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East Coast Repetitive Seafloor Mapping 1979/1990

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EAST COAST REPETITIVE SEAFLOOR MAPPING

1979/1990

Geonautics Limited

St. John's, Newfoundland.

Scientific Authority: Mr. R. Parrott.
Atlantic Geoscience Centre.

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The 1990 remapping survey was carried out during Cruise DN90-021 of the Atlantic Geoscience Centre, Geological Survey of Canada onboard the Department of Fisheries and Oceans vessel C.S.S. DAWSON. Portions of the data collection and interpretation were supported by Task 63201 (Ice Scour) and 63202 (Seafloor Stability) of the Offshore Geotechnics Program - East Coast of the federal Panel on Energy Research and Development (PERD).

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EXECUTIVE SUMMARY

Detailed analysis of sidescan sonograms collected along identical survey tracks using identical 100 kHz ORE systems in 1979 and 1990 reveal no conclusive evidence of any new scour features or other recognizable changes to the seabed over that period. Six crater type scours which are well-defined on the 1990 ORE sonographs for one of the survey lines may be new features related to two separate scouring events, however, this cannot be confirmed because of limited seabed coverage of the 1979 data in the area of these features. Furthermore, interpretation of high resolution sonar data collected in 1990 using a Klein 50 kHz system mounted in a Huntec sub-bottom profiler towfish has revealed many more scours than are evident on either of the 100 kHz data sets. In total, some 280 individual scour features have been documented using the 1990 sidescan sonar (100 and 50 kHz) and sub-bottom profiler data. This compares with 43 features documented for the same area in 1979 using 100 kHz ORE sidescan sonar data alone. Comparison of scour metrics, including orientation, length and width for 30 scours which were recognized on the 100 kHz ORE sonographs collected in both 1979 and 1990 reveal significant differences. However, these differences are interpreted to be an artifact of natural variability, interpreter judgement and measurement/calculation methods, rather than real changes. Other scour metrics compiled as part of the 1990 scour catalogue, including scour depth, berm height and profile shape information provided by the subbottom profiler data, result in a much more complete understanding of the scour population. For example, it is interesting to note that the maximum recorded scour depth (4 metres) corresponds with one of only two possible new scour features recognized during this analysis.

These results highlight two key criteria which must be satisfied when attempting to use acoustic remote sensing methods for detecting seabed changes, namely (i) the remote sensing system which is being used must be sufficiently sensitive to detect the scale of changes to be anticipated and (ii) if any changes are observed to exist, there must be some objective means of determining if they are real or an artifact of the remote sensing system (in this case, sidescan sonar) or methods. One must never forget that the sonograph generated by any sidescan sonar system is a visual representation of sonic phenomena. A number of factors including the nature of the sonic source, interaction of the signal with the target, scattering of the signal by the transmission medium and the mechanism whereby the reflected signal is recorded and displayed all have some effect on the resulting 'picture'. With regard to iceberg scours, the question 'How much seabed disturbance am I missing?' is every bit as valid as 'How much seabed disturbance do I see?'. Much more work is required in order to document the accuracy and precision of scour parameter measurements taken from sidescan sonograms, particularly if these measurements are to be used in engineering design calculations.

RÉSUMÉ

L'analyse approfondie de sonogrammes obtenus le long de lignes de levé identiques à l'aide de sonars à balayage latéral ORE de 100 kHz identiques en 1979 et 1990 n'a pas révélé de preuves concluantes de nouvelles cicatrices d'affouillement ou autres modifications identifiables du fond marin pendant la période considérée. Six cicatrices de type cratère bien définies sur les sonogrammes de 1990, sur l'une des lignes de levé, pourraient être nouvelles et elles pourraient être le résultat de deux affouillements distincts; cependant, cette hypothèse ne peut être confirmée en raison de la couverture limitée des données de 1979 dans la zone où se trouvent ces cicatrices. En outre, l'interprétation de données sonar recueillies en 1990 à l'aide d'un système Klein de 50 kHz à haute résolution installé dans un profileur de matériaux sous le fond logé dans un poisson remorqué (système Huntec) a révélé un nombre de cicatrices beaucoup plus élevé que celui indiqué par l'un ou l'autre des ensembles de données obtenus avec les sonars de 100 kHz. En tout, quelque 280 cicatrices individuelles ont été répertoriées à l'aide des données fournies par les sonars à balayage latéral (100 et 50 kHz) et le profileur de matériaux sous le fond en 1990. En 1979, les données fournies par le seul sonar à balayage latéral ORE de 100 kHz n'avaient permis de répertorier que 43 cicatrices dans la même région. La comparaison des paramètres mesurables des cicatrices, à savoir l'orientation, la longueur et la largeur, pour 30 cicatrices observées sur les sonogrammes recueillis en 1979 et 1990 à l'aide du sonar de 100 kHz, a révélé des différences importantes. Toutefois, on considère que ces différences sont attribuables à une variabilité naturelle, à la manière d'interpréter et aux méthodes de mesure et de calcul, plutôt qu'à des changements réels. D'autres mesures incluses dans le catalogue de 1990, telles que la profondeur de la cicatrice, la hauteur de la berme et la forme du profil, fournies par le profileur de matériaux sous le fond, permettent de beaucoup mieux comprendre la population de cicatrices. Par exemple, il est intéressant de noter que la profondeur de cicatrice maximale enregistrée (4 mètres) correspond à l'une des deux seules nouvelles cicatrices possibles identifiées au cours de cette analyse.

Ces résultats mettent en lumière deux conditions essentielles qui doivent être satisfaites lorsqu'on tente d'utiliser les méthodes de télédétection acoustique pour détecter les modifications des fonds marins, soit : i) le système de télédétection utilisé doit être suffisamment sensible pour détecter les changements que l'on s'attend à observer et ii) si des changements sont observés, on doit disposer de moyens objectifs permettant de déterminer si ces changements sont réels ou s'ils sont une conséquence du système de télédétection (dans le cas présent, le sonar à balayage latéral) ou des méthodes de détection. Il ne faut jamais oublier que le sonogramme produit par tout système sonar à balayage latéral est une représentation visuelle de phénomènes soniques. Plusieurs facteurs interviennent dans la formation de l'"image" résultante, tels la nature de la source sonique, l'interaction du signal avec la cible, la diffusion du signal par le milieu de

transmission et le mécanisme d'enregistrement et d'affichage du signal réfléchi. En ce qui concerne les cicatrices d'affouillement par les icebergs, la question "Quelle fraction des perturbations du fond marin est-ce que je manque?" est tout aussi valide que la question "Quelle fraction des perturbations du fond marin est-ce que je vois?". Un travail considérable est encore nécessaire pour établir l'exactitude et la précision des mesures des paramètres des cicatrices fournies par les sonars à balayage latéral, surtout si ces mesures doivent être utilisées dans des calculs d'ingénierie.

1.0 INTRODUCTION

During the early part of December, 1979, McElhanney Surveying and Engineering Ltd. (now McElhanney Offshore Surveys Limited) and Geomarine Associates Ltd. conducted a sidescan sonar survey between the North Hibernia and Trave-White Rose wellsites on northeastern Grand Bank under contract to Mobil Oil Canada, Ltd. This survey consisted of a total of ten survey lines roughly 70 kilometers in length, spaced 2 km apart and oriented N070E. The survey lines which comprise this data set are referred to as the '4000 Series'.

The purpose of the '4000 Series' survey was to document the character and distribution of iceberg scours in the Hibernia development area as a basis for improved understanding of the scouring process and better information concerning the severity of scouring and potential impacts on the future oil-related seabed installations such as wellheads or pipelines. Analysis of the '4000 Series' data by Geomarine Associates revealed 43 linear scour features predominantly oriented NNE-SSW and ranging in width from 17 to 93 m. No scour depth data were compiled. Scours were observed to be less abundant below 140 m water depth, and no scours were observed in water depths greater than 150 m (Geomarine, 1980).

Scour statistics derived from the '4000 Series' survey data, together with those derived from site specific wellsite survey data (Nordco Limited, 1982) and regional survey lines (Geonautics Limited, 1989), represent the sum total of our knowledge concerning the character and distribution of iceberg scours on this part of northeastern Grand Bank. While these statistics are important, they represent at best individual snapshots of a dynamic process. As was recognized by ESRF in funding the "Design of an iceberg scour repetitive mapping network for the Canadian east coast" (Geonautics Limited, 1987), a time series of data is required to better quantify the frequency of scouring and the rate of scour degradation.

2.0 BACKGROUND

Southward-drifting icebergs are common during the spring season along the northeastern Canadian continental shelf, and pose a threat to the safe development of offshore resources in the region. One of the most serious dangers is the potential damage to well-head structures, pipelines or telecommunications cables when these icebergs impact and drag across (scour) the seabed. In order to properly design bottom sited facilities a thorough knowledge of the frequency (both spatial and temporal) of scouring events and the scour depth distribution is essential. In the past, several studies sponsored by ESRF have concentrated on various aspects of this problem including the mechanics of the scouring process (Woodworth-Lynas et al, 1986; Hodgson et al, 1988) and detailed compilation of scour dimensions from available geophysical records (Geonautics Limited, 1989).

An obvious means of protecting a seabed installation from scouring is to bury it to a depth which exceeds the maximum known scour depth in the area. However, this approach is expensive and the accuracy and validity of the scour measurement data must be carefully considered in order to avoid over design. Recently completed research has demonstrated that significant scour-induced soil displacement may occur beneath the scour trough under the right soil conditions (eg. Woodworth-Lynas and Guigne, 1990; Poorooshasb et al. 1989). In addition Gaskill et al (1985) pointed out that caution must be exercised when attempting to design an optimum burial depth for a pipeline or wellhead structure based on some measurement of existing scour depths since, once formed, scours are subject to degradation and infilling by sediment transport and biological reworking. Woodworth-Lynas et al (1986) have suggested that the infilling process may begin immediately in the turbulent wake of the scouring iceberg, and evidence from Makkovik Bank (Hodgson et al, 1988) has shown that the effects of biological reworking can also be immediate.

In order to assess the frequency of iceberg scouring and the rate of scour degradation, areas which have previously been surveyed and interpreted for iceberg scouring may be resurveyed at a later date using identical acquisition and analysis techniques to ensure compatibility of successive data sets (Geonautics Limited, 1987). The feasibility of remapping existing survey lines to obtain scour frequency information was assessed by AGC scientists in 1986 (Lewis and Parrott, 1987). Approximately 130 line kilometers of data were successfully resurveyed on northeastern Grand Bank in water depths of between 80 and 200 m. The results indicated that such an exercise can be very effective, providing that system and survey parameters are consistent.

Comparison of such multi-temporal data sets can provide valuable insight into the rate of both scour frequency and scour degradation. This information may then be used, together with knowledge of local physical conditions including sediment properties, the nature of the local benthic community and hydraulic conditions, to calibrate existing models of scour frequency (d'Appolonia and Lewis, 1986; Gaskill et al, 1985; Lewis, 1978) thereby assisting in the development of design criteria for subsea installations.

3.0 OBJECTIVES

The objectives of this study were to resurvey the '4000 Series' survey lines using identical equipment and operating parameters, and to analyse the data for the purposes of identifying new scour events and/or documenting observable changes to previously mapped features. The results will lead to a better understanding of the frequency of iceberg scouring and the rate of scour degradation on northeastern Grand Bank.

4.0 METHODOLOGY

4.1 Data Acquisition

Past experience indicates that successful resurveying of the seabed using sidescan sonar depends strongly on consistent survey methods and comparable equipment specifications. As discussed by Woodworth-Lynas and Barrie (1985) and Geonautics Limited (1987), a change in either the spacing or orientation of survey lines can cause dramatic changes in the apparent acoustic reflectivity characteristics of individual scours and, hence, they may 'appear' so different on the sonograph record that no positive correlation between surveys is possible. Similarly, different system specifications (particulary source frequency and pulse length) or operating/recording parameters (such as fire rate, sweep width or paper speed) can yield sonographs of the same area of the seabed which are difficult to compare.

Because of the above, every effort was made during the 1990 survey to duplicate exactly the 1979 '4000 Series' survey conditions. This included:

(i) preparation of a navigation preplot file based on the original navigation data;

(ii) analysis of the 1979 operator logs to determine the original layback and elevation of the sidescan towfish above the seabed;

(iii) use of identical survey equipment including an Ocean Research Equipment (ORE) Model 1036 100 kHz sidescan sonar and EPC 3200 dual channel recorder running at 0.5 sec sweep (theoretical slant range 375 m per channel);

(iv) constant comparison with the original songraphs during survey operations as a basis for fine tuning instrument settings and as a check on towfish position relative to the original survey track.

These measures were designed to ensure compatibility between the 1979 and 1990 data sets. At the same time, however, it was recognized that a combination of factors such as sea state, ocean currents and fluctuations in vessel speed may also have an impact on data quality, and that such conditions cannot necessarily be duplicated. Also, there was understandably no attempt to duplicate poor quality data during the 1990 resurvey.

Survey operations (1990) were carried out from the CSS DAWSON during the period August 22 through September 11 (AGC cruise number DN90-021; see Appendix

C for cruise report). Data acquisition totalled roughly 980 line kilometers including most of the '4000 Series' lines and a set of closely spaced, north-south trending lines previously surveyed by Geonautics (in 1983) and AGC (in 1983, 1986 and 1990) as part of an investigation of a grounded iceberg dubbed "Berg 95". Navigation and positioning were accomplished using ARGO, a medium frequency (1.6 to 1.9 MHz), phase comparison type positioning system, with Loran-C as secondary back-up. The ORE 100 kHz sidescan sonar data were displayed using an EPC 3200 recorder with an aspect ratio of roughly 6:1 (slant to ground range), and were also recorded on a modified EPC which corrected for slant to ground range distortion by compensating for vessel speed. Both the raw and corrected data were recorded at one half second sweep (375 m per channel). All navigation data were recorded on magnetic tape for post-cruise processing and final track plot preparation. Copies of the recorded sidescan data, sonographs, sidescan operator logs and navigation logs may be obtained by contacting the Scientific Authority, Mr. R. Parrott, AGC, or the Curation Section at AGC.

In addition to the ORE sidescan, other survey instruments operated by AGC staff during the DN90-021 cruise (including the '4000 Series' resurvey) included 10 cubic inch airgun, Huntec DTS sub-bottom profiler, Klein 50 kHz sidescan sonar (contained in Huntec towfish) and Raytheon 12 kHz echo sounder.

4.2 Data Processing

4.2.1 Navigation

Following completion of the survey in September, 1990, McElhanney Offshore Surveys Ltd. processed the navigation data and created a track plot. Data processing involved reformatting the recorded NAVPAK data and conversion to AutoCAD line files. The final track plot was produced at a scale of 1:150,000 (UTM Projection). The complete processing report, together with floppy disk containing all relevant navigation data, have been archived at the Atlantic Geoscience Centre. Interested parties are advised to contact the Scientific Authority, Mr. Russ Parrott, or the Curation Section at AGC for copies.

4.2.2 Sidescan Sonar

As indicated in the previous section, the ORE sidescan sonar data were recorded in hardcopy format on an EPC 3200 paper recorder (0.5 second sweep rate). Concurrent slant range/aspect ratio-corrected data were displayed on a modified EPC recorder in an attempt to facilitate scalar measurement of scour attributes.

The Klein 50 kHz sidescan data, which were collected as an ancillary data set during this study, were recorded in "mapping mode" (approximately 1:1 ratio) at 0.5 second sweep (300 m per channel) on a Klein 595 thermal recorder owned and operated by AGC.

4.2.3 Sub-bottom Profiler

A Huntec DTS sub-bottom profiler was deployed during the 1990 survey to record seabed morphology along the survey lines. Data recorded by the internal, motion-compensated hydrophone were displayed on an EPC 4100 graphic recorder. These data provided detailed information concerning variations in seabed elevation as small as 12 cm (Hutchins, 1978), and are ideal for studying scour depths and associated berm heights. Also, the Huntec system can provide information concerning the presence and thickness of any scour infill material, and the sub-seabed character of the sediments which have been scoured.

4.3 Data Analysis

Data analysis focused primarily on a detailed comparison of ORE 100 kHz sidescan sonographs collected in 1979 and 1990 to confirm the existence of new scour features and/or document observable changes to previously-mapped features over the eleven year period between surveys. This included quantitative measurement of relevant scour attributes and input of these measurements to a digital scour catalogue (see Section 4.3.2 and Appendix D).

From a strictly repetitive mapping perspective, it was important to compare data collected by the same instrument under similar operating conditions (as per Section 4.1) to avoid potentially confusing variability that may be intrinsic to the sonar system (as opposed to real changes to the seabed). However, while the ORE sidescan sonographs created in 1979 and 1990 represent the primary data set for comparative analysis, the available 1990 Huntec DTS sub-bottom profiler data provided important new information concerning the depth and profile shape of individual scour features, the apparent width of each scour, and the height and apparent width of the sediment berms displaced by the iceberg keel. This information was not available from the original '4000 Series' survey data set, thus precluding any comparative analysis, but does allow for a more complete understanding of the physical characteristics of the scour population under investigation.

It was also deemed to be important to consider the available 1990 Klein 50 kHz sidescan sonar data set when conducting the comparative analysis. This high-quality, high-resolution data set illustrated numerous details of individual scours and general seabed conditions which were not visible on the ORE data. In certain cases, the Klein data were used to confirm the existence of scoured features which were only vaguely recognizable on the ORE data and which would not otherwise have been confidently catalogued. More significantly, the Klein data revealed numerous scour features which were not visible on either ORE data set (1979 or 1990). With reference to repetitive mapping this is not relevant since, in the absence of corroborating evidence there is no basis to assume that any or all of these features are "new". However, the enhanced scour data set provided by the Klein data is significant in terms of a more complete understanding of the scour regime in the Hibernia development area. As such, separate funding was awarded to Geonautics Limited under Tasks 63201 (Ice Scour) and 63202 (Seafloor Stability) of the Offshore Geotechnics Program, PERD to compile an expanded scour catalogue from the Klein 50 kHz (and corresponding Huntec DTS) data in a format compatible with the '4000 Series' repetitive mapping data base. Results of this work are reported under separate cover (Geonautics Limited, in prep.) and summarized in Section 5.3 of this report.

4.3.1 Comparative Analysis

The following procedure was adopted to ensure a thorough comparison of the 1979 and 1990 ORE sidescan records on a scour by scour basis:

STEP 1: detailed examination of the 1990 ORE data and identification of scour feature.

STEP 2: comparison with 1979 ORE data to determine whether feature was (a) previously documented; (b) present on the 1979 sonograph but not documented; or (c) not present on the 1979 sonograph (i.e. potential new scour).

STEP 3: comparison with 1990 Klein data to determine any additional details concerning scour morphology.

STEP 4: measurement of scour parameters from available 1990 ORE, Klein and Huntec data sets, and input to a digital scour catalogue (refer to next section for details).

STEP 5: cross-check of 1979 survey report (Geomarine, 1980) to ensure no previously-mapped features were overlooked on the 1990 data.

STEP 6: photographic record of each new and/or previously recognized (1979 data) scour for illustrative purposes.

This procedure ensured that all scours visible on the 1990 ORE sonographs were documented without bias towards previously mapped features, and that all previously-mapped features were re-examined to determine whether there were any recognizable changes over the eleven year period between surveys.

4.3.2 Scour Catalogue

Relevant scour dimensions were compiled in a format similar to that adopted by Geonautics Limited (1989) for the east coast regional ice scour data base, except for certain modifications which are described below. Figure 1 illustrates the measured scour parameters. Figure 2 (a and b) shows a sample data compilation sheet.

The most significant difference between the data base compiled here and the East coast regional ice scour data base is that the regional data base represents a statistical subset of the entire scour population in any given area (King and Gillespie, 1986), whereas the data set compiled during this study is a catalogue of all visible and measurable scour features. Each scour is assigned a unique alpha-numeric identifier and the coordinates of the observed endpoints are recorded. This approach is similar to that adopted by Nordco Limited (1982) when compiling the Mobil ice scour catalogue and ensures that each feature may be further investigated or resurveyed at a later data. A complete listing and description of each parameter compiled for the '4000 Series' repetitive mapping scour catalogue is contained in Appendix D. The following discussion highlights specific characteristics which are unique to this catalogue.

First, some explanation regarding the scour identification code is required. Each scour in the 1990 repetitive mapping catalogue has been assigned a three-character numeric identifier beginning at 001. A prefix `N' is added to signify scours which are interpreted to be 'new' based on comparative analysis of the 1979 and 1990 data sets. Various suffixes are also added to indicate whether the scour is visible on the 1990 ORE data only (O), the Klein data only (K), or both (B).

Second, because both Klein 50 kHz and ORE 100 kHz sidescan sonar data were available, it was necessary to record which data set was used to compile measurements of scour orientation, width, length and plan-form shape. This was done by flagging with an asterisk those instruments which were used to compile the actual measurements contained in the catalogue. Since the precision of the 50 kHz and 100 kHz instruments differ significantly, re-measurement of scour parameters for those scours which had been

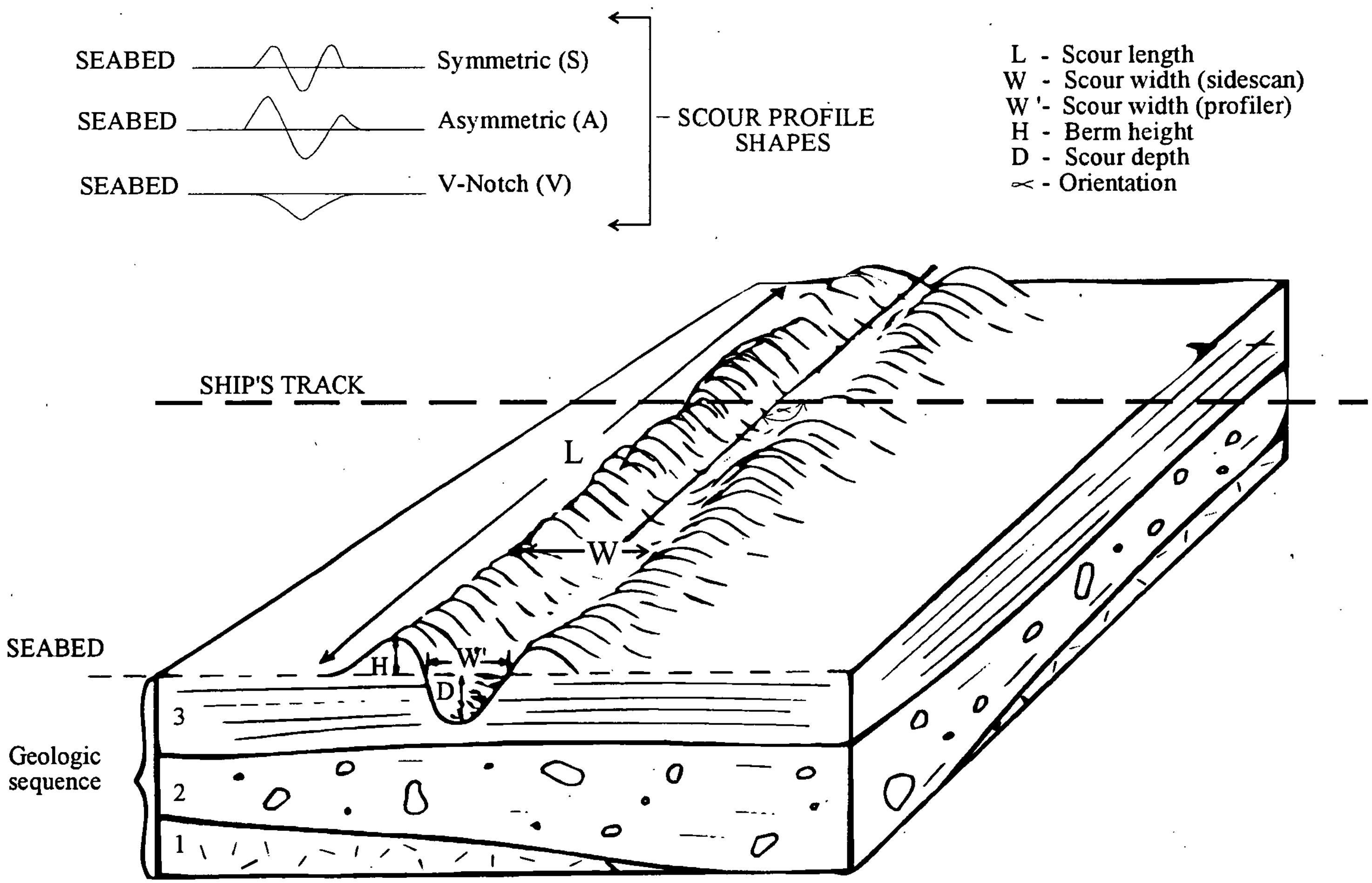
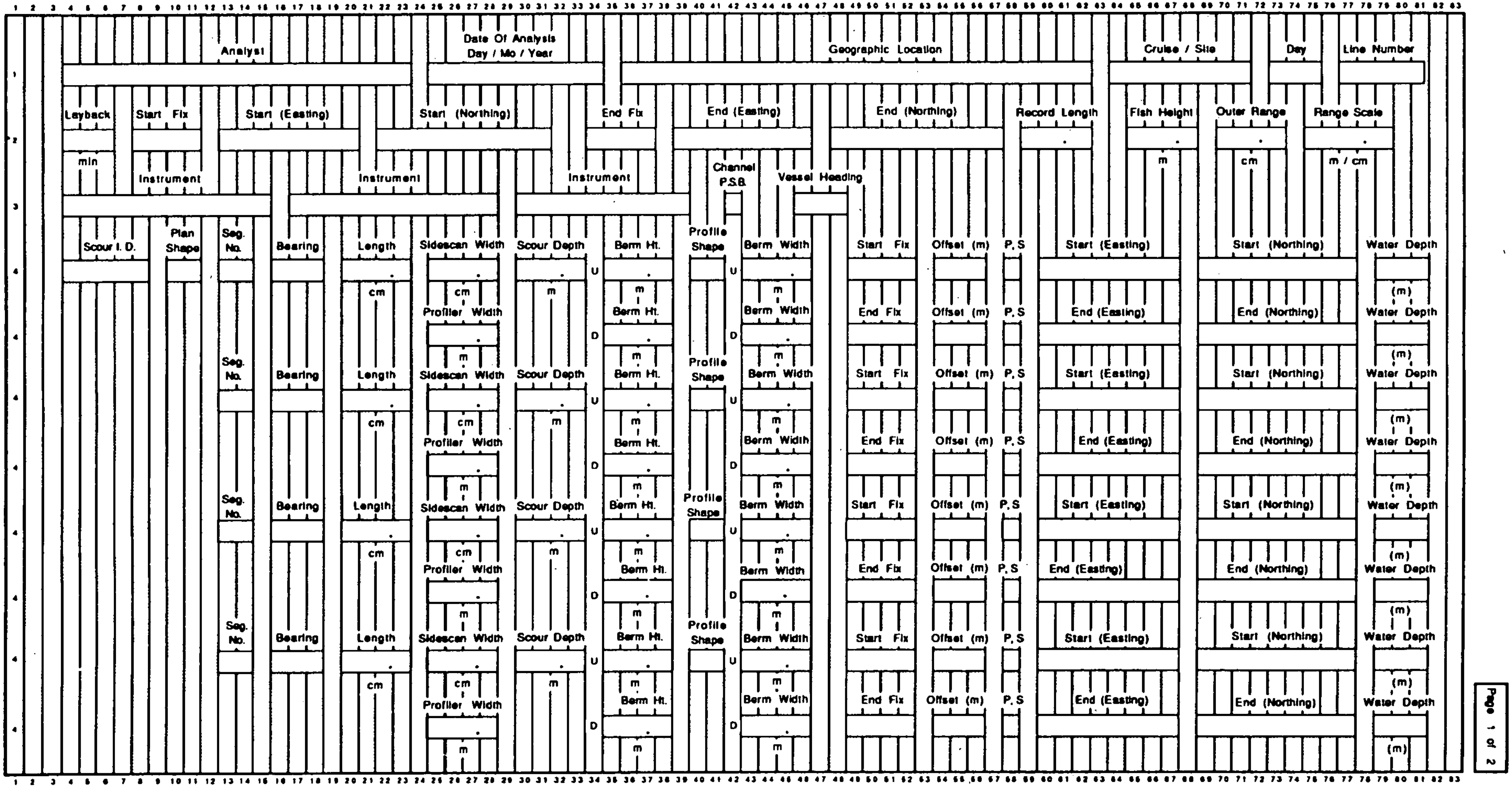


FIGURE 1: Illustration of scour parameters measured and recorded in data base.

GEONAUTICS / ESRF REPETITIVE MAPPING ICEBERG SCOUR ANALYSIS SHEET



1: Analyst | Date Of Analysis Day / Mo / Year | Geographic Location | Cruise / Site | Day | Line Number

2: Layback (min) | Start Fix | Start (Easting) | Start (Northing) | End Fix | End (Easting) | End (Northing) | Record Length | Fish Height (m) | Outer Range (cm) | Range Scale (m / cm)

3: Instrument | Instrument | Instrument | Channel P.S.B. | Vessel Heading

4: Scour I. D. | Plan Shape | Seg. No. | Bearing | Length (cm) | Sidescan Width (cm) | Scour Depth (m) | U Berm Ht. (m) | Profile Shape | U Berm Width (m) | Start Fix | Offset (m) | P, S | Start (Easting) | Start (Northing) | Water Depth (m)

4: Profiler Width (m) | D Berm Ht. (m) | D Berm Width (m) | End Fix | Offset (m) | P, S | End (Easting) | End (Northing) | Water Depth (m)

4: Seg. No. | Bearing | Length (cm) | Sidescan Width (cm) | Scour Depth (m) | U Berm Ht. (m) | Profile Shape | U Berm Width (m) | Start Fix | Offset (m) | P, S | Start (Easting) | Start (Northing) | Water Depth (m)

4: Profiler Width (m) | D Berm Ht. (m) | D Berm Width (m) | End Fix | Offset (m) | P, S | End (Easting) | End (Northing) | Water Depth (m)

4: Seg. No. | Bearing | Length (cm) | Sidescan Width (cm) | Scour Depth (m) | U Berm Ht. (m) | Profile Shape | U Berm Width (m) | Start Fix | Offset (m) | P, S | Start (Easting) | Start (Northing) | Water Depth (m)

4: Profiler Width (m) | D Berm Ht. (m) | D Berm Width (m) | End Fix | Offset (m) | P, S | End (Easting) | End (Northing) | Water Depth (m)

4: Seg. No. | Bearing | Length (cm) | Sidescan Width (cm) | Scour Depth (m) | U Berm Ht. (m) | Profile Shape | U Berm Width (m) | Start Fix | Offset (m) | P, S | Start (Easting) | Start (Northing) | Water Depth (m)

4: Profiler Width (m) | D Berm Ht. (m) | D Berm Width (m) | End Fix | Offset (m) | P, S | End (Easting) | End (Northing) | Water Depth (m)

Page 1 of 2

FIGURE 2(a)

GEONAUTICS / ESRF REPETITIVE MAPPING ICEBERG SCOUR ANALYSIS SHEET

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83

Cat

Comment

Cat

Comment

Seq

Code

Geologic, Unit Description

Geologic, Unit Thickness

%

Page 2 of 2

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83

FIGURE 2(b)

previously surveyed and measured by Geomarine was always done using the ORE sonographs, with the exception of those cases where the Klein data provided a significantly clearer representation of the feature in question.

Third, for those scours which are visible on the sub-bottom profiler data an apparent width has been tabulated. This measure may be corrected to true width when the orientation of the scour relative to the survey track is known. It should be noted, however, that scour width measured in this way is not the same as the width measured from the sidescan record (see Figure 1). In fact, the width as measured from the profiler record (W', Figure 1) is a more realistic measurement since it more closely represents the width of seabed disturbed by the scouring iceberg.

Fourth, for each scour visible on the sub-bottom profiler data, berm height and apparent berm width on both the upslope and downslope sides (relative to local seafloor gradient) of the scour have been tabulated. These measurements should provide engineers with a better appreciation for the amount of material displaced during the scouring process, and may also provide scour researchers with valuable information concerning the mechanics of scouring (i.e. berm size and geometry relative to slope of seabed).

Fifth, the perpendicular offsets to the start and end of each scour segment have been measured and are used in a subroutine to calculate the exact endpoint positions relative to a UTM grid.

Finally, a new comment concerning scour completeness has been added (Category 1) in recognition of the importance of this factor when attempting to use scour population statistics to calculate the probability that a scour will intersect a segment of a pipeline or other seabed installation, as suggested by Gaskill and Lewis (1987).

The complete scour catalogue has been compiled in dBase III format. Floppies containing the data base may be obtained by contacting the Scientific Authority or the Curation Section at AGC.

4.4 Quality Assessment/Quality Control

Two aspects of quality are relevant to this study. The first involves an evaluation of the geophysical data sets (sidescan sonar, sub-bottom profiler) and implications concerning the precision and accuracy of the measured scour parameter dimensions. The second involves the need to control the quality of the analysis and compilation procedures, and the final content of the data base, in an effort to ensure a consistent, reliable product.

4.4.1 Data Quality Evaluation

It is well known that sidescan sonar data quality may be affected by several factors including the operating conditions (sea state), the skill and diligence of the operator, and various physical anisotropies which may exist within the water column. With reference to the 1979 and 1990 ORE 100 kHz sidescan sonar data there is little evidence of diminished quality due to rough sea conditions causing roll, pitch or yaw of the towfish. Similarly none of the 1979 data and only two of the 1990 survey lines (4004R and 4009R) appear to suffer any reduction in data quality in the outer ranges due to ray path bending (thermocline noise).

There is, however, a significant difference in data quality between the 1979 and 1990 data sets with respect to the effective range of data coverage. In general, the effective range during the 1979 survey was limited to roughly 200 m for most of the survey lines. This compares with the 1990 survey during which the full 375 m range coverage was achieved on most lines. As explained in Appendix E, our interpretation of the reasons for this difference relate to the operating mode of the ORE system. It is assumed (in the absence of documentation) that the ORE system was operated in 'narrow beam' mode during the 1979 survey (Geomarine 1980). As the name implies, this mode is characterized by a narrow beam configuration for the transducer and was devised to reduce sea-surface reflections in shallow water conditions (Ferranti ORE, pers comm, 1991). The advantages of this mode also include improved feature resolution and reduced side-lobe interference (beam pattern on the recorded data).

During the 1990 survey, the ORE system was operated in 'wide beam' mode because optimum data coverage (effective range) was critical to real-time cross correlation of the two ORE data sets as a basis for making any necessary small-scale adjustments to the survey track. Wide beam mode is characterized by slightly lower resolution than narrow beam mode and by a strong beam pattern which results in a narrow strip of poor data close to the fish.

The implications of changing the mode of operation for the sidescan system are both positive and negative. On the positive side, wide beam mode allowed for maximum data coverage which aided in on-line navigation (as mentioned above) and scour feature recognition and correlation (see Section 5.0). On the negative side, the slightly lower resolution of the wide beam mode resulted in some loss of finer details of the seabed and scour features. As such, caution was necessary to ensure that any observed differences between the 1979 and 1990 data sets could be related to actual changes to the seabed (as opposed to apparent changes due to differences in resolution). Further details concerning this aspect of data quality are discussed in Section 5.3 and Appendix E of this report.

In light of the above discussion it may be stated that, in general, the ORE 100 kHz sidescan sonar data collected during the 1990 survey were of good quality and, given the physical limitations imposed by frequency and pulse length, did not in any way restrict the documentation of scour features and comparison with the existing 1979 data. The relatively large aspect ratio distortion of the recorded raw data (roughly 6:1) did result in distortion of the shape and orientation of the individual features but did not preclude their recognition by a skilled interpreter. However, as will be discussed in Section 5.1, the aspect ratio distortions can lead to significant errors in calculated scour dimensions. A qualitative estimate of data quality has been entered into the scour catalogue for each scour feature (comment category 3; see Appendix D), taking into consideration data clarity, gain settings, range limitations and evidence of fish motion.

It is noteworthy here that slant range/aspect ratio-corrected sidescan sonographs recorded by a separate EPC 3200 recorder were not used during the measurement process because the correction algorithm, which stretched the azimuth (along track) direction, resulted in a significant reduction in data clarity.

With respect to the Huntec DTS system, the patented motion compensation system appeared to be functioning properly. As such, it is assumed that seabed morphology should be repesented with an accuracy of +/-0.25 m or better.

4.4.2 Quality Control

Quality control procedures were implemented during compilation of the iceberg scour database in several stages as follows:

(i) all scour parameters were measured by a single, skilled interpreter to avoid interpreter variability. A second interpreter was consulted in the case of questionable features.

(ii) raw measurements were compiled on data sheets (see Figure 2a and b; Appendix D) and subsequently keyed into an ASCII text file by a data-entry specialist.

(iii) a print-out of the ASCII text file was edited for errors/omissions by the interpreter.

(iv) the raw data were processed to yield aspect ratio-corrected scour dimensions using software created in-house in consultation with AGC staff. During this stage, subtle key punch errors (such as mixed alpha-numerics) were revealed via malfunctions within sub-routines.

(v) corrected scour metrics were checked for outliers (i.e. entries which were obviously in error such as a measured scour depth of 20 m rather than 2.0 m) by the interpreter.

(vi) a random sample of 10 scours were selected and scour metrics were manually calculated by the interpreter and checked against subroutine results.

(vii) where possible, corrected scour metrics were compared with previous measurements reported by Geomarine (1980) (see Section 5.1).

5.0 RESULTS

In general there has been little or no recognizable change to previously surveyed scour features or the distribution of surficial sediments at the scale resolvable by the ORE 100 kHz sidescan sonar over the period 1979 through 1990. As an illustration of this, the reader is referred in particular to the representative photos for scours 118B (Feature #10, 1979), 040B (Feature #13, 1979), 197B (Feature #24B, 1979) and 261B (Feature #34, 1979) in Appendix A. Close examination of these representative photos reveals virtually no change to the shape or clarity of the scour features, or the distribution of interpreted hydraulic bedforms including sand waves and megaripples (allowing for reasonable differences in data quality and aspect ratio distortions). Comparisons of the remaining scours are not as obvious (largely due to the relatively poor clarity of these features) but are equally valid based on careful analysis of the original sidescan sonographs. The following sections present the resurvey results in detail.

5.1 Comparison of Scour Metrics 1979/1990

Of the 43 iceberg scour features compiled by Geomarine Associates in 1979, 30 have been re-investigated during this study. The remaining 13 were not resurveyed in 1990 due to reduced line length or failure to resurvey precisely the same swath of seafloor. Therefore, for these 13 scours, no new data exist upon which to base a comparison. Appendix A contains photographs of each resurveyed scour feature as a basis for visual comparison with similar photographs presented in the Geomarine (1980) report. Table 1 presents a summary of the measured dimensions for each resurveyed scour.

The differences in measured orientations, lengths and widths evident in Table 1 are somewhat disconcerting considering the qualitative evaluation of a basically static seabed presented above. However, prior to discussing any specific discrepancies it is necessary to consider, in general terms, the potential sources of error or variability involved in compiling scour metrics from visual representations of sonic data. Three basic sources of error or variability exist:

(i) Natural variability: As with most natural phenomena, iceberg scours have an inherent variability of dimension. No scour is perfectly straight or consistently wide or deep. Previous studies of iceberg scour dimensions on the eastern Canadian continental shelf have shown that this natural variability may be as large as 20 to 25 percent (Geonautics Limited, 1989). Thus, unless successive measurements of scour dimensions are made at the same location along the length of the scour, some discrepancy is to be anticipated.

TABLE 1
Scour Dimension Comparisons
1979/1990

Scour I.D		Orientation		Length (m)		Width (m)	
1979	1990	1979	1990	1979	1990	1979	1990
4	061B	130°	139°	300	743.3	25	28.0
5	063O	180°	162°	400	184.8	92	92.3
5B	064B	270°	34°/276°	500	765/483	92	33/21.4
6	111B	200°	221.8°	100	263.6	17	18
6A	112B	200°	198.1°	400	586.8	17	9.1
7	126B	130°	124.3°	100	546.1	34	17.9
9	121B	230°	220.6°	500	783.1	34	6.2
10	118B	220°	234.3°	1300	535.9	25	11.9
12	037B	220°	221.5°	600	472.5	50	21.2
13	040B	180°	192.1°	200	503.9	21	13.6
16	130B	230°	225.4°	400	260.5	38	26.1
17	132B	200°	204.1°	200	299.7	25	16.7
18	137B	190°	182.6°	400	332.8	25	18.3
19	148B	210°	217.2°	400	667.5	17	8.7
20	160B	210°	201.6°	600	496.5	34	21.1
21	226B	210°	218°	1000	601.5	42	9.2
21A	227B	220°	211.1°	1000	943.9	42	9.5
22	229B	200°	202.2°	400	585.4	17	7.8
24	187B	210°	201.5°	400	675.8	17	20.7
24A	192B	200°	198.8°	400	653.0	42	10.0
24B	197B	140°	125°	300	336.3	34	19.9
25	210K	170°	170.6°	300	427.5	25	22.1
26	222B	120°/190°	96.6°/205.7°	1600	1009.4/694.7	34	25.4/17.6
27	069B	250°	360°/271°	600	402.6/986.8	93	38.3/43.6
31	250B	210°	204.3°	500	231.7	42	13.9
32	251B	220°	215.2°	300	513.5	34	8.3
33	254B	110°	98.1°	600	639.0	42	4.8
40	010B	230°/340°	340°	1500	600.6	42	9.1
41	012B	190°	174.9°	300	487.6	60	12.7
43	027B	200°	183.4°	600	636.0	76	19.0

(ii) Sidescan sonar system effects: Sidescan sonar represents a remote sensing system in the truest sense. One must consider a number of factors including the nature of the source, interaction of the signal with the seabed, distortion and scattering of the signal by the medium, sensor characteristics, and the mechanism whereby the reflected sonic energy is recorded and displayed as a sonograph (visual representation of sonic phenomena).

It is well known that the wavelength (frequency), bandwidth and pulse length of the sonic source directly control the scale of the phenomena which may be detected by the sonar. It is also well known that the nature of the reflected signal is a function of the acoustic impedance contrast (hardness), roughness (texture) and morphology (specifically slope and aspect relative to the source) of the bottom (eg. Flemming, 1976). These factors in concert dictate the theoretical capabilities of the sonar system (i.e. what elements of the bottom the system is capable of sensing) and serve to explain why identical sidescan systems and survey techniques must be employed during any repetitive mapping program. It is incorrect to assume that different systems will image the bottom in exactly the same way, or even that the same system will capture the same image detail from two different angles.

The single largest source of error when attempting to compile quantitative scour metrics from sidescan sonographs arises because of the way in which the sonar data are recorded. Most data recorders allow for certain incremental adjustments to paper speed (along-track scale) which, when compared with the range setting of the system (across-track scale) inevitably yield an aspect ratio distortion which can be significant. For example, the 100 kHz ORE data collected for this study were recorded at a 6:1 aspect ratio. In other words, one unit of measure in the across-track (range) direction is equivalent to six units in the along-track (azimuth) direction. This distortion impacts the accuracy of scour measurements in two ways. First, because measurement precision is static, the accuracy of the range measurements will be greater than that of azimuth measurements. For example, consider a feature which is 2 mm wide on the sonograph when oriented perpendicular to the survey track. This same feature would be 12 mm wide on the sonograph when oriented parallel to the survey track for an aspect ratio distortion of 6:1. Thus, a variation of +/-1 mm in the measurement of the feature when oriented perpendicular to the survey track will have a more significant effect on the distortion-corrected width of the feature than will a similar variation if the feature is oriented parallel to the survey track. It should be noted that for the study conducted here measurement precision was as follows: orientation - to the nearest degree; width - to the nearest millimetre; length - to the nearest half centimetre.

The need to convert raw measurements taken from the distorted sonographs to corrected scour dimensions can further magnify the measurement errors discussed above. Table 2 lists the correction equations which were used to remove the effect of aspect ratio distortions. It may be seen that relatively small changes in raw measurements can lead to significant differences in the distortion-corrected dimensions under certain circumstances. For example, for scours oriented close to perpendicular to the survey track a change of 2 degrees in the measured orientation can lead to a 10 degree difference in the corrected orientation relative to the survey track.

As will be discussed below, another significant source of potential error when converting raw measurements to corrected scour metrics lies in the assumptions made concerning the range (swath width) and azimuth (along-track) scales of the sonograph records. For the purposes of this work, the swath width of the ORE systems is assumed to be constant at 375m/channel, while the azimuth scale is calculated based on the assumption that the distance between navigation fixes is always 400m. Variations in the distance between fix marks on the sonograph records is attributed to variations in vessel speed over that portion of the survey track.

(iii) Data quality: Besides the obvious detrimental effects caused by towfish motion (heave, pitch, yaw, surge and sway), distortion of the sonar signal by thermal anisotropies within the water column can have a serious impact on the quality of the recorded data. In turn, poor data quality can result in a certain amount of inaccuracy in the measurement of scour parameters, and increases the potential for variability between interpreters.

In general, the quality of the ORE sidescan data collected in 1979 and 1990 is good and did not adversely effect the results of the analyses. It is noteworthy, however, that the effective range of the system during the 1990 survey was greater than during the 1979 survey (see Section 4.4.1), which has an obvious impact on the re-measured length of each scour.

TABLE 2

Sonograph Aspect Ratio Correction Equations

(A) Scour Length and Orientation:

$$Xm = Lm \, . \, \cos a$$
$$Ym = Lm \, . \, \sin a$$

$$Xt = Xm \, . \, Sx$$
$$Yt = Ym \, . \, Sy$$

$$Lt = \sqrt{Xt^2 + Yt^2}$$

$$A = 90 - \tan^{-1} \frac{Xt}{Yt} \; *$$

where Lm = measured length, uncorrected (cm)

a = measured, uncorrected angle relative to vessel heading

Xm = length component parallel to vessel heading (cm)

Ym = length component perpendicular to vessel heading (cm)

Xt = corrected length component parallel to vessel heading (m)

Yt = corrected length component perpendicular to vessel heading (m)

Sx = azimuth scale on sonograph (m/cm)

Sy = range scale on sonograph (m/cm)

Lt = corrected length (m)

A = corrected angle relative to vessel heading *

*Note: Orientation relative to grid north subsequently calculated based on vessel heading.

TABLE 2 (Cont'd)

(B) Scour Width:

$Xm = Wm \cdot \sin a$
$Ym = Wm \cdot \cos a$

$Xt = Xm \cdot Sx$
$Yt = Ym \cdot Sy$

$Wt = \sqrt{Xt^2 + Yt^2}$

where Wm = measured width, uncorrected (cm)

a = measured, uncorrected angle relative to vessel heading (cm)

Xm = width component parallel to vessel heading (cm)

Ym = width component perpendicular to vessel heading (cm)

Xt = corrected width component parallel to vessel heading (m)

Yt = corrected width component perpendicular to vessel heading (m)

Sx = azimuth scale on sonograph (m/cm)

Sy = range scale on sonograph (m/cm)

Wt = corrected width (m)

Having considered the general scources of error or variability above, it is now appropriate to discuss the discrepancies evident in the comparison of orientations, lengths and widths presented in Table 1.

(i) Scour Orientation: There is no reason why the orientation of any given scour should vary over time. As such, it is logical to conclude that the observed differences of up to 21 degrees reflect either (a) real differences which can arise if different portions of the same scour are surveyed and measured (i.e. natural variability) or (b) apparent differences caused by variability in the measurement or correction procedures as discussed above. Also, minor variations in vessel heading as it progressed along the survey track could result in changes in the orientation of the sidescan sonar towfish, and since the towfish was not instrumented there is no way of knowing it's true orientation at any given point in time. This too could result in apparent variations in recorded scour orientations. Figure 3 is a rose diagram which illustrates the differences in measured orientations between the 30 resurveyed scours. It is evident that the general trends are the same, even if the measurements of individual scours do not compare well.

(ii) Scour Length: Given the difference in the effective sonar range during the two surveys (see Section 4.4.1) it is not surprising that two-thirds of the scour lengths recorded in 1990 are longer than those recorded in 1979. Those scours which were shorter in 1990 reflect cases in which the overlap in survey coverage between 1979 and 1990 was less than one hundred percent.

(iii) Scour Width: Degradation of scour berms and infilling of the scour troughs over time may be expected to cause some change in the observed width (and depth) of any given scour. As such, a portion of the differences in scour widths listed in Table 1 may be due to scour degradation. However, it is felt that the observed differences are too large to be attributed to scour degradation alone. Also, it is notable that the majority (90%) of the scour widths measured from the 1990 sonographs are significantly less than corresponding measurements from the 1979 sonographs. Interpreter variability, natural variability and differences in the methodologies used to measure scour width and/or correct for aspect ratio distortion may all be invoked as possible causes for general variability in comparative width measurements, as discussed above. The reasons for the observed trend towards narrower measured widths in 1990 are not obvious.

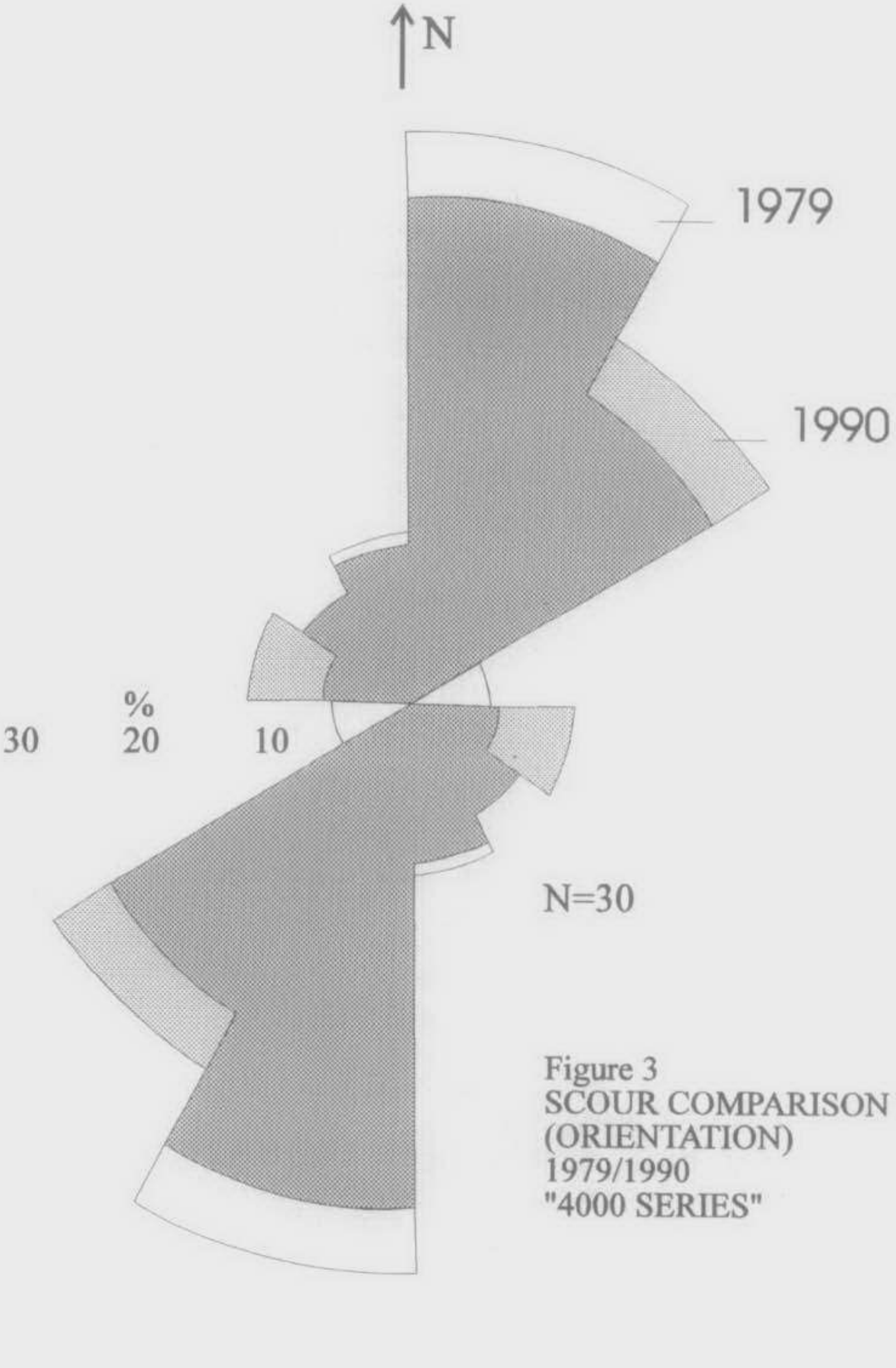


Figure 3
SCOUR COMPARISON
(ORIENTATION)
1979/1990
"4000 SERIES"

TABLE 3

Measurement of Scour Dimensions for the Same Scour from Three Separate Sonograph Records.

Measurement	Scour 24B (1979)	Scour 197B (1990)	Scour 197B (1990)
Measured length (cm)	15	19	21
Measured orientation (cm)	86°	86°	64°
Measured width (cm)	.30	.30	1.0
Range scale (m/cm)	15.4	15.4	14.6
Azimuth scale (m/cm)	96.8	94.5	20.9
Corrected length (m)	251.8	317.7	336.1
Corrected orientation	136°	137°	125°
Corrected width (m)	29.0	28.4	19.9
Instrument	ORE	ORE	Klein

Table 3 lists measured and calculated dimensional data for a single well-defined scour observed with equal clarity on both the 1979 and 1990 sonographs. Because this feature is a well-defined scour we assume that the possibility for interpreter variability is minimal. Comparison of the corrected width and orientation data as measured by the same interpreter from both the 1979 and 1990 ORE sonographs reveals results which are effectively the same. It is noteworthy, however, that the remeasured, recalculated width measurement from the 1979 ORE sonograph is 5 metres less than the 34 metres reported by Geomarine (1980). This difference is well within the measurement precision constraints discussed above.

Also noteworthy is the fact that the width as measured from the Klein sonograph is significantly (i.e. 30%) less than the widths measured from either of the ORE sonographs. It is tempting to conclude that there is some fundamental difference between the Klein and ORE systems which gives rise to this difference. However, when one considers the whole data set in Table 1 it becomes obvious that large differences are just as likely no matter whether the 1990 remeasurements were taken from the ORE or the Klein sonographs. If anything, it is logical to presume that the measurements taken from the Klein data would be more precise due to the smaller range and azimuth display scales and lower aspect ratio distortion (roughly 1.4:1). We feel that the differences in orientations measured from the ORE and Klein data result because a smaller segment of the scour is captured by the Klein and recorded in greater detail, again at a lower aspect ratio distortion.

In an effort to better understand the source(s) of the discrepancies noted above, Geonautics undertook a detailed remeasurement and re-evaluation of 26 of the 30 scours evident on the 1979 ORE sonographs and resurveyed in 1990 (the original ORE records for the other 4 could not be located). Results of this exercise are presented in Table 4. These results show that even when the measurements are made by the same interpreter and the same conversion methodology is applied to calculate scour metrics (i.e. the effects of interpreter variability and differences in methodology are minimized or removed) significant differences remain. On a scour-by-scour basis a certain amount of the observed variance can be attributed to natural variability (e.g. Feature 26/Scour #222B) and/or differences in data quality (e.g. Feature 6/Scour 111B). However, our analysis suggests that most of the observed differences arise as a result of the cumulative effects of (i) the aspect ratio distortions of the ORE sonographs; (ii) the need to convert the raw measurements to absolute scour metrics; and (iii) the range (Sy) and azimuth (Sx) scales that are used to convert the raw measurements into absolute dimensions. As discussed earlier, aspect ratio distortions of roughly 6:1 for the ORE sonographs result in severe azimuth compression. Thus, small differences in the measured width (+/- 1mm) or orientation (+/- 1 degree) can lead to significant differences in calculated scour metrics, particularly for scours which are more or less perpendicular to the survey track (as is the

TABLE 4

Comparison of raw measurements and calculated dimensions for re-surveyed scours

(all measurements performed by Geonautics Limited)

Scour ID	Sx*	Sy	a	Lm	Wm	A	Wt	Sonar
4	71.43	15.5	81	15	0.4	53.9	28.2	ORE
061B	93.46	15.4	86	44	0.3	67	28	ORE
5	74.77	15.5	97	17	1.1	120.6	81.7	ORE
063O	92.31	15.4	91	12	1	96	92.3	ORE
5B	76.92	15.5	87	12	0.4	75.4	30.7	ORE
064B	111.63	15.4	100	31	0.3	142	33	ORE
6	80	15.5	105	12	0.25	144.1	19.3	ORE
111B	31.62	29.4	148	8.5	0.6	149.8	18	Klein
6A	68.97	15.5	98	21	0.25	122	17.1	ORE
112B	91.6	15.4	97	31	0.1	126.1	9.1	ORE
7	93.02	15.5	83	5.5	0.3	53.6	27.7	ORE
126B	90.23	15.4	83	29	0.2	54.3	17.9	ORE
9	82.47	15.5	108	10	0.4	150	31.4	ORE
121B	33.9	29.4	147	24	0.2	150.6	6.2	Klein
10	86.02	15.5	100	26	0.3	134.4	25.4	ORE
118B	33.9	29.4	137	20	0.3	141	11.9	Klein
12	71.43	15.5	100	16	0.45	129.1	31.7	ORE
037B	75.12	15.5	100	20	0.3	130.7	21.2	ORE
13	73.39	15.5	94	23	0.3	108.3	22	ORE
040B	68.67	15.4	98	28	0.2	122.1	13.6	ORE

TABLE 4 (CONT)

16	111.11	15.5	107	11	0.4	155.5	42.5	ORE
130B	92.31	15.4	110	7.5	0.3	155.4	26.1	ORE
17	111.11	15.5	99	6	0.5	138.6	54.9	ORE
132B	20.2	14.6	125	18	0.9	134.1	16.7	Klein
18	97.56	15.5	93	24	0.55	108.3	53.6	ORE
137B	91.6	15.4	94	20	0.2	112.6	18.3	ORE
19	95.24	15.5	99	17	0.3	134.2	28.2	ORE
148B	20.41	14.6	136	37	0.5	145.4	8.7	Klein
20		15.5	102	24	0.4	90	34	ORE
160B	20.72	14.6	122	30	1.1	131.6	21.1	Klein
24	98.76	15.5	99	25	0.4	135.3	39	ORE
187B	22.41	14.6	120	40	1	131.5	20.7	Klein
24A	97.56	15.5	103	23	0.7	145.5	66.6	ORE
192B	21.33	14.6	118	40	0.5	127.8	10	Klein
24B	102.56	15.5	86	16	0.3	65.2	30.7	ORE
197B	20.92	14.6	64	21	1	55.1	19.9	Klein
25	97.56	15.5	93	20	0.3	108.3	29.2	ORE
210K	22.22	14.6	97	29	1	100.6	22.1	Klein
26	93.46	15.5	77	20	0.4	35.7	36.4	ORE
222B	89.46	15.4	71	31	0.3	26.6	25.4	ORE
31	86.02	15.5	99	17	0.3	131.3	25.5	ORE
250B	70.8	15.4	102	11	0.2	134.3	13.9	ORE
32	83.33	15.5	108	28	0.2	150.2	15.9	ORE
251B	18.91	14.6	138	30	0.5	145.2	8.3	Klein

TABLE 4 (CONT)

33	80.81	15.5	74	28	0.3	33.8	23.3	ORE
254B	18.43	14.6	34	40	0.3	28.1	4.8	Klein
40	66.67	15.5	93	24	0.45	102.7	30	ORE
010B	90.91	15.4	91	39	0.1	95.9	9.1	ORE
41	64.52	15.5	93	14	0.65	102.3	41.9	ORE
012B	18.26	14.6	102	33	0.7	104.9	12.7	Klein
43	76.92	15.5	95	27	0.6	113.5	46	ORE
027B	95.24	15.4	94	38	0.2	113.4	19	ORE

*Note: see Table 2 for explanation of symbols.

case for most scours investigated here. See Table 4). For example, the seven metre difference in calculated scour widths for Feature 25/Scour #210K is significant, yet consistent with the +/- 1 mm measurement precision when one considers that the azimuth scale (Sx) is 9.8 metres per millimetre. We suggest that when the differences in calculated orientations or widths are larger than anticipated given the raw measurement and range and azimuth scales (Sx and Sy), then the most logical conclusion is that the assumptions used to derive the azimuth and range scales must be in error. Our assumption when calculating Sx was that the distance between navigation fix marks is constant at 400m. Thus, any differences in the record length between fix marks is attributed to variations in the speed of the vessel (and towfish) over the bottom (the paper speed of the recorder is generally constant). This fails to consider the errors in navigation/positioning which are possible when using ARGO. Similarly, errors can arise for Sy (range scale) if the height of the towfish varies significantly, but the magnitude of these errors is significantly less than those in the azimuth direction. One conclusion to be drawn from this analysis is that all planar scour dimensions (particularly orientation and width) measured from both the 1979 and 1990 sonograph records should be considered to be in error by a magnitude which is at the very least commensurate with the accepted navigational uncertainty. Errors in the position of the navigational antenna of the survey vessel may be calculated based on the recorded nav data (see McElhanney report archived at AGC). However, additional errors which may result from variations in the position and attitude of the sensor platform (i.e. the towfish) relative to the survey vessel are much more difficult to surmise. The results for certain scours presented in Table 4 suggest that these combined positional errors can result in significant differences in calculated scour metrics. This obviously has serious implications if the scour measurements derived from the sonograph records are to be used in engineering design calculations.

5.2 New Scours

5.2.1 '4000 Series' Resurvey

Perhaps the most significant result of this study is the recognition of only two potentially 'new' scour occurrences within the survey area over the period 1979 to 1990 based on interpretation of ORE 100 kHz sidescan sonar records. Both examples of 'new' scours occur on line 4002R and both may be classified as crater or pit type scours. Representative photographs are presented in Appendix A (Scours N060O and N103B to N106B).

Scour N060O is present on the starboard channel of the ORE sonograph for Line 4002R in 130 - 140 m of water. This feature is most accurately characterized as a crater-chain type scour (Bass and Woodworth-Lynas, 1988) with well developed berms which create relatively sharp, well defined shadows on the sonograph record. It is unclear whether the large seabed depression which exists in-line with this feature on the sidescan sonograph and Huntec profile is related to the crater chain which is visible on the sonograph, but in the absence of evidence to the contrary it has been measured as part of this feature. The diminishing spacing between craters and evidence of a large backwall berm (relative to the sidescan towfish) and little or no fore-berm suggest that the iceberg moved from north to south. This is consistent with known iceberg drift patterns in this region.

Scour N060O has been tentatively classified as a 'new' scour based largely on apparent scour clarity. This feature is not evident on the 1979 ORE data for Line 4002, however, close examination of correlative features on the two data sets reveals that Line 4002R is roughly 200 m to the port of Line 4002 at this locale, and therefore the feature is just beyond the range of the 1979 survey coverage.

Four circular craters or pits which exist on the port channel of Line 4002R near Fix #65 have also been interpreted as 'new' scour features. These features have been catalogued individually (N103B to N106B) but most likely were created by the same iceberg. As illustrated on the representative photographs of the ORE and Klein sonographs (Appendix A), these craters are all approximately circular in shape with well formed, symmetrical berms. The shape and berm symmetry suggest very little forward motion of the iceberg at the time that the craters were formed.

Comparison of Lines 4002 and 4002R reveals that 4002R is shifted roughly 100 m southeast of 4002 in the vicinity of Fix #65. This shift, combined with the fact that the effective range on the ORE data for Line 4002 is limited to 150 m or less, results in less than complete overlap of the 1979 and 1990 sonographs, and, therefore, an uncertain interpretation of these craters as 'new' scour features. However, their 'fresh' appearance on the sidescan sonograph from Line 4002R supports this interpretation.

As mentioned in Section 4.3, a significant number of scour features are evident on the 1990 Klein data alone. In fact, of a total of 280 scours which have been catalogued based on detailed analysis and interpretation of the 1979 and 1990 '4000 Series' Klein and ORE data sets, 116 are visible on the 1990 Klein sonographs only (see Appendix B). In other words, 42 percent of the total population, are simply not evident on either of the ORE data sets. Many of these scours appear very degraded (i.e. poorly defined) on the Klein sonographs and are obviously not 'new'; however, a significant number appear 'fresh' (i.e. well defined) and may well represent very recent events. In the absence of an earlier corroborating data set it is impossible to state unequivocably that any of these features are indeed 'new'. Therefore, any additional discussion of these features is not relevant to the repetitive mapping process. However, recognition of these additional scours allows for a more accurate comprehension of the scour regime in the area. As such, Geonautics was awarded additional funding by the Panel on Energy Research and Development (PERD) to compile a catalogue of all scours recognized on the Klein sonographs. This work is described completely under separate cover (Geonautics Limited, in prep), and summarized here under Section 5.3.

Finally, it is interesting to note that of the 280 scours catalogued, 84 are visible on all three sonographs (as opposed to a total of 43 mapped by Geomarine, 1980), 66 are evident on both 1990 data sets but not on the 1979 data, and 9 are represented on the 1990 ORE sonographs only. These results suggest that it is obvious that the original data interpretation performed by Geomarine (1980) resulted in a conservative estimate of the amount of scouring within the study area. In certain instances the discrepancy must be attributed to the judgement of the interpreter. However, in many cases the higher resolution of the Klein data were critical to confident recognition of features which were otherwise only vaguely evident on the ORE sonographs (both 1979 and 1990). The question which one must ask from a risk assessment viewpoint is whether such errors of omission are more or less significant than errors of commission. In other words, is it more serious to map fewer scours than actually exist, or more scours than actually exist?

5.2.2 Scour '89-001' Resurvey

In 1989 the Atlantic Geoscience Centre conducted a detailed geophysical survey over the site of a well documented iceberg grounding dubbed '89-001' (Parrott et al, 1990). This survey employed the Bedford Institute of Oceanography (BIO) 70 kHz sidescan sonar to document a 14 km long, 20 to 30 m wide, fresh iceberg scour trending approximately north/south and terminating in a well-defined pit at the southern end, estimated to be 90 m wide and 5 m deep. Near it's northern end this scour crossed two of the '4000 Series' survey lines (4008 and 4009) at a high angle. A resurvey of this portion of that scour during the DN90-021 cruise using the ORE 100 kHz sidescan sonar provides the opportunity to compare roughly orthogonal views of the same seabed feature collected using survey instruments with significantly different operating characteristics. As per earlier examples (Woodworth-Lynas and Barrie, 1985), the results are, at best, inconclusive.

A preliminary analysis of the various sonographs collected over scour '89-001' yielded very inconclusive results with regard to the location and morphology of this feature. On Line 11 of cruise DN90-021, scour '89-001' is clearly visible as a sinuous, 20 to 30 m wide, light-coloured (sandy) band across a darker (mixed sand and gravel) bottom (Figure 4). An elongate crater and straight, narrow scour (labelled "A" and "B" respectively on Figure 4) are evident nearby. The crater in particular is a distinctive

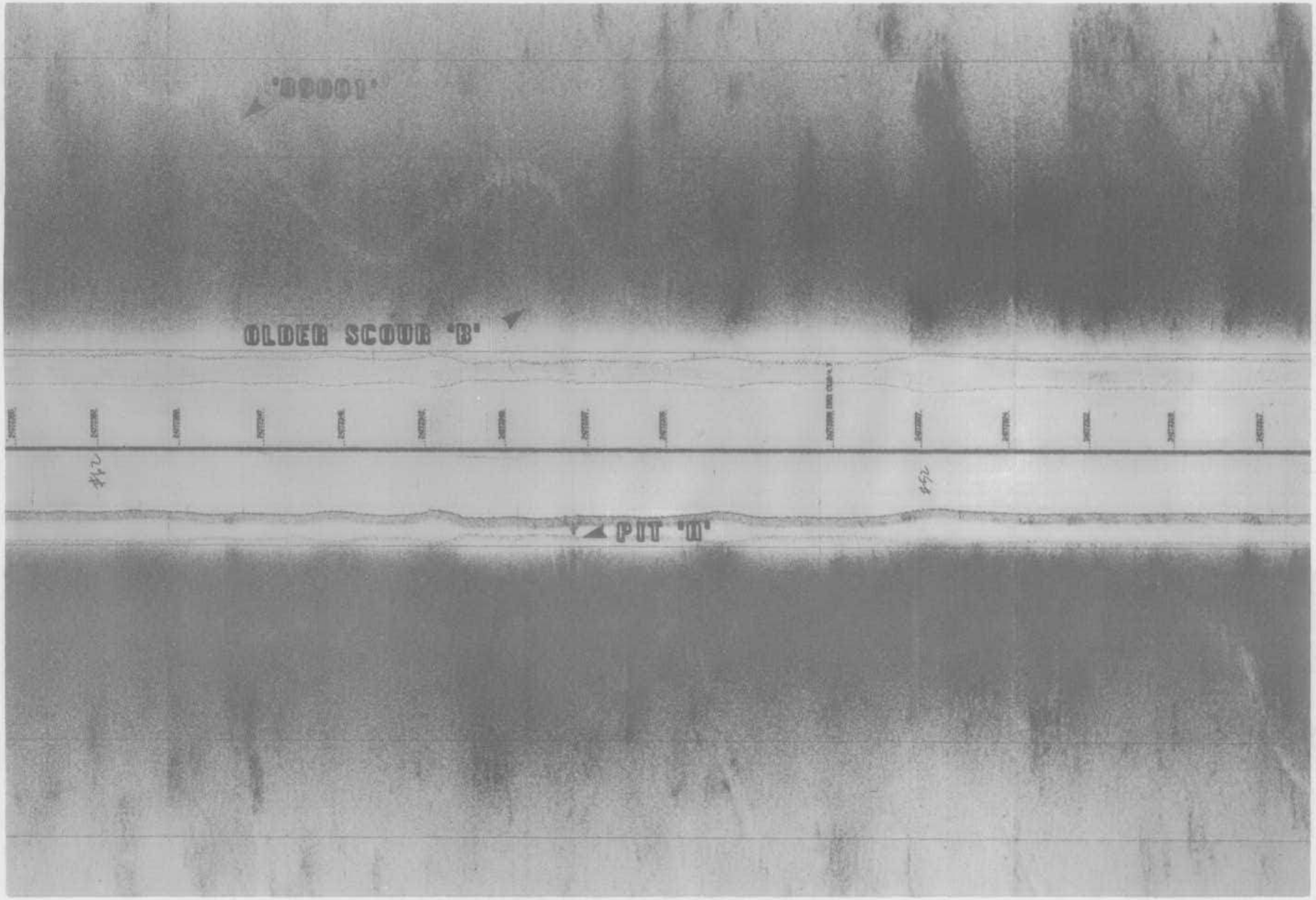


Figure 4: ORE 100 kHz sonograph, Line 11, Cruise DN90-021 showing new scour '89-001', older crater (A) and older scour (B). Range 375 m per channel. Distance between fixes = 400m.

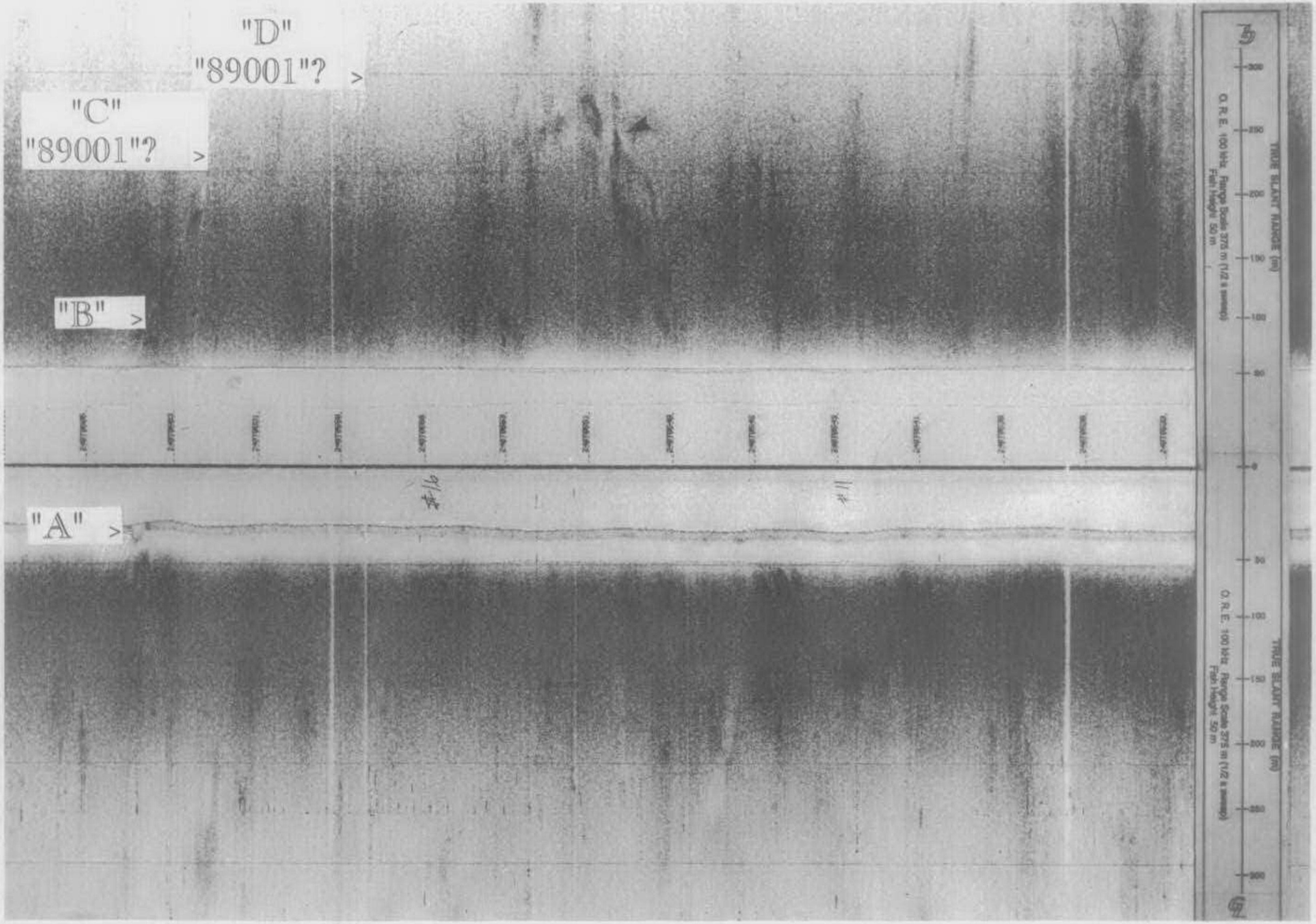


Figure 5: 100 kHz ORE sonograph showing crater (A), older scour (B) and possible candidates for new scour '89-001' (C or D ?).

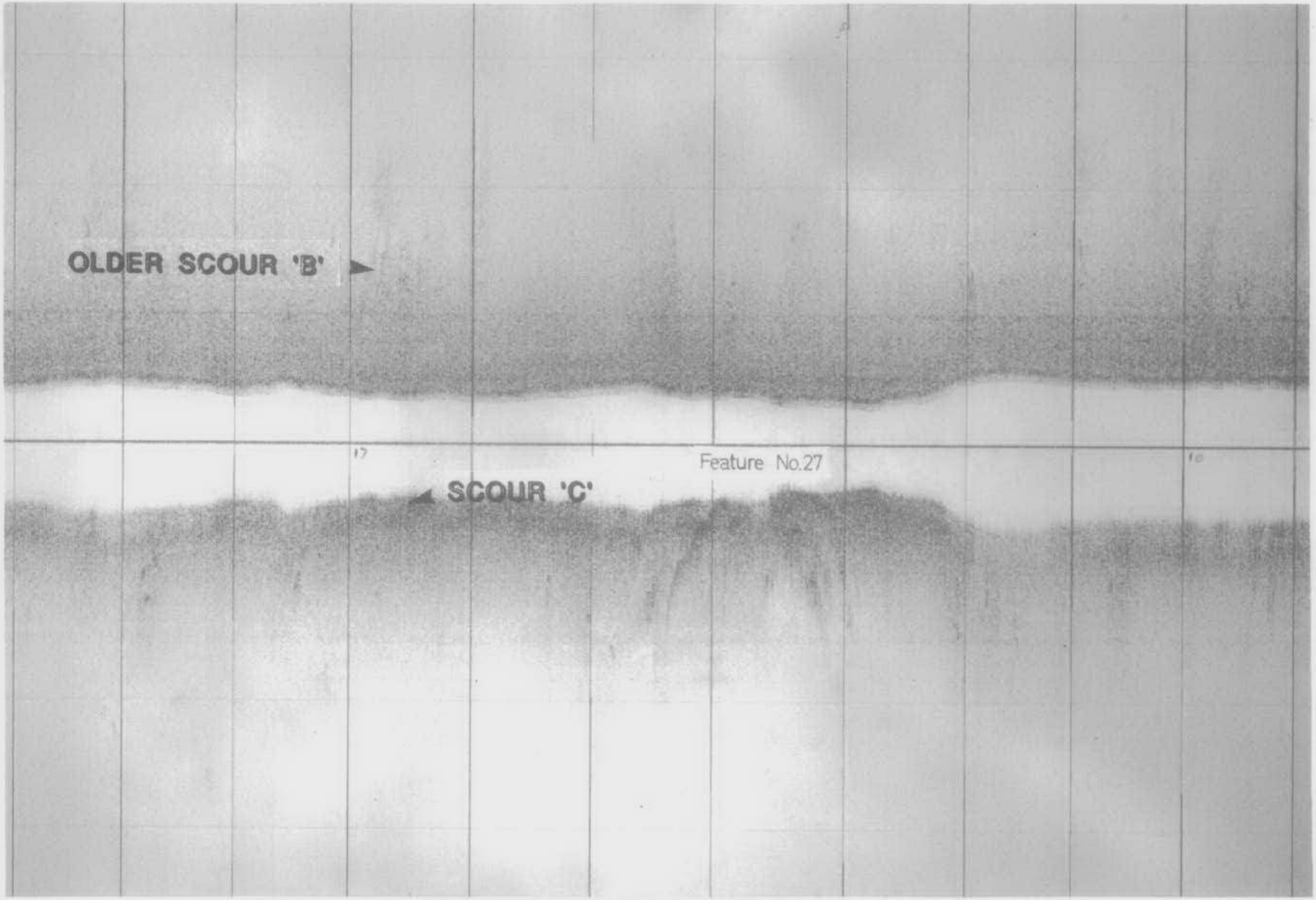


Figure 6: ORE 100 kHz sonograph, Line 4009 showing older scour (B), faint scour (C) and previously mapped Feature #27 (equivalent to scour 069B in 1990 update). Range 375 m per channel. Distance between fixes = 400m.

feature and also easily recognizable on both Line 4009R (Figure 5) and 4009 (Figure 6). Obviously, since it is visible on Line 4009 this crater is not a 'new' feature.

Confident recognition of scour '89-001' on Line 4008R or Line 4009R based on a qualitative evaluation of the raw data records was not possible (i.e. the scour was not immediately obvious as a fresh, clear feature). Only by plotting the track of the scour onto a 1:15,000 scale map based on the interpretation of the sonograph from Line 11 and the original BIO 70 kHz data was it possible to pick exactly where this feature should cross Lines 4008R and 4009R. Figure 7 illustrates scour '89-001' as it appears on Line 4008R. This feature was recognized during an independent compilation of a scour catalogue for the '4000 Series' (see Section 5.3), but was characterized on the basis of its clarity as a relict scour. This qualitative interpretation of the age of the feature in obviously not conclusive, but it does raise some doubt as to whether it truly represents scour '89-001'. On Line 4009R, confident identification of scour '89-001' was not possible even following construction of the detailed map. As illustrated in Figure 5, the crater and older scour are recognizable (again labelled "A" and "B" for consistency), however, the light, straight scour which crosses Line 4009R where '89-001' should be (labelled "C") is also faintly visible on the 1979 ORE sonograph from Line 4009 (Figure 6, also labelled "C"). Thus, it would seem that feature "C" is not a new scour, and therefore cannot be '89-001'. The faint linear scour labelled "D" on Figure 5 is also a questionable candidate for '89-001' since it is located roughly 500m from where it should be based on the detailed map created using the data from Line 11. However, navigational inaccuracies may account for this discrepancy. Finally, as shown in Figure 8, feature "C" appears much 'fresher' on the Klein 50 kHz data from Line 4009R than does "D". So the question remains as to how "C" can be a new feature when an apparent correlative is visible on a sonograph collected in 1979? And, more significantly, why doesn't a well-documented, fresh scour appear with equal clarity on sonographs acquired from different angles when older scours and craters (such as "A" and "B") do?

This example serves to illustrate a basic reality of remote sensing of iceberg scours using sidescan sonar, namely: the image of an iceberg scour recorded on a sonograph is the product of several independent factors including the resolution characteristics of the sonar, loss or modification of the transmitted and reflected signal due to the properties of the transmission medium, the physical interaction between the signal and the target and, finally, the limitations of the recording subsystem. As with many remote sensing systems, the transmission, reception and recording effects can be as significant as the actual basic physical relationship between the signal and target. In general, scours which trend nearly parallel to the survey track (perpendicular to the sonar beam) are more clearly imaged because the sonic shadows cast by the berms are more pronounced and the recorded data are much less compressed in the range direction than in the azimuth (along-track) direction.

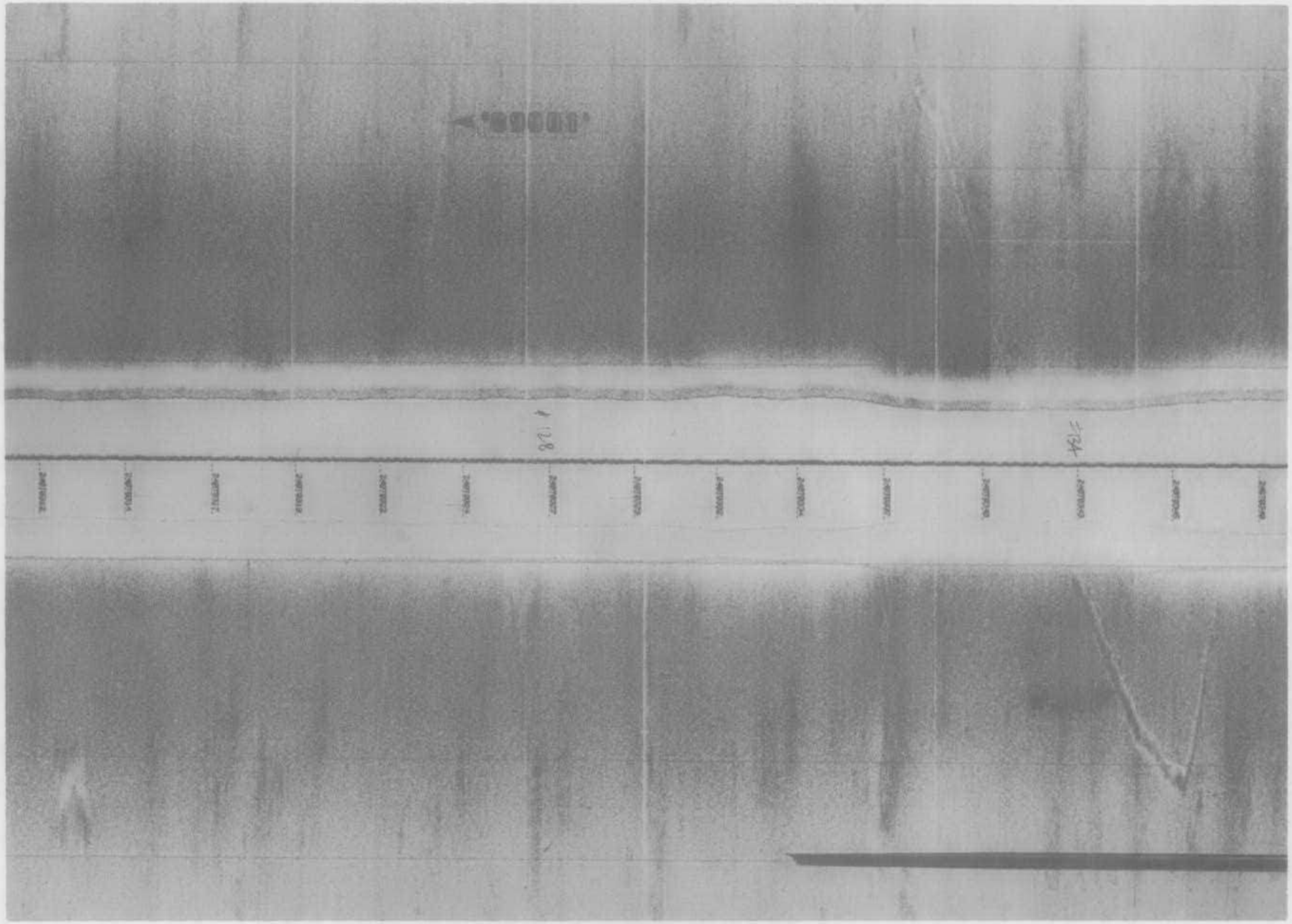


Figure 7: ORE 100 kHz sonograph, Line 4008R, Cruise DN90-021 showing new scour '89-001' and previously mapped Feature #26 (Geomarine, 1980). Range 375 m per channel. Distance between fixes = 400 m.

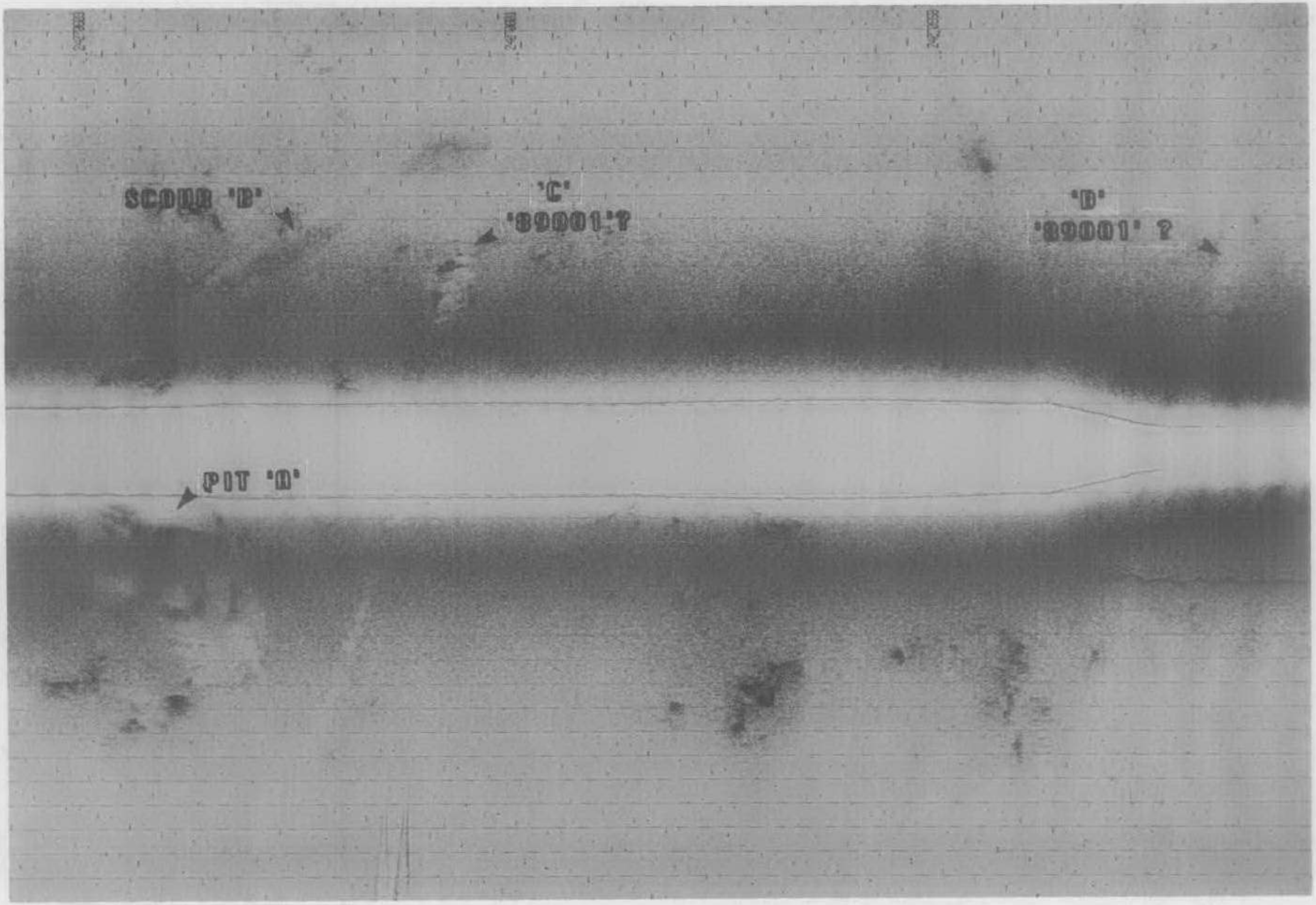


Figure 8: Klein 50 kHz sonograph, Line 4009R, Cruise DN90-021 showing crater (A) and older scour (B), plus possible candidates for new scour '89-001' (C or D ?).

5.2.3 Scour '95' Resurvey

Resurvey of Scour '95' during the DN90-021 cruise provided an opportunity to compare several images of the same iceberg scour acquired over a period of ten years (1980-1990) using three different sidescan sonar systems. Figures 9 through 11 illustrate a portion of Scour '95' acquired in 1980 (HU80-010; BIO 70 kHz sidescan), 1983 (HU83-033; Klein 100 kHz sidescan) and 1990 (DN90-021; Klein 50 kHz sidescan), respectively. The reader will note that in this instance all three survey lines are more or less parallel, thus minimizing the confounding effect of differing look directions.

Figure 9 illustrates a significant portion of Scour '95' and the surrounding seabed because of the large slant range capability of the BIO system (750 m per channel). The benefits of the BIO system as a reconnaissance survey tool are obvious when one compares this sonograph with the small area captured by the 100 and 50 kHz systems (refer to box outline on Figure 9). A significant drawback of the BIO system in this case however is the thermocline noise in the outer ranges of the sonograph, such as is evident on the starboard channel (top) of this example.

Comparison of Figures 10 and 11 with Figure 9 shows the same distribution of seabed sediments and no identifiable change in the character of Scour '95' at the resolution of the sonar systems. The 100 and 50 kHz systems capture more detail (note trawl marks, Figure 11), but in this instance the additional detail does not provide any useful information concerning changes to the width or shape of Scour '95'.

This example illustrates the potential benefits of a two-phased approach to repetitive seafloor mapping. The first phase would involve reconnaissance mapping to identify the distribution and general character of seabed sediments and the scour population, while the second phase would involve detailed resurveying of specific areas. The advantages of this approach are that the reconnaissance data provide valuable information concerning the gross details of the scour population (including the complete length of many scours) and serve to focus the efforts of subsequent detailed surveys. The disadvantage is that the higher resolution data may reveal additional scours which are not evident on the reconnaissance data, leading to possible confusion as to whether these scours are new or not (see next section).

5.3 1990 Scour Catalogue

As has been noted above, complete analysis of the ORE 100 kHz, Klein 50 kHz and Huntec DTS data collected in 1990 during the '4000 Series' resurvey, plus additional data acquired over the '89-001' and 'Scour 95' areas was undertaken under separate

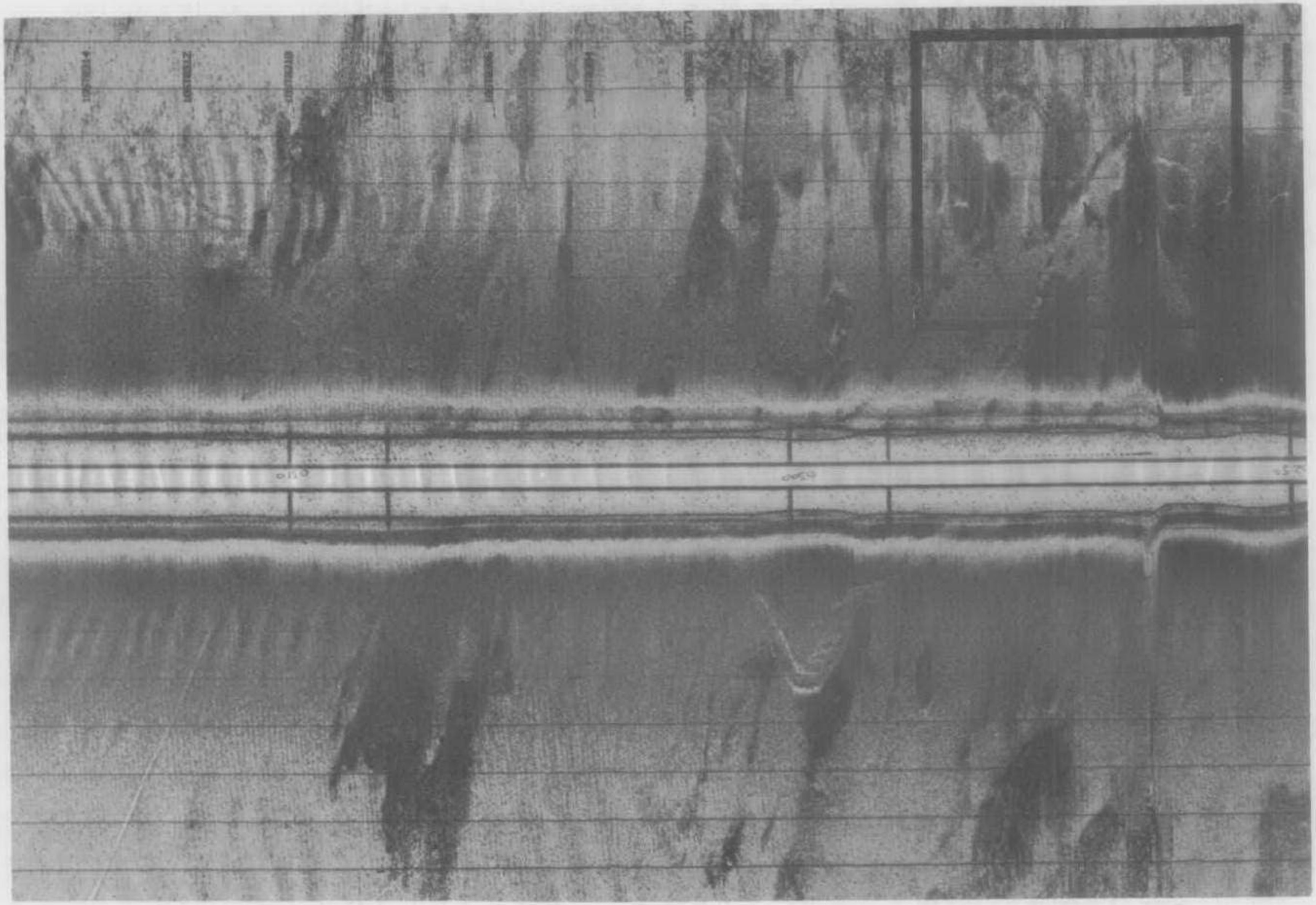


Figure 9: BIO 70 kHz sidescan sonograph collected during Cruise HU80-010 showing a portion of Scour '95' (arrows) and approximate area of seafloor illustrated in Figures 10 and 11. Range 750 m per channel. Distance between fixes = 1125 m.

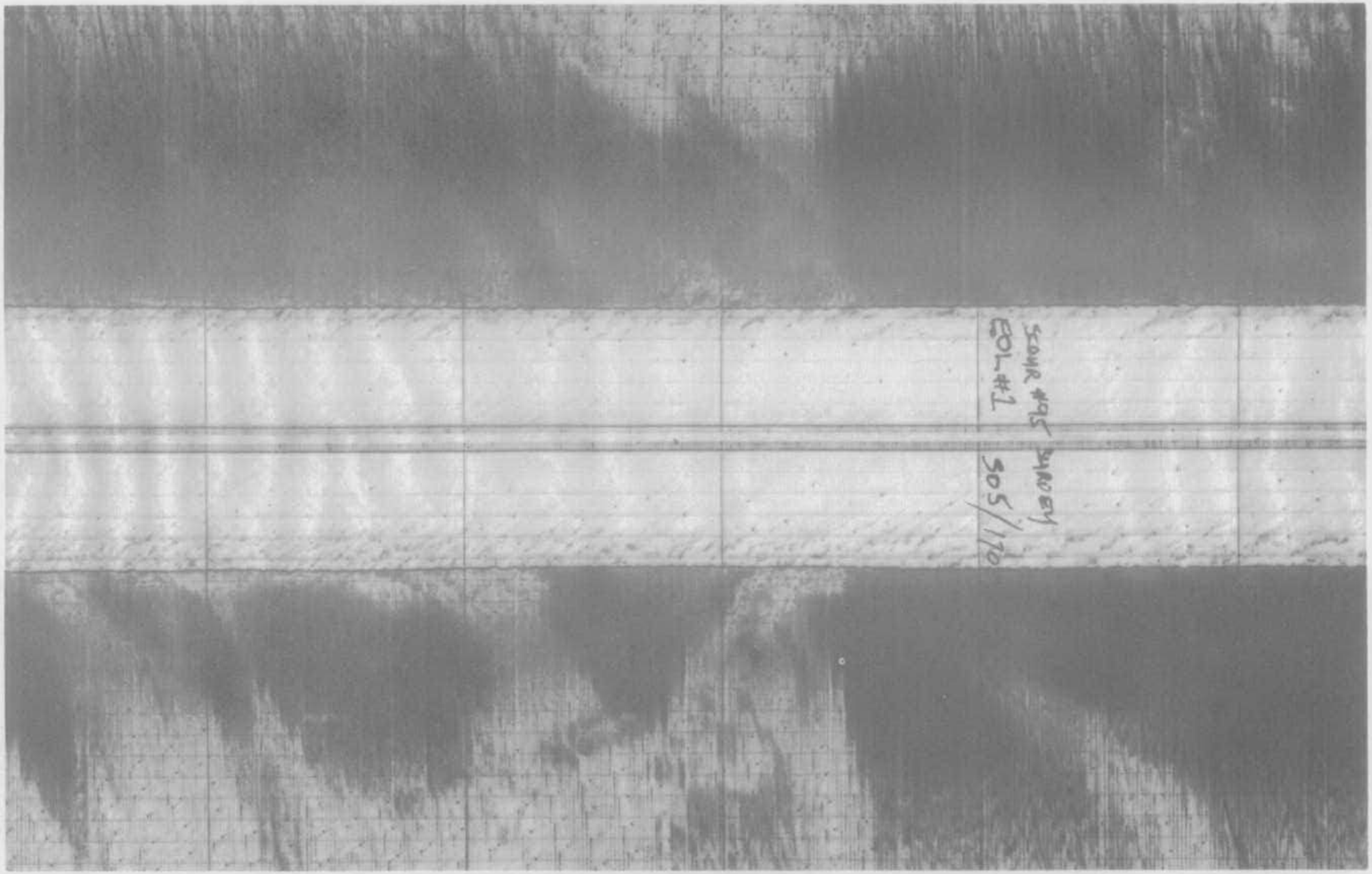


Figure 10: Klein 100 kHz sidescan sonograph collected during Cruise HU83-033 showing a portion of Scour '95' (arrow). Compare distribution of sediments with Figures 9 and 11. Range 300 m per channel. Distance between fixes = 225 m.

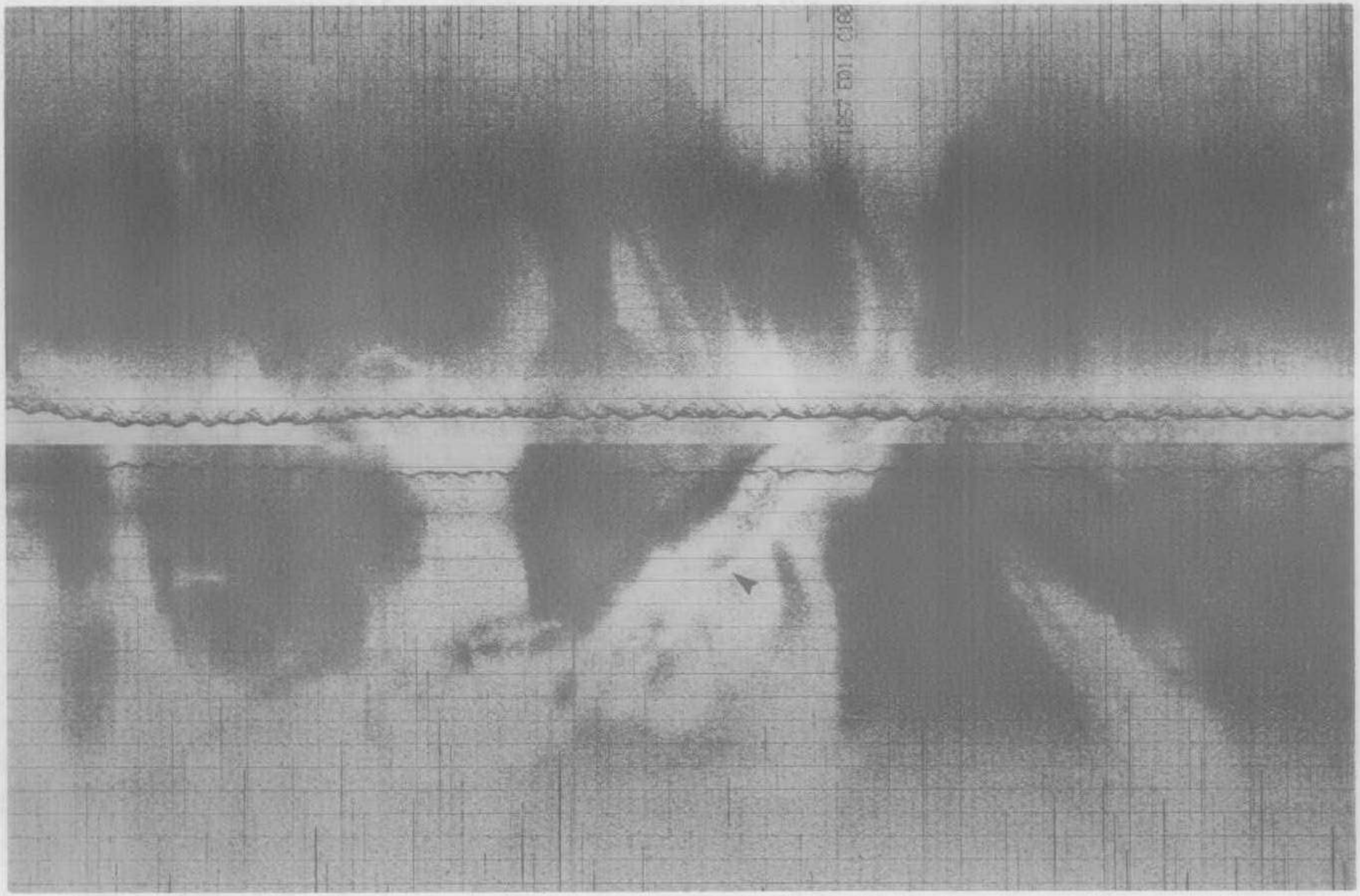


Figure 11: Klein 50 kHz sidescan sonograph collected during Cruise DN90-021 showing a portion of Scour '95' (arrow). Compare distribution of sediments with Figures 9 and 10. Note trawl marks. Range 300 m per channel. Distance between fixes = 400 m.

contract to the Panel on Energy Research and Development (PERD) (Geonautics Limited, in prep). This analysis revealed a total of 280 scours, of which 116 were visible on the Klein data alone, 9 were evident on the ORE data alone, and 155 were present on both sonar data sets. Only 47 of the 280 scours were represented on the Huntec profiles, an interesting fact considering that 161 of the measured scours cross the survey track (i.e. are visible on both channels of the sonographs). It is assumed that these features are either less than 20 cm deep (roughly the resolution limit of the Huntec system) or cross the survey lines at such an oblique angle that the typical scour profile is stretched to the point of being unrecognizable. An examination of scour orientation relative to the survey track may help to resolve this issue.

A complete listing of the 1990 scour catalogue is presented in Appendix B. These data are also available from the Scientific Authority on floppy disk in dBase III format. Figure 12 is a rose diagram showing the distribution of scour orientations. The predominant orientation is NNE-SSW, approximately parallel to regional isobaths and to the Labrador Current in this region. Mean scour depth is 60 cm, based on 47 measured depths (mode is 50 cm). The maximum recorded scour depth of 4.0 m corresponds with one of only two 'new' scour features (N060O) interpreted as part of this remapping project. The mean scour width is 17 m, and the maximum recorded width of 92.3 m (corrected for slant to ground range distortions) corresponds with an older scour first mapped by Geomarine (1980; Feature No. 5) based on the original '4000 Series' sonographs. The fact that the deepest scour is also one of the newest scours and the widest scour is an older feature is consistent with the findings of Geonautics Limited (1989).

In addition to the detailed analysis of all scours discussed above and reported in Geonautics Limited (in prep), part of the PERD funding was designated to perform a detailed analysis of any possible physical differences between the ORE systems used to acquire data in 1979 and 1990, and to determine if and how these differences might translate into a perceived difference in data quality. Geonautics Limited sub-contracted Dr. Peter Simpkin of IKB Technologies in St. John's to conduct this analysis. His complete analysis is presented in Appendix E of this report.

Dr. Simpkin's analysis confirms the increased range but slightly reduced resolution of the 1990 ORE data noted in Section 4.4.1. Choice of transducer beam pattern (wide versus narrow beam modes), addition of a time variant gain (TVG) feature to the model 160 transceiver during the period between surveys, and selection of 'raw' versus processed tranceiver outputs during the 1990 survey are all cited as possible causes for the observed differences in data quality. Detailed information on all equipment, including model/serial numbers and specifications, used during this and subsequent repetitive mapping surveys is offered as a logical recommendation to avoid such problems in the future.

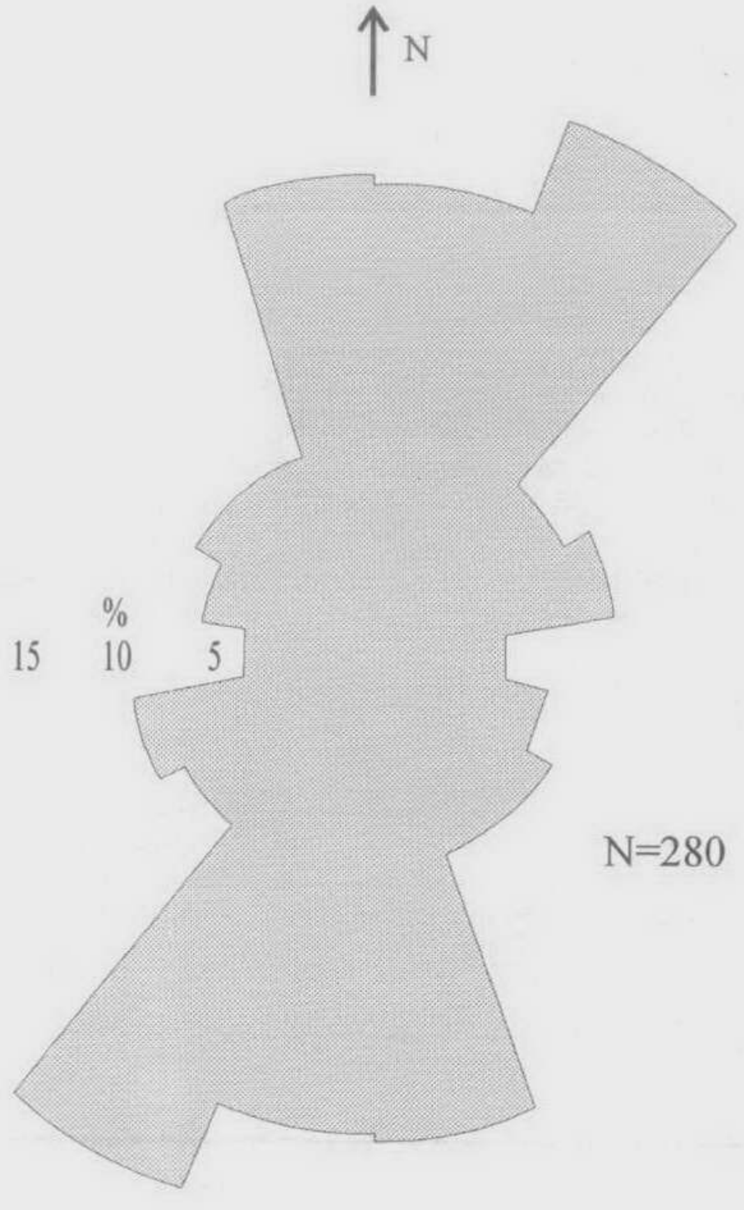


Figure 12
1990 SCOUR CATALOGUE
"4000 SERIES"
ALL SCOURS

6.0 RECOMMENDATIONS

A number of modifications should be considered in future applications of the sidescan sonar repetitive mapping method for monitoring scour return rates and degradation.

(i) The example of scour '89-001' clearly demonstrates the extreme differences which commonly exist between sonographs acquired along survey lines with near-orthogonal orientations. High quality, aspect ratio corrected sonographs (similar to those acquired using the Klein 50 kHz sonar and Model 595 thermal recorder) may go a long way towards resolving this problem by maintaining orientation and width characteristics of any given scour imaged from any given angle. However, one must remember that scours will always appear different when imaged from different directions as a result of changing morphology relative to the sonar "look" direction.

(ii) The example of scour '89-001' also raises the question of how many other scours are missed by collecting data along survey lines with the same (or reciprocal) orientation. It has long been recognized that scours are visible on sidescan sonographs by virtue of both textural and morphological variations, and that a scour can look very different when imaged along versus across its axis. As such, for each survey it would be preferable to run survey lines in orthogonal directions in order to best characterize all scours. This approach is well established for geophysical well-site surveys and for airborne synthetic aperture radar surveys, where the phenomenon of preferential enhancement of features oriented nearly perpendicular to the look direction is also well documented (Siegal and Gillespie, 1980).

(iii) The findings of this study suggest that the scale of any changes resulting from normal seabed hydraulic processes which may be anticipated on northeast Grand Bank over a 10 year period are not resolvable using an ORE 100 kHz sonar system. It is therefore recommended that, during any future repetitive mapping surveys, additional sidescan sonar data should be collected concurrently using a system which complements the capabilities of the ORE system (i.e. higher resolution at the expense of range).

(iv) The relative benefits of full data coverage (100% of seabed) versus large area coverage should be considered. The '4000 Series' survey lines cover a relatively large area, but the probability of cataloguing the same scour as two or more separate features (rather than segments of the same scour) is high because of the large gaps between lines. As a result, a potentially biased statistical summary of a scour population is created. Important pieces of information relating to the length of individual scours and changes in depth, width and orientation along the length of any given scour are missing. Surveying infill lines between the '4000 Series' lines during subsequent programs would alleviate this shortcoming and ultimately lead to a better understanding of the scouring process on this part of northeastern Grand Bank. The use of a fully instrumented sidescan sonar towfish and creation of a fully georeferenced mosaic would assist in quantitative repetitive analysis of the seabed when complete coverage is available.

(v) In light of the significant discrepancies in measured scour metrics derived from the 1979 and 1990 ORE sidescan sonographs, it is recommended that a fully instrumented sidescan sonar towfish, including highly accurate towfish navigation and positioning, be used during any subsequent surveys where reasonably accurate and reliable estimates of planar scour metrics (length, orientation, width) are required. This is critically important in order to accurately calculate the range and azimuth scales of the sonograph records.

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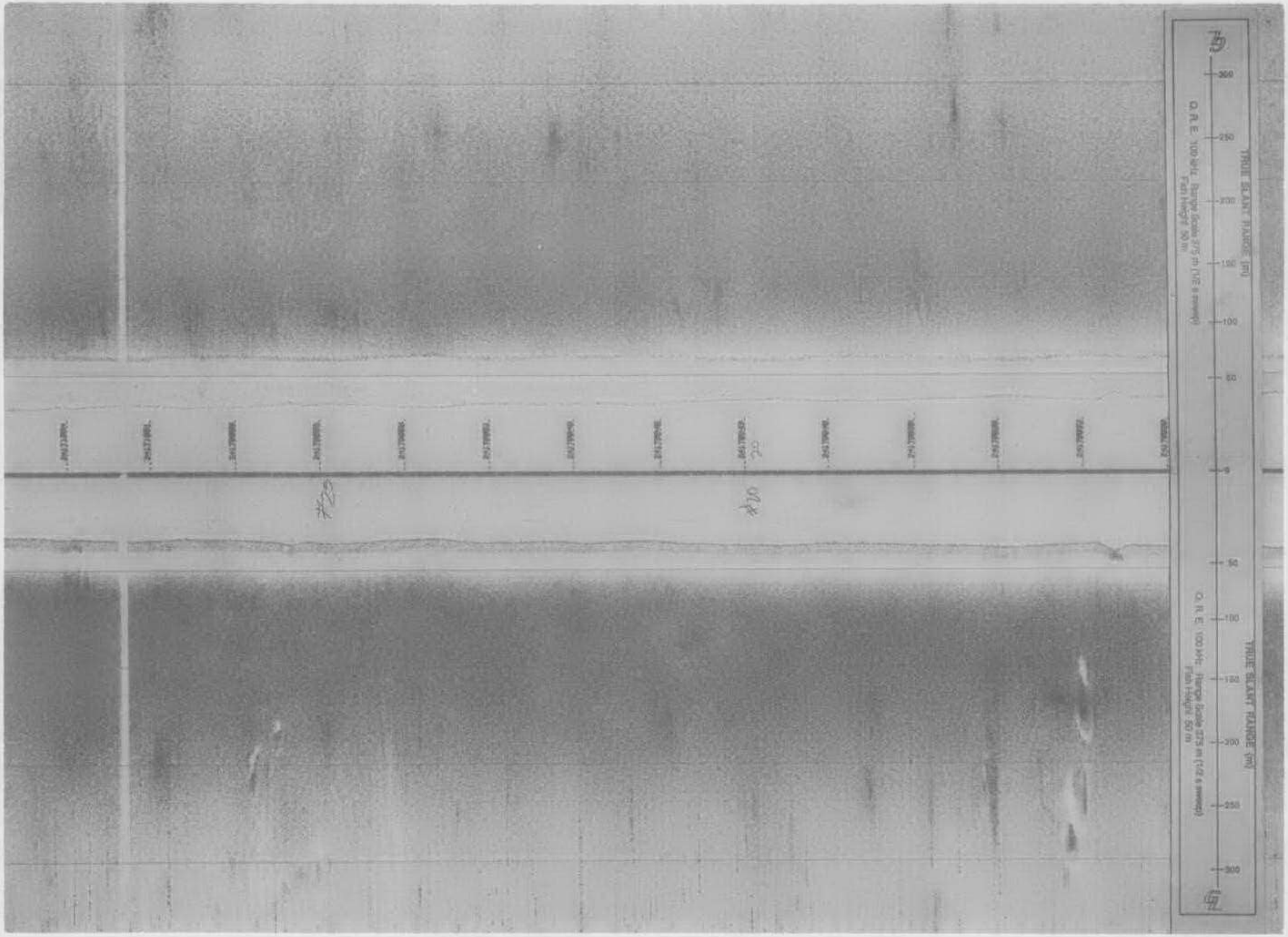
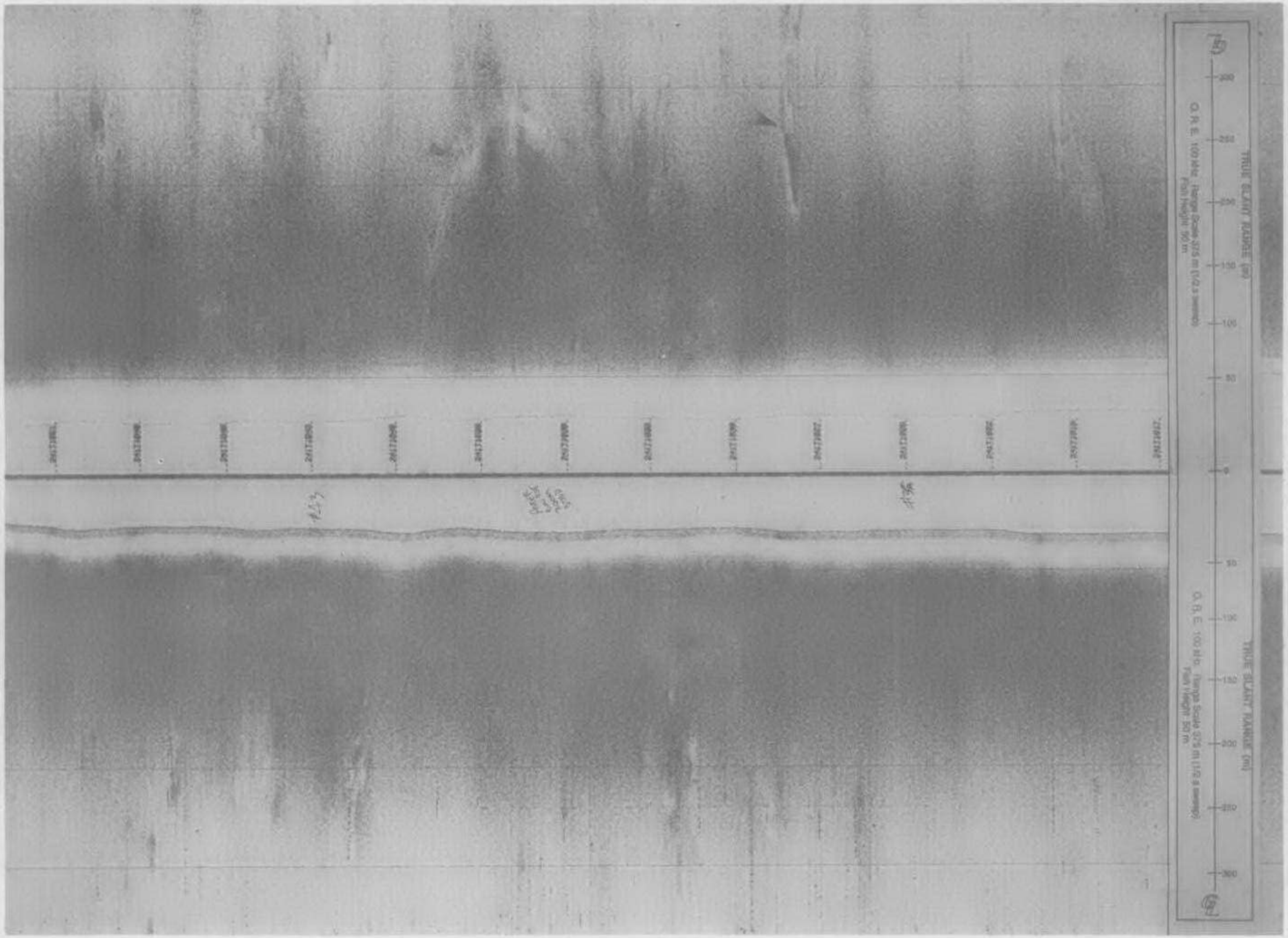
APPENDIX A

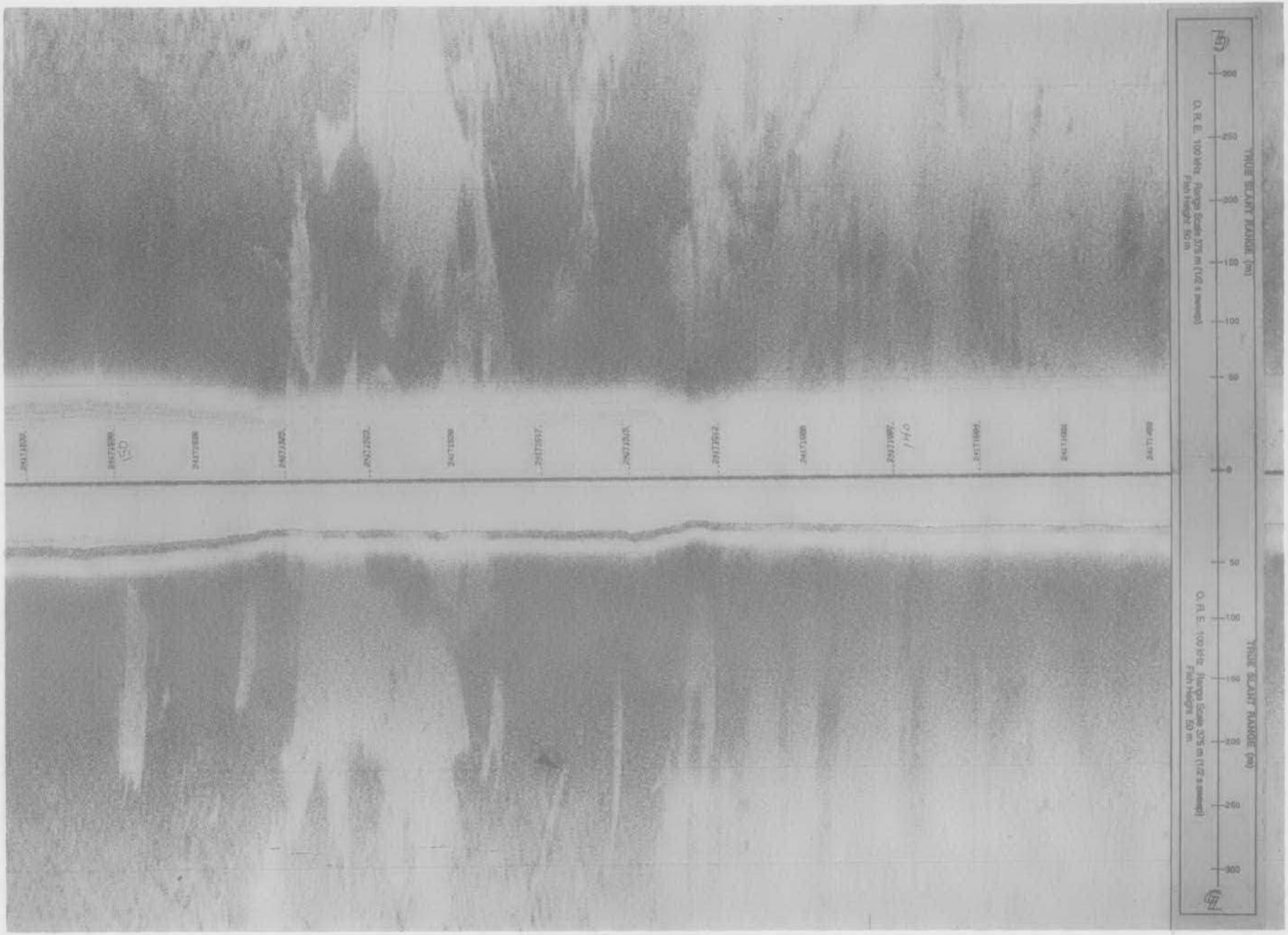
Representative Sonographs



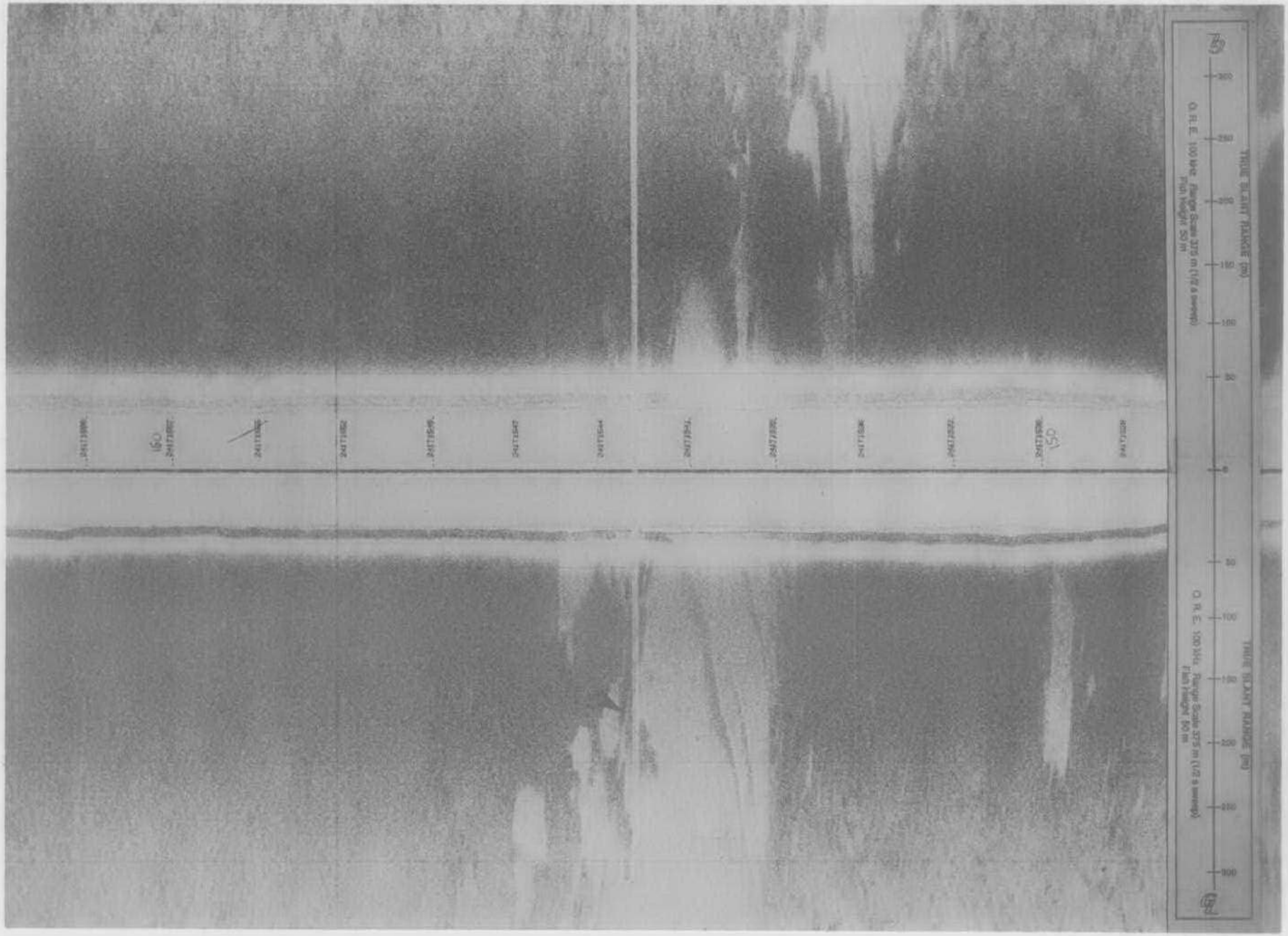
Line 4002R - Scour 061B (Geomarine Feature #4) water depth 130 - 140 m. Possible new scour N060O (arrow right).



Line 4002R - Scour 063O, 064B (Geomarine Feature #5, 5B) water depth 120 - 130 m.

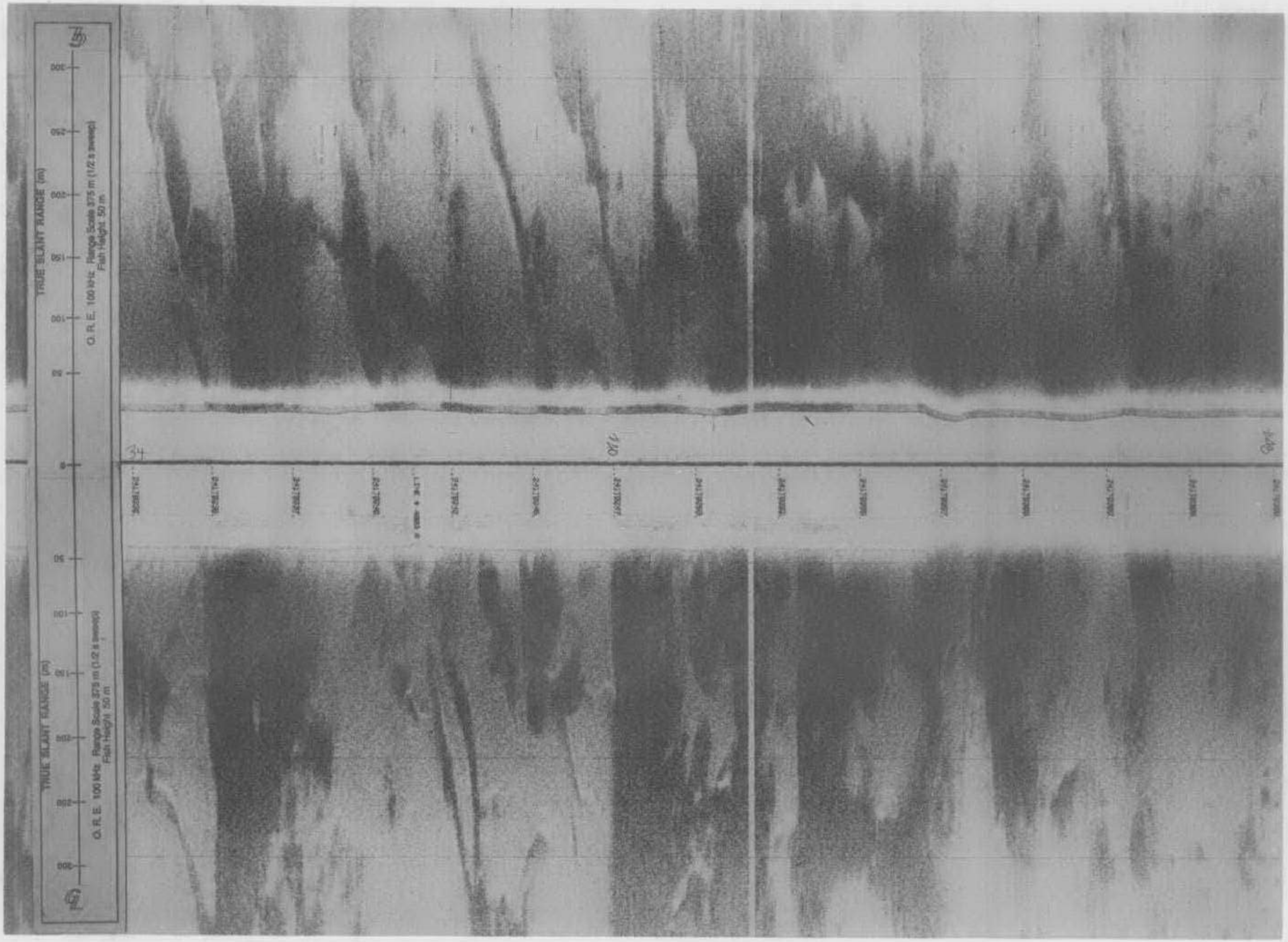


Line 4002R - Scour 111B (Geomarine Feature #6) water depth 90 - 100 m.

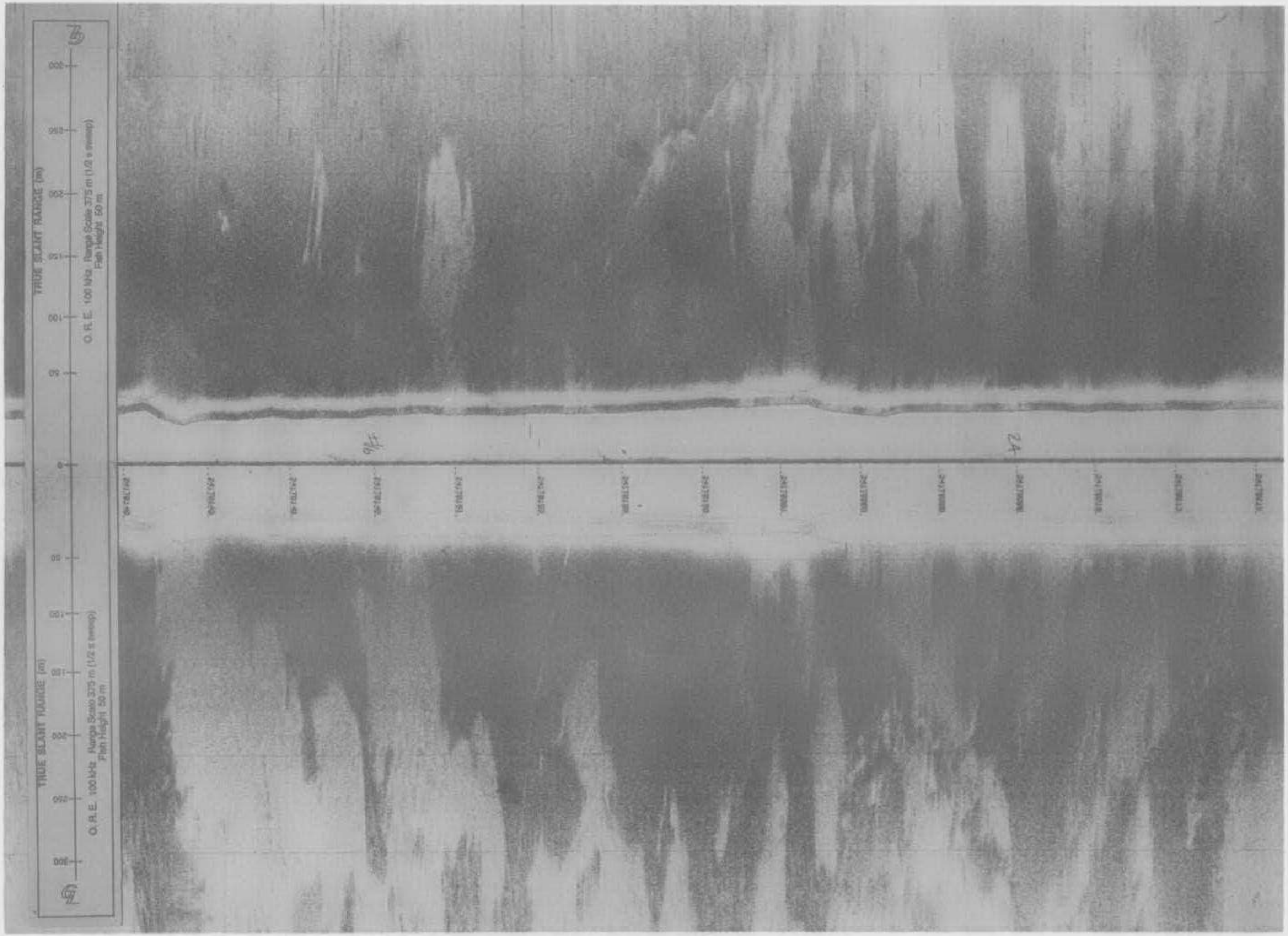


Line 4002R - Scour 112B (Geomarine Feature #6A) water depth 80 - 90 m.

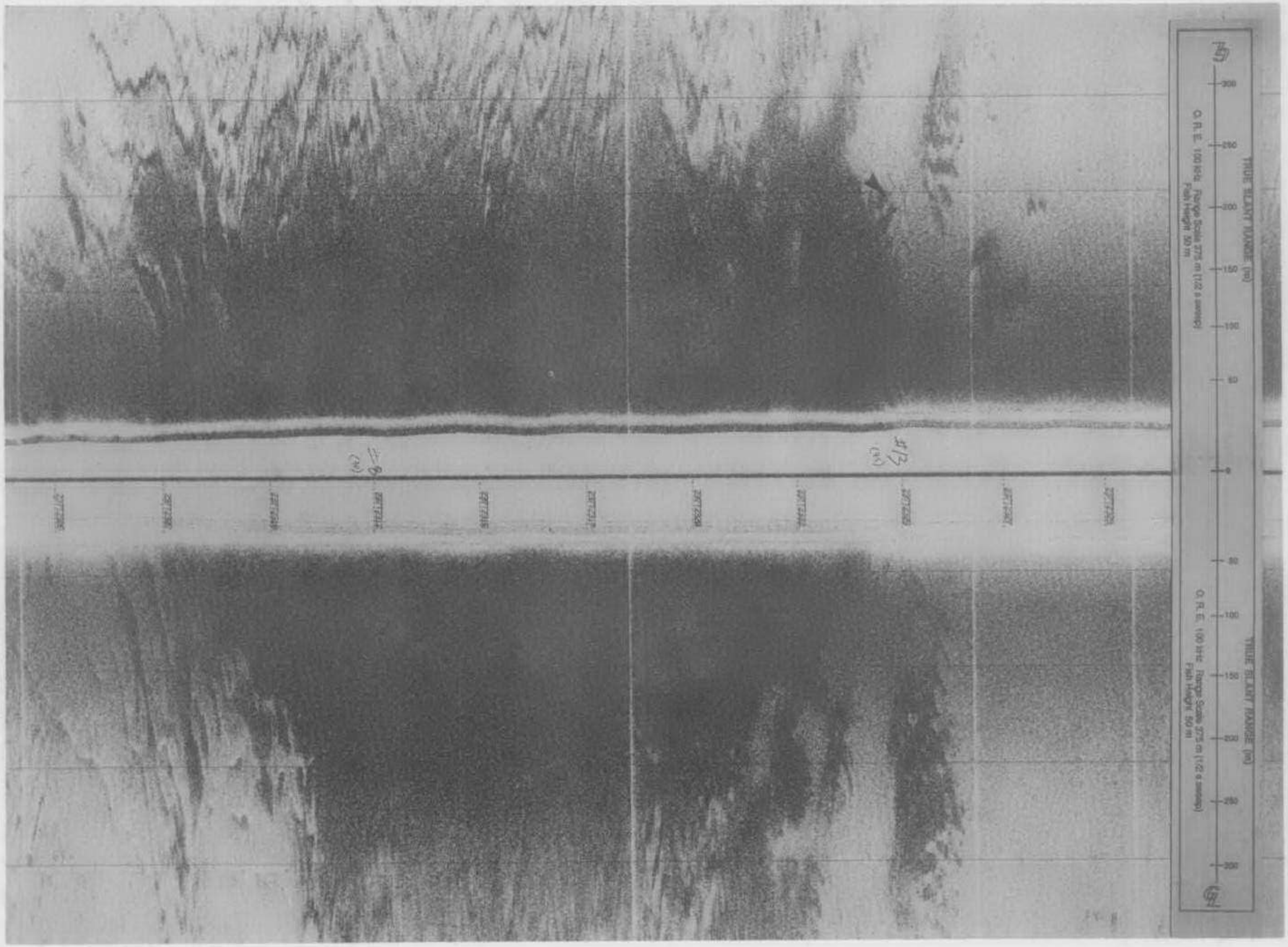
Line 4003R - Scour 126B (Geomarine Feature #7) water depth 120 - 130 m.



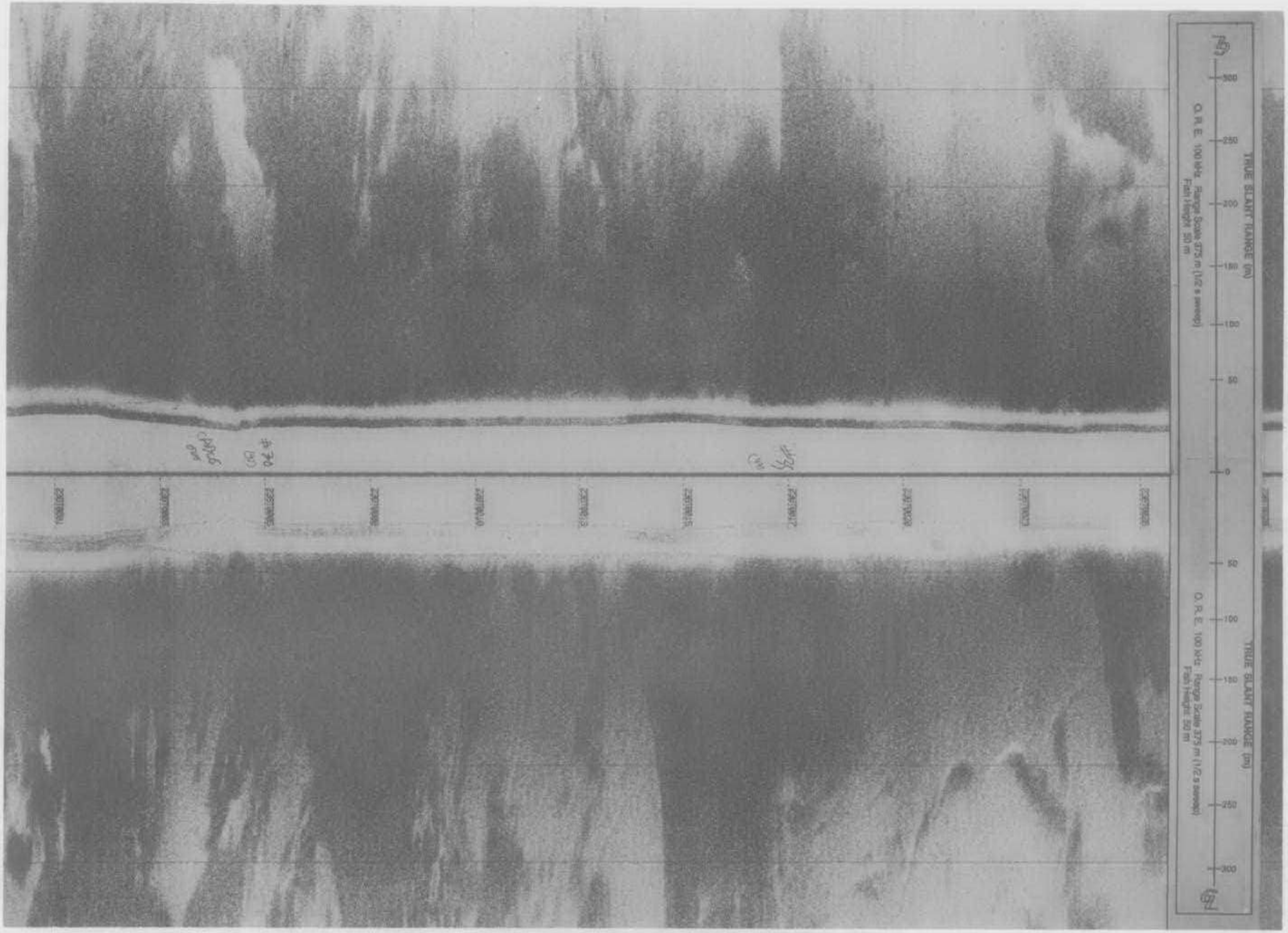
Line 4003R - Scour 121B (Geomarine Feature #9) water depth 100 - 110 m.



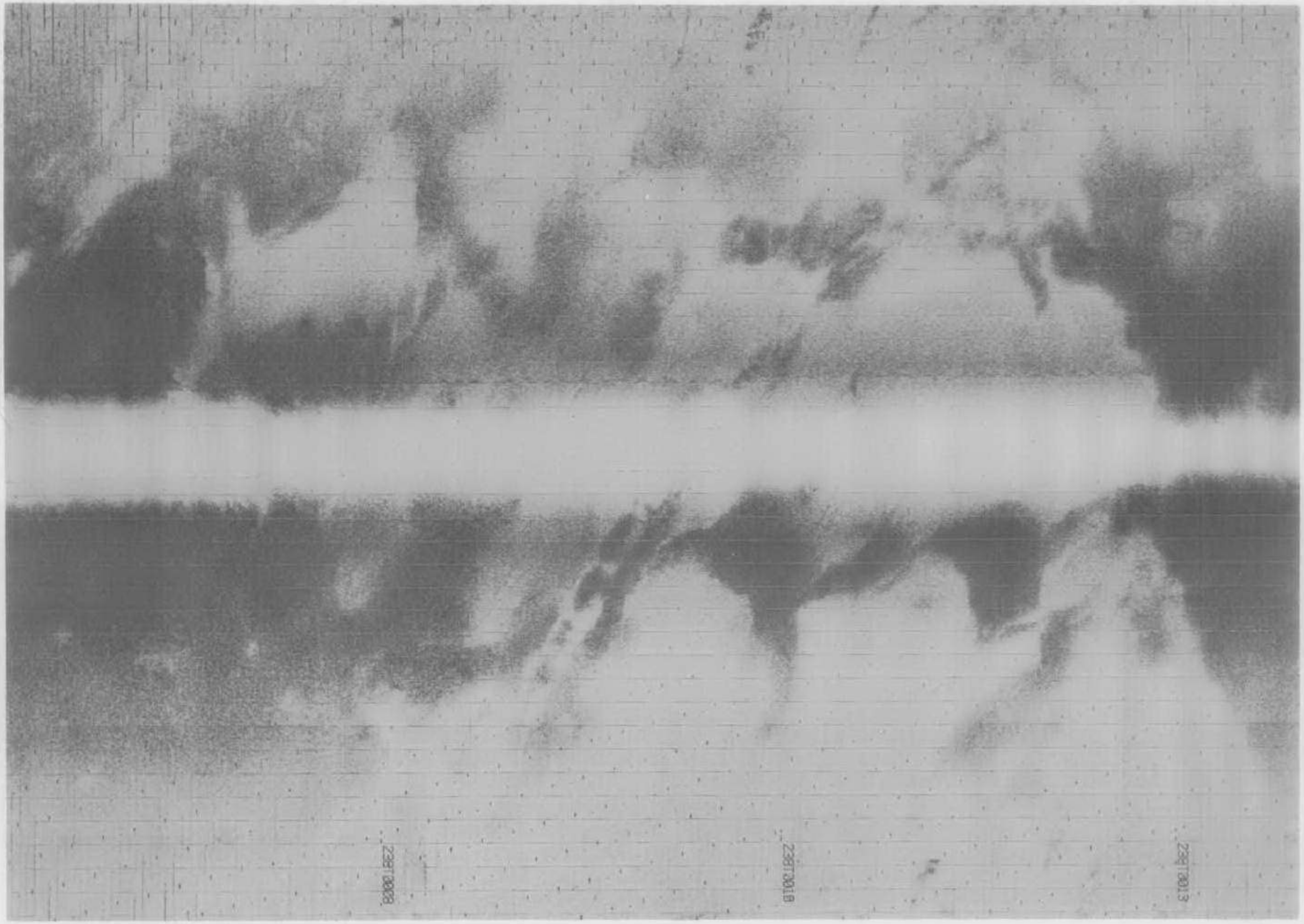
Line 4003R - Scour 118B (Geomarine Feature #10) water depth 90 - 100 m.



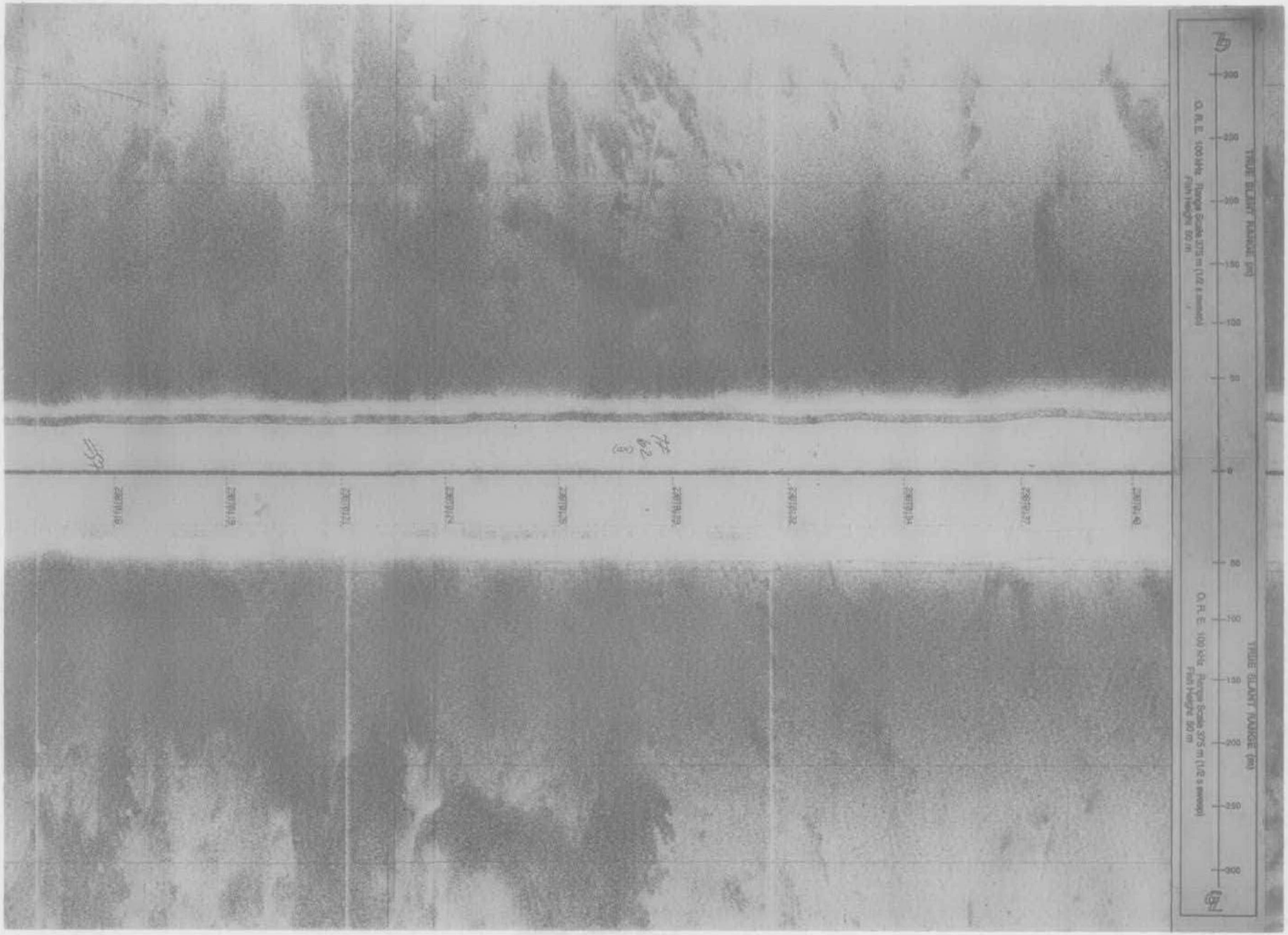
Line 4004R - Not Catalogued (Geomarine Feature #11) water depth 80 - 90 m.



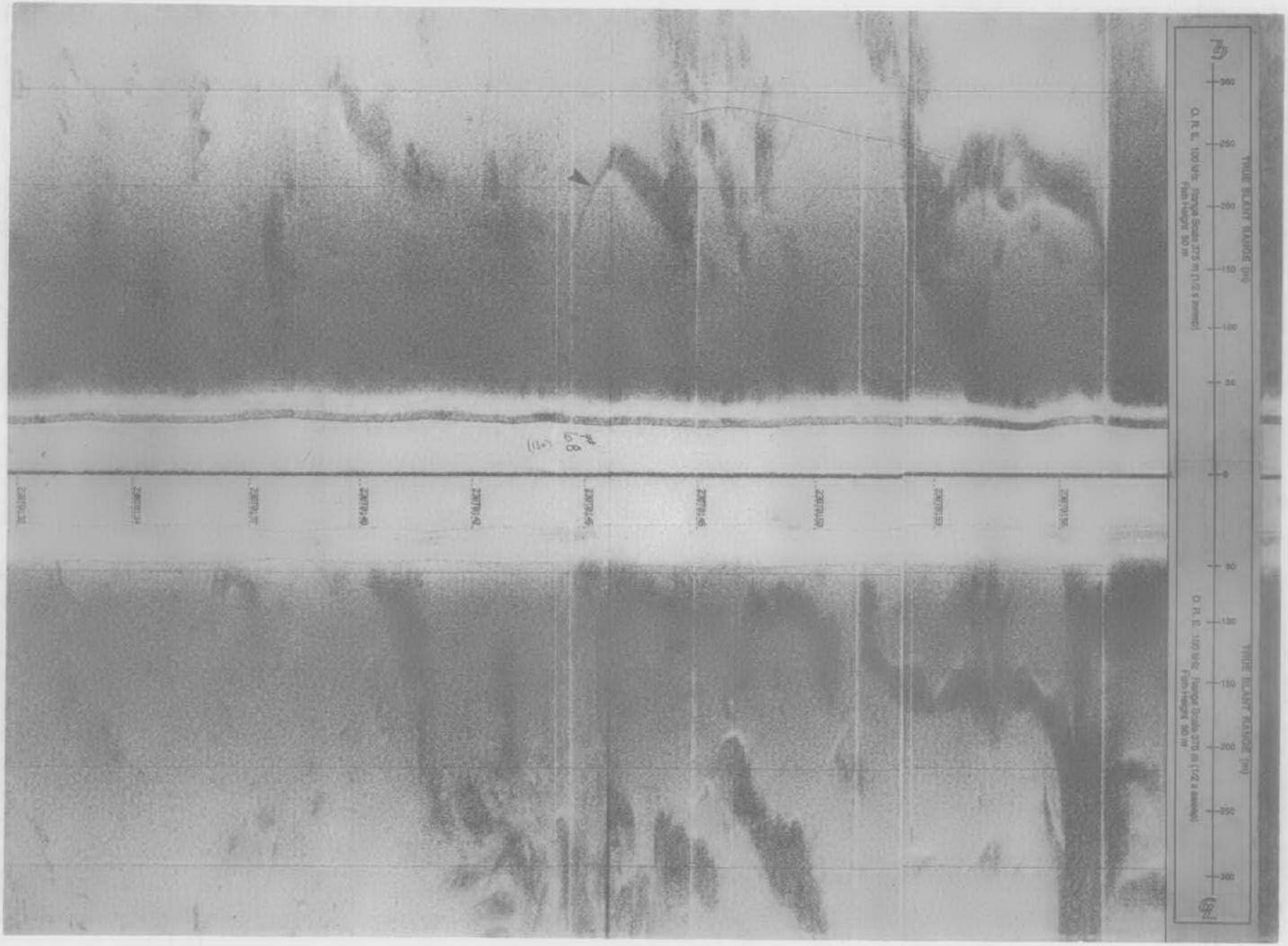
Line 4004R - Scour 037B (Geomarine Feature #12) water depth 90 - 100 m.



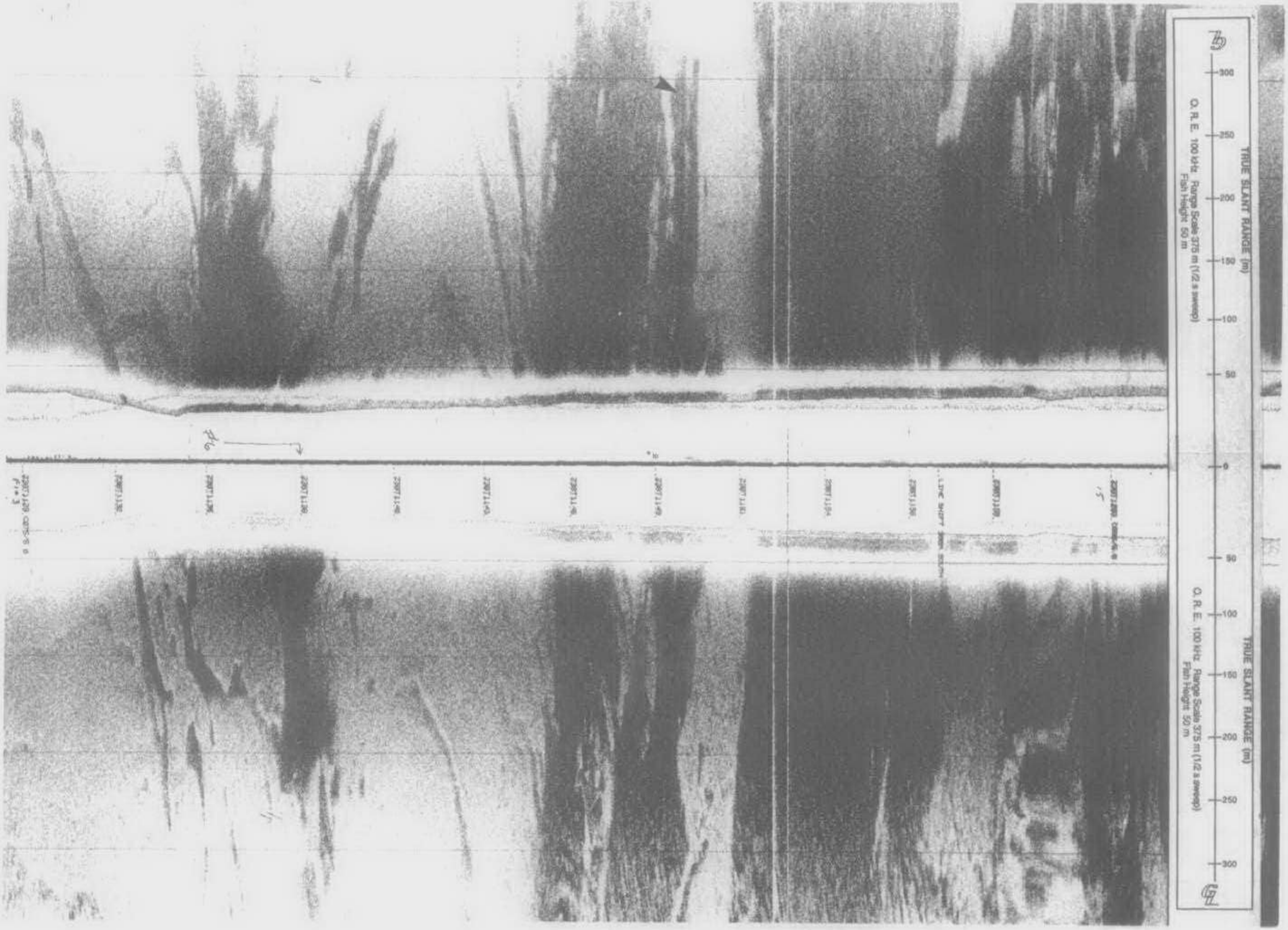
Line 4004R - Scour 037B showing ribbed character. Klein 50 kHz sonograph, range = 300 m.
Compare with previous ORE sonograph and Geomarine (1980) report.



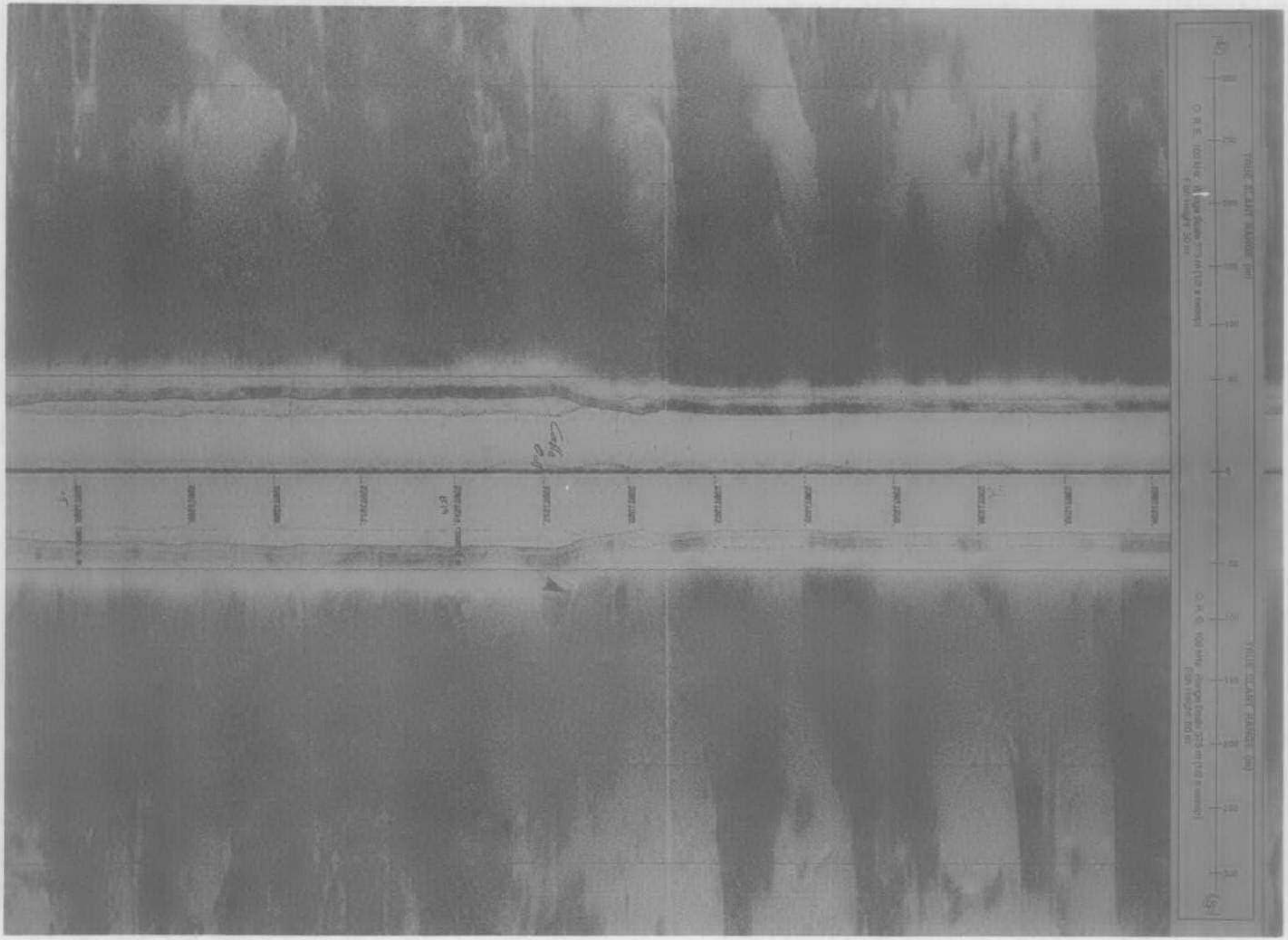
Line 4004R - Scour 040B (Geomarine Feature #13) water depth 100 - 110 m.



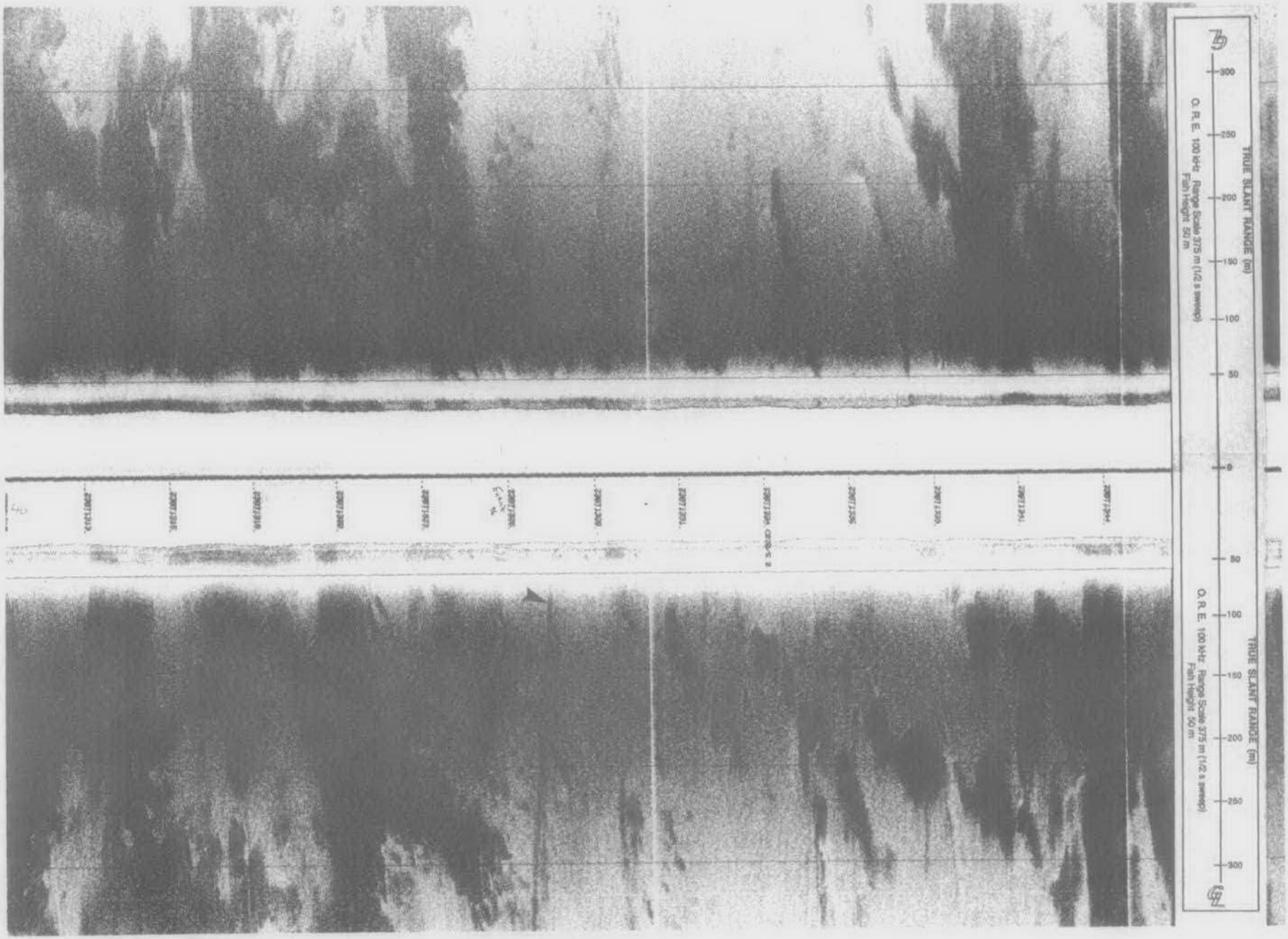
Line 4004R - Sand Wave (Geomarine Feature #14) water depth 100 - 110 m.



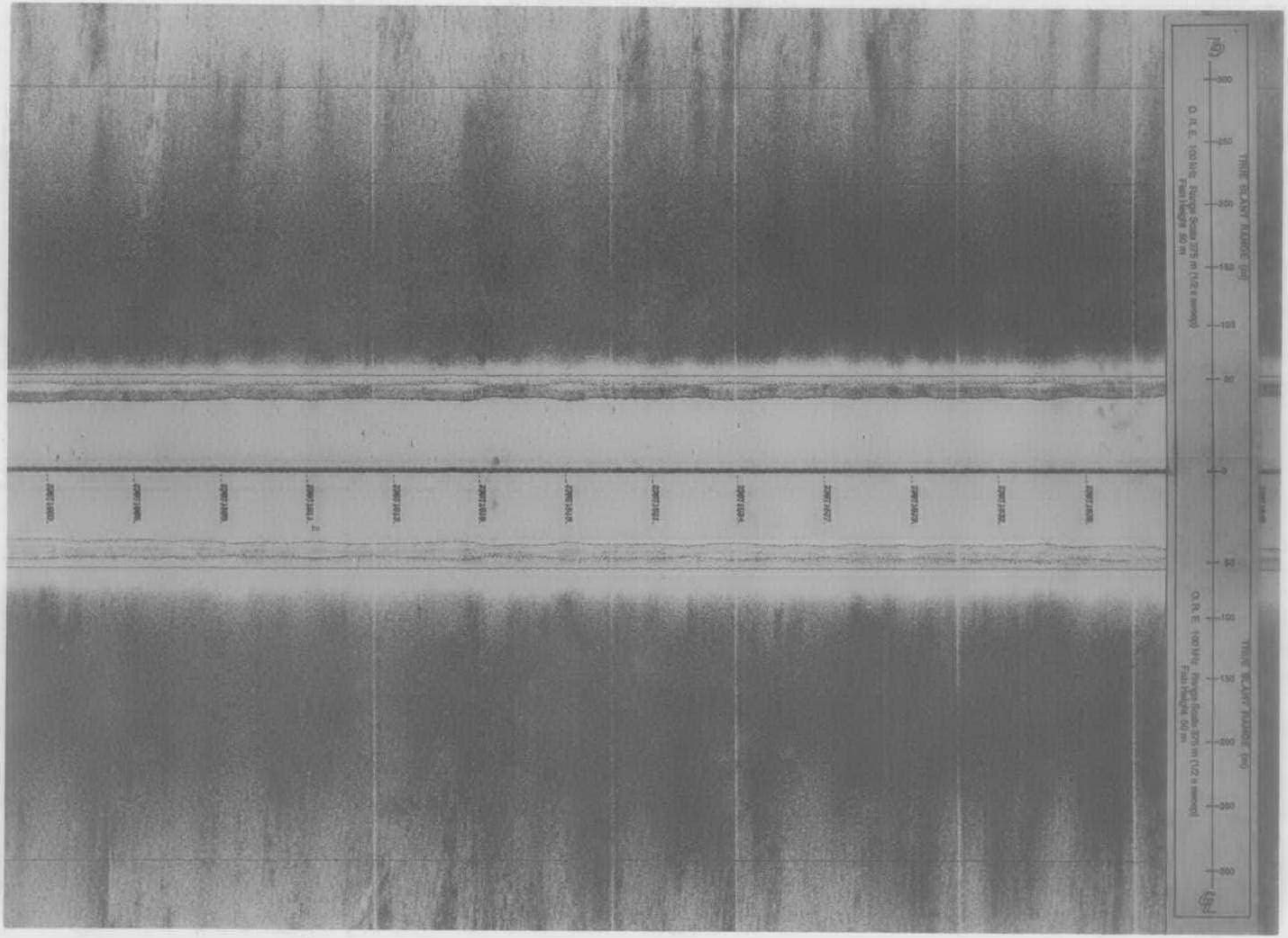
Line 4005R - Scour 130B (Geomarine Feature #16) water depth 80 - 90 m.



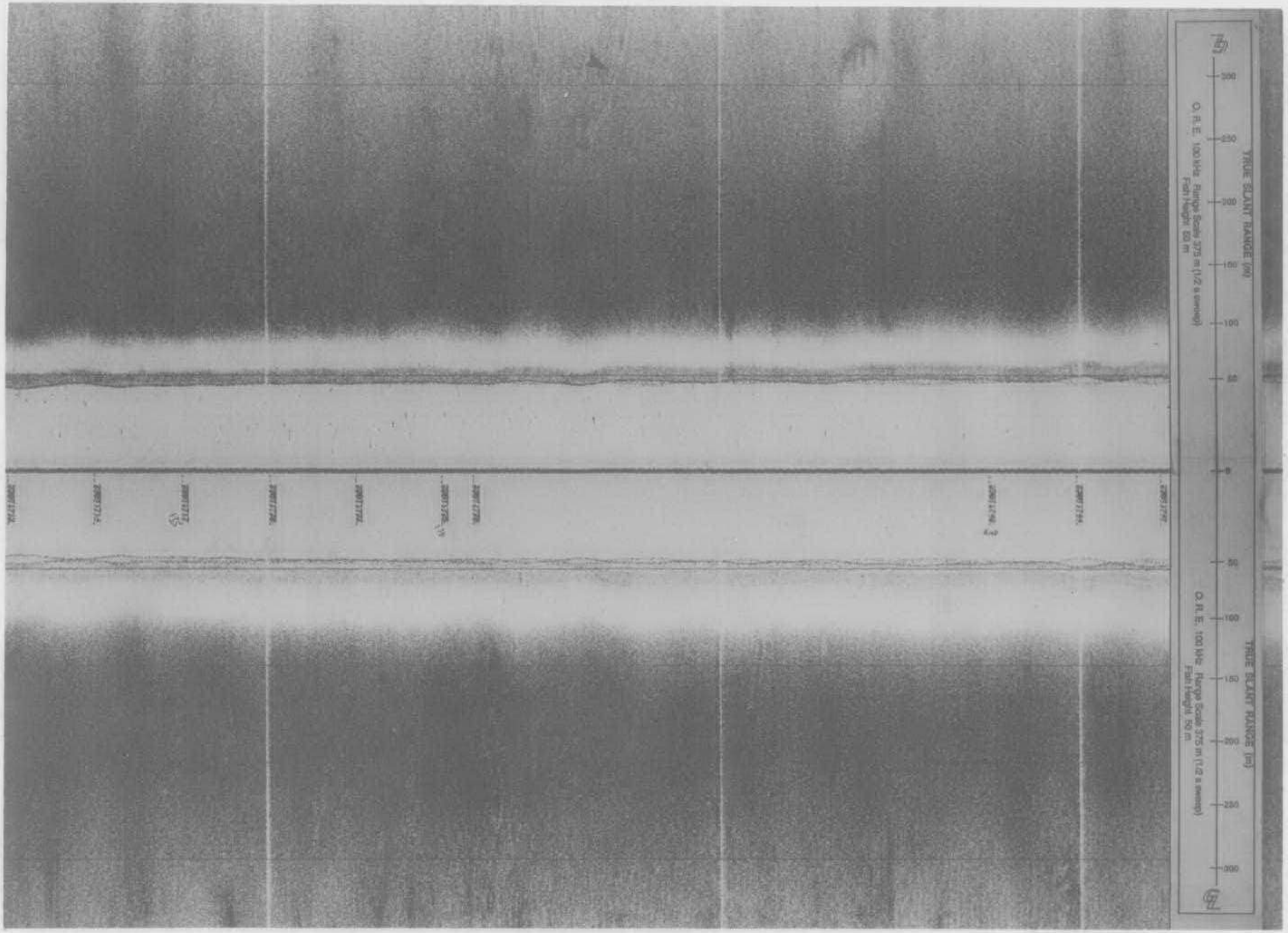
Line 4005R - Scour 132B (Geomarine Feature #17) water depth 90 - 100 m.



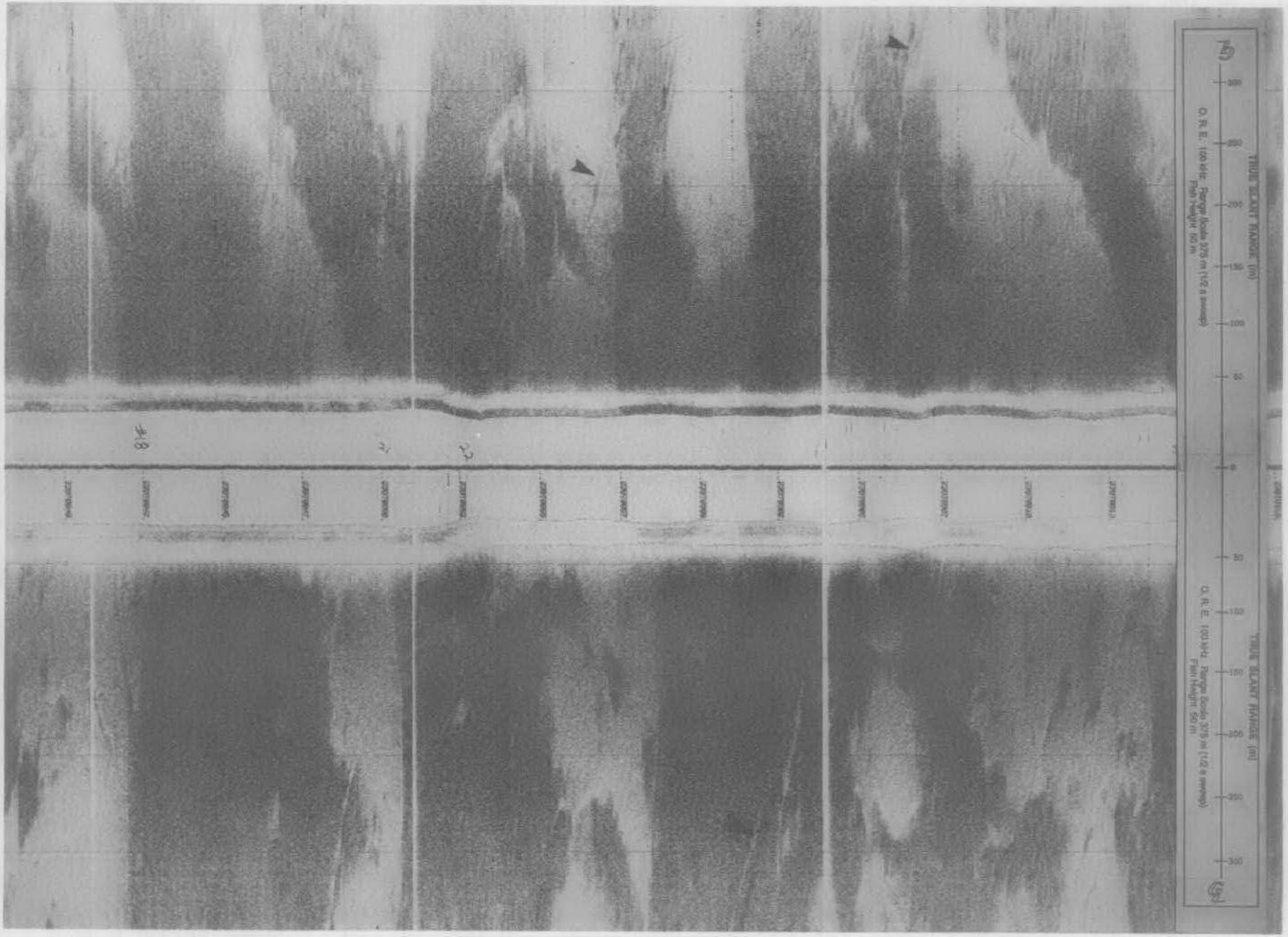
Line 4005R - Scour 137B (Geomarine Feature #18) water depth 100 - 110 m.



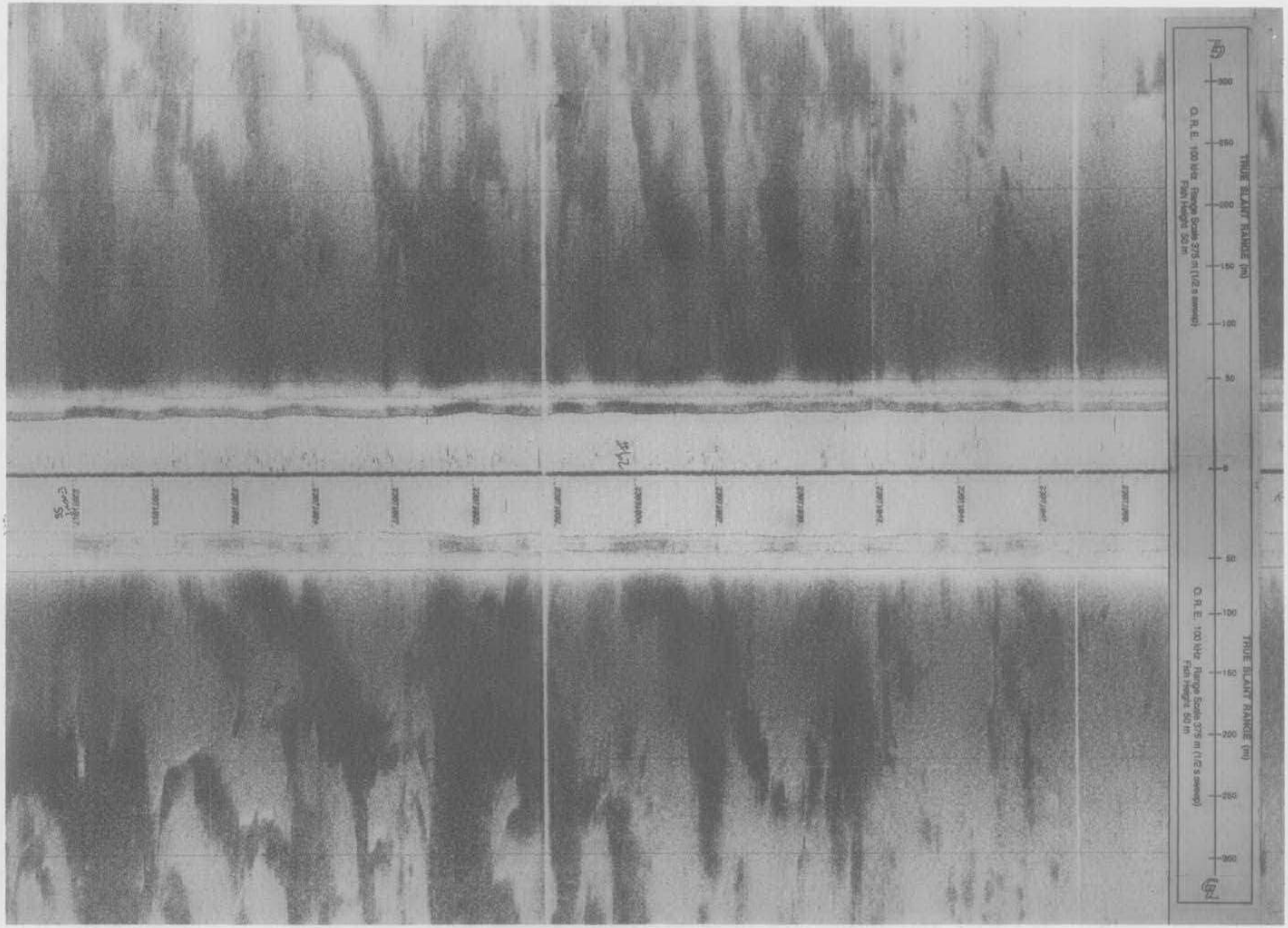
Line 4005R - Scour 148B (Geomarine Feature #19) water depth 120 - 130 m.



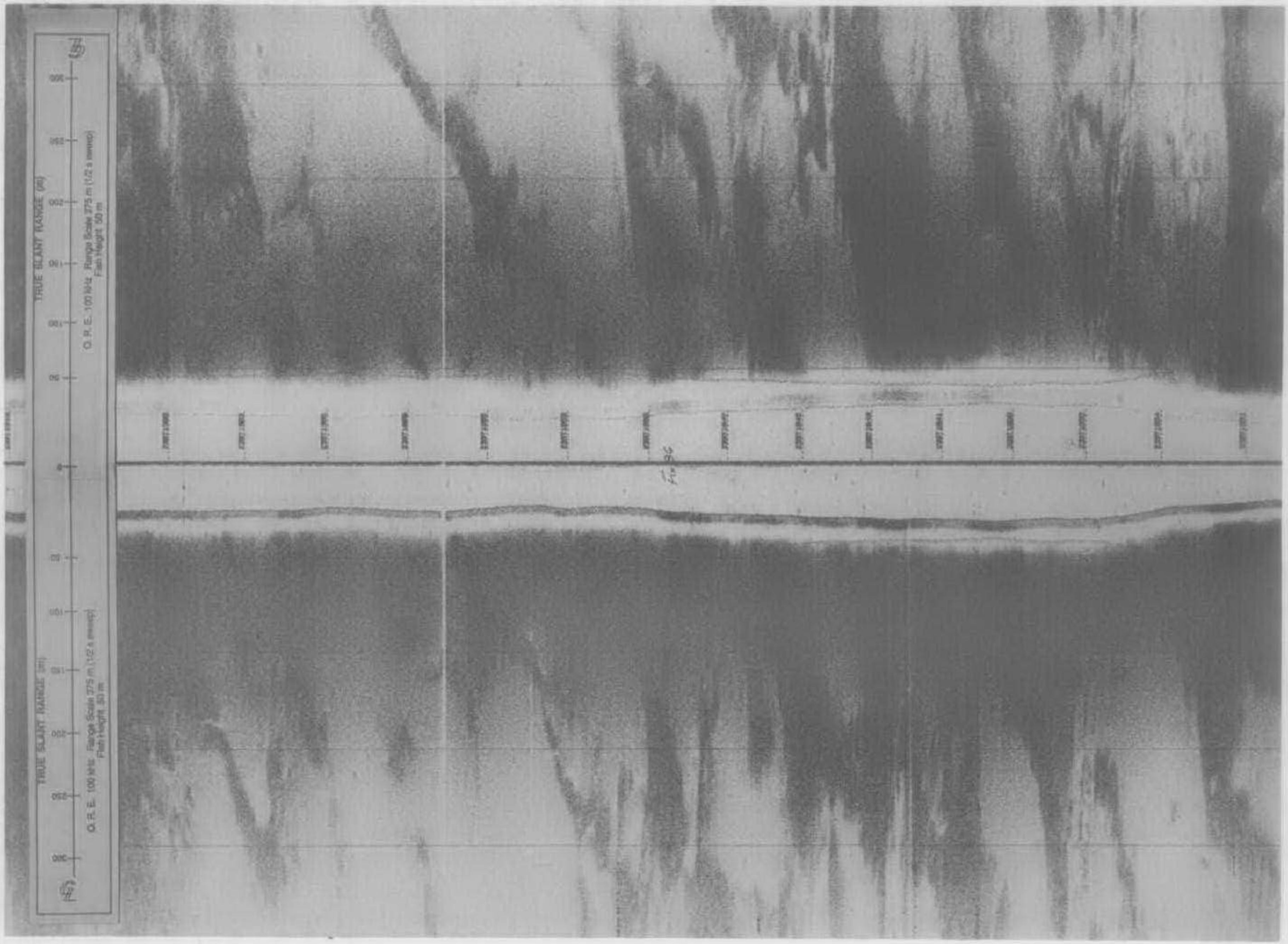
Line 4005R - Scour 160B (Geomarine Feature #20) water depth 130 - 140 m.



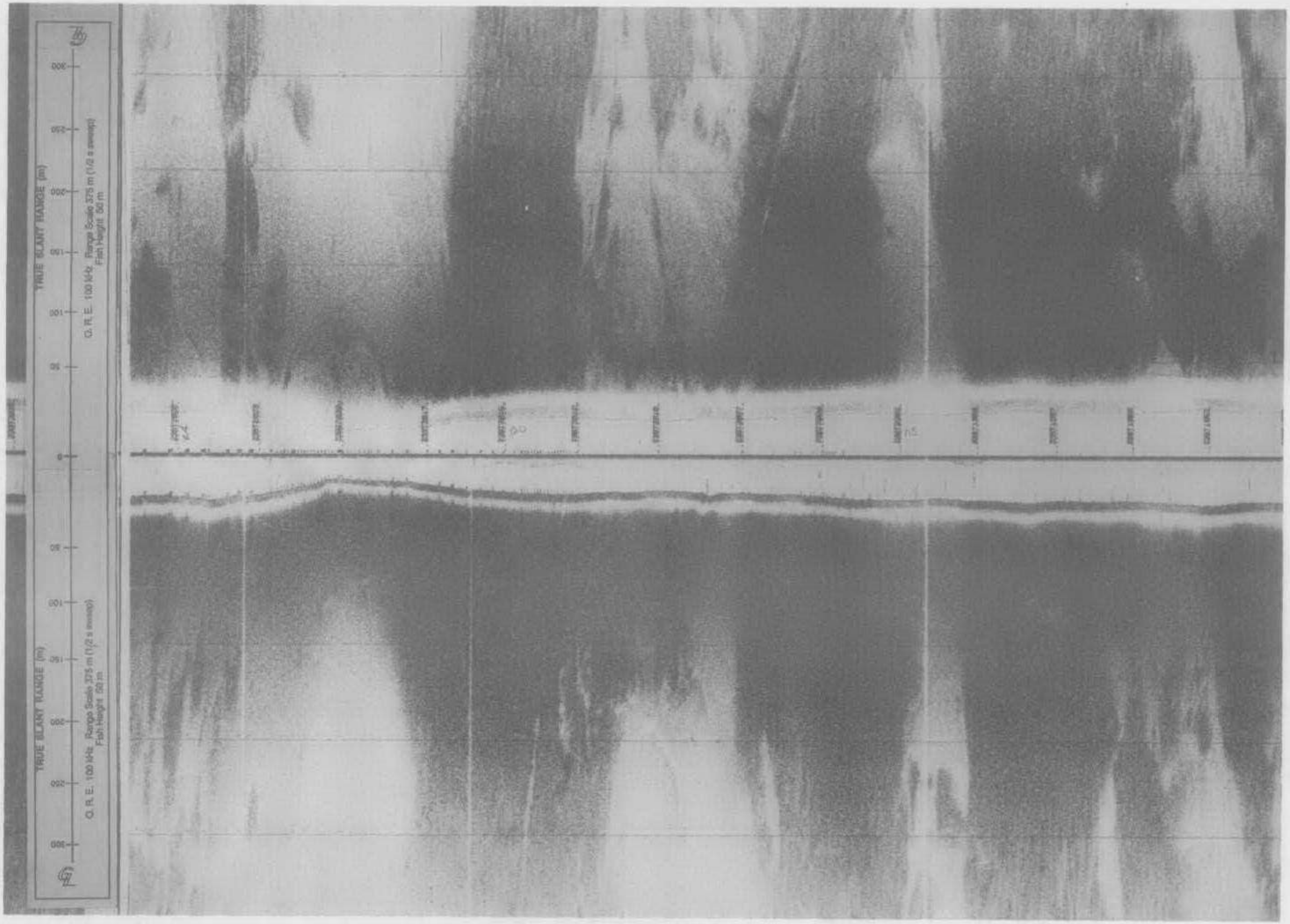
Line 4006R - Scour 226B, 227B (Geomarine Feature #21, 21A) water depth 90 - 100 m.



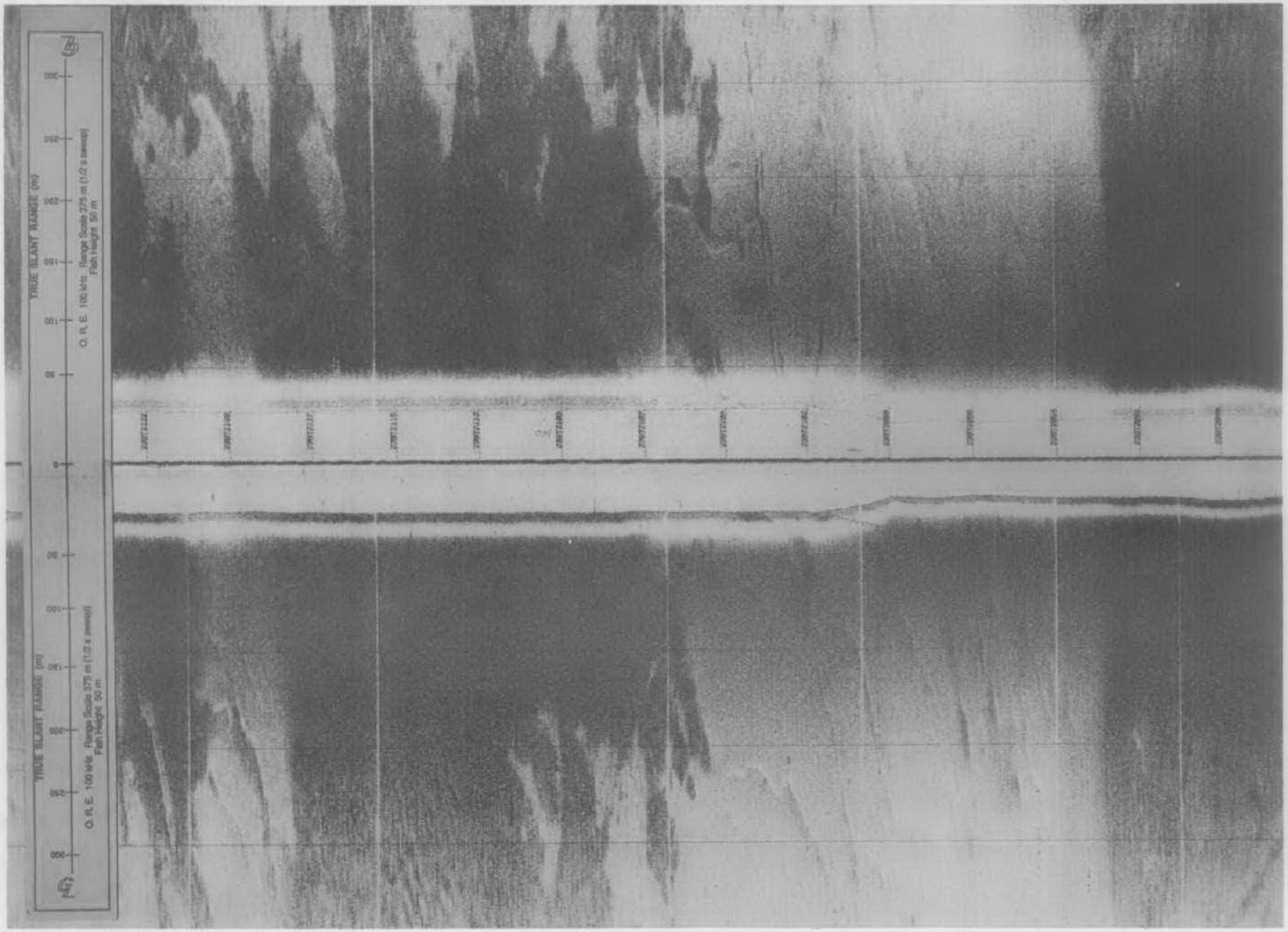
Line 4006R - Scour 229B (Geomarine Feature #22) water depth 100 - 110 m.



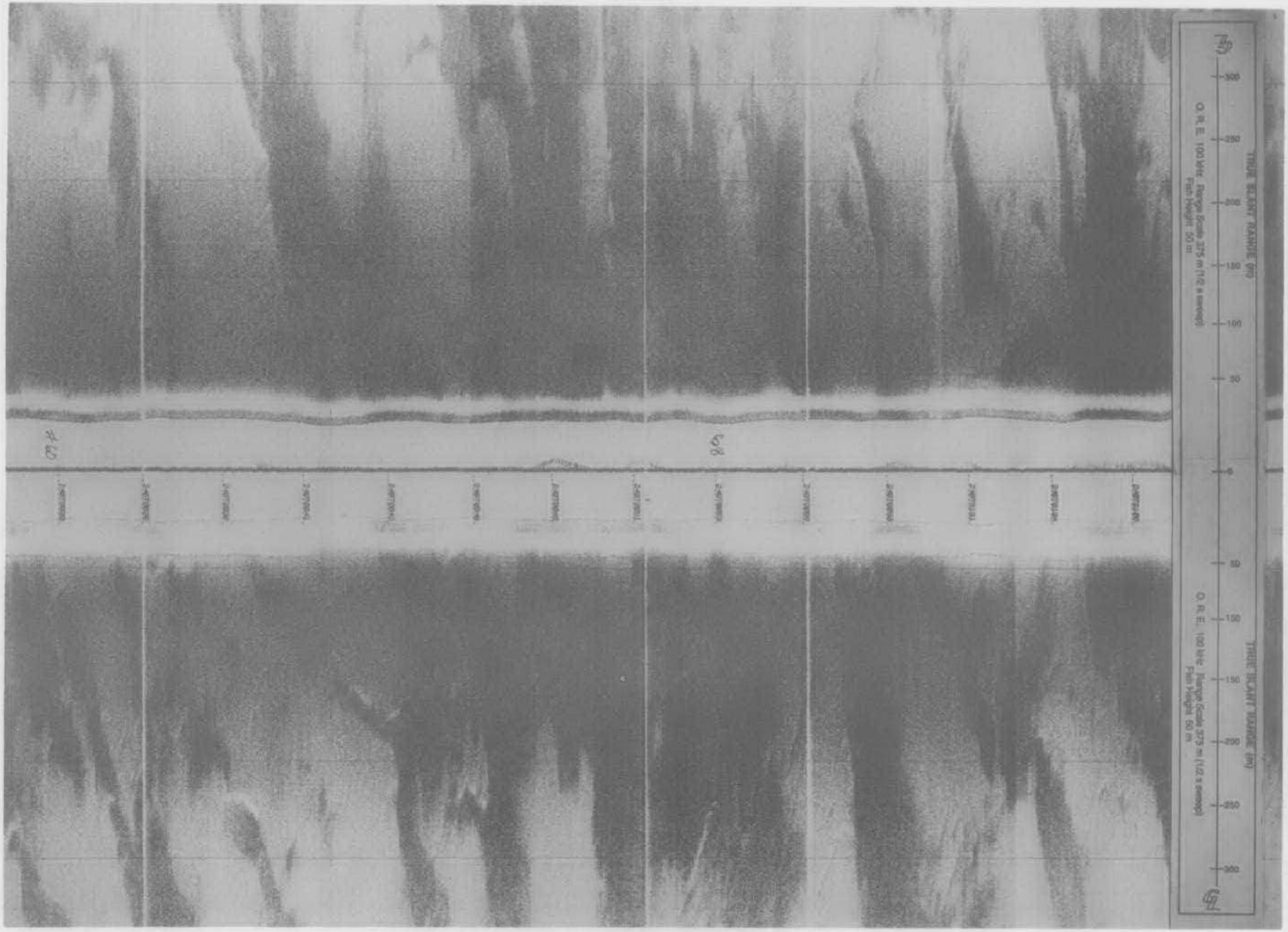
Line 4007R - Scour 187B (Geomarine Feature #24) water depth 100 - 110 m.
Also visible - Scour 185B (arrow right).



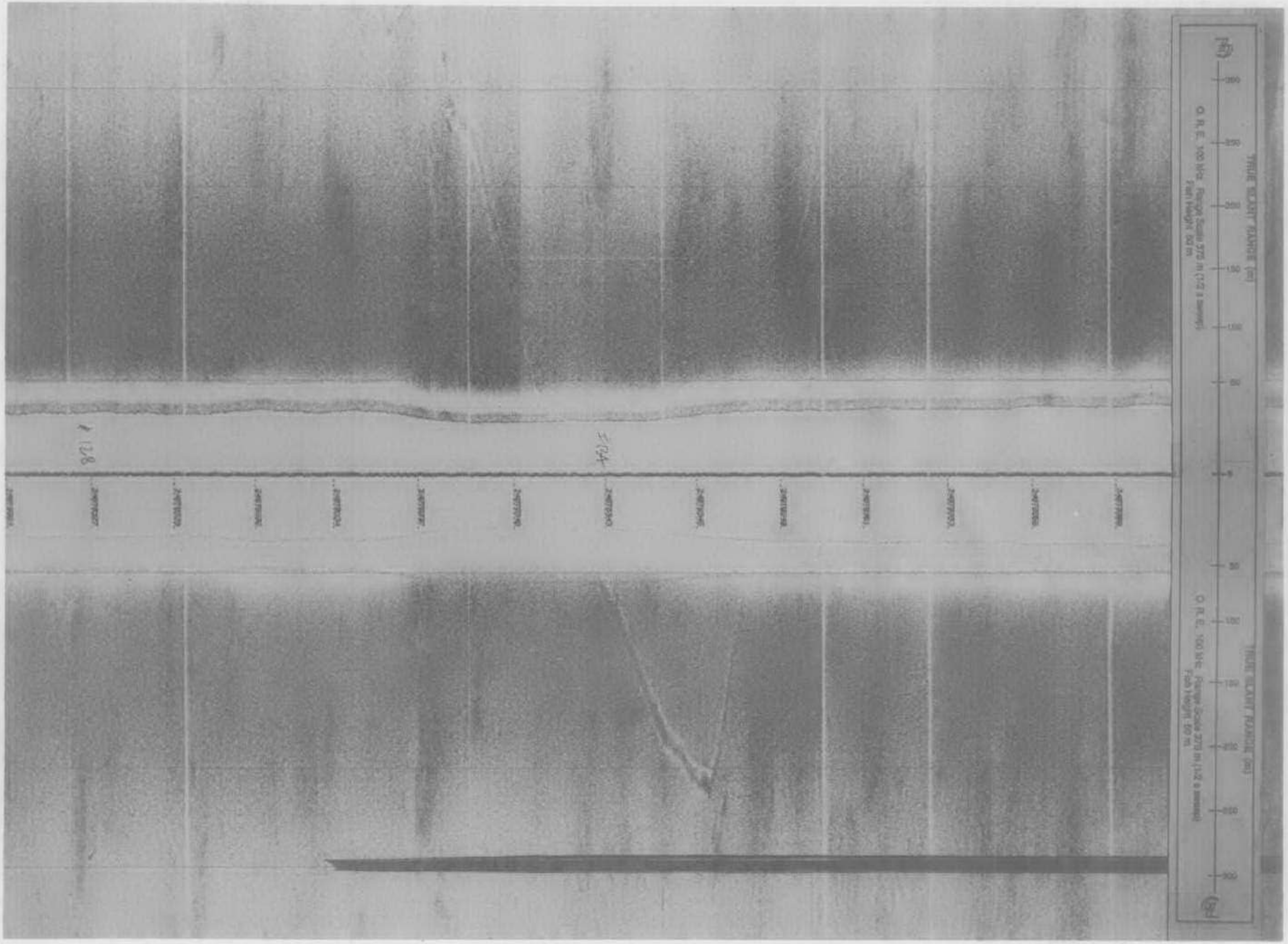
Line 4007R - Scour 192B (Geomarine Feature #24A).



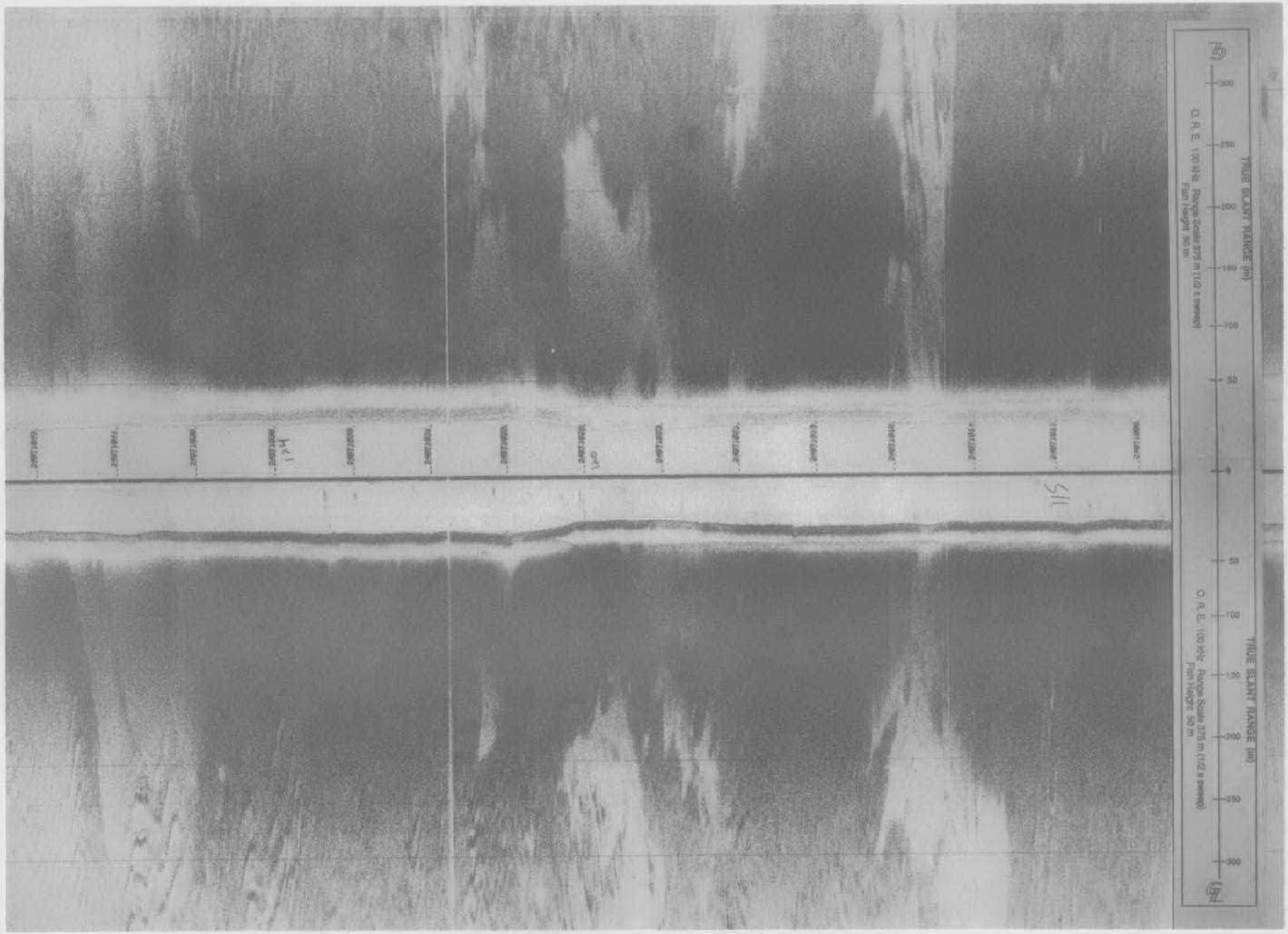
Line 4007R - Scour 197B (Geomarine Feature #24B) water depth 80 - 90 m.



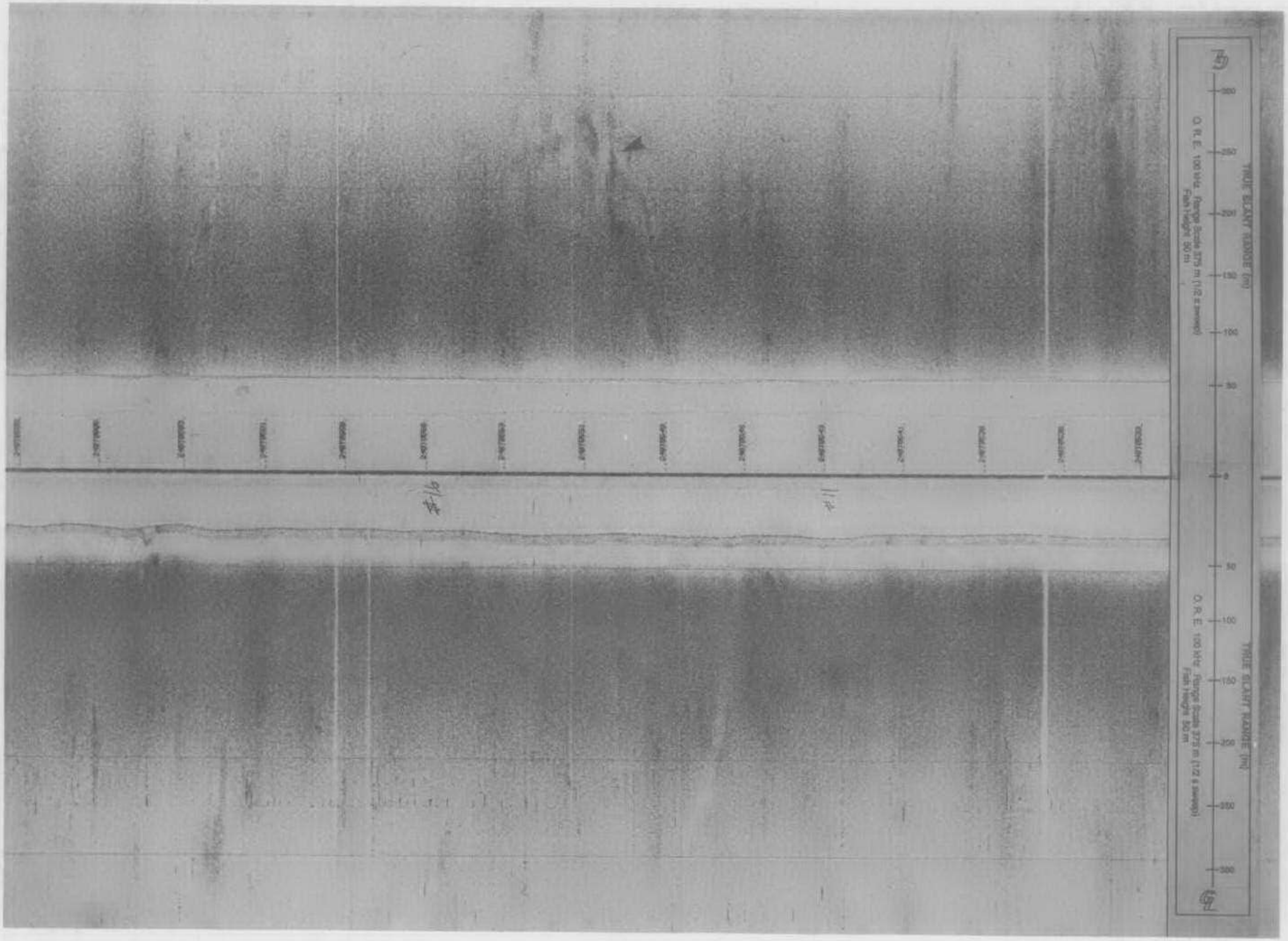
Line 4008R - Scour 210K (Geomarine Feature #25) water depth 100 - 110 m.



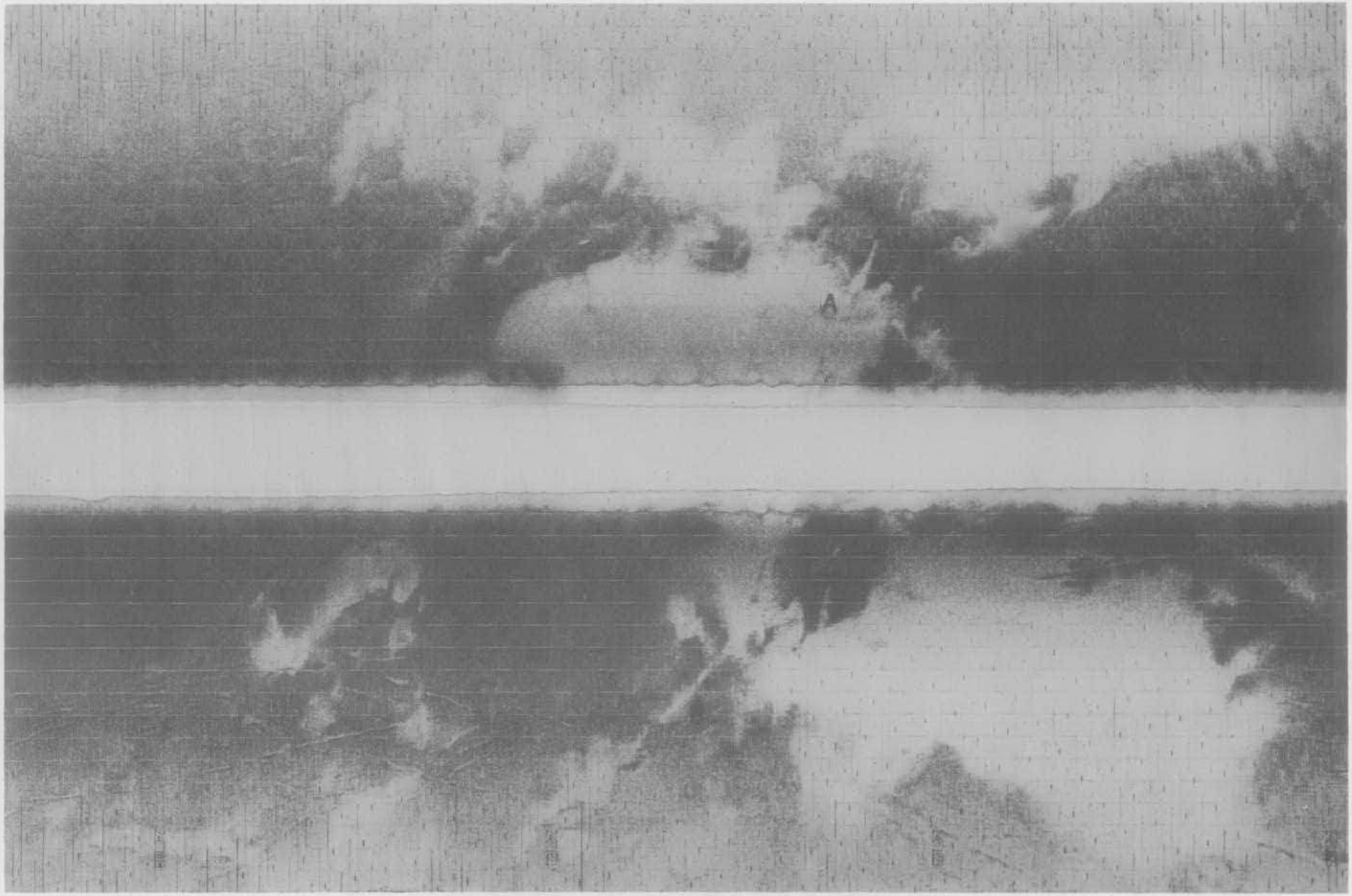
Line 4008R - Scour 222B (Geomarine Feature #26) water depth 120 - 130 m.



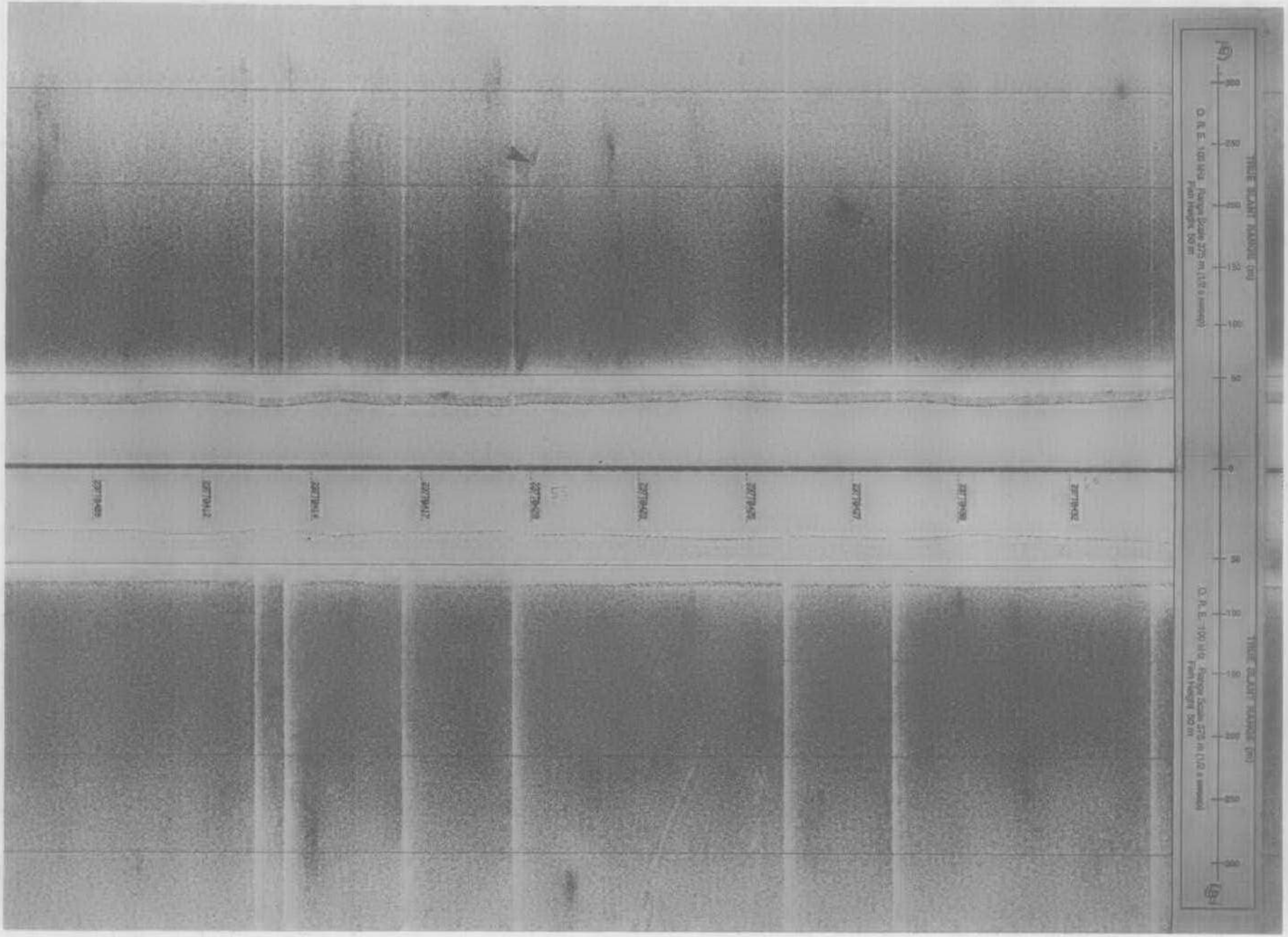
Line 4009R - Scour 095K (Geomarine Feature #28) water depth 90 - 100 m.



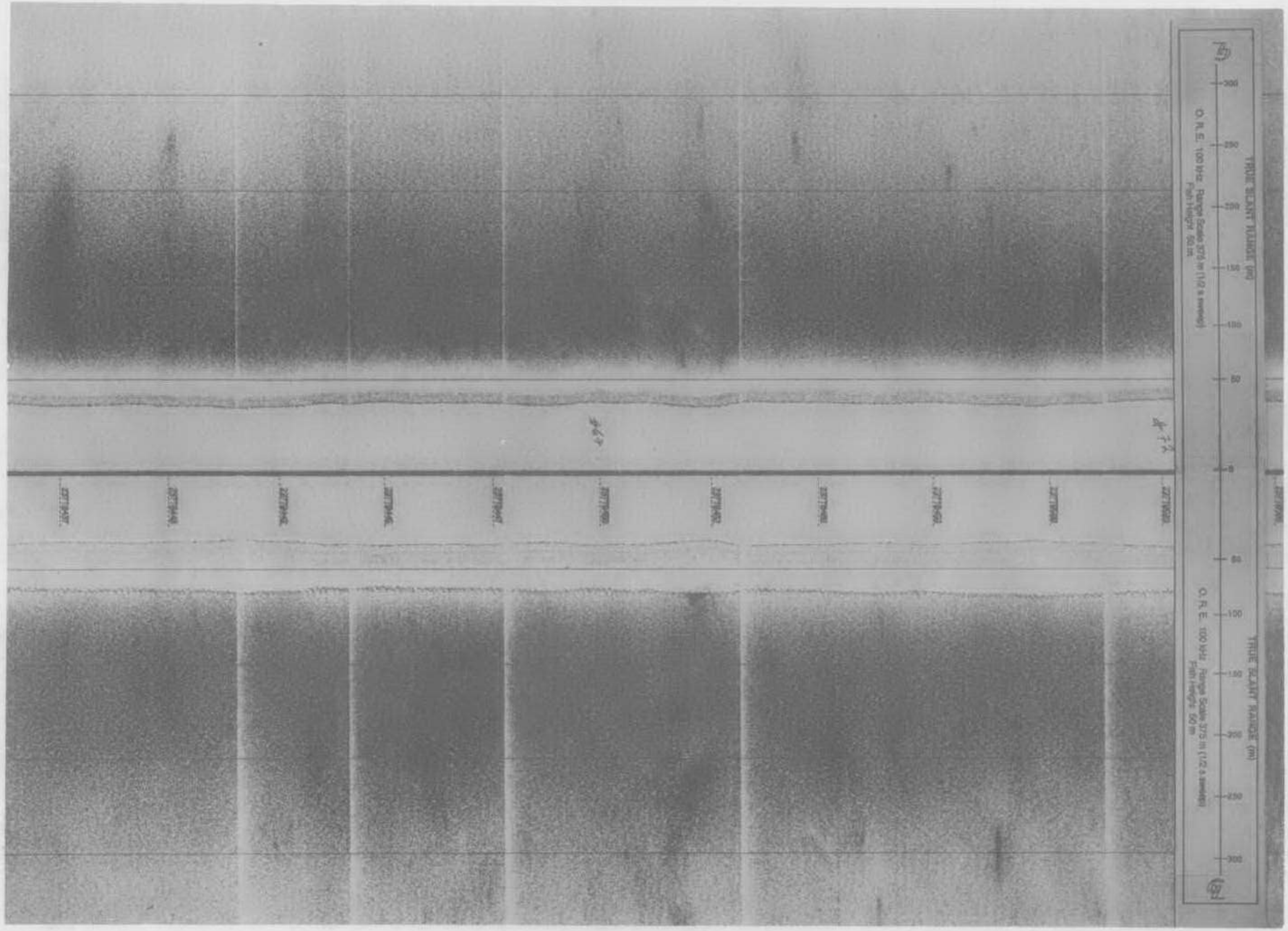
Line 4009R - Scour 069B (Geomarine Feature #27) water depth 110 - 120 m.



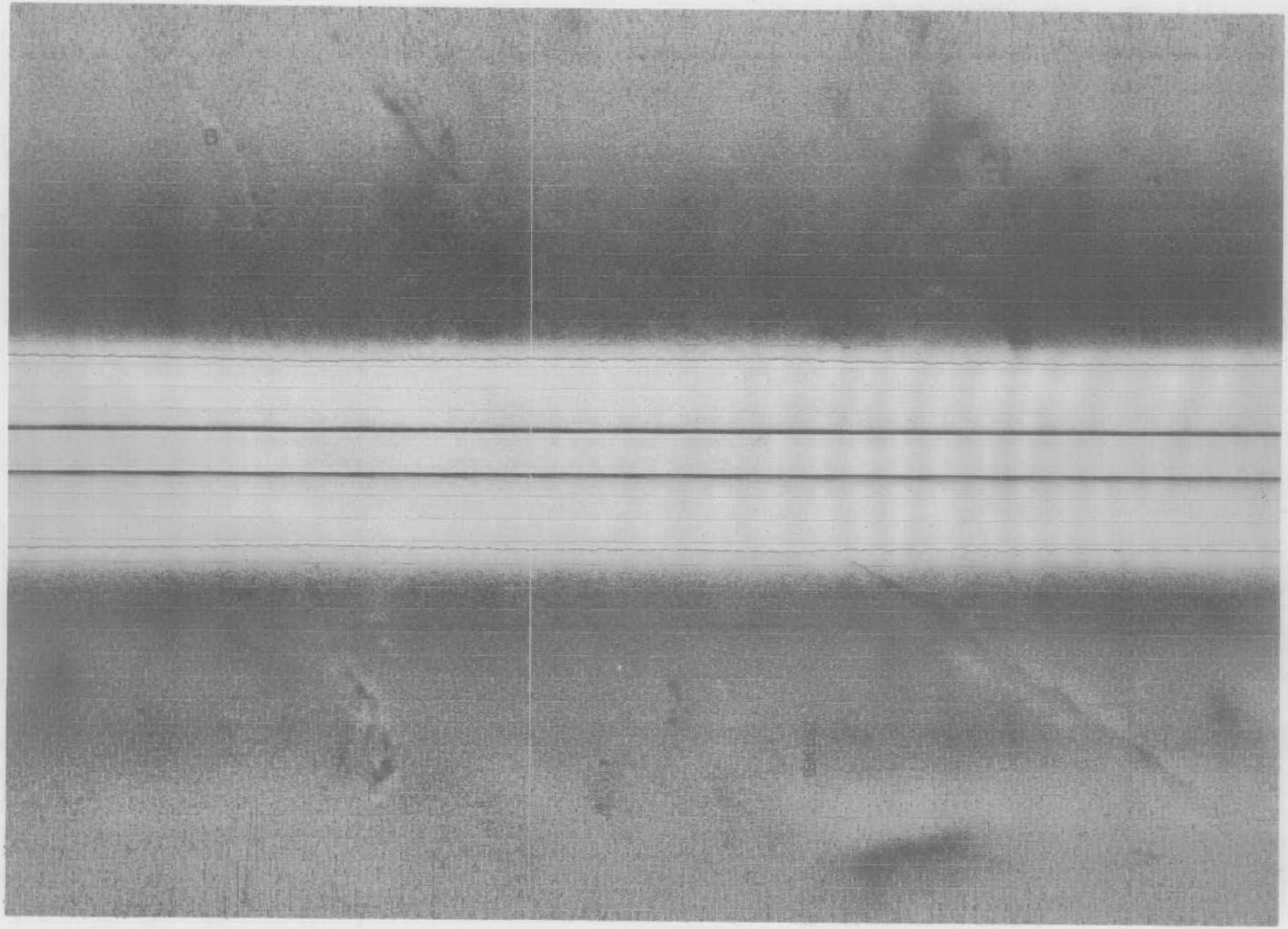
Line 4009R- Scour 095K (A) and 096K (B). Klein 50 kHz sonograph, range = 300 m.
Note trawl marks. Compare with previous ORE sonograph.



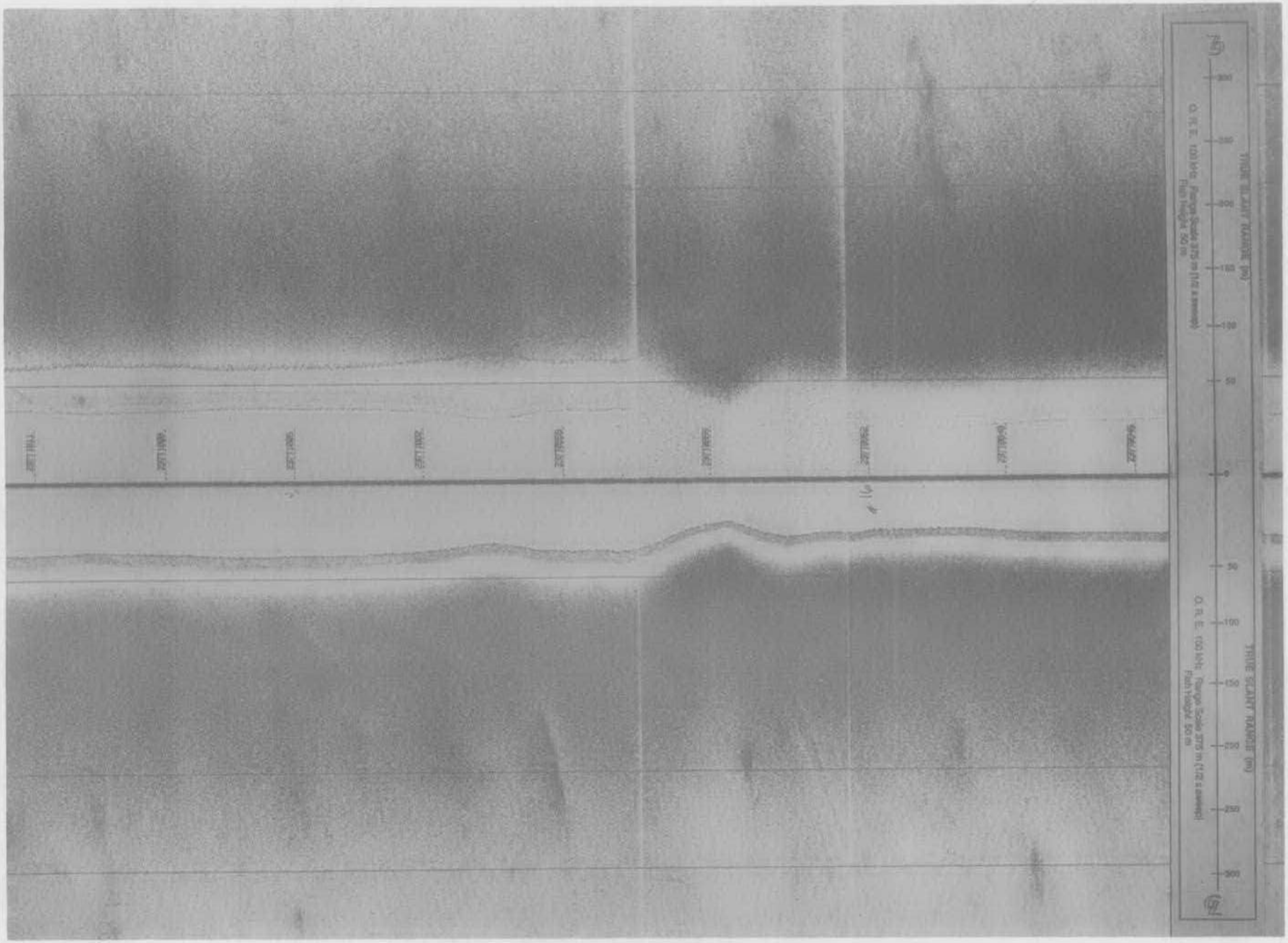
Line 4010R - Scour 250B, 251B (Geomarine Feature #31, 32) water depth 140 - 150 m.



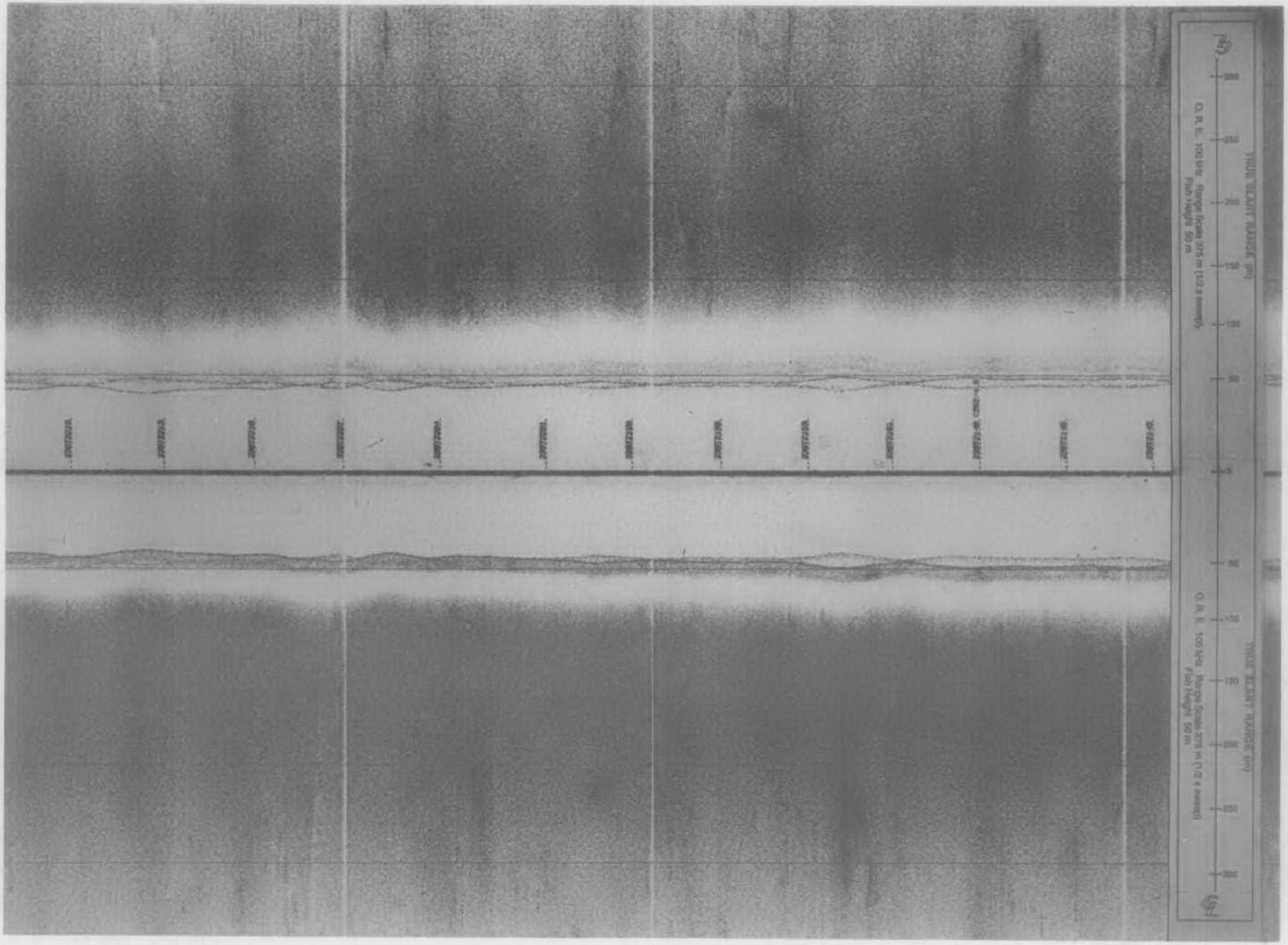
Line 4010R - Scour 254B (Geomarine Feature #33) water depth 140 - 150 m.



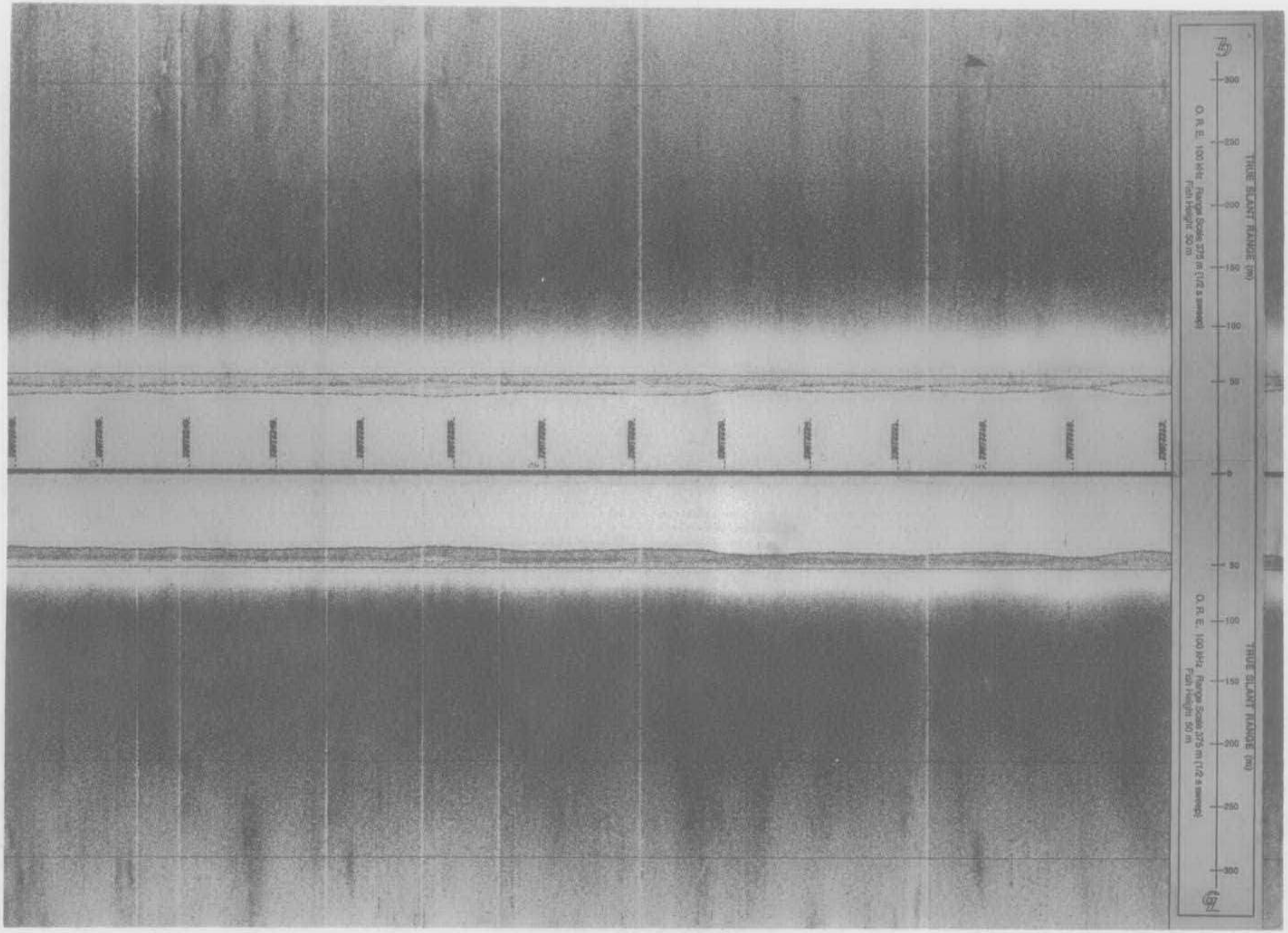
Line 4010R - Scour 254B (A) and 253K (B). Klein 50 kHz sonograph, range = 300 m.
Compare with previous ORE sonograph.



Line 4001RB - Scour 261B (Geomarine Feature #34) water depth 135 - 145 m.

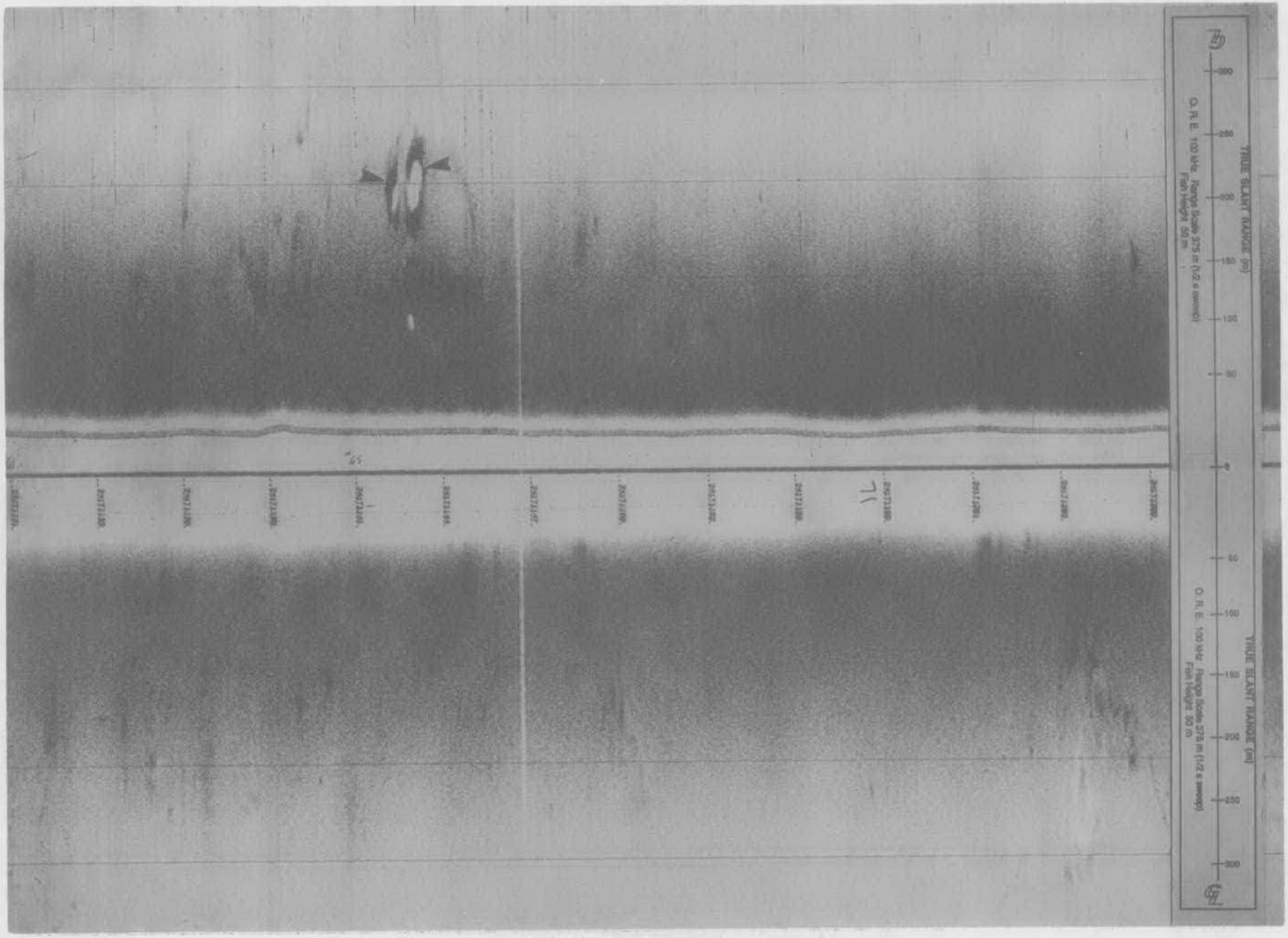


Line 4021R - Scour 010B (Geomarine Feature #40) water depth 130 - 140 m.

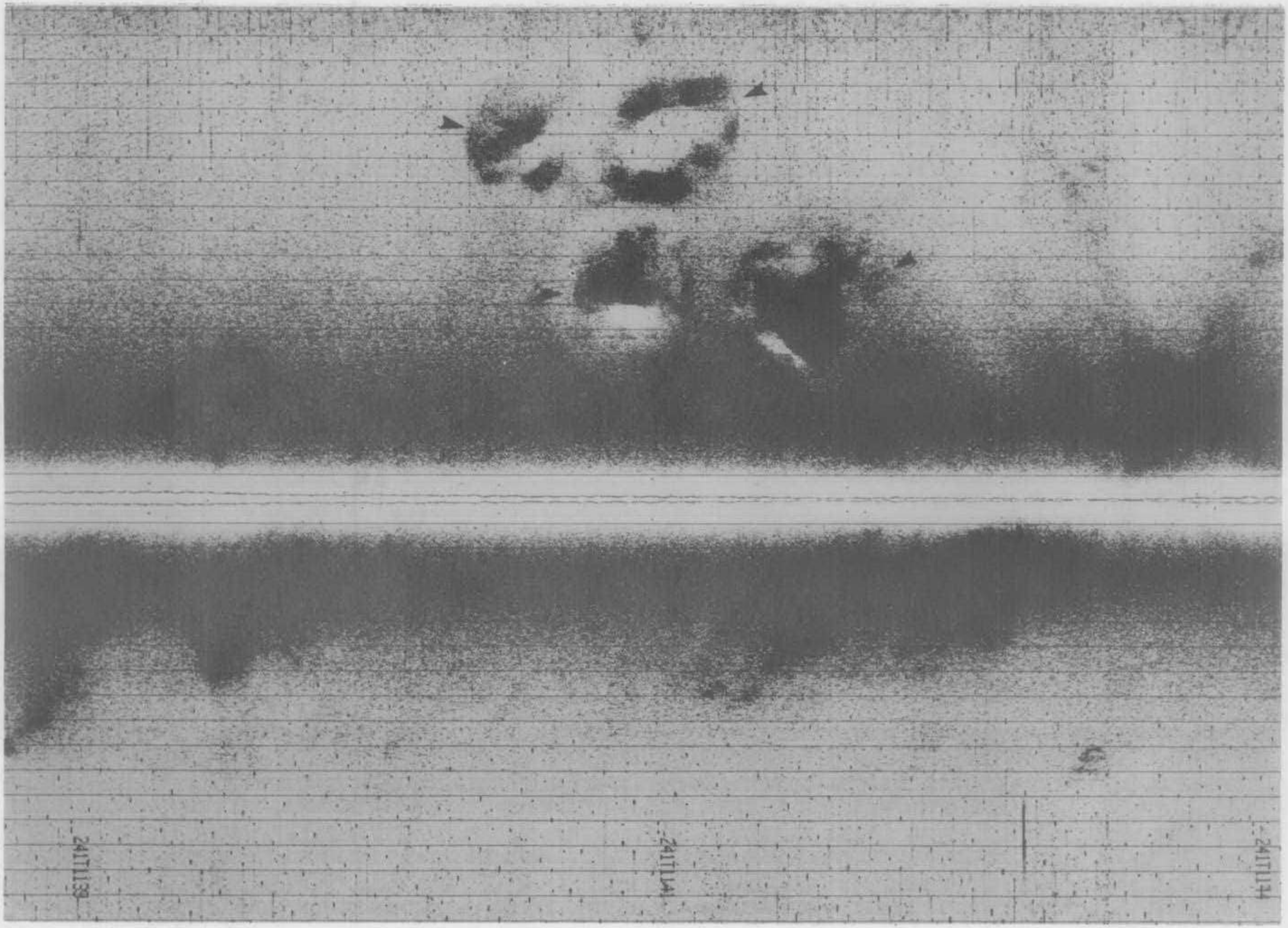


Line 4021R - Scour 012B (Geomarine Feature #41) water depth 120 - 130 m.
Note : Geomarine Feature #42 Not Evident.

Line 4021R - Scour 027B (Geomarine Feature #43) water depth 100 - 110 m.



Line 4002R - Possible New Scours (N103B, N104B, N105B, N106B). ORE 100kHz Data.



Line 4002R - Possible New Scours (N103B, N104B, N105B, N106B). Klein 50 kHz Data. Range = 300 m / Channel.

APPENDIX B

Scour Measurement Data

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
001B	AR	01	67.0	391.7	21.9	0	0	0	0	0	0	
		02	254.5	371.6	26.4	0	0	0	0	0	0	
		03	279.3	170.6	21.6	0	0	0	0	0	0	
	SCOUR NOT VISIBLE ON ORIGINAL ORE DATA. SURVEY TRACK ROUGHLY 400 M PORT OF ORIGINAL SURVEY TRACK.											
002K	ST	01	62.5	233.1	14.8	0	0	0	0	0	0	
	SCOUR NOT VISIBLE ON ORE SONOGRAPH.											
003B	ST	01	340.0	175.2	47.5	0	0	0	0	0	0	
	SCOUR CONSISTS OF A SERIES OF OVER LAPPING CRATERS (I.E. RIBBED).											
005B	ST	01	36.5	404.7	33.6	0	0	0	0	0	0	
006B	ST	01	34.6	877.3	50.7	0.2	40.0	0.5	0.5	40.0	40.0	S
	SCOUR NOT VISIBLE ON ORIGINAL ORE SONOGRAPHS. NEW SURVEY TRACK 400 M TO PORT OF ORIGINAL SURVEY TRACK.											
007O	ST	01	301.6	155.7	51.7	0	0	0	0	0	0	
008B	ST	01	25.1	601.6	17.3	0	0	0	0	0	0	
009B	ST	01	345.7	154.7	26.5	0	0	0	0	0	0	
010B	ST	01	340.0	600.6	9.1	0.2	25.0	0.2	0.2	25.0	25.0	S
	PART OF THIS SCOUR INCLUDED WITH FEATURE NO. 40 IN ORIGINAL REPORT.											
011B	SN	01	325.3	88.2	5.0	0	0	0	0	0	0	
		02	300.4	229.8	6.4	0	0	0	0	0	0	
		03	323.1	88.5	6.6	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE 100 KHz DATA BUT NOT RECORDED.											

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
012B	ST	01	345.9	487.6	12.7	0.5	20.0	0.0	0.5	0.0	40.0	A
	EQUIVALENT TO FEATURE NO. 41 ON ORIGINAL ORE 100 KHz DATA.											
013K	ST	01	342.0	175.1	4.0	0.5	15.0	0.0	0.0	0.0	0.0	V
014B	ST	01	26.1	869.5	17.8	0.5	32.0	0.1	0.1	20.0	20.0	S
	SCOUR NOT APPARENT ON ORIGINAL ORE 100 HKz SONOGRAPHS.											
015K	ST	01	4.2	243.6	9.9	0	0	0	0	0	0	
016K	SN	01	273.3	171.4	0	0	0	0	0	0	0	
		02	35.4	107.1	8.8	0	0	0	0	0	0	
		03	335.8	204.7	12.2	0.4	15.0	0.1	0.4	15.0	20.0	A
		04	285.6	71.0	8.9	0	0	0	0	0	0	
		05	44.2	131.5	11.6	0	0	0	0	0	0	
		06	273.3	133.3	8.2	0	0	0	0	0	0	
		07	62.1	141.6	5.9	0	0	0	0	0	0	
		08	296.7	99.8	7.5	0	0	0	0	0	0	
017O	ST	01	358.3	209.2	48.1	0	0	0	0	0	0	
	SCOUR NOT VISIBLE ON ORIGINAL ORE DATA OR KLEIN 50 KHz.											
018B	ST	01	352.8	209.2	48.1	0	0	0	0	0	0	A
019K	ST	01	330.3	191.1	6.1	0	0	0	0	0	0	
020K	ST	01	10.8	313.0	9.9	0	0	0	0	0	0	
021B	ST	01	346.0	588.3	18.5	0	0	0	0	0	0	
022B	ST	01	346.0	588.3	27.7	0	0	0	0	0	0	

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
023K	ST	01	288.4	354.5	13.0	0	0	0	0	0	0	
024K	ST	01	6.5	277.7	6.2	0	0	0	0	0	0	
025K	CC	01	250.0	25.2	17.5	0	0	0	0	0	0	
026K	ST	01	35.1	288.8	12.6	0	0	0	0	0	0	
027B	ST	01	3.4	636.0	19.0	0.7	40.0	0.7	0.3	30.0	30.0	A
	FEATURE NO. 43 ON ORIGINAL ORE SONOGRAPH											
028K	ST	01	338.5	262.8	10.7	0	0	0	0	0	0	
029K	ST	01	11.7	331.6	8.1	0	0	0	0	0	0	
030K	ST	01	48.5	217.2	5.4	0	0	0	0	0	0	
	COMPARISON OF ORE SONOGRAPHS REVEALS SEABEAD TO BE VIRTUALLY UNCHANGED											
031O	ST	01	157.2	245.6	29.2	0	0	0	0	0	0	
032K	ST	01	153.3	242.1	27.9	0	0	0	0	0	0	
033K	ST	01	206.2	190.1	15.7	0	0	0	0	0	0	
034K	ST	01	2419	864.8	7.6	0	0	0	0	0	0	
035K	AR	01	2255	323.6	15.8	0	0	0	0	0	0	
		02	193.2	224.7	25.7	0	0	0	0	0	0	
036K	ST	01	182.3	274.4	21.9	0	0	0	0	0	0	
	SCOUR VERY DEGRADED.											

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
037B	AR	01	201.5	401.6	22.2	0	0	0	0	0	0	
		02	221.5	472.5	21.2	0	0	0	0	0	0	
	LINKED CRATER CHAIN CHARACTER EVIDENT ON ORIGINAL ORE DATA AND ON KLEIN 50 KHZ. SAME AS FEATURE NO. 12 ON ORIGINAL ORE DATA.											
038K	ST	01	111.2	118.8	8.9	0	0	0	0	0	0	
039B	AR	01	201.7	131.1	14.9	0	0	0	0	0	0	
		02	215.8	318.5	19.1	0	0	0	0	0	0	
		03	238.2	196.4	15.1	0	0	0	0	0	0	
	SCOUR IS VISIBLE ON ORIGINAL ORE DATA.											
040B	ST	01	192.1	503.9	13.6	0	0	0	0	0	0	
	SAME AS FEATURE NO. 13 ON ORIGINAL ORE DATA.											
041K	ST	01	185.3	182.0	10.2	0	0	0	0	0	0	
042K	ST	01	195.2	189.8	9.8	0	0	0	0	0	0	
	POSSIBLY EQUIVALENT TO FEATURE NO. 15 ON ORIGINAL ORE DATA.											
043B	ST	01	195.4	209.3	10.1	0	0	0	0	0	0	
	SCOUR LESS DISTINCT ON ORE. PRESENT ON ORIGINAL ORE DATA ALSO.											
044B	ST	01	173.3	695.2	27.7	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA.											
045B	ST	01	212.2	1063.0	0	0	0	0	0	0	0	
	SCOUR VERY INDISTINCT. DIFFICULT TO DETERMINE WIDTH.											
046K	ST	01	181.2	179.7	14.4	0	0	0	0	0	0	

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
047B	ST	01	175.5	268.2	14.1	0	0	0	0	0	0	
	RELICT SCOUR. OTHERS NEARBY.											
048B	ST	01	164.7	116.9	18.0	0	0	0	0	0	0	
049B	ST	01	206.9	426.3	20.6	0.4	30.0	0.2	0.2	40.0	40.0	S
	SCOUR ALSO VISIBLE ON ORIGINAL ORE DATA.											
050B	ST	01	161.7	679.4	6.7	0.5	20.0	0.2	0.5	20.0	30.0	A
	SCOUR ALSO VISIBLE ON ORIGINAL ORE DATA.											
051B	ST	01	217.5	591.8	43.8	0	0	0	0	0	0	
	SCOUR NOT VISIBLE ON ORIGINAL ORE DATA. NOT INTERPRETED TO BE A NEW SCOUR; VERY DEGRADED.											
052K	ST	01	186.5	170.1	8.1	0	0	0	0	0	0	
053B	ST	01	160.0	248.2	19.4	0	0	0	0	0	0	
	SCOUR NOT VISIBLE ON ORIGINAL ORE DATA DUE TO POOR DATA QUALITY.											
054B	ST	01	106.9	386.1	48.4	0	0	0	0	0	0	
	SCOUR NOT VISIBLE ON ORIGINAL ORE DATA DUE TO POOR DATA QUALITY.											
055B	ST	01	195.4	602.7	42.9	0	20.0	0.2	0.2	20.0	20.0	S
	SCOUR FAINTLY VISIBLE ON ORIGINAL ORE DATA.											
056B	ST	01	162.0	231.0	72.2	0	0	0	0	0	0	
	SCOUR FAINTLY VISIBLE ON ORIGINAL ORE DATA.											
057B	ST	01	209.0	967.3	62.7	0	0	0	0	0	0	
	SCOUR FAINTLY VISIBLE ON ORIGINAL ORE DATA.											
058K	ST	01	172.0	235.5	6.3	0	0	0	0	0	0	

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
059K	ST	01	205.1	134.2	9.7	0	0	0	0	0	0	
N060O	ST	01	27.1	381.0	83.7	4.0	140.0	1.0	0.5	80.0	80.0	A
	SCOUR APPEARS FRESH ON ORE DATA. PROFILE ROUNDED ON HUNTEC DATA.											
061B	ST	01	319.0	734.3	28.0	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 4 ON ORIGINAL ORE DATA.											
062B	AR	01	58.8	247.8	15.4	0	0	0	0	0	0	
		02	295.1	55.5	18.4	0	0	0	0	0	0	
	SCOUR NOT VISIBLE ON ORIGINAL ORE DATA.											
063O	ST	01	342.0	184.8	92.3	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 5 ON ORIGINAL ORE DATA.											
064B	AR	01	34.0	763.0	33.0	0.5	20.0	0.2	0.5	20.0	20.0	A
		02	276.3	483.4	21.4	0.6	20.0	0.0	0.3	0.0	20.0	A
	SCOUR VISIBLE ON ORIGINAL ORE DATA. EACH SCOUR SEGMENT RELATIVELY SINUOUS ON 50 KHZ DATA.											
065K	ST	01	337.9	241.2	6.0	0.5	10.0	0.3	0.4	15.0	15.0	S
066K	ST	01	309.5	93.6	11.7	0	0	0	0	0	0	
067K	ST	01	354.5	125.4	10.5	0	0	0	0	0	0	
	REPRESENTATIVE OF RELICT POPULATION.											
068K	ST	01	10.4	203.9	6.1	0	0	0	0	0	0	
069B	AR	01	0.1	420.6	38.3	0	0	0	0	0	0	
		02	271.0	986.8	43.6	0	0	0	0	0	0	
	PARTLY EQUIVALENT TO FEATURE NO. 27 ON ORIGINAL ORE DATA.											

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
070B	ST	01	5.6	670.3	19.2	0	0	0	0	0	0	
	SCOUR FAINTLY VISIBLE ON ORIGINAL ORE DATA.											
071B	ST	01	26.6	320.6	47.4	0	0	0	0	0	0	
072K	ST	01	16.6	128.6	12.3	0	0	0	0	0	0	
073K	ST	01	327.4	118.9	25.7	0	0	0	0	0	0	
074B	ST	01	5.4	251.1	19.0	0	0	0	0	0	0	
075B	ST	01	52.0	412.1	17.4	0	0	0	0	0	0	
	POSSIBLE PIT AT NORTH END OF SCOUR. SCOUR VISIBLE ON ORIGINAL ORE DATA.											
076K	ST	01	339.1	279.5	8.6	0	0	0	0	0	0	
077K	ST	01	0.3	188.6	20.8	0	0	0	0	0	0	
078K	SN	01	282.3	168.6	7.1	0	0	0	0	0	0	
		02	252.0	95.0	7.3	0	0	0	0	0	0	
		03	293.7	34.8	7.6	0	0	0	0	0	0	
079B	ST	01	359.4	301.4	10.7	0	0	0	0	0	0	
080K	ST	01	8.3	170.6	6.2	0.6	25.0	0	0	0	0	V
081B	ST	01	311.7	331.3	8.2	0	0	0	0	0	0	
082K	ST	01	30.0	311.5	7.5	0	0	0	0	0	0	
	RELICT SCOUR.											

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
083K	ST	01	342.0	264.6	10.4	0	0	0	0	0	0	
	RELICT SCOUR.											
084B	ST	01	3.2	266.6	10.5	0.5	20.0	0.3	0.3	20.0	40.0	A
085B	ST	01	263.4	1023.3	7.6	0	0	0	0	0	0	
	SCOUR FAIRLE DEGRADED. SCOUR PARTLY VISIBLE ON ORIGINAL ORE DATA.											
086B	ST	01	14.2	382.7	18.5	0	0	0	0	0	0	
087K	ST	01	280.4	240.2	15.2	0	0	0	0	0	0	
	SCOUR VERY DEGRADED.											
088B	ST	01	33.3	489.7	7.2	0	0	0	0	0	0	
	SCOUR APPEARS VERY DEGRADED.											
089B	ST	01	32.4	452.1	5.5	0	0	0	0	0	0	
	SCOUR VERY DEGRADED.											
090B	ST	01	295.0	463.9	9.2	0	0	0	0	0	0	
	SCOUR IS VISIBLE ON ORIGINAL ORE DATA.											
091B	ST	01	22.1	408.8	36.6	0	0	0	0	0	0	
	SCOUR TROUGH APPEARS RIBBED ON 50 KHZ DATA. SCOUR IS DEGRADED. VISIBLE ON ORIGINAL ORE DATA.											
092B	SN	01	275.6	539.3	68.8	0	0	0	0	0	0	
		02	40.0	196.5	53.3	0	0	0	0	0	0	
		03	63.1	476.5	38.2	0	0	0	0	0	0	
	SCOUR NOT VISIBLE ON ORIGINAL ORE DATA PROBABLY DUE TO REDUCED RANGE. SCOUR IS NOT FRESH.											
093B	ST	01	18.2	511.7	18.3	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA.											

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
094B	ST	01	14.1	488.2	18.3	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA.											
095K	ST	01	15.9	307.6	6.3	0	0	0	0	0	0	
	THIS SCOUR AND SCOUR #096K ARE IN VICINITY OF FEATURE NO. 28 ON ORIGINAL ORE DATA.											
096K	ST	01	39.4	284.5	5.6	0	0	0	0	0	0	
	THIS SCOUR AND SCOUR #O95K ARE IN VICINITY OF FEATURE NO. 28 ON ORIGINAL ORE DATA.											
097K	AR	01	319.4	119.7	6.6	0.4	10.0	0.0	0.2	0.0	10.0	A
		02	355.7	103.6	6.7	0.4	10.0	0.0	0.2	0.0	10.0	A
	DEGRADED SCOUR NEARBY MAY BE EQUIVALENT TO FEATURE NO. 5 ON ORIGINAL ORE DATA.											
098K	ST	01	308.4	242.1	6.3	0	0	0	0	0	0	
099K	ST	01	311.6	210.6	6.4	0.4	15.0	0.0	0.0	0.0	0.0	S
100K	ST	01	275.8	191.7	12.0	0	0	0	0	0	0	
	VERY DEGRADED SCOUR.											
101K	ST	01	25.9	215.5	12.5	0	0	0	0	0	0	
	VERY DEGRADED SCOUR.											
102B	ST	01	39.5	532.9	6.1	0	0	0	0	0	0	
	SCOUR MAY BE FAINTLY VISIBLE ON ORIGINAL ORE DATA.											
N103B	CC	01	252.0	70.7	38.2	0	0	0	0	0	0	
	ONE OF FOUR NEW CRATER FEATURES.											
N104B	CC	01	252.0	38.6	26.5	0	0	0	0	0	0	
	ONE OF FOUR NEW CRATER FEATURES.											

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
N105B	CC	01	252.0	64.3	44.1	0	0	0	0	0	0	
	ONE OF FOUR NEW CRATER FEATURES.											
N106B	CC	01	252.0	64.3	50.0	0	0	0	0	0	0	
	ONE OF FOUR NEW CRATER FEATURES.											
107B	ST	01	303.9	211.9	18.6	0	0	0	0	0	0	
	RELICT SCOUR.											
108B	ST	01	342.0	662.2	8.9	0	0	0	0	0	0	
	SCOUR IS VISIBLE ON ORIGINAL ORE DATA, BUT NOT RECORDED.											
109B	ST	01	346.2	588.1	15.4	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA, BUT NOT RECORDED.											
110B	ST	01	6.2	534.1	9.3	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA, BUT NOT RECORDED.											
111B	ST	01	41.8	263.6	18.0	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 6 ON ORIGINAL ORE DATA.											
112B	ST	01	18.1	586.8	9.1	0.5	20.0	0.5	0.4	15.0	20.0	A
	EQUIVALENT TO FEATURE NO. 6A ON ORIGINAL ORE DATA.											
113B	ST	01	11.3	660.9	15.9	0	0	0	0	0	0	
	SCOUR NOT VISIBLE ON ORIGINAL ORE DATA BECAUSE OF SEVERE THERMOCLINE NOISE.											
114B	ST	01	198.9	254.0	23.3	0	0	0	0	0	0	
115B	AR	01	170.1	297.0	23.5	0	0	0	0	0	0	
		02	207.3	399.6	23.0	0	0	0	0	0	0	

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
116B	ST	01	204.2	466.6	28.0	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA, BUT NOT RECORDED.											
117B	ST	01	193.4	366.1	13.0	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA, BUT NOT RECORDED.											
118B	AR	01	211.0	637.7	9.5	0	0	0	0	0	0	
		02	234.3	535.9	11.9	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 10 ON ORIGINAL ORE DATA.											
119B	ST	01	135.8	185.3	9.9	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
120K	ST	01	154.1	265.0	10.4	0	0	0	0	0	0	
	VERY DEGRADED-LOOKING SCOUR.											
121B	ST	01	220.6	783.1	6.2	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 9 ON ORIGINAL ORE DATA.											
122K	ST	01	162.3	264.6	13.4	0	0	0	0	0	0	
	DEGRADED SCOUR.											
123K	ST	01	224.0	786.1	6.0	0	0	0	0	0	0	
	VERY DEGRADED SCOUR.											
124K	CC	01	70.0	64.3	20.6	0	0	0	0	0	0	
125K	ST	01	193.3	331.6	31.4	0.5	20.0	0.1	0.3	10.0	20.0	A
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
126B	ST	01	124.3	546.1	17.9	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 7 ON ORIGINAL ORE DATA.											

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
127O	ST	01	125.3	260.4	25.9	0	0	0	0	0	0	
128K	ST	01	179.1	207.2	12.5	0.7	10.0	0.8	0.5	15.0	10.0	A
	SCOUR VERY 'FRESH' ON HUNTEC RECORD.											
129B	ST	01	165.7	336.6	12.4	0	0	0	0	0	0	
130B	ST	01	225.4	260.5	26.1	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 16 ON ORIGINAL ORE DATA.											
131B	ST	01	187.3	216.1	6.0	0	0	0	0	0	0	
132B	ST	01	204.1	299.7	16.7	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 17 ON ORIGINAL ORE DATA.											
133B	ST	01	198.7	340.2	5.7	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
134B	ST	01	175.1	163.3	8.0	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
135B	ST	01	200.9	319.7	9.5	0	0	0	0	0	0	
	SCOUR DEGRADED.											
136K	ST	01	102.3	274.1	3.5	0	0	0	0	0	0	
	VERY DERADED SCOUR.											
137B	ST	01	182.6	332.8	18.3	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 18 ON ORIGINAL ORE DATA.											
138B	ST	01	145.9	192.7	8.2	0	0	0	0	0	0	
	SCOUR FAINTLY VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED. SCOUR DEGRADED.											

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
139B	ST	01	168.8	367.3	6.4	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
140B	ST	01	217.5	418.0	7.0	0	0	0	0	0	0	
141B	ST	01	160.0	175.2	8.6	0	0	0	0	0	0	
	SCOUR FAINTLY VISIBLE ON ORIGINAL ORE DATA.											
142B	ST	01	160.0	616.0	28.2	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
143K	ST	01	171.5	118.0	6.3	0	0	0	0	0	0	
	RELICT SCOUR. ONLY BERMS REMAIN.											
144B	ST	01	148.4	110.7	10.6	0	0	0	0	0	0	
	RELICT SCOUR.											
145K	ST	01	210.4	192.8	7.4	0	0	0	0	0	0	
	RELICT SCOUR.											
146B	ST	01	207.5	391.8	9.2	0	0	0	0	0	0	
	RELICT SCOUR.											
147K	ST	01	227.4	322.3	6.5	0	0	0	0	0	0	
	RELICT SCOUR.											
148B	ST	01	217.2	667.5	8.7	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 19 ON ORIGINAL ORE DATA.											

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
149B	SN	01	75.0	489.3	13.2	0	0	0	0	0	0	
		02	233.9	177.7	15.6	0	0	0	0	0	0	
		03	83.1	399.5	9.2	0	0	0	0	0	0	
		04	232.4	137.3	14.1	0	0	0	0	0	0	
	RELICT SCOUR.											
150K	ST	01	184.5	335.7	8.0	0	0	0	0	0	0	
	RELICT SCOUR.											
151K	SN	01	217.3	217.0	10.5	0	0	0	0	0	0	
		02	245.7	122.5	10.3	0	0	0	0	0	0	
		03	206.6	322.3	11.1	0	0	0	0	0	0	
		04	153.0	146.5	4.1	0	0	0	0	0	0	
	BERG APPEARS TO HAVE STOPPED, CREATING CRATERS BETWEEN SEGMENTS.											
152K	ST	01	112.9	337.9	5.5	0	0	0	0	0	0	
153B	CC	01	70.0	42.4	36.5	0	0	0	0	0	0	
154B	ST	01	116.0	133.1	11.1	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
155B	ST	01	139.4	421.8	14.1	1.2	20.0	0.0	0.4	0.0	40.0	A
	SCOUR FAINTLY VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
156B	ST	01	99.4	131.1	26.1	0	0	0	0	0	0	
157K	AR	01	189.9	156.2	4.0	0	0	0	0	0	0	
		02	120.6	114.6	3.9	0	0	0	0	0	0	
158K	ST	01	166.9	58.6	10.1	0	0	0	0	0	0	

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
159K	CC	01	70.0	30.3	39.4	0	0	0	0	0	0	
160B	ST	01	201.6	496.5	21.1	0.5	15.0	0.3	0.3	30.0	30.0	S
	EQUIVALENT TO FEATURE NO. 20 ON ORIGINAL ORE DATA.											
161K	ST	01	143.2	447.5	4.1	0	0	0	0	0	0	
162K	ST	01	239.3	244.5	7.5	0	0	0	0	0	0	
163B	ST	01	193.5	396.7	9.9	0	0	0	0	0	0	
164B	ST	01	176.6	357.7	6.1	0.2	10.0	0.2	0.2	20.0	40.0	A
	RELICT SCOUR.											
165O	ST	01	219.9	795.9	17.8	0	0	0	0	0	0	
169B	AR	01	8.7	281.6	80.7	0	0	0	0	0	0	
		02	303.7	97.7	60.2	0	0	0	0	0	0	
	RELICT SCOUR.											
170K	ST	01	332.5	264.1	11.0	0	0	0	0	0	0	
	RELICT SCOUR.											
171K	ST	01	313.9	154.7	4.3	0	0	0	0	0	0	
172K	ST	01	23.6	341.7	8.1	0	0	0	0	0	0	
	RELICT SCOUR.											
173B	ST	01	34.0	277.1	7.7	0	0	0	0	0	0	
	RELICT SCOUR. NOT VISIBLE ON ORIGINAL ORE DATA DUE TO LIMITED RANGE.											

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
174K	AR	01	48.0	103.3	10.3	0	0	0	0	0	0	
		02	306.7	289.5	10.8	0	0	0	0	0	0	
	RELICT SCOUR.											
175B	ST	01	350.6	265.4	8.9	0	0	0	0	0	0	
176K	ST	01	17.4	181.6	10.8	0	0	0	0	0	0	
	RELICT SCOUR.											
177B	ST	01	9.6	705.8	29.9	0.6	25.0	0.4	0.4	20.0	20.0	S
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
178K	ST	01	347.5	205.4	11.0	0	0	0	0	0	0	
	RELICT SCOUR.											
179B	ST	01	7.7	327.3	15.1	0	0	0	0	0	0	
	RELICT SCOUR. VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
180K	ST	01	350.7	295.0	11.2	0	0	0	0	0	0	
	RELICT SCOUR.											
181B	ST	01	2.5	412.0	8.8	0	0	0	0	0	0	
	RELICT SCOUR. VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
182K	ST	01	18.6	233.0	10.7	0	0	0	0	0	0	
	RELICT SCOUR.											
183B	ST	01	355.6	149.3	18.3	0	0	0	0	0	0	
	RELICT SCOUR.											
184K	ST	01	347.8	175.2	16.0	0	0	0	0	0	0	
	RELICT SCOUR.											

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
185B	ST	01	350.2	559.5	59.5	1.0	60.0	0.5	0.5	40.0	40.0	S
	SCOUR FAINTLY VISIBLE ON ORIGINAL ORE DATA.											
186K	ST	01	23.8	665.6	11.1	0	0	0	0	0	0	
	RELICT SCOUR.											
187B	ST	01	21.5	675.8	20.7	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 24 ON ORIGINAL ORE DATA.											
188K	ST	01	357.9	525.3	24.1	0.5	40.0	0.4	0.4	30.0	30.0	S
189B	ST	01	354.9	461.2	10.9	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
190K	ST	01	325.0	491.3	4.4	0	0	0	0	0	0	
191B	ST	01	34.0	697.4	27.1	1.5	40.0	0.5	0.5	40.0	60.0	S
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
192B	ST	01	17.8	653.0	10.0	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 24A ON ORIGINAL ORE DATA.											
193K	ST	01	29.8	181.9	5.0	0	0	0	0	0	0	
194K	ST	01	355.1	162.7	3.7	0	0	0	0	0	0	
195B	AR	01	22.1	322.6	26.4	0	0	0	0	0	0	
		02	0.3	299.3	18.6	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
196B	AR	01	34.1	679.3	13.4	0.5	20.0	0.5	0.5	40.0	40.0	S
		02	55.0	625.9	12.1	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
197B	ST	01	305.0	336.3	19.9	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 24B ON ORIGINAL ORE DATA.											
198K	CC	01	70.0	16.0	29.2	0	0	0	0	0	0	
199K	ST	01	167.6	205.4	4.5	0	0	0	0	0	0	
200O	ST	01	202.9	270.5	30.2	0	0	0	0	0	0	
	SCOUR NOT VISIBLE ON KLEIN DATA DUE TO REDUCED RANGE.											
201K	ST	01	181.1	378.0	4.1	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT ON NEW ORE DATA.											
202B	ST	01	153.6	185.9	9.8	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
203K	ST	01	219.1	323.5	7.3	0	0	0	0	0	0	
204B	ST	01	207.5	192.3	7.9	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
205B	ST	01	160.0	138.6	9.8	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
206K	ST	01	84.5	458.8	1.6	0	0	0	0	0	0	
	MAY BE TRAWL MARK.											
207K	ST	01	202.4	373.1	10.2	0	0	0	0	0	0	

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
208K	ST	01	217.5	704.7	10.8	0	0	0	0	0	0	
	RELICT SCOUR. VERY DEGRADED.											
209B	ST	01	172.3	630.0	19.2	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
210K	ST	01	170.6	427.5	22.1	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 25 ON ORIGINAL ORE DATA. NOT VISIBLE ON NEW ORE DATA.											
211K	SN	01	221.6	221.8	5.1	0	0	0	0	0	0	
		02	77.2	202.1	4.4	0	0	0	0	0	0	
		03	217.1	324.1	5.2	0	0	0	0	0	0	
		04	183.1	136.6	6.0	0	0	0	0	0	0	
212K	ST	01	192.2	127.0	6.2	0	0	0	0	0	0	
213B	ST	01	201.8	436.6	14.1	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
214B	ST	01	225.6	900.4	8.2	0.6	40.0	0.5	0.5	50.0	30.0	A
	LARGE RELICT SCOUR. VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
215B	ST	01	165.8	278.2	12.7	0	0	0	0	0	0	
	RELICT SCOUR. NOT VISIBLE ON ORIGINAL ORE DATA BECAUSE OF GAIN SETTING.											
216B	ST	01	131.6	235.5	19.0	0.5	20.0	0.2	0.5	40.0	30.0	A
	RELICT SCOUR. VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
217K	ST	01	201.3	322.8	10.7	0	0	0	0	0	0	
	RELICT SCOUR.											

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
218B	ST	01	119.9	413.1	7.9	0.4	25.0	0.4	0.5	25.0	40.0	A
	RELICT SCOUR.											
219B	ST	01	192.0	396.3	6.2	0	0	0	0	0	0	
	RELICT SCOUR. NOT VISIBLE ON ORIGINAL ORE DATA.											
220K	AR	01	238.6	324.3	10.8	0	0	0	0	0	0	
		02	218.4	418.5	11.1	0	0	0	0	0	0	
221B	ST	01	174.1	296.4	41.1	0	0	0	0	0	0	
	SCOUR ONLY FAINTLY VISIBLE ON ORIGINAL ORE DATA.											
222B	AR	01	96.6	1009.4	25.4	0.5	40.0	0.5	0.5	50.0	40.0	A
		02	205.7	694.7	17.6	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 26 ON ORIGINAL ORE DATA.											
223K	ST	01	201.8	167.9	20.1	0	0	0	0	0	0	
224K	ST	01	163.0	409.1	8.8	0	0	0	0	0	0	
225K	ST	01	217.3	845.2	7.4	0	0	0	0	0	0	
	VERY FAINT SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT ON NEW ORE DATA.											
226B	ST	01	218.0	601.5	9.2	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 21 ON ORIGINAL ORE DATA.											
227B	ST	01	211.1	943.9	9.5	0.6	30.0	0.0	0.3	0.0	20.0	A
	EQUIVALENT TO FEATURE NO. 21A ON ORIGINAL ORE DATA.											
228K	ST	01	194.9	355.0	10.4	0	0	0	0	0	0	

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
229B	ST	01	202.2	585.4	7.8	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 22 ON ORIGINAL ORE DATA.											
230K	ST	01	182.8	411.2	6.3	0	0	0	0	0	0	
231K	ST	01	236.8	437.4	4.6	0	0	0	0	0	0	
232B	ST	01	164.5	351.0	21.8	0	0	0	0	0	0	
233B	ST	01	138.2	379.7	12.8	0	0	0	0	0	0	
234B	ST	01	197.3	523.6	10.3	0.5	20.0	0.4	0.4	20.0	20.0	S
235B	ST	01	200.5	515.7	24.1	0.5	40.0	0.5	0.3	30.0	20.0	A
236K	ST	01	177.6	269.6	8.6	0	0	0	0	0	0	
	RELICT SCOUR.											
237K	CC	01	70.0	34.3	7.3	0	0	0	0	0	0	
238K	ST	01	191.0	477.1	15.4	0.4	10.0	0.5	0.5	30.0	30.0	S
239K	AR	01	237.2	338.7	17.5	0	0	0	0	0	0	
		02	85.5	488.8	23.0	0	0	0	0	0	0	
240K	ST	01	115.9	348.4	23.7	1.3	20.0	0.3	0.5	20.0	25.0	A
241K	CC	01	70.0	58.1	36.5	0	0	0	0	0	0	
	TWO SMALL SCOURS POSSIBLY ASSOCIATED WITH THIS CRATER.											
243B	ST	01	117.7	517.2	22.9	0.5	60.0	0.0	0.5	0.0	80.0	A
	SCOUR FAINTLY VISIBLE ON ORIGINAL ORE DATA.											

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
244K	CC	01	70.0	46.3	65.7	0	0	0	0	0	0	
	FAINT SCOUR NEARBY MAY BE ASSOCIATED WITH THIS CRATER.											
245B	ST	01	150.6	78.0	21.8	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
246K	ST	01	187.2	426.3	7.2	0	0	0	0	0	0	
	SMALL CRATER AT TERMINUS OF SCOUR, STARBOARD SIDE.											
247K	AR	01	199.0	159.3	10.7	0	0	0	0	0	0	
		02	109.6	167.4	10.2	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 30 ON ORIGINAL ORE DATA.											
248K	ST	01	242.3	752.5	41.3	1.5	160.0	0.3	0.0	80.0	0.0	A
	RIBBED SCOUR NOT VISIBLE ON EITHER ORE DATA SET.											
249B	ST	01	149.9	367.1	9.2	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
250B	ST	01	204.3	231.7	13.9	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 31 ON ORIGINAL ORE DATA.											
251B	ST	01	215.2	513.5	8.3	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 32 ON ORIGINAL ORE DATA.											
252K	ST	01	218.5	172.3	6.5	0	0	0	0	0	0	
253K	SN	01	112.1	115.0	5.1	0	0	0	0	0	0	
		02	142.4	297.2	5.5	0	0	0	0	0	0	
		03	170.1	345.1	5.5	0.4	20.0	0.0	0.4	0.0	25.0	A

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
254B	ST	01	98.1	693.0	4.8	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 33 ON ORIGINAL ORE DATA; ONLY FAINTLY VISIBLE ON NEW ORE DATA.											
255B	ST	01	136.1	180.1	8.7	0	0	0	0	0	0	
	SCOUR NOT VISIBLE ON ORIGINAL ORE DATA.											
256B	AR	01	146.2	102.1	30.1	0	0	0	0	0	0	
		02	202.5	173.7	40.5	0	0	0	0	0	0	
	SCOUR LOCATED BEYOND END OF ORIGINAL SURVEY LINE.											
257K	ST	01	105.8	491.7	16.0	0.2	15.0	0.4	0.7	20.0	40.0	A
258K	CC	01	250.0	33.5	23.4	0	0	0	0	0	0	
259K	AR	01	354.8	206.0	16.6	0	0	0	0	0	0	
		02	320.7	192.3	16.6	0	0	0	0	0	0	
	SCOUR FAINTLY VISIBLE ON ORIGINAL ORE DATA.											
260K	ST	01	285.0	529.2	7.8	0.3	10.0	0.2	0.4	20.0	30.0	A
261B	SN	01	293.0	193.3	17.8	0	0	0	0	0	0	
		02	65.2	423.0	11.7	0	0	0	0	0	0	
		03	273.3	225.4	8.8	0	0	0	0	0	0	
		04	52.6	451.9	7.3	0	0	0	0	0	0	
		05	264.5	301.6	22.0	0	0	0	0	0	0	
		06	266.5	632.9	14.6	0	0	0	0	0	0	
		07	68.1	680.0	0	0	0	0	0	0	0	
		08	47.7	255.6	0	0	0	0	0	0	0	
	EQUIVALENT TO FEATURE NO. 34 ON ORIGINAL ORE DATA.											
262K	AR	01	355.8	304.7	5.4	0	0	0	0	0	0	
		02	37.0	262.1	5.7	0	0	0	0	0	0	

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
263B	AR	01	334.6	102.3	0	0	0	0	0	0	0	
		02	4.6	221.7	7.8	0	0	0	0	0	0	
264B	ST	01	311.2	243.7	17.9	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
265B	ST	01	288.4	129.6	28.5	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
266B	ST	01	29.8	913.5	22.9	0	0	0	0	0	0	
	SCOUR VISIBLE ON ORIGINAL ORE DATA BUT NOT RECORDED.											
267O	ST	01	317.9	661.1	17.7	0	0	0	0	0	0	
268B	ST	01	319.8	323.6	10.8	0	0	0	0	0	0	
	SCOUR NO. 269K MAY BE ASSOCIATED WITH THIS SCOUR.											
269K	CC	01	250.0	28.1	26.2	0	0	0	0	0	0	
	MAY BE RELATED TO SCOUR NO. 268B.											
270B	CC	01	250.0	12.5	33.6	0	0	0	0	0	0	
271B	CC	01	250.0	18.9	17.5	0	0	0	0	0	0	
272K	ST	01	313.4	268.4	6.4	0	0	0	0	0	0	
273B	ST	01	325.3	487.2	17.9	0.5	40.0	0.3	0.0	30.0	0.0	A
274B	ST	01	5.5	285.0	8.4	0	0	0	0	0	0	
275B	ST	01	352.5	630.1	39.1	0	0	0	0	0	0	

ID	PLAN SHAPE	SEG NUM	TRUE BEAR	TRUE LENGTH	TRUE WIDTH	DEPTH	PROFILE WIDTH	UP BERM HEIGHT	DOWN BERM HEIGHT	UP BERM WIDTH	DOWN BERM WIDTH	PROFILE SHAPE
276B	ST	01	36.5	416.0	5.0	0	0	0	0	0	0	
277B	ST	01	20.5	321.9	14.4	0	0	0	0	0	0	
	RELICT SCOUR.											
278B	ST	01	43.9	541.6	8.1	0	0	0	0	0	0	
	RELICT SCOUR.											
279B	ST	01	193.6	262.9	30.0	0	0	0	0	0	0	
	SCOUR IS VISIBLE ON PORT CHANNEL OF HU80010 BIO 70 KHZ SIDESCAN SONOGRAPH.											
280B	ST	01	208.5	521.1	19.6	0	0	0	0	0	0	
	SCOUR VISIBLE ON HU80010 BIO 70 KHZ SIDESCAN SONOGRAPH.											
281B	ST	01	206.9	712.5	18.4	0.5	30.0	0.2	0.5	40.0	50.0	A
	SCOUR IS VISIBLE ON HU80010 BIO 70 KHZ SIDESCAN SONOGRAPH.											
282B	ST	01	191.8	299.4	6.7	0	0	0	0	0	0	
283B	ST	01	190.5	476.4	11.9	0	0	0	0	0	0	
284K	ST	01	138.0	244.9	15.8	0.3	20.0	0.5	0.2	30.0	30.0	A
	SCOUR VAGUELY EVIDENT ON HU80010 BIO 70 KHZ SONOGRAPH.											
285K	ST	01	203.2	303.3	14.1	0	0	0	0	0	0	
	MAY BE VISIBLE ON HU80010 BIO 70 KHZ SONOGRAPH.											

APPENDIX C

Cruise Report

TRIP REPORT AND EQUIPMENT DETAILS
EAST COAST REPETITIVE MAPPING
CSS DAWSON CRUISE DN 90-021

COMPILED BY
WES SMITH (GEONAUTICS)
AND
B. JOHNSTON, A. BOYCE, G. CHAFFEY (MCELHANNEY)

TRIP REPORT (W. SMITH)

August 18, 1990

Departed airport at St. John's 0815, NFT. Arrived at airport in Halifax 0930 NST. Checked into Holiday Inn Dartmouth and made arrangements to go to McElhanney office to set up ORE System for checkout. Arrived at McElhanney office and set up system. Programmers at McElhanney having problems interfacing speed log to ORE System, much effort, still no success. However, ORE System checked out fine. Departed McElhanney 1815 NST.

August 19, 1990

Spent most of the day familiarizing myself with operation of ORE System. Disassembled system and repacked for transport to BIO in morning. Departed McElhanney 1730 NST.

August 20, 1990

Arrived at McElhanney 0800 NST. Made arrangements to rent a pick-up truck to transport winch and equipment to BIO Dock. After loading winch into pick-up truck, decided it was too risky (winch was too heavy) to transport winch that way. Made arrangements for a boom truck to pick up winch. Moved remainder of equipment with pick-up truck. (Boom truck billed McElhanney to be transferred to NORDCO). Mobilized system on CSS Dawson by 2000 NST, everything quickly powered up ok.

August 21, 1990

Checked out of Holiday Inn 0730 NST. Returned pick-up truck rental 0830 NST. Went to McElhanney to make final arrangements.

Went to BIO, spent day doing final checks, running cable, and securing equipment. Boat delayed due to mechanical difficulty.

August 22, 1990

Mechanical problems sorted out with vessel. CSS Dawson departed BIO Jetty 1300 NST. Enroute to Grand Banks.

Deployed S.S.S., for wet check 1800 NST. Difficulty in getting fish down close to bottom, water depth approximately 150 m, but otherwise system appeared to be working although tuning difficult. Will add more weight to tow fish. ORE/S.S.S., retrieved 2000 NST.

August 23, 1990

Added lead weight to tow fish assembly. Deployed ORE sidescan 1900 NST for more wet testing. Difficulty in tuning system. Retrieved 2130 NST.

August 24, 1990

Ensured data would play back from HP3968A. Changed beam width on tow fish from wide to narrow, arrived on site 2130 NST. ORE deployed and tuned, signal ok, poor resolution but good coverage. Started lines as outlined by Senior Scientist. Data gap in record caused by side lobbing of transducers in narrow beam. Not much to do about it.

August 25, 1990

Still running lines. Problem with HP 3968A; changed with HP3964A. Both recorders overheating; rearranged equipment. See tape log for recorder. All lines recorded on AGC's TEAC 500 anyway on channels 10, 11, 12.

August 25th - September 2nd . Running lines. See line log.

September 2, 1990

ORE retrieved, heading for St. John's, impending bad weather for survey area.

September 3, 1990

Departed St. John's 1115 NST, enroute to survey area.

Resumed survey 1830 NST.

September 3rd - September 8th, 1990

Running lines; see line log.

September 8, 1990

ORE S.S.S., retrieved 1618 NST. End of survey. Dawson departed survey area 1900 NST for Halifax.

September 8th - September 10th, 1990

Enroute to Halifax. Disassembling equipment.

September 10, 1990

CSS Dawson at BIO Jetty 2200 NST.

September 11, 1990

Demobilizing equipment from Dawson. Delayed in getting winch and boxes off boat. Bob Murphy to look after loading of winch and boxes with Hibbs & Kaizer transport. ORE to be shipped to Texas by McEhlanney. Boxes and ORE Tow Cable dropped off at McEhlanney office. Departed Halifax 1415 NST; arrived St. John's 1530 NST.

EQUIPMENT DETAILS (MCELHANNEY)

ORE Sidescan Sonar:
The ORE sidescan system consisted of: ORE model 159 towfish; ORE model 160 transciever; ORE model 158a graphic recorder (complete with modified EPC for display of corrected data); a data display terminal for alteration of display parameters; variable speed electric winch complete with 500m of ORE armoured cable; EPC 3200 recorder for display of raw data; and HP3698a analogue recorder with channel designation as follows:

CH1	Key raw direct
CH2	Port raw direct
CH4	Key 158a direct
CH6	Starboard raw direct
CH7	Data 158a FM
CH8	Voice FM

These channels were recommended for recording by ORE. The EPC 3200 displaying uncorrected data was the master recorder keying the transciever and graphic processor.

Klein 100/500 kHz Sidescan Sonar:

The Klein sidescan sonar was used to generate short range, high resolution 100/500 kHz data of 300 to 600m swath. A Klein 595 thermal recorder was used to record the data (when not used for the DTS 50 kHz sidescan). Data (both 50 and 100 kHz) were stored on a TEAC XR-5000 recorder in the FM unipolar (+) record mode and a direct record track for recorder sync pulses. A Klein 422S-101HF towfish (100/500 kHz) with K-Wing-1 depressor was towed at the end of a 400m tow cable. With all 400m deployed layback was about 3 minutes behind the navigation antenna at 5 knots.

Huntec Deep Tow System (DTS)

The Huntec DTS number AGC-3 was deployed to generate high resolution seismic data. A high voltage boomer sound source of 540 joules generated the signal for a LC-10 single hydrophone internally mounted under the boomer plate and a Nova Scotia Research Foundation (NSRF) type LT-10 element 10 streamer towed behind the vehicle connected to the ship via a 750m tow cable on a Hydromac winch. The LC-10 hydrophone data is the 'internal' dta which was amplified and TVG'ed through an adaptive signal processor unit and bandpass filtered in the system console before displaying on an EPC 4100 graphic recorder. The towed streamer ('external') data was similarly processed but at lower filter settings through an external Krohn-Hite Model 3700 bandpass filter. These external data were also displayed on an EPC 4100 graphic recorder.
The internal and external data were recorded on mag tape using a TEAC XR-5000 VHS recorder on direct record channels along with two other channels for (i) the

trigger sync signal of 1 volt peak, 6.4 kHz EPC sync pulse train with a negative master trigger pulse and then a positive fire point pulse; and (ii) a zero pulse graphic recorder trigger signal. All data were tow vehicle heave compensated in pressure mode.
An Automatic Reflectivity Monitor (ARM) signal was superimposed on the internal graphic recorder data showing sea bottom reflectivity in the form of mean percentile bar graphs of surface back scatter called 'R1', and sub-surface reflectivity called 'R2'. The R1 and R2 values were also recorded on a PC hard disk using the IKB C-ARM software along with the time, depth, etc. values.
The AGC-3 DTS was also equiped with a 50 kHz Klein sidescan sonar. Data from this sonar were displayed on the Klein 595 thermal recorder at 600 to 800 metre swath settings. The 50 kHz recorder amp/TVG boards were modified with on-board gain pots and installed in the 100 kHz (CH 1 and CH 2) slots in the 595 unit.

Navigation

Contract navigation was provided by McElhanney Offshore Surveys Ltd.
The following is a list of equipment supplied by McElhanney with a brief description of each piece:

*Two Cubic Western ARGO DM54 positioning systems; complete with antennas, ALU's, RPU's and cables. ARGO is a medium frequency, phase comparison type positioning system operating in the 1.6 MHz - 1.9 MHz range. It was the prime navigation system on-board, providing up to 18 hours of reliable operation per day. The second ARGO system provided 100% redundancy in case of failure of the primary system.

*Two Internav LC-404 Loran-C receivers and antennas; plus one FTS 4050 frequency standard. This was the secondary navigation system. It was hooked to the FTS 4050 Cesium beam (atomic clock) which synchronized timing with the master shore station and its slaves, providing positioning in a passive Rho/Rho mode. The Loran-C provided navigation data during times of ARGO blackout.

*One Trimble 4000SX GPS receiver and antenna; one Kenwood R-5000 HF radio; one Pakratt multi-mode data controller. The Trimble GPS was utilized in differential mode by using the Kenwood HF radio and Pakratt data controller to relay information from a second GPS base station in St. John's. This yields range corrections to each satellite in the constellation and enhances the relative accuracy and overall performance of the GPS.

*One Magnavox MX1107 Satellite Navigator. The Magnavox system is a dual channel receiver which works with signals from polar orbiting satellites on the 400 MHz and 150 MHz frequencies. This system has good absolute positioning but poor repeatibility, and was used during the cruise to provide ongoing accuracy checks on the other systems.

*Two McElhanney PEGI boxes. The Printer Event Gyro Interface (PEGI) box provides navigation fix marks to the geophysical recording equipment at predetermined intervals.

*Three Hewlett Packard 9826 computers plus McElhanney NAVPAK software system.

Other details concerning the navigation equipment, calibration, quality control and data processing may be found in the McElhanney navigation report for Cruise DN90-021 (contact AGC Curation Section).

TAPE LIST: ESRF - CSS DAWSON 90-021

Tape No.	Line No.	Start Day/Time	Stop Day/Time	Comment
1	Test			
2	4010R	237/0000	237/0900	HP3964A
3	4010R	237/0900	237/1340	HP3964A
4	4001RB	237/1342	237/1555	HP3964A
5	4001RB	237/1559	237/1956	HP3968A
6	4001RB/4004R	237/1956	237/2210	HP3964A
7	4004R	237/2218	238/6026	HP3964A
8	4004R	238/0026	238/0308	HP3964A
9	4004R	238/0308	238/0515	HP4964A
10	4004R-4005R	238/0156	238/13	HP4964A
11	4005R	238/1316	238/1525	HP4964A
12	4005R	238/1527	238/1735	HP4964A
13	4005R	238/1736	238/1912	HP4964A
14	4021R	238/2006	238/2141	HP4964A
15	4021R	238/2143	238/2310	HP4964A
16	4021R	238/2320	239/0055	HP4964A
17	4021R	239/0056	239/0407	HP4964A
18	4021R-4006R	239/0410	239/0840	HP4964A
19	4006R-4007R	239/0842	239/1155	HP4964A
20	4007R	239/1155	239/1625	HP4964A
21	4007R	239/1627	239/1942	HP4964A
22	4007R-4008R	239/1944	239/2356	HP4964A
23	4008R	239/2358	240/0210	HP4964A
24	4008R-4009R	240/0212	240/0615	HP4964A
25	4009R	240/0620	240/0933	HP4964A
26	4009R	240/0935	240/1248	HP4964A
27	B-PIT-4003R	240/1250	241/0320	HP4964A
28	4003R	241/0321	241/0633	HP4964A
29	4003R-4002R	241/0634	241/1021	HP4964A
30	4002R	241/1022	241/1319	HP4964A
31	4002R	241/1321	241/1628	HP4964A
32	4002R-#5	241/1630	241/1930	HP4964A
33	#5 thru #6.8	241/1931	242/0045	HP4964A
34	#6.8 thru #7	242/0049	242/0413	HP4964A
35	#7 and #9	242/0415	242/0744	HP4964A
36	#9 and #9	242/0745	242/1106	HP4964A
37	#11	242/2118	242/2323	HP4964A
38	#11 and #12	242/2326	243/0140	HP4964A
39	#12	243/0141	243/0346	HP4964A
40	#12 and#13	243/0037	243/0614	HP4964A
41	#13 and #14	243/0615	243/0832	HP4964A
42	#14	243/0833	243/1037	HP4964A
43	#14 and #15	243/1038	243/1241	HP4964A
44	#16 and #17	243/1247	243/1424	HP4964A
45	#27	244/2338	245/0141	HP4964A
46	#27	245/0142	245/0346	HP4964A
47	#30	246/2140	246/2346	HP4964A

Tape No.	Line No.	Start Day/Time	Stop Day/Time	Comment
48	#30	246/2347	247/0151	HP4964A
49	#30	247/0153	247/0357	HP4964A
50	#30	247/0359	247/0603	HP4964A
51	#30	247/0605	247/0811	HP3968A
52	#30	247/0813	247/1017	HP3968A
53	#30 and G234	247/1018	248/0046	HP3968A
54	G234 and #36	248/0048	248/0301	HP3968A
55	#36	248/0302	248/0438	HP3968A
56	#36	248/0438	248/0614	HP3968A
57	#36	248/0016	248/0752	HP3968A
58	#36	248/0753	248/0929	HP3968A
59	#36	248/0930	248/1102	HP3968A
60	#37	248/1108	248/1244	HP3968A
61	#37	248/1246	248/1423	HP3968A
62	#38	248/1425	248/1600	HP3968A
63	#38	248/1603	248/1738	HP3968A
64	#38	248/1744	248/1920	HP3968A
65	#38	248/1921	248/2057	HP3968A
66	#38 and #39	248/2058	248/2234	HP3968A
67	#39	248/2236	249/0305	HP3968A
68	#39	249/0307	249/0442	HP3968A
69	#39	249/0444	249/0620	HP3968A
70	#39	249/0621	249/0756	HP3968A
71	#39	249/0758	249/0932	HP3968A
72	#39	249/0933	249/1111	HP3968A
73	#39	249/1112	249/1249	HP3968A
74	DIVE 147 & #40	249/1250	249/2129	HP3968A
75	#40	249/2131	249/2306	HP3968A
76	#40	249/2307	250/0045	HP3968A
77	#40	250/0045	250/10222	HP3968A
78	#40 and #41	250/0223	250/0359	HP3968A
79	#40 and #42	250/0400	250/0536	HP3968A
80	#42	250/0537	250/0719	HP3968A
81	#42	250/0720	250/0856	HP3968A
82	#42	250/0858	250/1033	HP3968A
83	#42	250/1034	250/1919	HP3968A
84	#42	250/1921	250/2057	HP3968A
85	#42 and #44	250/2058	250/2235	HP3968A
86	#42 and #44	250/2237	251/0025	HP3968A
87	#44	251/0025	251/0201	HP3968A
88	#44	251/0202	251/0344	HP3968A
89	#44,#45 and #46	251/0345	251/0517	HP3968A
90	#46	251/0518	251/0703	HP3968A
91	#46	251/0704	251/0839	HP3968A
92	#46	251/1016	251/1016	HP3968A
93	#46	251/1017	251/1153	HP3968A
94	#46	251/1155	251/1320	HP3968A
95	#47	251/1526	251/1702	HP3968A
96	#47	251/1704	251/1840	HP3968A
97	#47	251/1842	251/1918	HP3968A

APPENDIX D

Parameter Descriptions

GEONAUTICS/ESRF REPETITIVE MAPPING ICEBERG SCOUR CATALOGUE PARAMETER DESCRIPTIONS

(Please refer to sample analysis sheet, Figure 2a and 2b)

Line 1,	Column 4-23:	Person responsible for the analysis.
	Column 25-34:	Date of analysis.
	Column 36-62:	General geographic location of scour.
	Column 64-71:	Unique name or code to identify cruise (for regional AGC data) or site for which data were acquired.
	Column 73-75:	Julian date of data collection.
	Column 77-81:	Unique identifier of survey line.
Line 2,	Column 4-6:	Layback (in minutes) of survey instrument behind navigation antenna.
	Column 8-11:	Fix number corresponding to start of record segment containing scour.
	Column 13-20:	UMT easting coordinate for start of record segment containing scour.
	Column 22-31:	UMT northing coordinate for start of record segment countaining scour.
	Column 34-37:	Fix number corresponding to end of record segment containing scour.
	Column 39-46:	UMT easting coordinate for end of record segment containing scour.
	Column 48-57:	UTM northing coordinate for end of record segment containing scour.
	Column 59-62:	Length of sidescan record segment containing scour (centimeters).

	Column 65-68:	Elevation of sidescan towfish above seabed (metres).
	Column 70-73:	Distance between trigger (centre) line and outer range of data (one channel only) on sidescan record (centimeters).
Line 2,	Column 75-79:	Ratio of sidescan range setting over width of record (m/cm).
Line 3,	Column 4-15, 17-28, and 30-39:	Survey instruments used to acquire data.
	NOTE:	Specific instruments used during compilation of scour measurements are flagged by an asterisk.
	Column 42:	Channel of sidescan record on which scour is visible. P-Port; S-Starboard; B-Both.
	Column 46-48:	Vessel heading from navigation data files (degrees from north).
Line 4,	Column 4-8:	Alpha-numeric scour identifier. (see text, Section 4.3.2 for explanation).
	Column 10-11:	Plan shape of scour as visible on sidescan record. ST-Straight; SN-Sinuous; AR-Arcuate; CC-crater or pit.
	Column 13-14:	Segment number. Arcuate and sinuous scours will be comprised of two or more relatively straight segments.
	Column 16-18:	Orientation of scour segment relative to ship's track.
	Column 20-23:	Length of scour segment as measured from sidescan record (centimetres).
	Column 25-28:	Width of scour segment as measured from sidescan record (centimetres).
Line 4.1,	Column 25-28:	Apparent width of scour segment as measured from sub-bottom profiler record (metres).

Line 4, bottom	Column 30-33:	Depth of scour segment measured from sub- profiler record (metres).
	Column 35-38:	Height of scour berm on upslope side as measured from sub-bottom profiler record (metres).
Line 4.1,	Column 35-38:	Height of scour berm on downslope side as measured from sub-bottom profiler record (metres).
Line 4,	Column 40-41:	Profile shape of scour segment as portrayed on sub-bottom profiler record. S-Symmetrical; A-Asymmetrical; V-V-notch (no berms).
Line 4,	Column 43-46:	Width of scour berm on upslope side as measured from sub-bottom profiler record (metres).
Line 4.1,	Column 43-46:	Width of scour berm on downslope side as measured from sub-bottom profiler record (metres).
Line 4,	Column 49-52:	Navigation fix coordinate (assuming layback) for start of scour segment. Measured from sidescan record.
	Column 54-56:	Perpendicular offset from centreline of sidescan record to start of scour segment (metres).
	Column 58:	Direction of offset to start of scour segment. P-Port; S-Starboard.
segment. offset.	Column 60-67:	UTM easting coordinate for start of scour Calculated by sub-routine using fix and
	Column 69-77:	UTM northing coordinate for start of scour segment. Calculated by sub-routine using fix and offset.
	Column 79-81:	Water depth at start of scour segment (metres).
Line 4.1,	Column 49-52:	Navigation fix coordinate (assuming layback) for end of scour segment. Measured from sidescan record.

	Column 54-56:	Perpendicular offset from centreline of sidescan record to end of scour segment (metres).
	Column 58:	Direction of offset to end of scour segment. P-Port; S-Starboard.
	Column 60-67:	UTM easting coordinate for end of scour segment. Calculated by sub-routine using fix and offset.
	Column 69-77:	UTM northing coordinate for end of scour segment. Calculated by sub-routine using fix and offset.
	Column 79-81:	Water depth at end of scour segment (metres).
Line 5,	Column 4 & 44:	Code descriptions for qualitative comment categories, as follows: 1) Scour completeness: 0 - neither end visible on sonar record; 1 - one end visible; 2 - both ends visible. 2) Other comments: General observations regarding unique characteristics, comparisons with previous data, etc.
Line 5,	Column 4 & 44:	3) Sidescan data quality: Qualitative estimate of data quality taking into consideration data clarity, gain setting, beam pattern, range limitations, fish motion (heave, pitch, yaw). Graded on a scale of 1 to 5. 1 = poor, 5 = very good. 4) Scour clarity: Qualitative estimate of scour clarity on a scale of 1 to 5. 1 = fuzzy; 2 = crisp. 5) Other seabed features: Includes comments on distinctive seabed features which are relevant to local hydraulics (e.g. megaripples) or give some further indication of data quality/resolution (e.g. otter board trawl marks).
	Columns 6-41 and 46-83:	Interpreter's comments.
Line 6,	Column 4:	A numerical code for each recognized geologic unit specific to it's local stratigraphic position. Units are numbered beginning with 00 at the seabed; 01 for the next unit down, etc. The unit designated 00 is the scoured (i.e surficial) unit.

Column 7-8:	Alphanumeric code for each recognized geologic unit. This code is specific to the geologic unit and is consistent with the most recent published stratigraphy for the area. For the purposes of this work, the stratigraphy of Fader and King (in prep) was applied.
Column 11-40:	Name and description of geologic unit.
Column 43-62:	Thickness of geologic unit as measured from sub-bottom profiler record (where possible) (metres).
Column 65-67:	Percentage of seabed covered by a given surficial unit locally (applies to 00 category units only).

APPENDIX E

Review of Sidescan Sonographs

Review of ORE Sidescan Sonographs from the Mobil 1979 and BIO 1990 surveys of the 4000 Series Lines on the Grand Banks of Newfoundland

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Introduction

In 1979, Geomarine Associates of Halifax, Nova Scotia surveyed an area of the Grand Banks west of the Flemish Pass and approximately 400 km east of St. John's using sidescan sonar. This survey was commissioned by Mobil Oil Canada to add to the limited amount of information available at the time on iceberg - seafloor interaction.

In the four days set aside for this survey, ten lines, called the 4000 series, were run between the North Hibernia and Trave-White Rose drilling prospects. The lines were spaced 2 km apart and 70 km long giving partial sidescan coverage of an area with dimensions approximately 20 km x 70 km.

A study of the sonographs for ice related features (1) indicated that iceberg generated scours in this area were aligned in a NE-SW direction and that in water depths greater than 140 m, the number of ice scours decreases dramatically.

In 1990, the Atlantic Geoscience Centre repeated this survey using similar equipment in a repetitive mapping program to see if any new scours had been produced over the intervening 10 year period and to estimate, if possible, a rate of degradation.

Although similar equipment was used in both surveys and the sonographs presented on similar scales, a noticeable difference in range and target resolution was observed between the two data sets. This brief study attempts to explain these differences.

Equipment Review

The ORE system used in the 1979 survey was a combined sidescan/3.5 kHz profiler which uses the sidescan components from the standard ORE 1500 system mounted on the ORE profiler tow body. An ORE model 160 Transceiver was used as a signal processor and an EPC 3200 grey scale recorder was used at 0.5 sec per sweep for hard copy. No taping of the Raw data was attempted.

In 1990, the ORE Model 159 - sidescan only - towfish was used to collect the sonographs. Other than this difference in configuration, all other equipment was nominally of the same type with similar settings and presentation scales.

Review of Sonographs

In comparing the sonographs from the two surveys at any location in the survey area, it is immediately obvious that the 1990 survey produced useful data at far greater ranges than did the 1979 survey. In an attempt to quantify the differences, 4 of the 10 lines were selected for a more detailed inspection. In the original 1979 study (1), a number of seabed features were used as sample points for comparing range and resolution.

Measurements taken in the vicinity of the selected features include:

a) Water depth
b) Tow fish depth
c) Range- port and starboard
d) Estimates of target resolution

Water depths to the nearest 5 metres were taken from the original photographs of the features and tow fish height measured directed from the sonographs. Effective range was estimated quantitatively as the maximum slant range that shading differences attributed to local targets could be observed above the background noise level. Resolution was more difficult to estimate and could not safely be quantified. However , one reasonable target zone for comparison is seen on line 4004 at Fix 12.5 on the 1979 data set (Fix 14.5 in 1990). This target consists of two pairs of small targets approximately 5 metres in extent to the north of the line close to identified feature No. 11 (1979). These data sections adequately show the range differences under similar tow vehicle operating conditions.

Table 1 gives the range information for the two data sets. It is obvious that using the above criteria the effective range of the 1990 data is in excess of 380 m whereas the 1979 data set rarely exceeds 200 m. Table 1 also indicates that the fish height in the 1990 cruise was generally 50 - 60 metres from the seafloor whereas in 1979, the fish was towed closer to the seafloor in the range 25 - 40 m. One other obvious visual difference is the sidelobe null which consistently "whites out" the 1990 sonograph at close distances.

Also, the 1990 data does not appear as detailed (sharpness of boundaries) as that of the earlier cruise.

Resolution of the two data sets is difficult to compare but from the few small individual targets observed, the resolution across track is in the order of 5 m and along track, approximately 20 m. With a display of 0.5 sec. representing a swath of approximately 375 m either side of the ship's track, the scale distortion is approximately 6:1. This makes interpretation of the orientation and shape of features difficult both to visualize and to measure.

Table 1 **Maximum Range Estimates in Metres for Lines 4002, 4003, 4004 and 4005.**

1979 Data 1990 Data

Water Depth	Fish Height	Range		Feature No.	Water Depth	Fish Height	Range	
		Port	Starboard				Port	Starboard
135m	40m	200m	240m	4	135m	55m	>380m	>380m
125	30	160	200	5	125	45	>380	>380
95	20	260	240	6	95	40	350	>380
125	45	200	200	7	125	56	350	350
105	25	200	200	9	105	40	>380	>380
95	35	200	240	10	95	40	>380	>380
85	30	260	220	11	85	35	>380	>380
95	45	220	260	12	85	35	>380	>380
105	43	220	320	13	105	40	>380	>380
105	36	180	180	15	105	40	>380	>380
85	33	200	200	16	85	50	>380	>380
95	30	220	220	17	95	60	>380	>380
125	33	180	200	19	125	58	>380	>380
135	50	240	250	20	135	68	>380	>380

The height of the fish above the seafloor will affect range but as with the data from line 4004, where the towing conditions for both cruises are approximately the same, greater range is observed in the 1990 data. So height of the fish is not felt to be the main factor here. However, the sidelobe null seen on the 1990 suggests that the vertical beam pattern characteristics may differ between the two system configurations.

Equipment Review

Several factors which affect the quality of sidescan sonographs will be discussed briefly below. These factors can be grouped as follows:

a) Tow fish configuration
b) Signal processing
c) Data presentation
d) Operational considerations
e) Equipment operator preferences.

(a) Tow Fish Configuration

As mentioned previously, the ORE system used on the 1979 survey was combined with a 3.5 kHz profiler in the larger Model 1036 tow vehicle as opposed to the Model 159, sidescan only, tow vehicle used in 1990. Providing the vehicles were configured correctly.no difference in sonar performance should be seen as the same type of sonar sub-units - transducers and electronics can, were used in both configurations. However, the depression angle of the two systems may have been different if for some reason, mechanical changes had been made.

However, there is a strong possibility of differences between the sonar sub-units themselves as:

i) Changes in specifications and performance characteristics may have been made by ORE over the years,

ii) Custom changes to some of the units by the contractors may have taken place.

The equipment used on the 1979 survey was purchased in 1978 by Geomarine Associates Limited of Halifax and the equipment used in 1990 was owned by McElhanney Surveys. It is beyond the scope of this review to investigate in detail equipment utilization but one fact regarding transducer beam pattern has come to light.

The product sheet dated 1983 for the ORE system indicates a selectable vertical transducer beam width of 14 and 28 degrees, whereas an ORE 1500 manual dated 1981 (2) obtained from Geonautics gives the equivalent beam widths as 28 and 55 degrees. This difference is a cause for concern and should be clarified with ORE. Similarly, any changes in the characteristics of the Model 162 Sub-Sea Transceiver over the period could also be investigated.

(b) Signal Processing

The ORE Model 160 Transceiver is a laboratory unit which provides power to the tow vehicle and processes the sonar echoes prior to display. The older 160 transceivers have two controls for both port and starboard channels and two different output modes. These operator controls are Signal Level (Gain) and Automatic Gain Control (AGC) - continously adjustable or off. A field installable modification was offered by ORE in 1982/3 which added a futher control function (TVG) for each channel. This would not have been available for the first survey but may have been used on the 1990 survey.

The two output modes available for display from the model 160 Transceiver are "Raw" and "Processed". The processed signal which presents the TVG and AGC signal would normally be used for the hard copy field record. The raw signal outputs are recommended for tape recording.

The 1979 equipment settings are not known at this time however, the 1990 hard copy data is annotated as "Raw".

(c) Data Presentation

In both surveys an EPC 3200 dual channel grey scale recorder was used for hard copy at similar sweep and paper feed rates. The performance characteristics of this recorder has changed little over the years except for minor changes in stylus registration and perhaps, in the quality of the recording paper. Neither of these changes will seriously affect the quality of the sonographs.

(d) Operational Considerations

There are several operational factors which could account for some differences in the data quality. The tow vessel was different. In 1979 an offshore pipe carrier, the MV Neiderntor was commissioned for the survey as opposed to a dedicated research vessel the CSS Dawson used in 1990. However, as far as the sidescan data is concerned, this factor is not seen as important. However, in towing deep vehicles, parameters outside the control of the operators such as weather, wind direction, currents and sea conditions do affect ship speed, and ability to remain on line at slow speeds. Sidescan systems are probably more tolerant of positional changes than other systems unless changes in tow conditions are relatively rapid. The only difference in towing characteristics observed in these surveys is the vehicle tow height discussed ealier. As with the vessel type, operational characteristics are not felt to contribute to the differences observed between the two data sets.

(e) Equipment Operator Preferences

Operator preferences as regards to data processing and recording equipment settings is probably the most likely area where quality can be in some way controlled. In 1979, ORE provided two operators to run the equipment who were, no doubt, familiar with the equipment. In 1990, experienced surveyors from Geonautics and McElhanney were involved with the program. Again with experienced operators, data quality could be expected to be equivalent so it is reasonable to assume that the maximum range differences could be instrumental. However, the question of the reduced resolution and sharpness in the 1990 data set may be explained by the selection of the "Raw" output from the model 160 Transceiver. Selection of the "Processed" outputcan lead to a better image since the AGC feature has the effect of compressing the signal amplitude to match the limited dynamic range of the EPC Recorder.

Transducer beam width selection is in effect an operator option. ORE has always provided a switch in the sub-surface transceiver to limit the vertical beam width for shallow water operation. In effect, a narrow beam width would be used in shallow water to reduce echoes derived from the sea/air surface boundary. This process involves exciting a second set of elements in the transducers. It is possible that this configuration also reduces the effects of sidelobes. However, it is difficult to get technical information regarding transducer directivity from Ferranti - ORE. These units are not presently in production either at the original plant in the USA or in the UK where only a support and service interest in this product line is maintained.

Conclusions

Several reasons for the differences in range and resolution between the 1979 and 1990 sonographs have been discussed. The following conclusions are drawn.

1) The difference in the tow vehicle height is not a factor in the reduced range seen in the 1979 data.

2) The most likely canadidate to explain the range reduction is the choice of the beam pattern of the transducers.

3) A secondary reason may be the lack of a TVG feature which was added to the Model 160 Transceiver in the period between the surveys.

4) The most likely cause of the reduction in clarity and resolution in the 1990 data is the use of the "Raw" outputs from the transceiver for hard copy.

Recommendations

1) The differences in the quoted beamwidth specifications of the transducers should be investigated to see if any changes have been made by Ferranti-ORE to the transducers during the period between the surveys.

2) The original cruise logs from the 1979 survey should be reviewed for information regarding beam pattern selection.

3) The owners of the equipment used on both surveys should be approached to provide information regarding any system changes that may have taken place over the years.

4) For future repetitive mapping studies detailed information of all equipment including sub-unit serial numbers and appropriate specifications be provided for future reference.

References

1) Mobil Oil Canada (1980). A Sidescan Sonar Study of Iceberg scours on the Grand Banks of Newfoundland between Hibernia and Trave/White Rose Wellsites. Geomarine Associates Ltd. Project No. 79-43. Report prepared for Mobil Oil Canada by Peter G. Simpkin, May 1980.

2) Ferranti-ORE, Operation and Maintainance Manual for the O.R.E. Model 1500 Side Scan Sonar System. Rev. 3, August 1981.