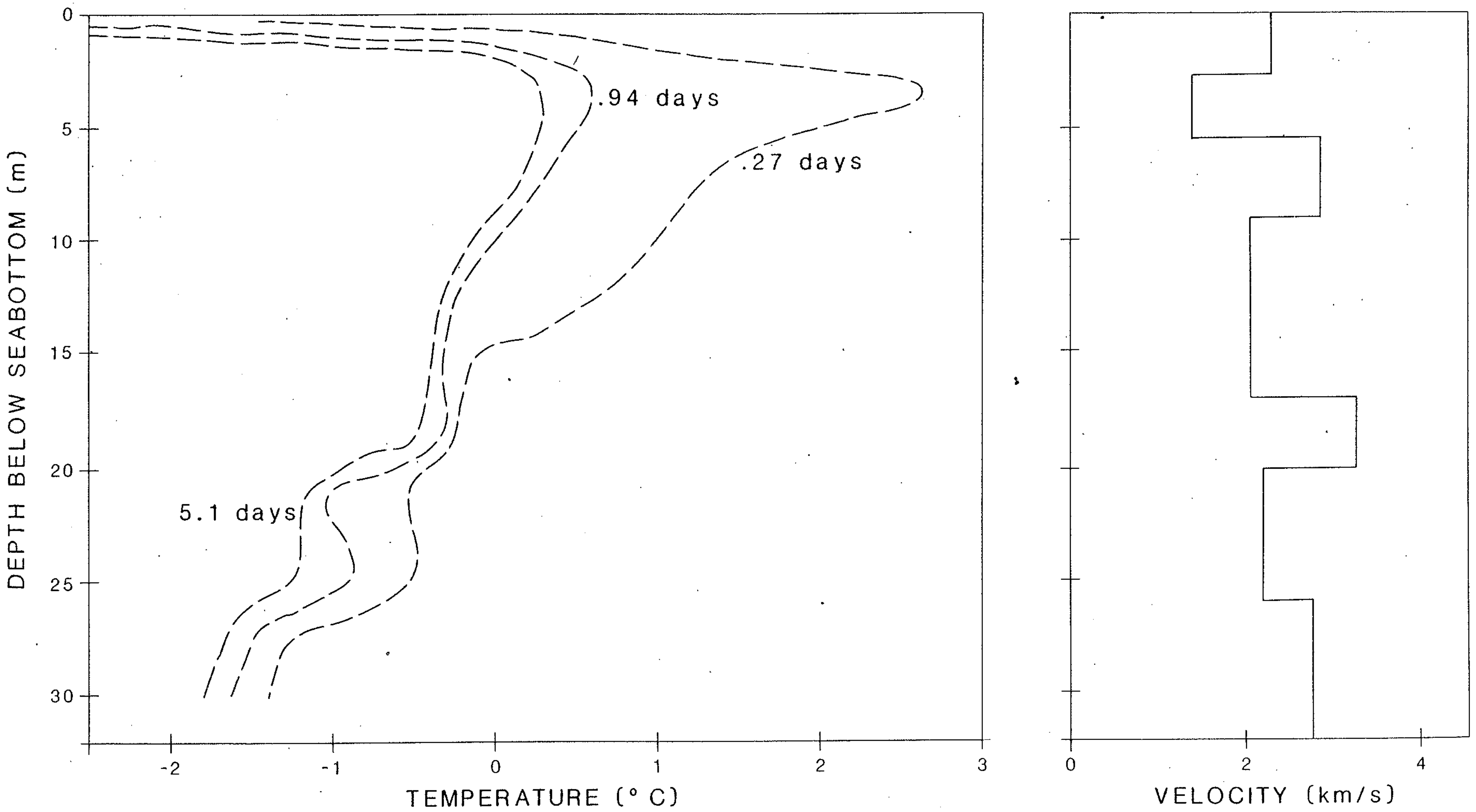


Fig. 12-2: Borehole heating and downhole seismic data - borehole 86-10

13. GROUND PROBING RADAR

S.R. Dallimore

Ground probing radar surveys were conducted along 850 metres of the main transect and along 1000 metres of a parallel transect 100 metres north of the main line. Radar surveys were carried out by A-Cubed Inc. of Toronto, using the pulse EKKO I and pulse EKKO II profilers (A-Cubed Inc., 1986). The pulse EKKO I is a modified Geophysical Survey Systems Inc. (GSSI) radar which was used for high resolution, continuous near-surface profiling. The pulse EKKO II profiler is a prototype digital radar system designed by A-Cubed Inc. for Energy, Mines and Resources. It operates at a lower frequency and provides greater depth penetration than the pulse EKKO I. The pulse EKKO II is operated in a step mode, with four metre spacing between readings being used for the survey.

The pulse EKKO I radar responded mainly to the sea-ice cover and the interfaces between the sea ice and sediment, and the sea ice and water. The boundary between the floating ice and the grounded ice was found to be at about 4+60 metres on the main line and about 5+00 metres on the north line. Some reflections were observed beneath the sea bottom in the areas between borehole 86-9 and borehole 86-10 on the main line and between 8+00 and 10+00 on the north line. A portion of the pulse EKKO I data on the main line showing the grounding line and some of the deeper reflections is shown on Figure 13-1. The depth scale has been estimated using a simplified two-layer model with 2 m of sea ice (v=0.15 m/ns) over unfrozen silt (v=0.06 m/ns).

Pulse EKKO II data were processed to remove multiple reflections covered by sea ice interfaces. The EKKO II profiles showed numerous reflectors in the underlying sediment beneath the grounded sea ice and beneath areas where a layer of water separated the ice from the sediment. Pulse EKKO II data from the

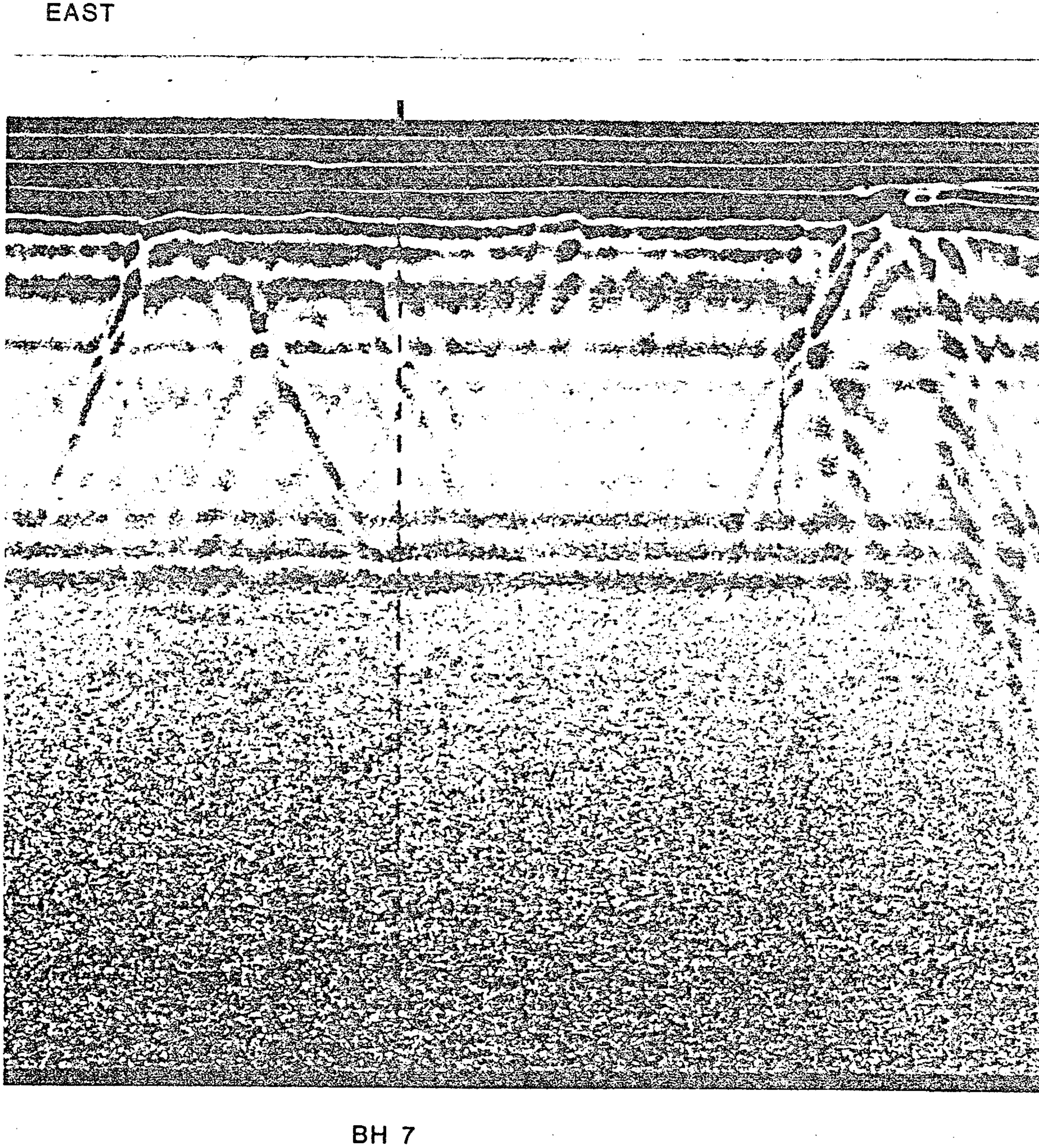
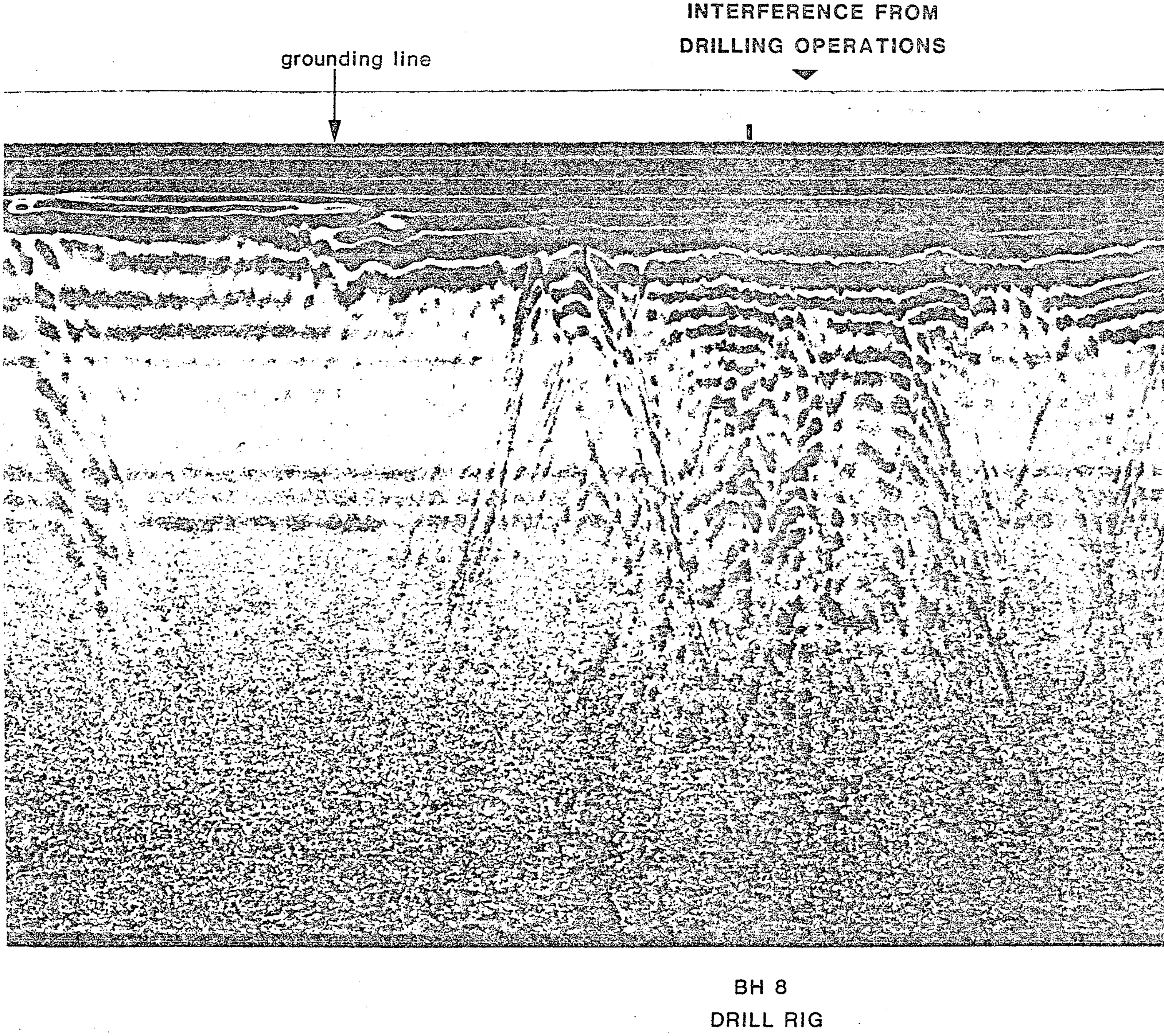
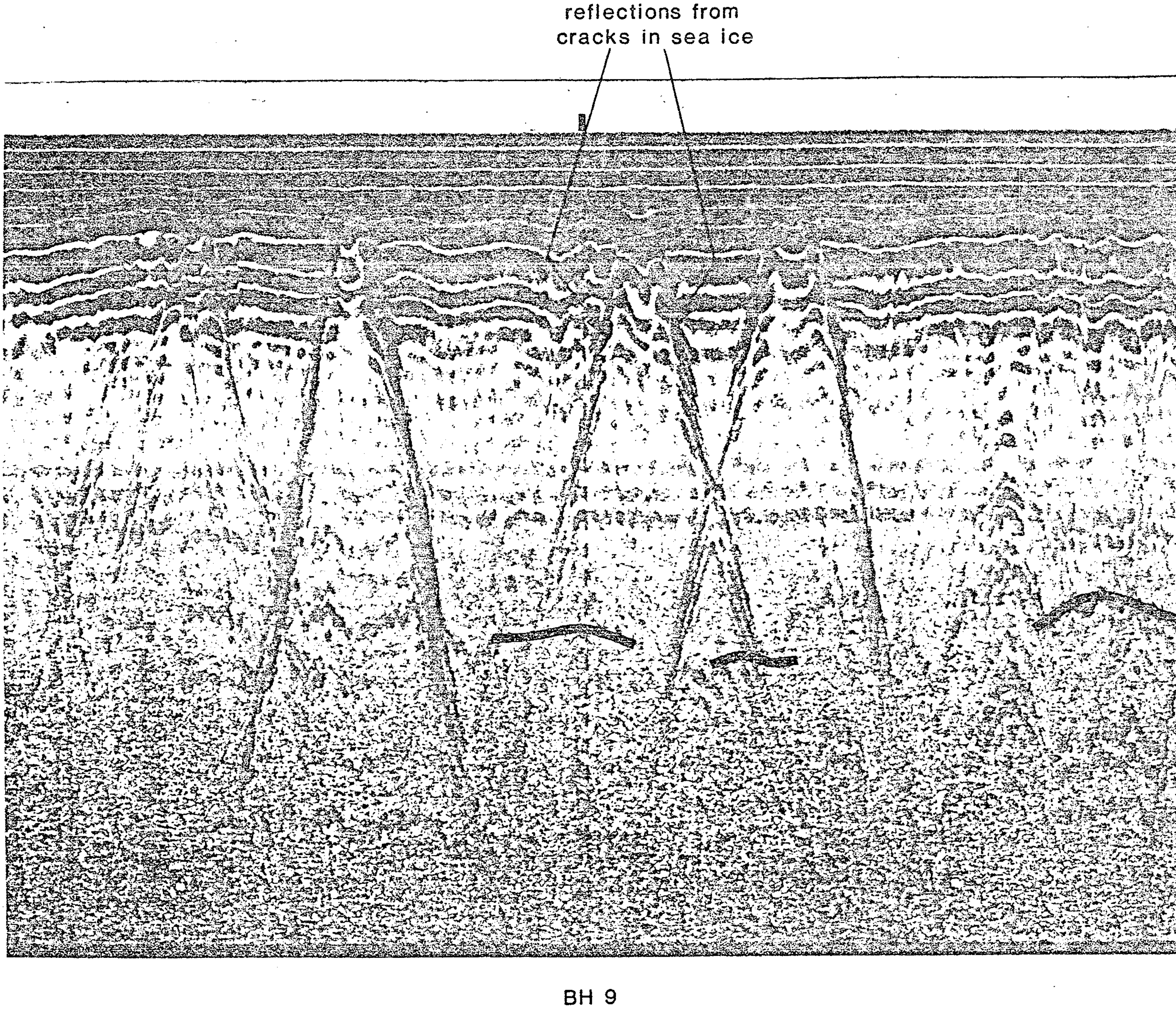
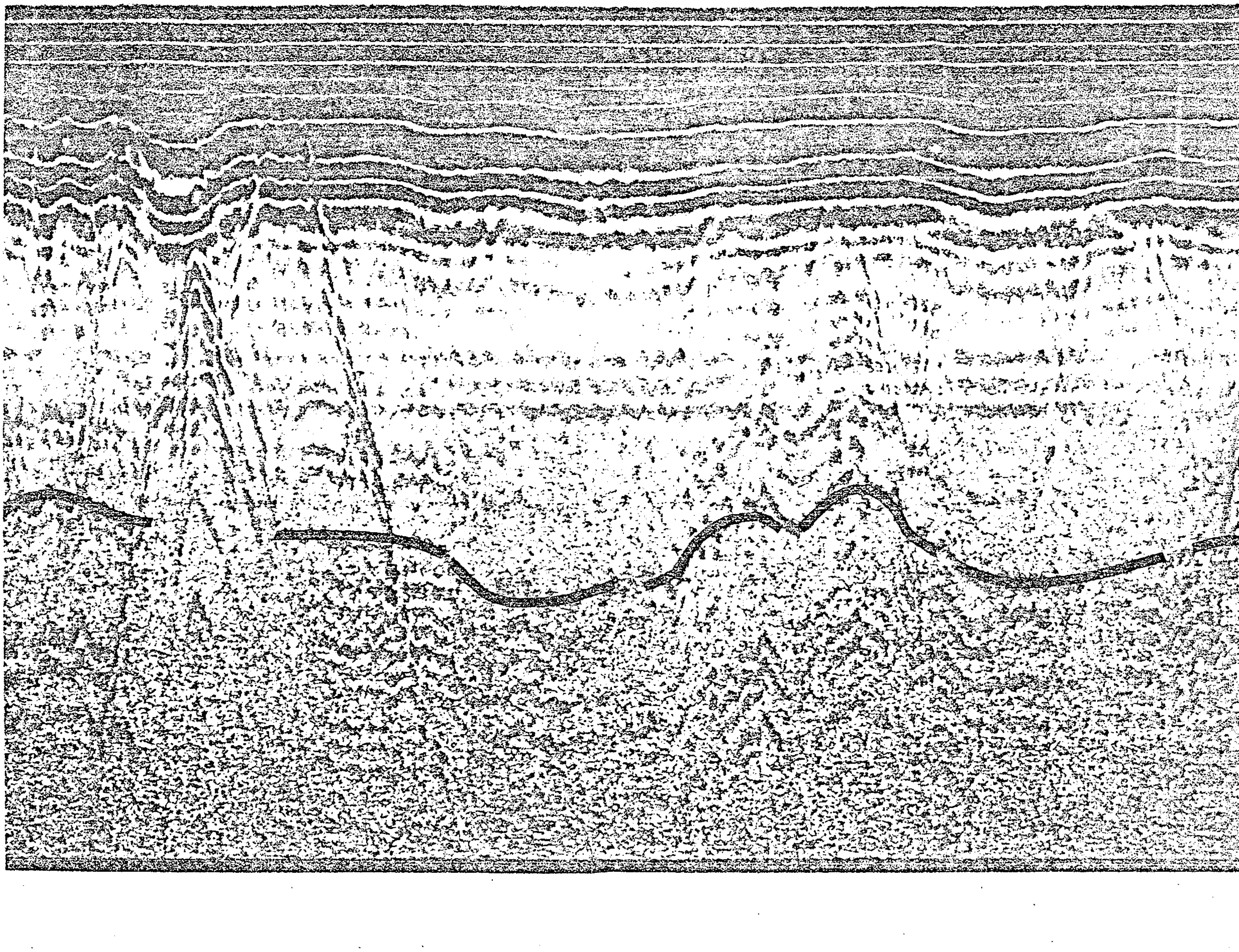


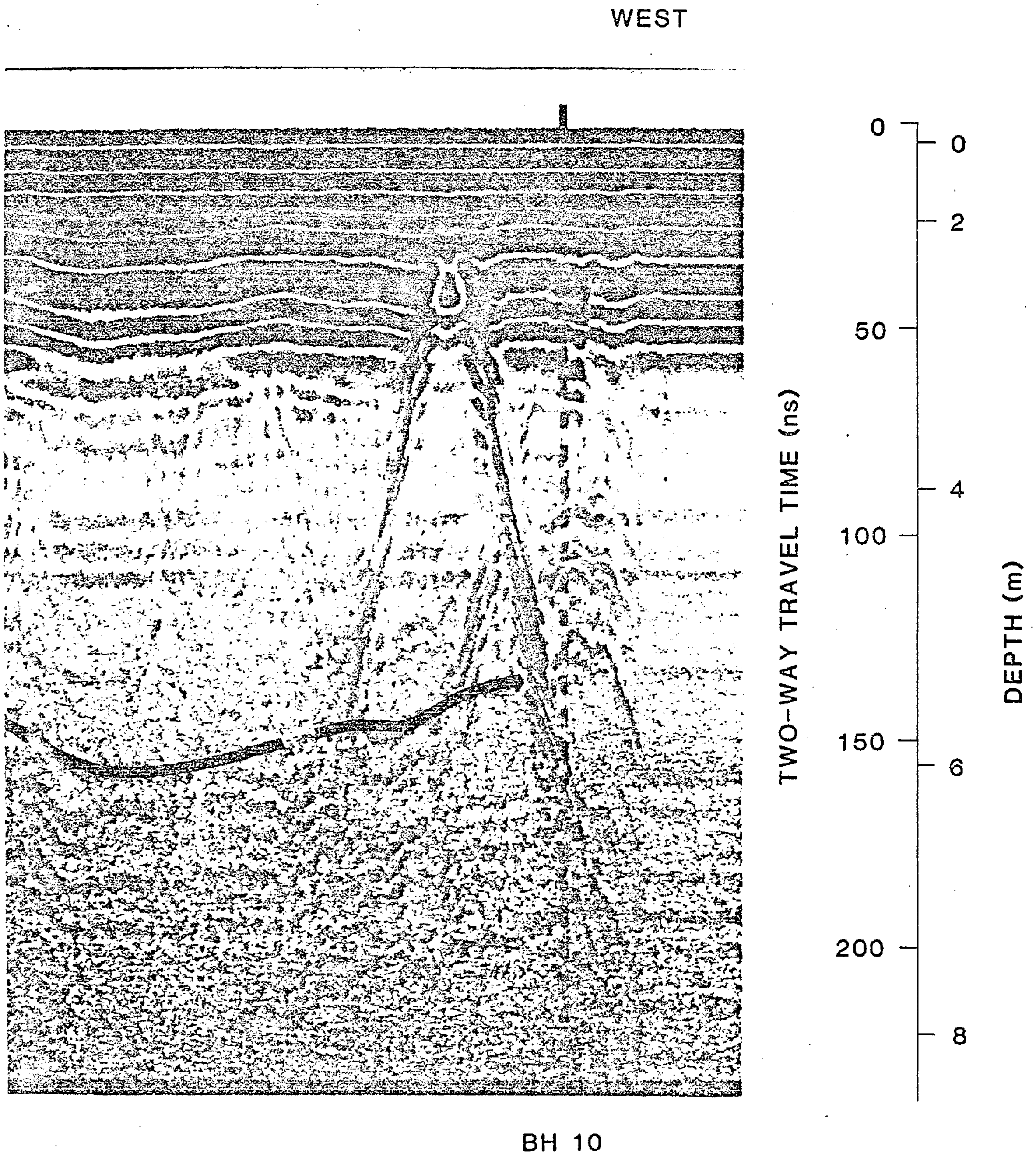
Fig. 13-1: Pulse EKKO I data - main line


INTERFERENCE FROM
DRILLING OPERATIONS
grounding line
BH 8
DRILL RIG



POSITION




WEST
0
50
100
150
200
TWO-WAY TRAVEL TIME (ns)
0
2
4
6
8
DEPTH (m)
BH 10

main transect are shown on Figure 13-2. The depth scale shown on the figure has been estimated using a one-layer model with an assumed velocity of 0.15 m/ns. A strong, flat-lying reflector between boreholes 86-4 and 86-6 probably represents the contact between the upper sand and the lower silty clay. The numerous reflectors in the area between boreholes 86-7 and 86-10 are largely in unfrozen sediments and probably represent stratification in the soil.

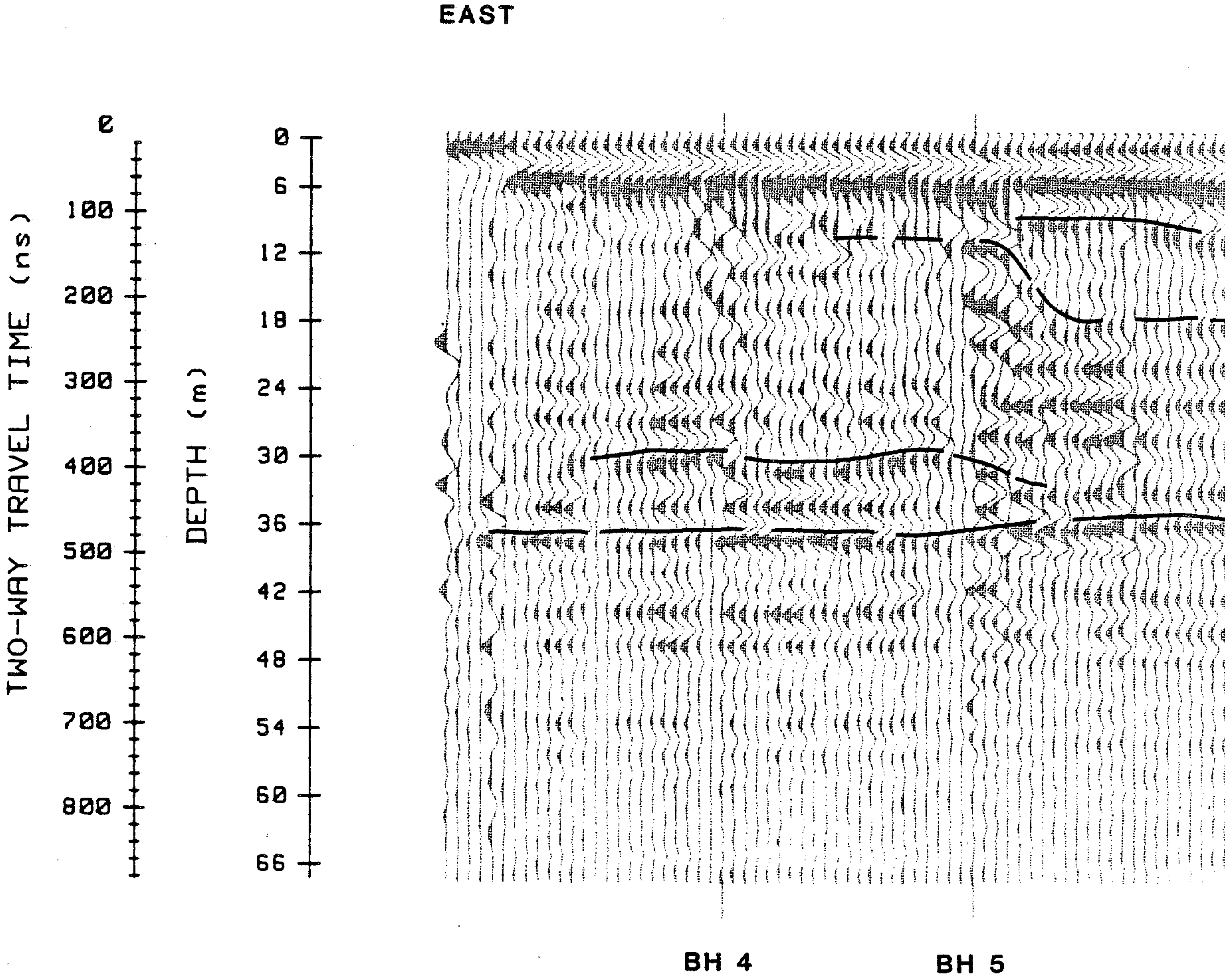
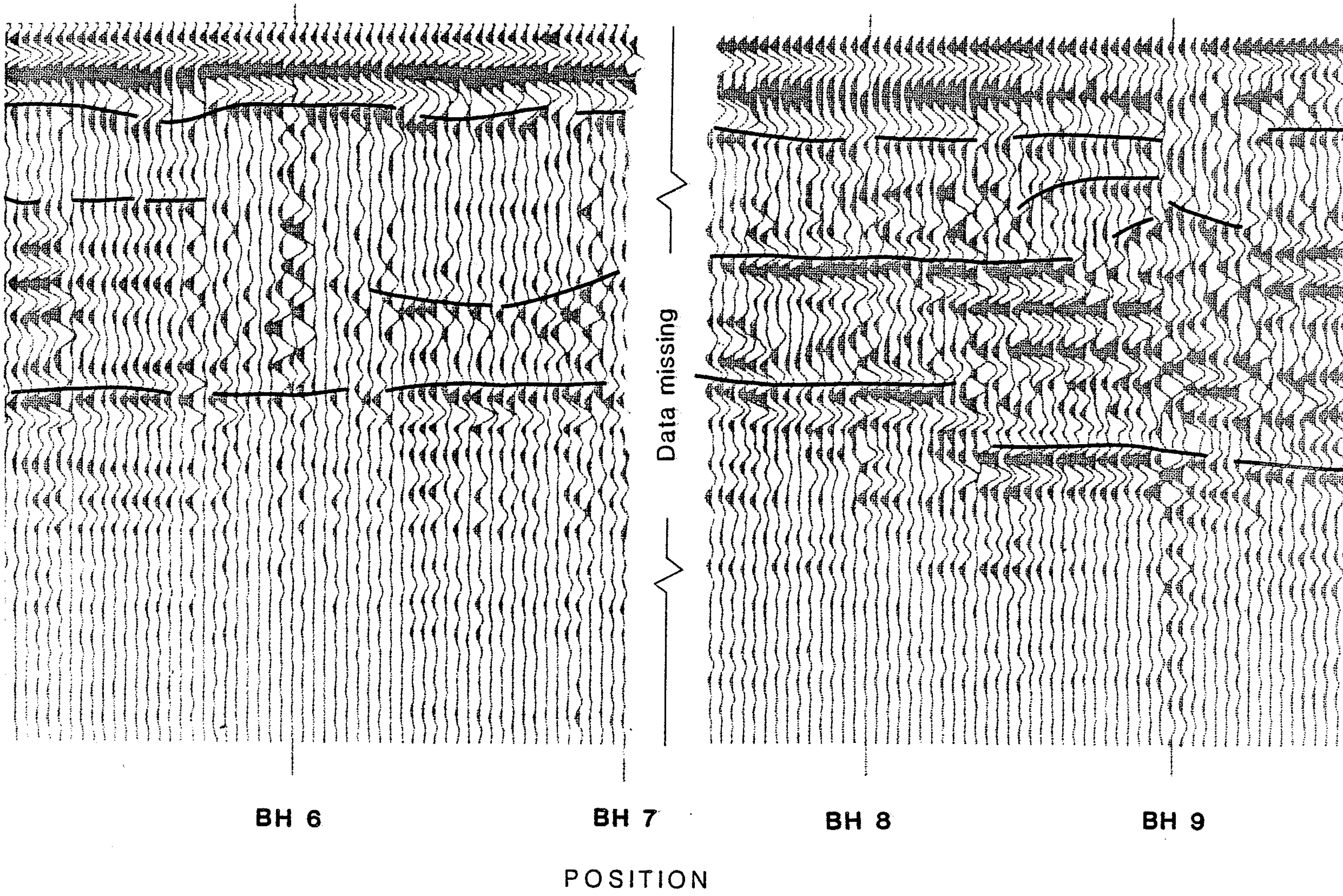
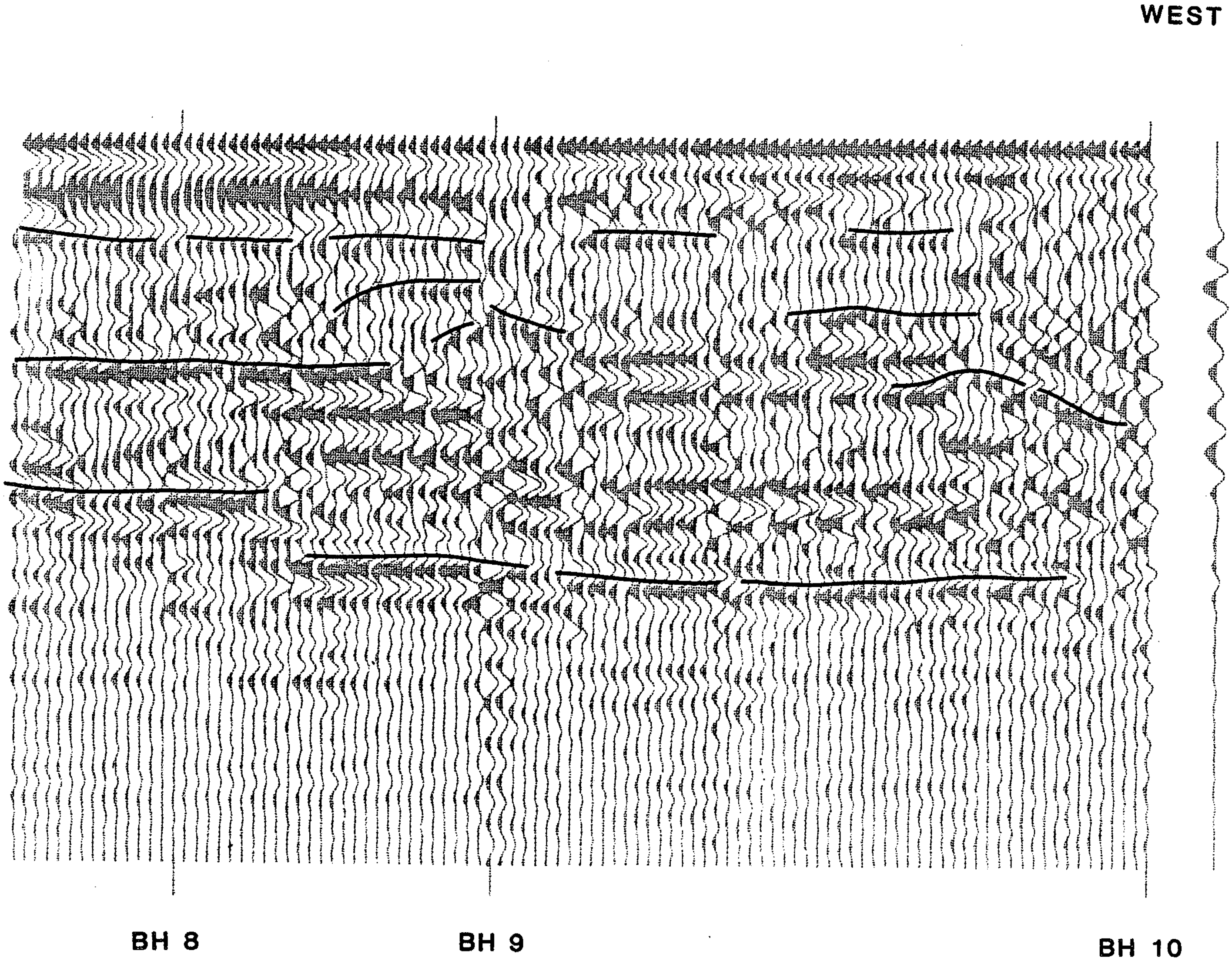


Fig. 13-2: Pulse EKKO II data - main line


Data missing
BH 6
BH 7
BH 8
BH 9
POSITION


WEST
BH 8
BH 9
BH 10

Acknowledgments

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