3. STUDY 1: PENETRATION DEPTH OF BEAMTRAWL GEAR.
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3.1 INTRODUCTION

If fishing gear disturbs the sediment and the sediment resettles after passage of the gear it may be expected that sediment characteristics will be changed as deep as the penetration depth of the beamtrawl. A method to determine the penetration depth is the measurement of sediment characteristics which show a distinctive depth profile. Such a profile may be measured before and after fishing whereby changes in the profiles may indicate the depth at which the gear has influenced the sediments. One of these characteristics is the reciprocal formation factor, which in general shows a distinctive profile into the sediment (Helder, 1989). Another closely related characteristic is the pore water content. Also lacker peels, X-ray photographs or mud contents may be used to yield insight into the penetration depth. Furthermore, the meiofauna distribution into the sediment often shows a distinctive pattern.

3.2 MATERIAL AND METHODS

After making side scan sonar records of the study area 13 boxcore samples were taken. Eight boxcore samples were taken in the trawl tracks, five (S1-S5) in one track and three (S6-S8) in the other. Another five boxcore samples (B9-B13) were taken approx. 100 m outside the trawl tracks (see table 1.1). In order to obtain sedimentary structures of each boxcore sample a lacker peel has been made of approx. 15 x 30 cm. Additional subsamples were taken in plastic liners in order to take X-ray photographs and to study the benthic foraminifera (S1-S5 and B9-B13). For determination of changes in the very fine sand fractions and the silt content, subsamples were taken at three depth intervals; 0-3 cm, 9-14 cm and 19-24 cm respectively. Profiles of reciprocal formation factors were measured by means of a resistivity probe made at the NIOZ workshop. This probe measures the electrical resistance inside the sediment. From each boxcore sample two subsamples were taken, each with a diameter of 10 cm and a length of 13-15 cm. In these subsamples the probe was driven into the sediment at 1 cm intervals and the resistivity at each depth was recorded. The reciprocal formation factor F^{-1} was calculated from:

$$F^{-1} = Ro/Rz$$

in which Rz and Ro are the electrical resistivity in sediment and overlying water,respectively. Porosity profiles were constructed by way of measurements of water content of the sediment. In each boxcore sample one core with a diameter of 3.5 cm and a length of 9-10 cm was taken. Starting at the sediment surface this sample was subdivided into 9 to 10 slices of 1 cm each and water content of these slices was determined by weight measurement before and after drying till constant weight at a temperature of 80°C. The porosity (vol%) was then calculated from:

$$\text{por.(vol/vol)} = 100 * (\text{vol.water/vol.total})$$

giving:

$$\frac{M_{water}/R_w}{(M_{water})/R_w + (M_{dry})/R_{dry}}$$

in which:

M_{water} = mass water (g)
M_{dry} = mass dry sediment (g)
R_w = 1 kg/litre
R_{dry} = 2.65 kg/litre

From each boxcore a subsample with a surface area of 10 cm^2 was taken and divided in slices of 1 cm each. These slices were stored in 4% formaldehyde in plastic jars. The meiofauna content of the slices was determined by washing the slices for 15 minutes in a washing-gutter with a length of 100 cm and a width of 2.5 cm. The total number of organisms, caught on a 50 μm sieve, was counted on counting trays of 50x50 mm with a 5x5 mm grid size.

3.3 RESULTS AND DISCUSSIONS

3.3.1 GEOMORPHOLOGY AND GEOLOGY OF THE AREA OF INVESTIGATION

The area of investigation (Fig. 0.1) lies Southwest of the Borkum Riff, an area with medium sand (250 to 500 micron) with gravel. The Borkum Riff is regarded as a remnant of a moraine of the Saalian glaciation. The area southwest of the Borkum Riffgrund consists of fine sand (<250 micron) (Figge, 1981), belonging to the Terschellingbank Member of the Nieuw Zeelandgronden Formation (Harrison et al, 1987). This formation consists mainly of during the Holocene transgression reworked glacial sand. According to the side scan sonar records the area has a flat bottom covered with current ripples with a height of 4 to 6 cm and a mean wavelength of 2 m (Allen, 1984).

3.3.2 SEDIMENTOLOGICAL DESCRIPTIONS OF THE CORES

Cores S1 to S8 in the trawl track

The cores S1 - S5 were most likely taken from a trawl track immediately after passing of the trawl. On the side scan sonar record the bottom shows a clear track of the trawl in which most of the sand ripples were destroyed by the net (Fig. 1.1 and 1.2). The uppermost 5 to 7 cm of those cores are without structures. Parallel horizontal lamination is present in core S1 at 5 to 12 cm below the surface and in core S3 from 7 cm below the surface down to the end of the core. In core S2 (top layers dipping, core disturbance?) a horizontal silty layer occurs at 4 cm below the top . In core S4 a distinct transition into finer sand with bioturbation underneath occurs at 4 cm. In core S5 a transition into more dense and finer sand at 2 cm depth is observed.

In the cores S6 to S8, (supposed to be taken from the second trawl track) (Fig. 0.7 and 1.1), parallel lamination is present from the top down to respectively 3 and 7.5 cm. This clearly indicates, that these samples were not taken from a trawl track. In core S8 cross bedding structures have been found pointing to deposition by current ripples. The laminated layers are overlying structureless beddings. The absence of structures in the deeper layers is possibly due to bioturbation. Near and at the base of cores S7 and S8 slightly dipping silty layers are present.

Cores B9 to B13 ± 100 m outside the trawl track

The cores B9, B10, B11, B12 and B13 taken at a distance of ± 100 m outside the trawl track show a parallel laminated bedding at the top down to respectively 4.5, 4.5, 1.5, 4 and 1 cm. In core B10 cross bedded structures are present. There is a strong similarity between the cores S6 - S8 and these cores. This once again indicates that the cores S6 - S8 were taken outside the track. Below the bedded layer a structureless layer occurs. The absence of sedimentary structures is possibly due to bioturbation. Below the structureless layer parallel lamination occurs towards the base. In core B13 at the base a layer of 5 cm with cross bedded structures is found (Fig. 1.1).

3.3.3 X-RAY PHOTOGRAPHS

From each boxcore additional cores (ϕ = 9 cm) have been taken for X-ray photographs. The cores were split and of both parts X-ray photographs were taken (L) + (R). In only one core (B10) clear sedimentary structures are visible. In core S7 at ± 5 cm some lamination is present. At the base of core S8 a laminated bedding occurs in silty sediments. The lacking of sedimentary structures in the X-ray photographs is probably due to the large diameter of the cores used.

3.3.4 GRAINSIZE ANALYSES

Subsamples for grainsize analyses were taken in all boxcores at a depth between 0 to 3 cm; 9 to 14 cm and 17 to 24 cm. It was expected that in the trawl track in the top few centimetres the grainsize should be coarser because of the whirling up and deposition by currents fine sand grains and mud, resulting in loss of part of the finer fraction. According to this assumption, finer grained sediments with a higher mud content were expected in the subsamples below the top .
From the cores taken in the trawl track (S1 to S5) only core S2 shows a difference between the mud content of the superficial sediments at 2 cm (2.1%) and the sediment at 14 cm. (6.0%). The d50 of the superficial sediments ranges from 193.7 (S1) to 240.8 (S5) micron. The d50 of the second subsample however is ranging from 215.0 to 254.2 micron (Fig. 1.2). The skewness of the cumulative curves of all subsamples does not vary much with the exception of the subsample of B1 at 24 cm which contains 26.3% of mud. The sediments were all very well sorted.
The d50 of the superficial sediments in the cores taken just outside the trawl track (S6 to S8) are ranging from 214.2 to 232.3 micron. The d50 of the second subsample ranges from 224.3 to 230.8 micron. The skewness was identical in all of the curves. The variation of the d50 is only 18.1 micron, except for the subsample at 24 cm depth of core S8 which contains 51.9% mud. The sediments are very well sorted.
The cores taken at ± 100 m outside the trawl track show an almost identical cummulative curve with a d50 of the superficial sediments ranging from 221.9 to 230.5 micron.
The sediments below the superficial layer are varying from 217.3 to 256.3 micron. The deepest subsamples are ranging from 217.9 to 242.9 micron. The sediments from this area are also very well sorted.

3.3.5 RECIPROCAL FORMATION FACTOR AND POROSITY PROFILES

Duplicate profiles of the reciprocal formation factor F^{-1} measured in 8 samples collected inside the trawl track (see Fig. 0.7 and 1.1) and in 5 samples collected outside the track are shown in figure 1.3. Porosity profiles measured in 5 samples collected in the trawl track and in 5 samples collected outside the track are shown in figure 1.4a and 1.4b, respectively. The mean values of these porosity profiles in and outside the trawl track are shown in Fig. 1.5a and 1.5b. At first there seems to be no statistically significant difference between the samples from the trawl track and the samples collected outside the track. The problem lies in the fact that not all samples which were supposed to be taken from a trawl track have indeed been taken there. As stated before the geological features indicate that samples S6-S8 were not taken inside a track. Apparently the very accurate positioning system of the survey vessel, including the sampling gear, does not guarantee that the samples come from inside a track. This seriously hampers comparative research, and in future research this needs to be taken into account. However, since there are clear indications that samples S1 - S5 come from inside the track we will treat those accordingly. Although there are remarkable differences between different profiles, these differences can be found both inside and outside the tracks. The lack of a fixed horizon or a reference depth inside the samples hampers possible general calculations and the drawing of general conclusions from all profiles together. A reference depth is needed not only because a part of the sediment stirred up by the passage of the beam trawl will resettle outside the fish track, but also because the depth of the disturbed bottom layer will depend on the position of the bottom sample (on top of the ripples or between them). Therefore, these techniques cannot accurately indicate the penetration depth of the fishing gear into the sediment. Only if natural

markers, e.g. shell layers or anaerobic colour change, are present at a fixed depth, or if divers introduce a marker in the sediment before the fishing takes place the actual penetration depth of the fishing gear may be established by measuring profiles in the sediment.
However, a closer look at the different profiles yields some interesting information. The F^{-1}-gradient in sample S1 (Fig.1.3a) is the only gradient showing a distinct increase of the reciprocal formation factor at 4-5 cm depth. This sample possibly was taken from the centre of the trawl track (Fig. 0.7) and apparently the sediment in this centre is less dense than the other sediments measured. This could indicate that after the passing of the net the resuspended sediment is partly collected at the spot where the cod-end of the net just passed. Apparently the net shape causes some turbulent flow behind the net which deposits part of the sediment in the centre of the trawl track. This would explain the relatively loosely packed sediment (high F^{-1}) at this spot. The side scan sonar record of the track (Fig. 0.7) showing a shade in the middle of the track supports this hypothesis. Furthermore, it is striking that none of the profiles taken inside the track show a dip in the reciprocal formation factor in the first few centimetres as was found in samples B10A and B13B. The fact that only the straight profiles were found in the samples from the track could indicate that the top 4 cm of the sediment was removed by the fishing gear. Some of the samples show higher reciprocal formation factors deeper in the sediment. This is related to the relatively high values measured in the overlying water, and could be a measure of disturbance of the boxcorer sample. The mean porosity profile in the trawl track (Fig. 1.5*) points to a sediment which is less dense in the uppermost 4 cm. This could be an indication of resuspended and redeposited layers. Analysis of the mean porosity profile in the trawl track, showing decreased porosity in the sediment deeper than 4 cm, (Fig. 1.5*), points to a removed upperlayer, forcing the sediment-water boundary towards the deeper more compact layers. Due to the lack of a reference depth the thickness of the removed or disturbed layer cannot be estimated. One possible reason could be that beam trawling compresses the sediment resulting in decreased porosity values. Sample B11 has relatively high F^{-1} values in the uppermost 4 cm and high porosity values in the top 6 cm. This is due to the muddy nature of this sediment. Assuming that samples S1 - S5 were taken inside the tracks and the other samples outside the tracks the reciprocal formation factor and the porosity both indicate that the uppermost 4-5 cm of the sediment within the track were disturbed by the trawling.

3.3.6 FORAMINIFERAL ASSEMBLAGES

Of two samples (SF1 and BF9) of the upper 10 cm of respectively the boxcores S1 (in the trawl track) and B9 (100 m outside the trawl track) foraminiferal analysis has been done at each centimetre. In order to recognise the living foraminifera Rose Bengal was used to stain the protoplasm. The samples contained a poor to very poor foraminiferal fauna. Only five specimens showed a red colour, indicating that they were possibly alive during the sampling. No living specimens were found in the top layer. Because of the lack of living specimen all foraminera were used. In Fig. 1.6 two curves are shown in which the percentages of the total number of foraminifera are given against the depth. In BF9 (100 m outside the trawl track) two peaks are present at respectively 2 cm and at 4 - 6 cm depth. In the curve of SF1 (in the middle of the trawl track) also two peaks occur at respectively 2 and 8 cm depth. Between those two peaks a layer of about 4 cm thick with a low percentage of foraminifera is present (Neele, 1990). A possible expla- nation is that the uppermost layer was disturbed by trawling down to a depth of 6.5 cm. This could explain the layers with low percentages of foraminifera. The peak in SF1 at 8 cm is probably similar to the peak at 4 - 6 cm in the curve of BF9. The peak in the top layer in curve SF1 was probably formed by redeposition after whirling up of sediments by the trawl. The sand fraction drops faster than the relative light foraminifera which will accumulate in the top layers.
This could point to a penetration of the trawl of ± 6.5 cm.

3.3.7 MEIOFAUNA

Of the different meiofauna organisms only the nematodes were present in sufficient numbers in all samples to draw conclusions. The results (Fig. 1.7) clearly indicate a difference between the samples taken inside the track and the samples taken outside the track. The typical profile with a distinctive maximum in the top centimeters and the relatively high numbers of nematodes which are found outside the track are completely missing inside the track. These results are influenced by different factors. The location where the shoes, or the cod-end of the net of the beamtrawl passed may cause different sediment movements leading to different profiles. Because of the high mobility of some of the species of the meiofauna the time lapse between trawling and sampling may have influenced the profiles. Nevertheless, the meiofauna distribution after passing of a trawl clearly indicates that the meiofauna is influenced till a depth of 7-8 cm in the sediment.

3.4 CONCLUSIONS

-- The absence of parallel lamination in the top few cm of the cores S1 to S5 is probably due to the trawling activities. This can be concluded from the cores S6 to S8 which must have been taken close to the trawl track and the cores B9 tot B13 taken ± 100 m from the trawl track. The parallel lamination in the top of the last mentioned cores is absent in the cores taken in the trawl track. The thickness of the laminated beds is mainly 3 to 7 cm, so the disturbance caused by the trawl is minimal 7 cm.

-- In the X-ray photographs the sedimentary structures as described from the lacker peels are not visible. The photographs mainly show fine sediments without sedimentary structures. At the top hardly no shells occur. Near the base the sediments become more shelly.

-- The grainsize analyses did not show the coarsening of the superficial sediments in the uppermost cm in the trawl track caused by trawling. The superficial sediments in the trawl track however show a wider ranges (47.1 micron) in the d50 than the cores taken outside of the track 18.1 (close to the trawl track) and 8.6 micron (± 100 metres from the trawl track). This difference in d50 in and outside of the trawl track probably points to the reworking due to the trawling.

-- *Measuring profiles of sediment characteristics in trawl tracks*, without knowledge of the original profile at the same spot, or without the presence of a fixed reference depth can not give an accurate measure for the penetration depth of fishing gear.

-- The passage of a beamtrawl passing disturbed the sediment at depths between at least 4 and 8 cm.

LITERATURE

Allen, R.L., 1984. Sedimentary structures their character and physical basis. Developments in Sedimentology 30. Elsevier.

Figge, K., 1981. Karte der Sedimentverteilung in der Deutschen Bucht. Deutsches Hydrographisches Institut, Hamburg. Zu nr. 2900.

Harrison, D.J., C. Laban and R.T.E. Schüttenhelm, 1987. The seabed sediments and Holocene geology of the Indefatigable sheet 53°N-02°E. BGS/RGD 1:250.000 series.

Helder, W., 1989. Early diagenesis and sediment-water exchange in the Saun Basin (eastern Indonesia). Neth. J. Sea. res. 24 (4): 555-572.

Neele, N.G., 1990. Micropaleontological investigation of two boxcores, SF1 and BF9, from the North Sea. Internal report 1610.

Table 1.1 List of sampling stations

STATION	Sample	Date	Time	Latitude	Longitude	Depth (m)
90BC1	S1	23/8/90	10.00-13.00	53°51'29.5"	5°48'32.3"	29.5
90BC2	S2	"	"	"	"	"
90BC3	S3	"	"	"	"	"
90BC4	S4	"	"	"	"	"
90BC5	S5	"	"	53°51'29.3"	5°48'32.9	"
90BC6	S6	"	"	"	"	"
90BC7	S7	"	"	53°51'28.9"	5°48'33.21"	"
90BC8	S8	"	"	53°51'28.8"	5°48'33.2"	"
90BC9	B9	"	16.00-18.00	53°51'24.5"	5°48'26.6"	28.8
90BC10	B10	"	"	"	"	"
90BC11	B11	"	"	"	"	"
90BC12	B12	"	"	"	"	"
90BC13	B13	"	"	"	"	"

S= trawl track
B= blanc, outside trawl track

Explanation of used code: 90BC1= 1990 BOXCORE 1; S1= CORE 1 supposed to be taken in the trawl track; B9= core 9 taken outside the trawl track.

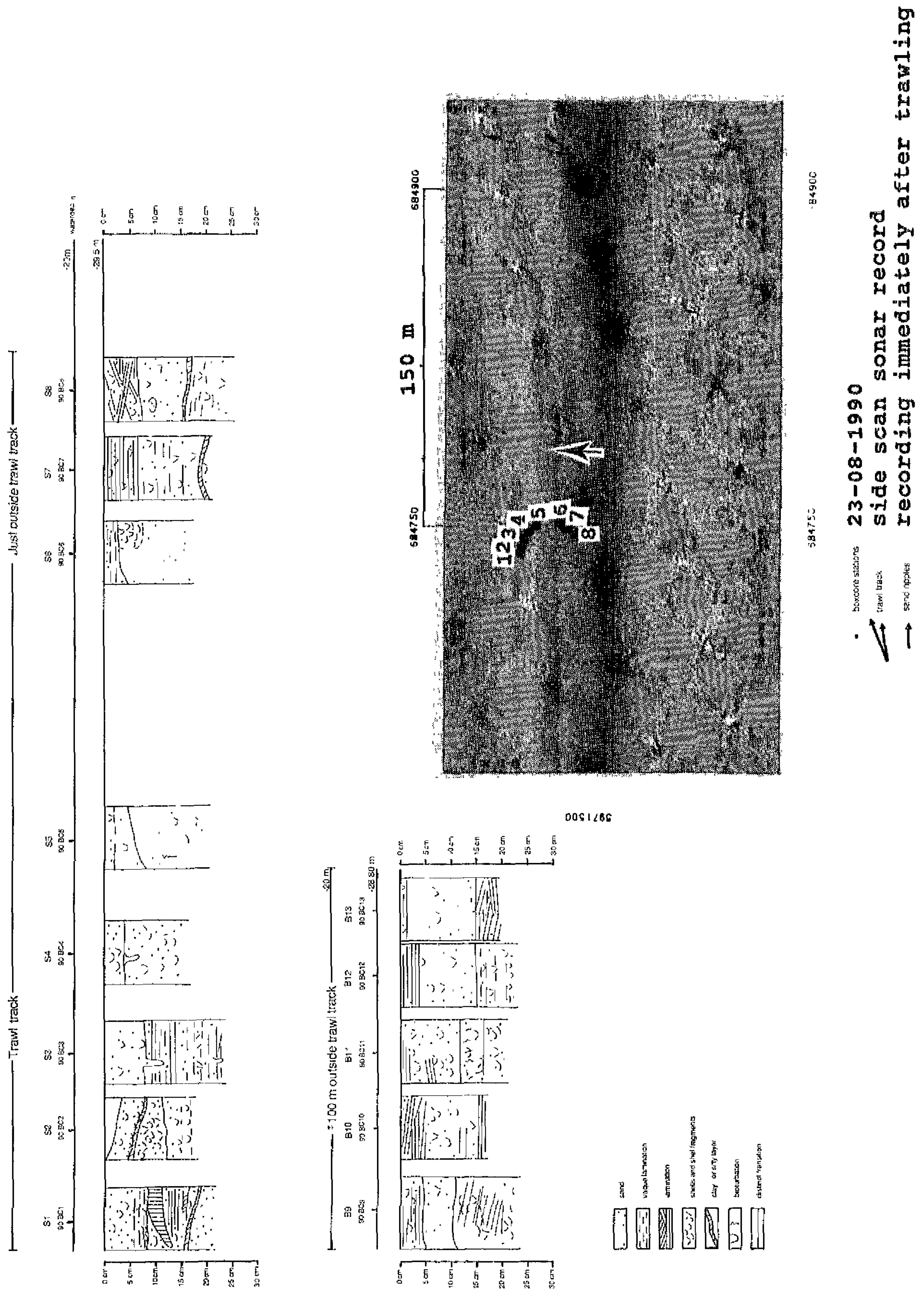


FIG. 1.1: Sedimentary stuctures as described from the lacker peels. In the uppermost cm of the cores S1 to S5 no sedimentary structures occur. In the cores taken just outside and at ± 100 m outside the trawl track in the uppermost cm of each core to a certain depth sedimentary structures occur. The lack of sedimentary structures in the first 5 cores points to a disturbance by the fishing gear to at least a depht of 7 cm.

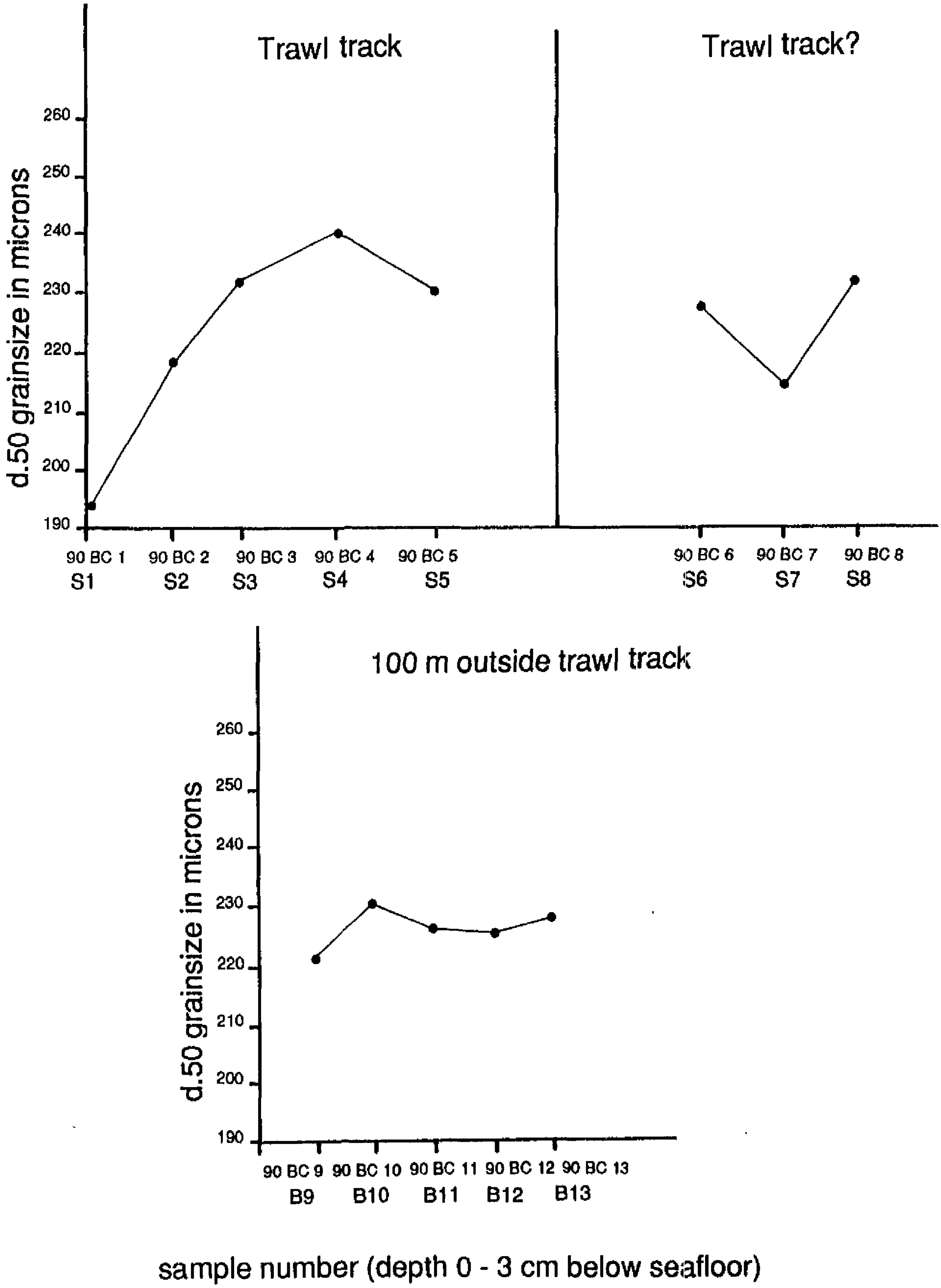


FIG. 1.2: The d50 of the sandfraction from 0 to 3 cm in the trawl track, just outside the trawl track and at 100 m outside the trawl track shows a range of respectively 47.1, 18.1 and 8.6 micron. The differences point to the reworking of the upper laminated beds by trawling.

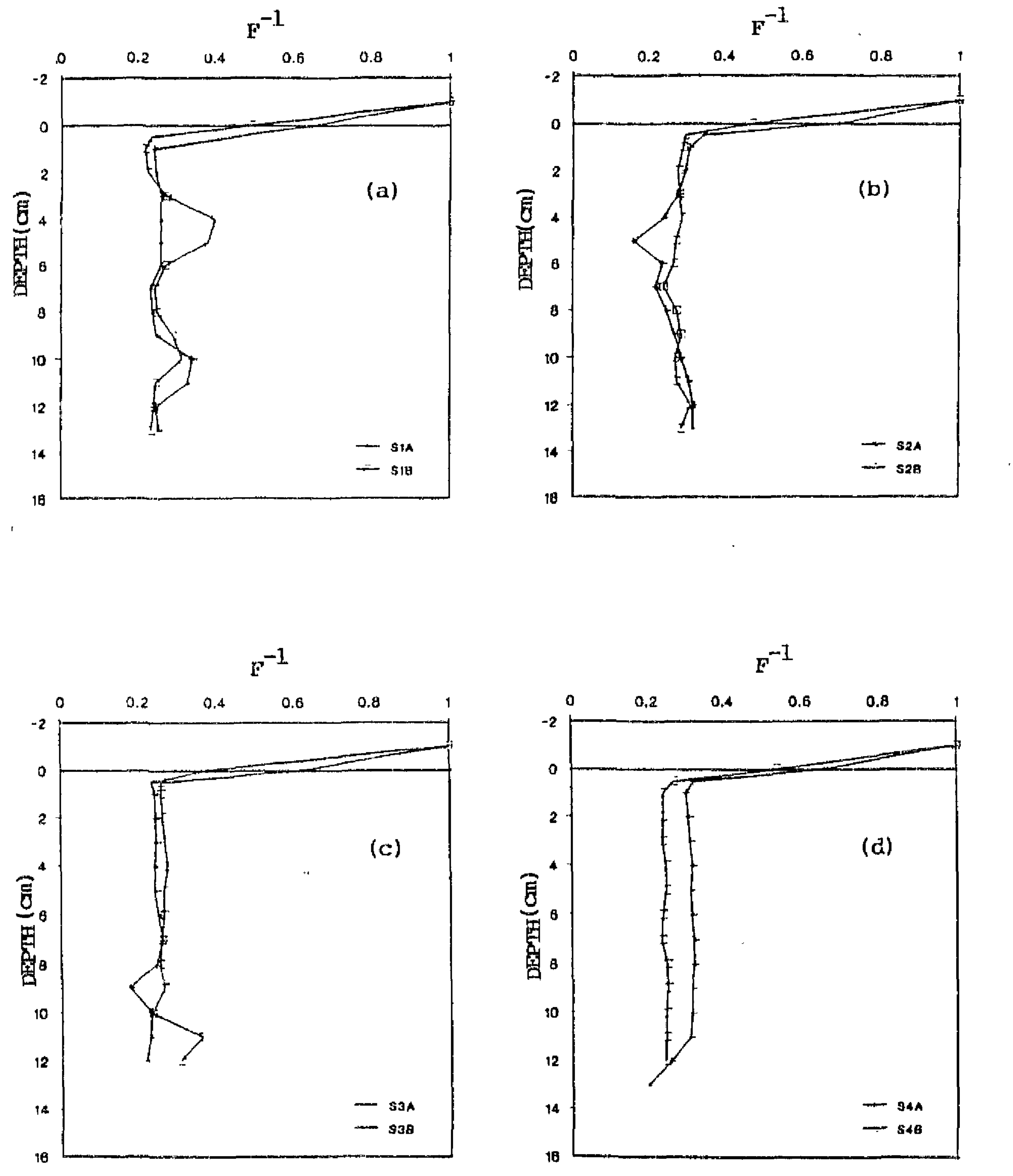


FIG. 1.3[a]: Depth profiles of the reciprocal formation factor in sediments collected in the trawl track (a-h) and outside the trawl track (i-m).

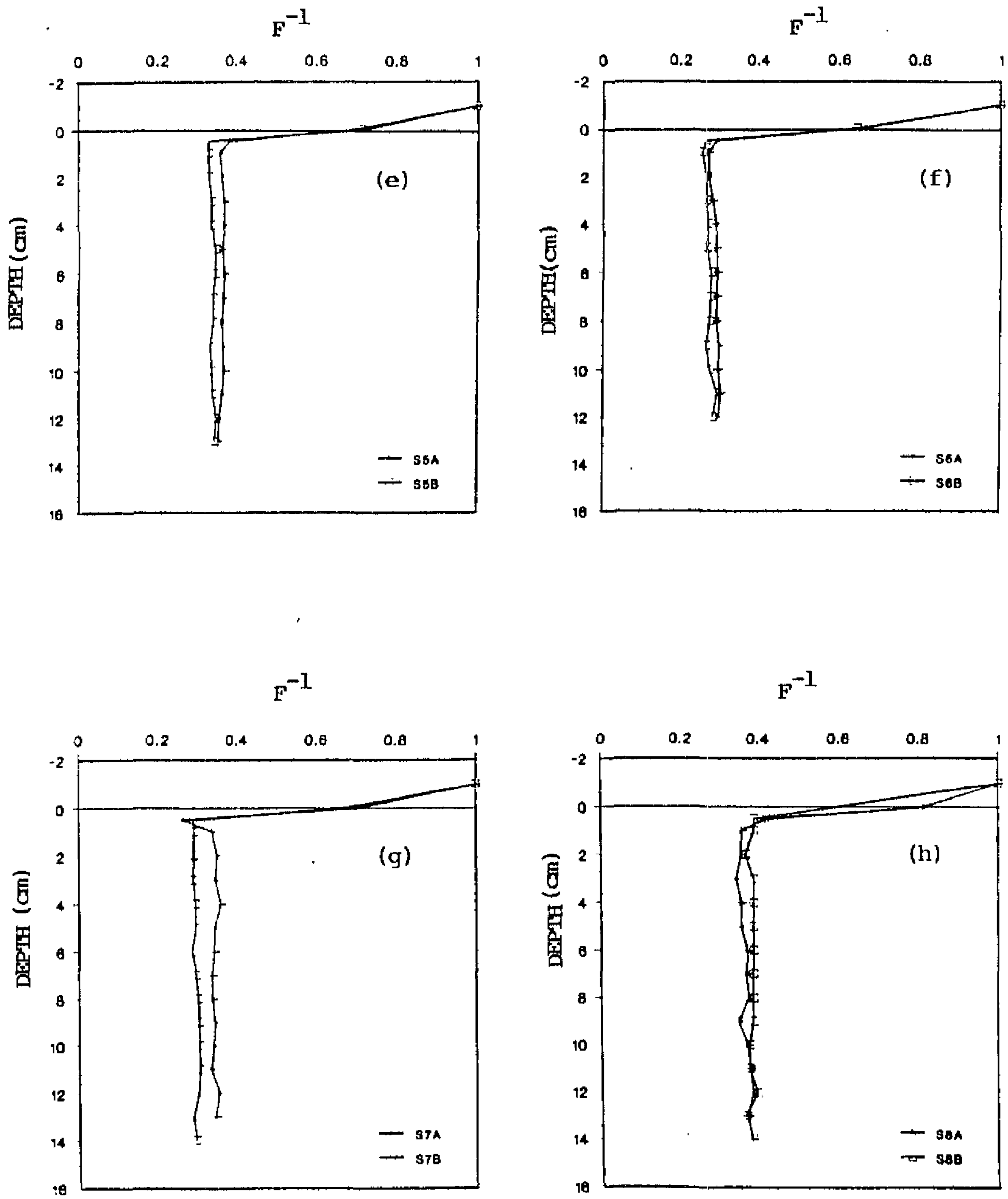


FIG. 1.3[b]: Depth profiles of the reciprocal formation factor in sediments collected in the trawl track (a-h) and outside the trawl track (i-m).

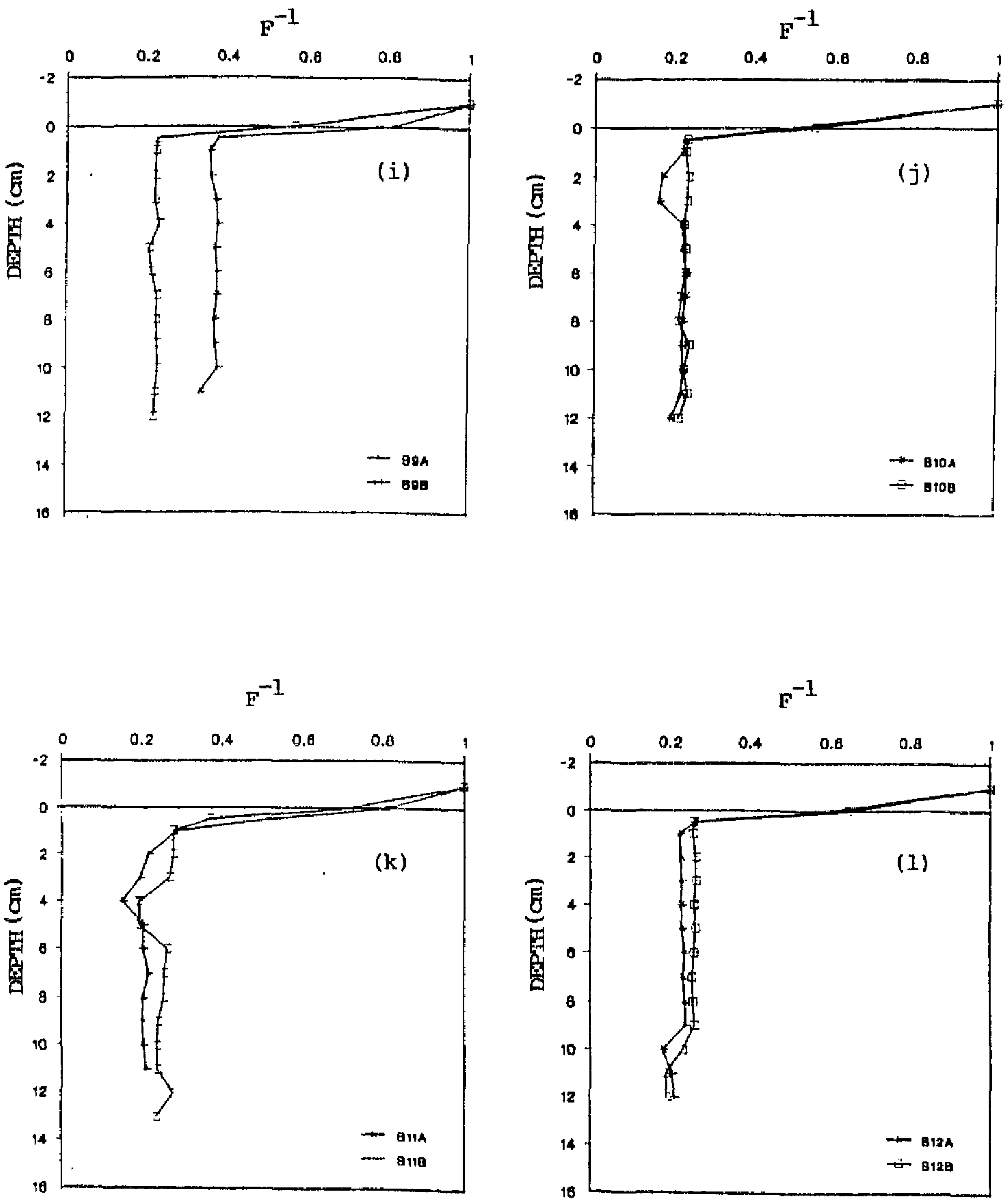


FIG. 1.3[c]: Depth profiles of the reciprocal formation factor in sediments collected in the trawl track (a-h) and outside the trawl track (i-m).

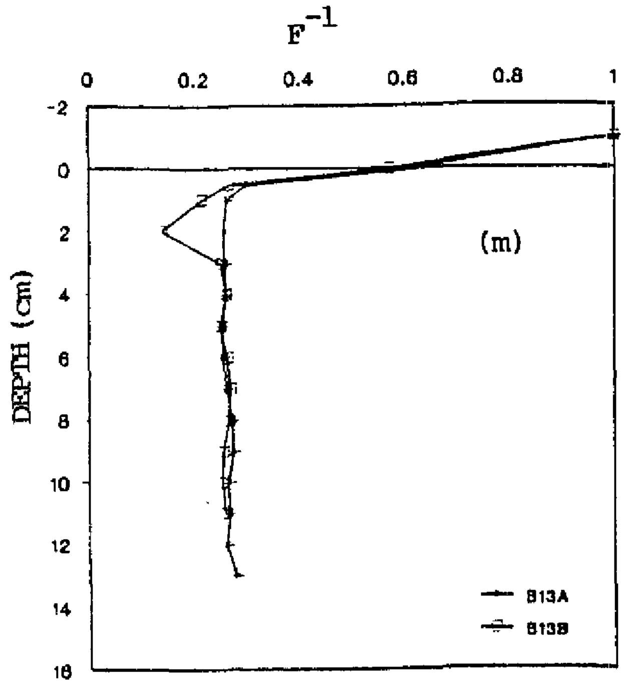


FIG. 1.3[d]: Depth profiles of the reciprocal formation factor in sediments collected in the trawl track (a-h) and outside the trawl track (i-m).

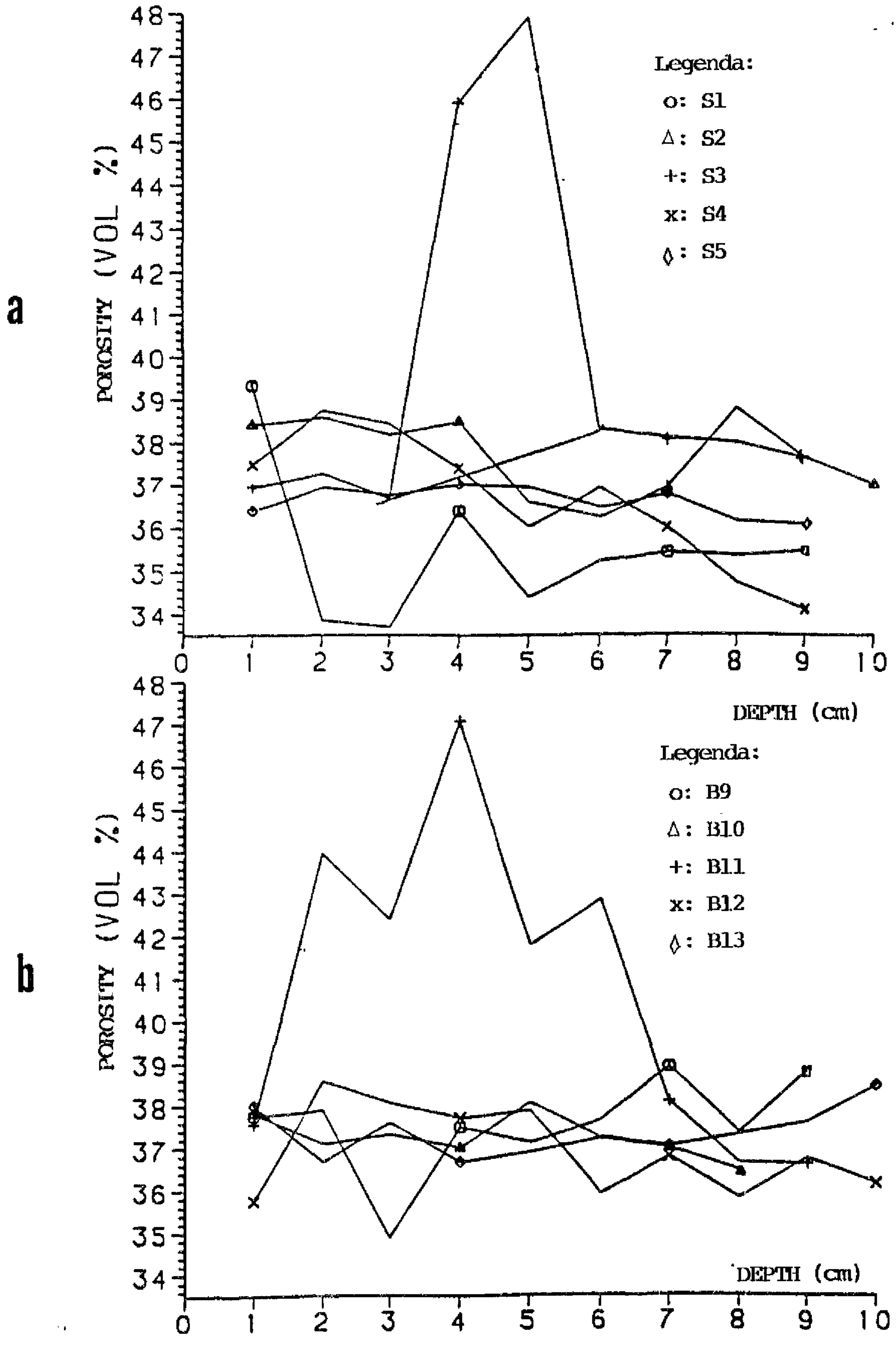


FIG. 1.4: Porosity profiles of the cores S1-S5 which are supposed to be taken in the trawl track (a) and B9-B13 which are taken outside the trawl track (b). The peak in core S3 is due to a shell fragment, the peak in the profile of core B11 is due to the high mudpercentage.

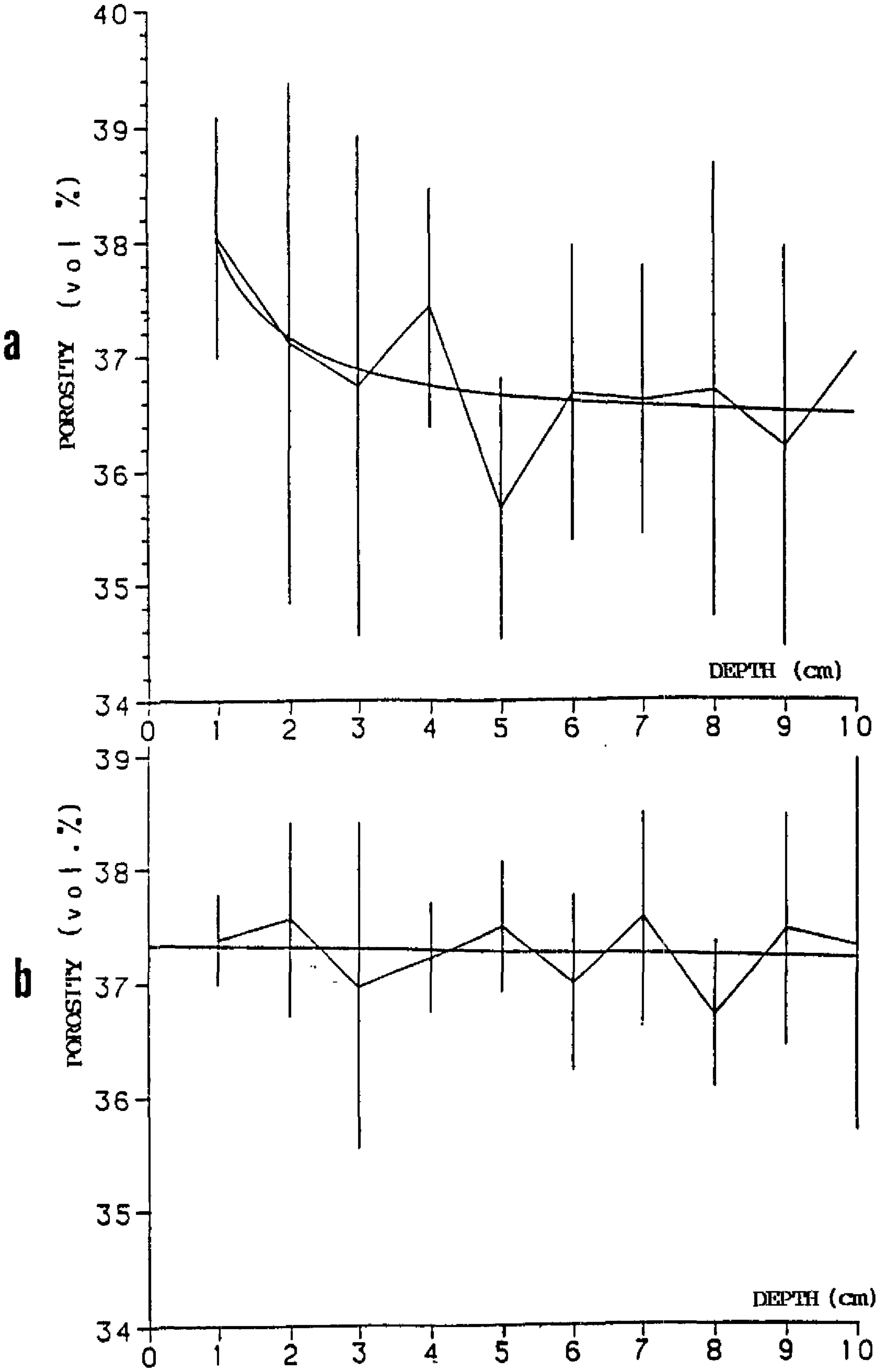


FIG. 1.5: Mean porosity profiles of the cores S1-S4 and B9-B13. S5 has been deleted because of the position at the edge of the trawl track and B11 because of high mud percentage.

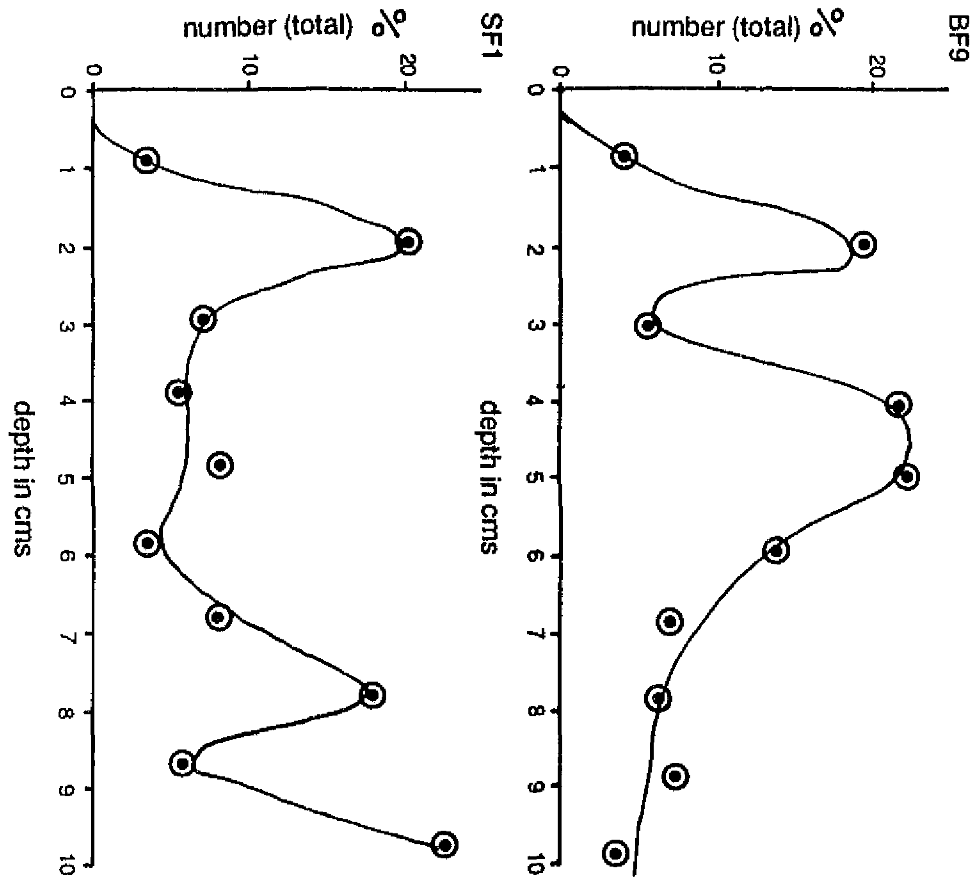
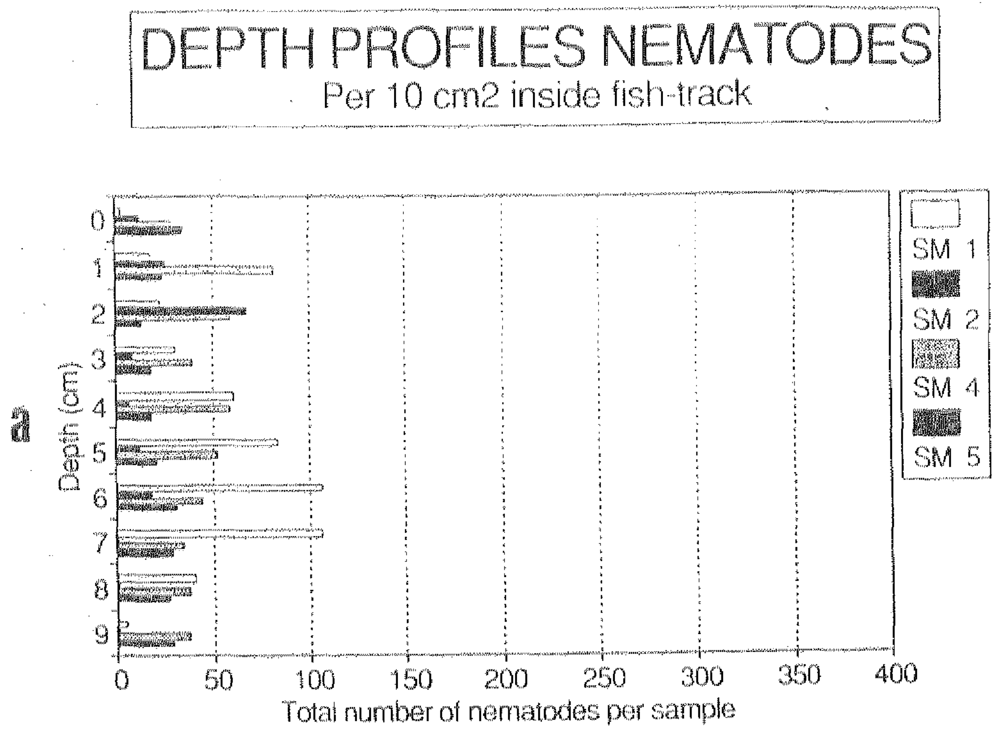


FIG. 1.6: Foraminifera in percentages of the total number in the middle of the trawl track (SF1) and 100 m outside the trawl track (BF9). The foraminifera are dominated by 2 species Ammonia beccari and Cribonium excavatum f selseyense. The lack of specimen in the curve at the left is probably due to trawling. The lower peak corresponds with the lower peak at the curve at the right. During the trawling the sediments are wirled up and the relative light foraminifera are deposited after the sandgrains which explains the second peak in SF1. The maximum reworking by trawling as read from the curves is ± 6.5 cm.



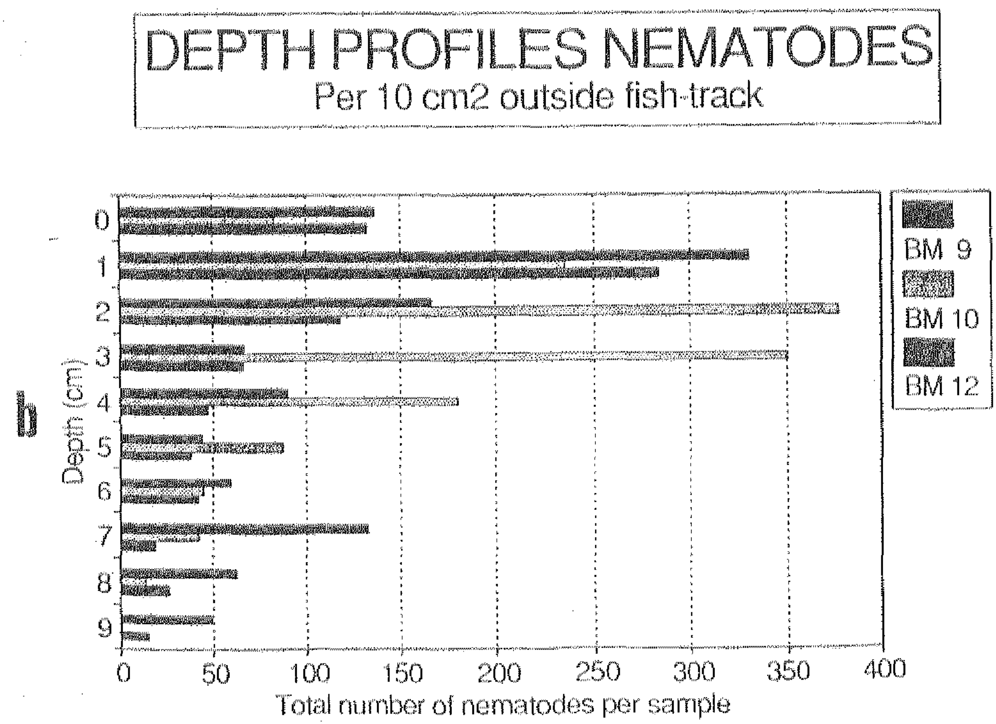


FIG. 1.7: Depth profiles with the numbers of nematodes in- and outside the trawl track, fig. 1.7[a] and fig. 1.7[b] respectively, clearly indicate a difference between the samples taken inside the track and the samples taken outside the track. The typical profile with a distinctive maximum in the top centimetres and the relatively high numbers of nematods which are found outside the track are completely missing inside the track.

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